Social finance as cultural evolution, transmission bias, and market dynamics

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The thoughts and behaviors of financial market participants depend upon adopted cultural traits, including information signals, beliefs, strategies, and folk economic models. Financial traits compete to survive in the human population and are modified in the process of being transmitted from one agent to another. These cultural evolutionary processes shape market outcomes, which in turn feed back into the success of competing traits. This evolutionary system is studied in an emerging paradigm, social finance. In this paradigm, social transmission biases determine the evolution of financial traits in the investor population. It considers an enriched set of cultural traits, both selection on traits and mutation pressure, and market equilibrium at different frequencies. Other key ingredients of the paradigm include psychological bias, social network structure, information asymmetries, and institutional environment.

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Financial market participants employ a variety of learning strategies and heuristics and are subject to different biases in judgments and decisions. These dispositions are shaped by the cultural traits that people adopt from others. These include macrocultural traits, such as national, religious, ethnic, and political beliefs, and more specific information signals, beliefs, financial strategies, and folk models of how the economy or financial markets work. As financial traits spread from person to person, they compete for survival in the population. Financial traits are also modified in the process of being transmitted—intensifying, lessening, or changing qualitatively.

The resulting population distribution of investor traits determines financial outcomes, such as project choices, market prices, and trading profits. These market outcomes feed back into the evolutionary success of competing cultural traits. So financial markets and traits are parts of a dual cultural evolutionary and market system.

We argue here for a different paradigm for understanding financial markets which we call social finance. Social finance studies the cultural evolution of financial traits, the transmission biases that shape this process, and resulting market dynamics. It draws upon concepts from classical and behavioral finance, evolutionary finance, and cultural evolutionary theory. We review the cultural evolution of beliefs, investment, and price setting in financial markets, in the context of social network structure and institutional environment. We also highlight connections between general evolutionary theory and financial applications and suggest directions for future research.

Cultural evolution is a shift in the distribution of cultural traits in a population over time (1). Cultural traits increase or decrease in frequency and are modified through individual and social learning. Financial economics has long studied learning by observing market price. Evolutionary finance recognizes that beliefs and behaviors are also transmitted via social interaction and observation. Social finance is distinguished by an explicit and broader examination of social transmission processes, cultural traits, and evolutionary dynamics.

There is growing evidence that culturally transmitted investor ideas or folk models affect trading behavior and price outcomes. This includes both macrocultural traits, as mentioned above, and microcultural traits, such as a belief in Bitcoin as a trading opportunity. Market participants, such as managers and investors, acquire and transmit understandings about how the economy and markets work—what

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Hirshleifer (2) refers to as folk economic and financial models. Folk financial models often reflect shallow cognition, as encapsulated in Wall Street catch phrases such as "dead-cat bounce" and "Don't fight the Fed." Folk models are also sometimes attached to vivid narratives that help them spread from person to person (3).

Despite a long history of evolutionary approaches to economics and finance (4), evolutionary finance, including "econophysics" (surveyed by ref. 5), has largely remained separate intellectual lineage from the rest of the finance field. However, a growing number of "calls to arms" endorse the study of social interactions and, in some cases, evolutionary processes in financial markets (2, 3, 6, 7).

Existing evolutionary and agent-based approaches to financial markets, including the econophysics literature, typically derive or simulate the aggregate consequences of zero-intelligence rules for how agents behave. These approaches provide valuable insights, but do not address the effects of agents thoughtfully seeking to optimize (even if imperfectly). Social finance encompasses agent-based modeling of transmission biases, but goes farther to allow for the effects of transmission bias when agents form beliefs and choose actions thoughtfully.

Building on previous advances in evolutionary finance and other disciplines, social finance offers several distinctive features and potential contributions:

1) Social Finance Nests Classical and Behavioral Finance as Special Cases and Endogenizes Traits That Are Typically Taken as Given. Social transmission helps explain how private signals are distributed across investors; in classical finance this distribution is often taken as given. Furthermore, social transmission of financial traits, including financial folk models, shapes the heuristics and biases taken as given in behavioral finance (as reviewed in ref. 8) and shapes how these traits vary across agents and over time.

For example, in behavioral finance investor belief in continuation or reversal of price trends is taken as given, as in the literature on positive feedback trading (9). The evolutionary perspective we propose seeks to explain how investors come to possess such beliefs or decision rules. In this approach, investors acquire trend-chasing or contrarian traits from others in a process of cultural transmission. The folk model that return trends tend to continue competes for investor attention and belief with the "buy on the dips" folk model that returns tend to reverse. Similarly, empirical behavioral finance research often takes investor sentiment to be an exogenous driver of behavior (10, 11). Social finance regards shifts in sentiment as an endogenous outcome of microevolutionary cultural processes.

Behavioral finance considers the special case of social finance in which psychological biases are effectively innate (for analytical purposes). Similarly, classical finance considers the special case in which investor traits such as discount rates and risk tolerance are fixed. In social finance, financial traits spread from person to person, so that the distribution of these traits in the population evolves.

Econophysics and evolutionary finance models that assume mechanistic trading rules do not endogenize the belief formation or preferences of classical finance. Other models allow only for given or mechanistically generated beliefs. Social finance allows for both social transmission of beliefs and the possibility of active thought processes on the part of decision makers.*

2) Social Finance Considers a Wider Universe of Investor Beliefs and Strategies. Previous literature on evolutionary finance often focuses on the competition between trend chasing and fundamental trading behaviors or optimism versus pessimistic beliefs (see reviews in refs. 12 and 13). Building upon these advances, social finance widens application of the evolutionary perspective to the rich diversity of actual financial traits and folk economic models. Examples include belief in the value versus growth investment philosophies or belief in the use of the payback criterion for managerial project decisions.

3) Social Finance Studies Evolution of the Cross-Investor Distribution of Traits, Not Just Wealths. Most research mentioned in point 2 studies shifts in the distribution of wealth over time across investors with given investment strategies. Social finance emphasizes that investors adopt and modify their financial traits, such as saving propensities, trading strategies, or belief in different investor philosophies. So the distribution of traits in the investor population, not just wealths, evolves.

4) Social Finance Recognizes That Investors Thoughtfully, Although Imperfectly, Analyze Alternatives, Which Affects Market Outcomes. Econophysics and other pioneering evolutionary finance models have often employed mechanistic assumptions about investor behavior or price determination. This can be a fruitful modeling strategy. Social finance recognizes that investors analyze alternatives, often in reasonable ways, as active processors of information.

5) Social Finance Studies a Richer Set of Social Transmission Biases. A subset of evolutionary finance models allows for social interaction. An important ingredient of existing evolutionary finance, as in many models of cultural evolution, is payoff-biased transmission—the copying of traits that have performed well (14) (for financial markets, see refs. 15 and 16). Social finance seeks to systematically delineate and explore a wide range of relevant social transmission biases (as analyzed, e.g., in ref. 14). These include greater transmission of actions that are more observable and salient to others, of ideas that are easier to understand, of folk models that are more heavily cued in the environment, and of traits that bearers have an incentive to disseminate to others.

6) Social Finance Accounts for Mutation Pressure, Not Just Copying and Selection. Social finance recognizes that new financial traits appear routinely and are often systematically modified as they are transmitted from one agent to another. In genetic evolution, such newly generated or modified inheritance is called mutation pressure. In cultural evolutionary applications, mutation pressure is commonplace. For example, when investors who have favorable information about a stock buy it, they often communicate with positive "spin" to others in the hope of driving up its price.

7) Social Finance Considers a Wider Set of Applications and Range of Time Scales Than Much of Past Evolutionary Finance. Econophysics and evolutionary models have often been applied to high-frequency trading and market microstructure, financial power laws, time decay in volatility and covariances, and chaotic dynamics (see review in ref. 17). Social finance widens the scope of financial phenomena and empirical puzzles to be addressed. These include medium- and low-frequency patterns of trading and asset pricing, long-term capital market equilibrium, the

*Also, one of the agendas of social finance is to analyze the social transmission of heuristics and biases that have been the focus of interest in behavioral finance, such as overconfidence, attention to different kinds of information signals, loss aversion, and so forth.

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pricing of factor risk, bubbles and crashes, asset pricing anomalies, and managerial and regulatory policy. Since such applications have been of great interest to financial economists and practitioners, greater focus on these topics promises to build bridges with an intellectual lineage that has been largely disjoint from econophysics and evolutionary finance.

Financial Markets as Culturally Evolving Systems

A financial market consists of a population of agents who transact based upon their preferences, beliefs, and folk models of how markets work. These cultural traits, and resulting financial strategies, are transmitted, potentially with modification, from person to person. Examples include trading strategies such as dollar cost averaging, technical strategies, and diversification versus stock picking. Investors copy, debate, modify, and persuade each other of these strategies and folk models.

The transmission of traits from one investor to another is a kind of inheritance—similarity in traits between an agent (or set of agents) that, for some set of social transactions, is designated as culturally ancestral and an agent (or set of agents) that is designated as descendant. In cultural evolution, selection and mutation pressure are often directional drivers of change. An example of selection is the high recent transmissibility of the idea that Bitcoin is a fabulous investment opportunity. Pro-Bitcoin ideas have recently had high fitness—many cultural descendants. An example of mutation pressure mentioned earlier is spin about purchased stocks.

Analytically, these cultural evolutionary forces can be precisely quantified. The evolution of such traits in a single generation can be decomposed into a selection component and a nonselection component (reflecting mutation pressure) using the Price equation (18–20).

Basic Insights from Cultural Evolution, with Examples from Finance

The study of cultural evolution is highly interdisciplinary. We highlight some theoretical and empirical insights from this literature that are especially relevant for financial markets.

Cultural Transmission Is Biased. Transmission biases influence both the intensity of a transmitted trait (mutation pressure) and whether a trait is transmitted from one person to another (selection). Shennan (21) distinguishes three types of bias in the transmission of cultural traits. Under results bias, transmission depends upon the results of neighbors' traits, as with payoff-biased imitation. Another type of results bias is visibility bias, wherein some actions have consequences that are more attention grabbing than others. This can result in undersaving (22).

Content bias is a direct influence of the content of the trait on transmission. For example, ideas that are vivid, fun, useful, or easy to understand are highly transmissible (23). The ease of transmitting simple ideas can cause very naive financial strategies to predominate.

Context bias is the influence of the context of the interaction, such as the credibility or prestige of the sender, and the degree of arousal of the receiver (24). These are agent characteristics (traits of senders versus receivers of signals). Context also includes features of the environment (the type of asset market or current market conditions). With respect to agent traits, transmission bias can derive from the sender (or observation target), the receiver, or both. For example, a sender may bias reports in favor of a financial product because the sender is trying to sell it.

Under conformist-biased transmission (14), observers copy the most popular traits. In a financial context, this suggests that once a folk model or activity (such as a faith in Bitcoin, high-tech startups, or corporate diversification) becomes sufficiently popular, a boom can persist until big news forces people to reconsider.

Payoff-biased transmission has beneficial effects, such as promoting investment in a low-fee over a comparable high-fee mutual fund. However, explicit modeling of payoff-biased transmission reveals possible dysfunctional effects, such as investor chasing of random short-term price trends.

Cultural Evolution Can Promote either Functional or Dysfunctional Traits

Darwinian selection in biology promotes adaptation, wherein organisms function well in some environment. Selection and adaptation are among the key premises of what Lo (7) calls the adaptive markets hypothesis. In cultural evolution, too, adaptation is about differential reproductive success—of cultural traits rather than genes. Adaptation of financial traits does not always promote the success of the vehicles that bear them (such as investors or managers), in terms of either welfare or reproduction. Even fallacious folk financial models often persist in the population of amateurs and professionals.

Nevertheless, there are myriad examples of cultural traits that spread owing to benefits conferred upon their bearers. Examples include belief in stock market participation and various quantitative methodologies used by investment professionals. Crucially, the conferred benefits need not be correctly understood by the bearer (25).

For example, popular books and websites almost uniformly recommend that borrowers refinance their fixed rate mortgages prematurely—as soon as the present value of doing so turns positive. Obeying would ensure that the borrower's gain from refinancing is virtually zero! However, the simplicity of this rule of thumb makes it highly transmissible. Furthermore, it may actually help borrowers, since many are prone to excessive delay and inertia. "Dollar cost averaging" is another strategy that might be beneficial for reasons that investors do not correctly understand (26).

Financial beliefs that are detrimental to their bearers can also be highly transmissible. For example, Rantala (27) provides evidence that participation in a major Finnish Ponzi scheme was mediated by social interaction between participants. The payback criterion for discounting projects causes mistaken investment decisions by ignoring the time value of resources, yet survives.

The transmissibility of a trait often depends on how common it is, one reason being that payoffs to the bearer are frequency dependent. For example, congestion costs in investing strategies are ubiquitous—adopting a strategy reduces the benefit to competitors of doing so. So security trading is an ecological interaction between different investor types whose activities influence each other's profitability via market price (28). Owing to frequency dependence, a diversity of traits (or investment strategies) can be maintained in a population.

Owing to frequency dependence and payoff interactions, a diversity of folk models can coexist in the population adapted to distinct ecological niches. In financial markets these niches are filled by retail investors and a variety of financial institutions and players. Indeed, Lo (7) refers to the panoply of specialized adaptations of hedge funds as the "Galapagos islands of finance."

Strategic complementarities can be positive as well as negative and can induce multiple equilibria, an example being either liquid or illiquid financial markets. Societies can pass through critical transitions between very different financial equilibria. Historically, some societies have evolved to attain thriving financial

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markets, legal systems that underpin such markets, and extensive financing of business innovation. This involves a coordinated shift in the beliefs and expectations of financial agents and regulators. It will be valuable to model the cultural evolutionary determinants of the critical transition from financial autarky to financial development.

Financial Traits Evolve Cumulatively. Cultural evolution can consolidate assemblies of traits that complement each other to promote their joint success. This is an example of epistasis, the interaction between units of inheritance in determining transmission success.

For example, the value-investing philosophy is a coadapted assembly of several distinct ideas: that it is best to invest in stocks that have low price relative to measures of fundamental value, that it is best to trade infrequently ("buy and hold"), and that it is best to avoid being swayed by other investors (contrarianism). The linkage of these ideas is not logically compelling. If stock mispricing fluctuates, then trading from overpriced to underpriced stocks is in conflict with buy and hold. But these ideas are emotionally complementary.

Assemblies of financial traits are often connected by shallow reasoning, and by emotional motivations, including moral attitudes (3, 29). For example, the value philosophy prizes the personal virtues of thrift, long-term planning, and independence of thought. However, logic is also an important source of linkage, as in the conceptual structures underlying the quantitative models of sophisticated professionals.

Empirically, the evolutionary history of descent with modification of various types of cultural traits, such as design features of canoes, has been traced out using phylogenetic methods (30). These methods apply even when there is cross-lineage borrowing, as is common in cultural evolution. A promising further direction for evolutionary financial research is to trace the evolution of folk economic models empirically through textual analysis of investment discussions.

Cultural Evolution Operates at Multiple Time Scales. The evolutionary dynamics of financial traits play out at multiple time scales. At a high frequency, there is microevolutionary rise and fall of beliefs about specific securities, strategies, and philosophies (such as optimism about cryptocurrencies). At a fast-to-medium frequency, regulations and financial organizations evolve. Specialized advisors and intermediaries tailor products and services (useful or otherwise) for either retail investors or financial institutions. Investment methodologies develop, such as fundamental analysis and quant investing.

At an even longer time scale, the preferences and mindsets of financial actors (risk preference, time preference, beliefs about how the world works) are influenced by slow-moving traits such as religious, ethnic, and national culture (31). Cumulative evolution shapes assemblies of folk economic models, such as investment philosophies. Finally, at the longest time scales, culture and genes can coevolve to influence economic attitudes and preferences (32).

Most models of cultural evolution have been at the fastest and slowest of the time scales described above. At the highest frequency, there is extensive modeling of how the spread of behavior is influenced by transmission biases and social network structure (33).

At lower frequencies, cultural evolutionary models of behavioral change across generations have captured the interplay between cultural and genetic selection (20, 34, 35). There is an opening for greater study of the intermediate time scales mentioned above in evolutionary finance.

Models of Evolutionary Dynamics in Finance

We now discuss models of the evolution of financial markets. We start with biased transmission of cultural traits and then turn to compartmental models and to avenues for empirical testing.

Biased Transmission of Financial Traits. **Payoff-biased trait transmission.** Econophysics models and early models in evolutionary finance focus on the effects of mechanistic rules of investors for updating beliefs, trading, and rules for market price setting. Such models can generate interesting system dynamics, such as bubbles and cycles, autoregressive second return moments (36), and power laws in returns and volatility (37). Several papers examine settings in which investors choose between different heuristic belief-updating functions based upon the past performance of each heuristic (38, 39). This can result in instability and complex dynamics.

Such models generally assume that information about strategy payoffs is transmitted without bias. However, evidence indicates that individual and professional investors talk more about their high than about their low return experiences (40–42)—self-enhancing transmission bias. This is a specific kind of payoff-biased transmission in which the payoff reports are subject to selection bias.

In ref. 43, investors adopt one of two strategies: "active" (A) or "passive" (P), where A has either higher variance or higher skewness. Investors are randomly selected to meet in pairs over time. In each meeting, the probability that the sender reports the sender's strategy and return to the receiver is increasing with that return. This self-enhancing transmission creates an upward selection bias in the returns seen by receivers—especially for the high-variance strategy.

Receivers fail to adjust for this selection bias and also think that reported past performance is indicative of future performance. So the high-variance strategy spreads through the population, even if its payoff distribution is inferior. This evolutionary pressure toward the A strategy causes it to become overpriced. This offers a possible explanation for the puzzle of retail investor nondiversification and active investing and some well-known return predictability anomalies.

If, in addition, extreme returns are highly salient, positive skewness strategies also tend to spread through the population. This is because positively skewed strategies generate the high-return outcomes that are heavily transmitted to, attended to, and persuasive to receivers. This implication is consistent with evidence of investor preference for positive skewness and apparent overpricing of "lottery stocks." Also, these effects are predicted to be stronger for more socially connected investors.

The multiplicative interaction of the sending and receiving functions implies that the rate of evolution toward A is an increasing convex function of past return. There is evidence that stock market entry, investor flows into mutual funds, and reallocation by investors from safe to risky assets are increasing in portfolio returns (44, 45).

Counteracting the selection for riskier strategies is a well-known evolutionary effect favoring lower variance strategies called bet hedging (46). Brennan and Lo (47) find that evolutionary bet hedging can explain a range of psychological effects, such as loss aversion, risk aversion, and probability matching. These

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financial traits can counteract the transmission biases toward risky strategies discussed above.

Salience-biased trait transmission. To be influenced by another's behavior, an agent usually needs to observe and pay attention to it. So behaviors that are more visible and salient to others tend to spread. Han et al. (22) argue that such visibility bias reduces saving, because consumption activities, such as carrying wearable electronics, generate sensory cues that are more salient to others than the nonevent of not consuming. People neglect this observation selection bias and perceive that others are consuming heavily, which leads them to infer that others have information favoring high consumption. So the trait of high consumption tends to spread in a positive feedback loop.

In this theory, overconsumption is an emergent social outcome; it does not derive from a direct preference for immediate consumption (as in ref. 48). As a result, the empirical and policy implications differ from the behavioral economics approach. For example, in the visibility bias model, overconsumption is driven by mistaken belief updating, so accurate disclosure about others' consumption can reduce overconsumption, which is not the case in a direct preference approach. There is evidence that such disclosure does indeed help (49).

In the model of Hirshleifer and Plotkin (50), successful investment projects are more salient to observers than unsuccessful ones. Everyone is familiar with Microsoft and Google, whereas many failed startups are forgotten. Observers fail to discount for this observation selection bias. As a result, there is overadoption of risky projects—especially "moonshot" projects with a low ex ante probability of success and high payoff conditional upon success.

Private information, trait modification, and intensification. Financial agents often exchange ideas, which they use to update their beliefs and select actions. This has usually been modeled assuming rational Bayesian agents (51, 52). The evolutionary approach further considers the possibility that culturally transmitted financial traits, such as signals or beliefs, can "mutate," i.e., be modified, intensified, or lessened during transmission.

Beliefs are subject to mutation pressure even under rational Bayesian updating. For example, the beliefs of the receiver of a signal may be a weakened version of the beliefs of the sender, owing to transmission noise or receiver skepticism. Imperfect rationality induces further transmission bias and can cause populations to evolve to systematically mistaken assessments (53).

Turning to actions, research on information cascades (also called "herding") studies how agents learn from the actions of others (54, 55). This induces a mimetic transmission bias—a tendency to adopt the traits and, to some extent, beliefs, of observation targets. Since actions are coarse indicators of the beliefs of the observation target, information is aggregated poorly even when agents are rational. Owing to information cascades, society often fixes upon mistaken behaviors, despite extensive privately available information.

Furthermore, small shocks to the system often cause the population to swing from one trait to the other ("fragility"). Investment cascades are also subject to sudden booms owing to agents waiting to see what others will do (56). In several other models, information cascades and related phenomena induce failures of information aggregation and sudden market crashes (57).

Several models examine the rational diffusion of private information through social networks of investors in securities markets and how network position and network structure affect investment performance, liquidity, volume, investor welfare, and the informativeness of market prices (52, 58). Models of information percolation consider sequential sharing of information when agents are randomly selected over time from a population to meet and share their signals (51).

In application to financial markets (59), if investors are rational, accumulating signals tends to cause beliefs and prices to correspond to the true state of the world. So social transmission bias induces a beneficial mutation pressure toward correct beliefs. However, if investors are imperfectly rational and if signals are distorted in the transmission process, there can be pernicious mutation pressure. In either case, mutation pressure in social learning models can potentially be captured by the nonselection term in the Price equation (18, 50).

Biased information transmission and mutation pressure can also cause market bubbles and crashes. In the biased percolation model of ref. 2, a constant bias b is added to each private signal about the asset payoff each time a signal is transmitted from one investor to another. With repeated sharing, the number of signals per investor grows exponentially. Bias compounds recursively, where the input of a biased average signal results in an output of an average signal with additional bias. If naive receivers fail to discount for transmission bias, then as signal biases accumulate, on average price bubbles start to grow. On average these start slowly and then accelerate; the effects of bias at first grow exponentially. However, at each discrete date, public signals of growing informativeness arrive, which oppose and eventually correct the action boom or price bubble.

This results in oscillatory dynamics that are most pronounced at the peak of the bubble. So the model may potentially help explain the empirical puzzle of short-term negative return autocorrelations (60). Furthermore, owing to the otherwise-smooth and hump-shaped expected price path, the model can also generate momentum and long-run reversal return patterns, consistent with evidence of lower-frequency return predictability (61, 62).

Such dynamics illustrate how the cultural evolutionary approach can explain the "beyond all reason" flavor of many bubble episodes, such as the swings in Bitcoin prices in recent years. Speculative investor trading also rises and falls with the bubble. This is a cultural evolutionary effect; investors do not have any direct bias, such as overconfidence, "for" trading aggressively.

Compartmental Models of Trait Transmission. There is growing evidence of contagion via social interaction for a wide array of economic behaviors (63). This includes contagion of the beliefs and behaviors of retail and professional investors (see review in ref. 64), such as retirement saving, market participation, and selection of individual stocks (65–70). General trading strategies also spread from person to person, such as the tendency of investors to sell winners more often than losers (71).

The biased transmission of such discrete cultural traits can be captured using epidemiological models of disease transmission, often called compartmental models (72). In such models, agents are typically viewed as randomly meeting over time, where in a mixed pair, there is some probability that an infectious agent transmits an initially rare cultural trait to the partner. There is usually also a spontaneous rate of from infection with the cultural trait. In the most famous compartmental model, the SIR model, there are susceptibles (S) who can become infected, infectious agents ($\mathcal{I}$) who can recover, and recovered or "removed" agents ($\mathcal{R}$) who never change.

Shiller (3) suggests applying the SIR model to explain the spread of investor ideas and bubbles. In several papers, being infected is viewed as being optimistic about the prospects of a financial asset. In the SIR and related models, the infection rate contains a term that is proportional to the product of the fractions of the population that are infectious and susceptible. This generates a positive feedback effect. Shive (69) provides evidence consistent with such a multiplicative effect in the trading behavior of investors in Finland.

The rise-and-fall epidemic curve in SIR-related models can induce price overshooting and bubbles. Burnside, Eichenbaum, and Rebelo (73) apply a modified compartmental model to bubbles in real estate markets. In their model, there are optimists, skeptics, and what we will call susceptibles. Optimists expect fundamentals to improve; skeptics and susceptibles do not. In a meeting, each type has some probability of converting to the type of the meeting partner. Susceptibles have the highest probabilities of being converted and are the least contagious. Over time, in the absence of conclusive news, the population evolves to the beliefs of the most contagious type. If the optimists have the second-highest contagiousness, then their fraction temporarily rises (by persuading susceptibles) before collapsing (owing to persuasion by skeptics). This results in a bubble and crash.

In the basic versions of compartmental models, the contagion parameter, which captures the probability that a meeting generates a new infection, is exogenous. Hirshleifer (2) describes a modified SIRS setting (the final *S* indicating that recovered agents can become susceptible again) in which "buzz," the degree of excitement about the folk model, makes the folk model more contagious. Buzz is proportional to the rate of growth in the number of adherents of a folk model. When many are jumping aboard the pro-Bitcoin bandwagon, Bitcoin becomes "hot," and meetings with Bitcoin adopters are more persuasive. When the popularity of a folk model is declining, there is negative buzz, so that meetings trigger abandonment of Bitcoin—an endogenously negative contagion parameter. Buzz effects can exacerbate the boom/crash pattern in prices.

Overshooting in the model (similar to epidemics) implies that when a bubble collapses, the infected fraction falls below its long-run equilibrium value and exhibits dampened cyclical fluctuations thereafter. So the compartmental approach is potentially consistent with a rich serial correlation pattern in asset returns at different lags. Chinco (74) estimates a compartmental model in which social interaction induces stock market bubbles and finds that industries with a high intensity of social interaction have more frequent bubbles.

The compartmental approach offers a possible explanation for the stylized fact that bubbles and panics repeatedly co-occur with the sudden popularity of "New Era" investment folk models (75). New Era folk models occasionally mutate to become highly infectious. When a mutation induces a high contagion parameter, the popularity of the investment folk model grows explosively, for a period, inducing a market bubble.

Empirical Avenues in Social Finance. A basic empirical implication of social finance is that outcomes depend on the transmissibility of different strategies, which in turn depend on the characteristics of the financial trait, investor characteristics in their roles as senders and receivers, and the structure of social interactions (social network structure and the intensity of social interaction). Below, we discuss each of these factors.

Characteristics of the financial trait include whether it is easily observable to others, it is vivid or fun to talk about, it is simple to observe or communicate, it has high prevalence of relevant environmental cues, and its potential senders or receivers have an incentive to discuss it. Textual analysis of folk economic models in blogs and traditional and social media can be used to measure such characteristics.

Relevant investor characteristics include communication incentives, psychological communication propensities, and position in the social network. For example, investors differ in sociability and in how strongly their incentives or personality favor censoring or distorting the messages sent to others. Investors also differ in their skepticism toward verbal reports of others and in their propensity to adjust for reporting selection biases. Datasets from social media, as well as survey evidence, have been used to estimate individual social network position and sociability (67, 76). Such network position data can also provide insight into whether different investors are locked into "echo chambers," resulting in sharp cross-investor divergence in financial traits.

Changes over time in communication technologies (such as the rise of the printing press and mass media; electronic communication; and later the internet, blogs, and social media) also provide natural experiments that can be used to test how the structure of social transmission affects financial behavior. Relevant characteristics include the connectivity of the social network, how homophilous it is (homophily being the tendency for investors with similar traits to be linked), and how intensely investors tend to communicate about their investment strategies or performance.

Many cultural evolutionary models predict stronger effects for more socially active agents and those who are more central in the social network. Similarly, the effects of transmission bias on market outcomes will be stronger in networks that are more connected. In sharp contrast, in rational information sharing models (51, 52, 58), more intense social interaction causes the system to evolve more quickly toward greater market efficiency.

In the model of Han et al. (43), sociability and connectedness are associated with more active investing, as measured by variance and skewness. Consistent with this, Heimer (77) documents that social interaction is more prevalent among active investors (who buy and/or sell stocks) than passive investors who hold US savings bonds. Furthermore, proxies for sociability or connectedness are associated with greater stock market participation (45, 67, 78) and investment in more volatile or skewed stocks (79). The model also implies that convexity of investment flows derives from social interaction, consistent with evidence on social influence on stock market participation in Finland (45).

Policy and Regulation

Regulation evolves as policymakers learn about the effectiveness of different regulatory systems. Greater heterogeneity in regulatory systems across principalities can promote effective regulation via mutation, in the form of experimentation, and selection of superior outcomes (80). Sunsetting of existing regulations also promotes experimentation and can prevent regulatory drift in the form of large mutations at the time of rare crises (81). Both heterogeneity and sunsetting can potentially help regulators adapt to rapidly changing environments, avoid the extinction of beneficial policies via random drift, and compete more effectively in the evolutionary arms race with investors (whose strategies evolve quickly).

The cultural evolutionary approach also suggests additional directions for promoting financial literacy and prudent investor behavior. Evolutionary design can be used to increase the transmissibility of accurate or functional investor beliefs and behaviors.

For example, a way to help people save more can be to increase cues about saving (or low spending) by others (49). This is because ideas that are cued more heavily by the environment tend to spread more readily (82). Cues about saving can help offset the many daily cues (such as social media posts) about new purchases of others.

Conclusion and Further Directions for Social Finance

Learning from others is central in financial markets, as both classical finance and behavioral finance have long recognized. However, to fully understand the learning and transmission of financial traits, we need an evolutionary perspective that clarifies the nature of transmission biases and the coevolution of cultural traits and financial outcomes. The perspective that we advance, social finance, provides such a paradigm shift. It goes beyond behavioral finance (the application of psychology to markets) in focusing explicitly on how social interaction shapes thought and behavior and on the selection, mutation pressure, and drift processes by which these traits evolve. Social finance studies these issues with a broadened set of financial traits, transmission biases, and focal applications.

Social finance has promise to help explain important financial phenomena, such as bubbles and stock return predictability anomalies at different time horizons. For example, commentators have long argued that market bubbles, crashes, and swings in market sentiment are social phenomena and reflect contagion of emotions as well as ideas. This perspective contrasts with the classical finance view that (apart from highly restrictive theoretical scenarios) bubbles do not exist. It also contrasts with behavioral theories in which bubbles result from individual-level misperceptions, wherein social interaction occurs only via observation of market price. In contrast, in social finance, bubbles derive from the transmission of financial ideas, feelings, and behaviors through conversation, mass media and social media, and personal observation, and explicitly analyzes biases in this transmission process. This approach can therefore capture extreme amplification of misperceptions.

Furthermore, social finance offers a natural line of attack for addressing the increasingly dynamic nature of empirical anomalies in trading and returns in finance research. For example, there are behavioral models of the momentum anomaly (62), but in recent years the further puzzle has been why momentum is sometimes especially strong, and in other periods there are predictable “momentum crashes” wherein momentum reverses (83). There have also been notable swings in the returns on value versus growth stocks. The usual high returns on value stocks relative to growth stocks (84) were strongly reversed, for example, at the time of the millennial tech bubble and during the recent pandemic period. The dynamics of booms and busts in corporate financial behaviors, such as takeover and restructuring waves, are another natural domain for the social finance approach.

Another major underexplored topic is how and why investor interest has shifted toward and between different kinds of investment funds, such as mutual funds, exchange-traded funds, and hedge funds. Given the efficiencies of fund investing relative to individual stocks, the slowness of the historical rise over decades in fund investing is a major phenomenon to be explained. Finally, social finance is uniquely suited for the study of the evolution and spread of both narrow investment ideas, such as the recommendation to buy on the dips, and wider assemblies of investment ideas, such as the value and growth investment philosophies.

Finance scholars have devoted vastly greater attention to how investors learn from market price than to how they update beliefs by talking to each other (including textual communication). Research has also focused far more on rational than on biased social updating. Evolutionary modeling of biased transmission of private signals is a promising direction.

A major topic of evolutionary biology is the study of how adaptations as functional systems, such as the eye, evolve through sequential accumulation of traits. A little-explored direction in social finance is to model how coadapted assemblies of folk models, such as the value investing or growth investing philosophies, evolve. Studying this requires paying attention to complementarities between financial ideas, which can arise for various reasons. The ideas underlying portfolio theory are transmissible among sophisticated investors owing to their logic and usefulness. Other financial ideas combine effectively by appealing to the same moralistic emotions, as with the value philosophy. Moral intuitions may also explain why macrocultural traits, such as religion, affect financial behaviors (31).

Another rich direction suggested by social finance is the study of how emotions bias the transmission of different kinds of investment narratives and behaviors (3, 7) and how this influences bubbles and swings in market sentiment. For example, when a bubble starts to feel precarious, does fear cause investors to start transmitting danger-related instead of opportunity-related narratives?

Finally, financial applications have the advantage of extensive datasets on prices and actions, along with textual and social network data from the business press and social media. Financial markets also have a very well-defined and measurable payoff score, trading profits, that influences the spread of investor traits. So financial markets are an attractive domain for testing and refining general cultural evolutionary hypotheses.

Data Availability There are no data underlying this work.

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