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SOCIAL TRANSMISSION BIAS AND CULTURAL EVOLUTION IN FINANCIAL MARKETS

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ABSTRACT

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, new evolutionary 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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1 Introduction

Participants in financial markets employ a variety of learning strategies and heuristics, and are subject to different biases. These dispositions differ across individuals, and 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. Financial traits spread from person to person, competing for survival in the human population. Financial traits are also modified in the process of being transmitted from one agent to another—weakening, intensifying, or changing qualitatively. The resulting investor behaviors and market outcomes feed back into the evolutionary success of competing cultural traits. So financial markets and traits are parts of a cultural evolutionary system.

We argue here for a new paradigm for understanding financial markets which we call *new evolutionary finance*. This paradigm 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 the 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 (Mesoudi et al., 2006). 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. *New* evolutionary finance is distinguished by an explicit and broader examination of 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. Financial market participants such as managers and investors acquire and transmit understandings about how the economy and markets work—what Hirshleifer 2020 refers to as *folk economic and financial models*. Folk financial models often reflect shallow cognition, as encapsulated in 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 (Shiller, 2017).

Despite a long history of evolutionary approaches to economics and finance (Alchian, 1950), evolutionary finance 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 (Farmer and Lo, 1999; Lo, 2017; Shiller, 2017; Hirshleifer, 2020).

Building on previous advances in evolutionary finance, new evolutionary finance offers several distinctive features and potential contributions.

1. New evolutionary finance nests classical and behavioral finance as special cases, and endogenizes traits that are typically taken as given.

Social transmission helps explain how private information varies 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 (Hirshleifer, 2015)), 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 (DeLong et al., 1990). The cultural evolutionary perspective 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. 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 (Lee et al., 1991; Baker and Wurgler, 2007). New evolutionary finance regards shifts in sentiment as an endogenous outcome of microevolutionary cultural processes.

2. New evolutionary finance considers a wider universe of investor beliefs and strategies.

Previous literature on evolutionary finance often focuses on the competition between trend-chasing versus fundamental trading behaviors, or optimism versus pessimistic beliefs (see the reviews of (Evstigneev et al., 2009) and (Blume and Easley, 2010)). Building upon these advances, new evolutionary finance widens application of the evolutionary perspective to the rich diversity of actual financial traits and folk economic models. Examples are belief in the value versus growth investment philosophies, or belief in the use of the payback criterion for managerial project decisions.

3. New evolutionary 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. New evolutionary 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. New evolutionary finance recognizes that investors thoughtfully, though imperfectly, analyze alternatives, which affects market outcomes.

Pioneering evolutionary finance models have often employed mechanistic assumptions about investor behavior or price determination. This can be a fruitful modeling strategy. However, new evolutionary finance recognizes that investors analyze alternatives, often in reasonable ways, resulting in arbitrage of mispricing and other market dynamics.

5. New evolutionary finance studies a richer set of social transmission biases.

Financial traits are transmitted and modified in many ways. As in many models of cultural evolution, an important ingredient of evolutionary finance is *payoff-biased transmission*, the tendency to copy traits that have performed well ((Boyd and Richerson, 1985); for financial markets, see (LeBaron, 2006; Hommes and Wagener, 2009)). However, new evolutionary finance further recognizes a rich set of other transmission biases. 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. New evolutionary finance accounts for the role of *mutation pressure*, not just copying and selection.

New evolutionary 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. An example of mutation pressure is when investors who have favorable information about a stock buy it, and then communicate with positive "spin" to others in the hope of driving up its price.

7. New evolutionary finance considers a wider set of applications at a wider range of time-scales than much of past evolutionary finance.

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 the review of (Lux and Alfarano, 2016)). Based on its cultural evolutionary perspective, new evolutionary finance expands 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 pricing of factor risk, bubbles and crashes, asset pricing anomalies, and optimal managerial and regulatory policy.

2 Financial markets as culturally evolving systems

A financial market consists of a population of investors who transact based upon their preferences, beliefs, and folk models of how markets work. Investor beliefs, preferences, folk models, and strategies are cultural traits that 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. As for mutation pressure, we discussed earlier the example of investor "spin" about stocks they have bought.

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 (Price, 1970; el Mouden et al., 2014; Aguilar and Akçay, 2018).

3 Basics insights from cultural evolution, with examples from finance

Cultural evolution is a highly interdisciplinary field that draws on a broad mix of models and data. Here, we highlight some insights from this literature that are especially relevant for financial markets.

3.1 Cultural transmission is biased

As people interact, information and behaviors are transmitted with systematic biases that influence the evolution of cultural traits (Boyd and Richerson, 1985). Shennan (Shennan, 2011) distinguishes three general types of transmission bias. *Results bias* is copying based on the results of neighbors' traits, as with payoff-biased imitation. Another type of results bias is *visibility bias*, wherein some action have consequences that are more attention-grabbing than others. This can result in undersaving (Han et al., 2019).

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 transmissable (Heath, 1996). The ease of transmitting simple ideas may drive the evolutionary success of surprisingly naive financial strategies.

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 (Berger, 2011). Two aspects of context are: (i) agent characteristics (traits of senders versus receivers of signals), and (ii) features of the environment (such as the type of asset market, or current market conditions). With respect to (i), transmission bias can derive from the sender (or observation target), the receiver or both. For example, in some contexts a sender may bias reports in favor of a financial product because the sender is selling it.

Another form of context bias is conformist-biased transmission ((Boyd and Richerson, 1985)), wherein observers tend to copy the most popular traits. This reinforces social inertia. In a financial context, conformist bias suggest that once a folk model or activity (such as a faith in Bitcoin, high tech startups, or corporate diversification) becomes sufficiently popular, an excessive boom can persist until big news forces people to reconsider.

Transmission biases influence both the *intensity* of a transmitted trait (mutation pressure), or *whether* a trait is transmitted from one person to another (selection).

Payoff-biased transmission can have beneficial effects, such as selecting for investing in a low-fee mutual fund over a comparable high-fee fund. However, explicit modeling of payoff-biased transmission reveals possible dysfunctional effects. For example, it can cause investors to chase random short-term trends, resulting in security mispricing.

3.2 Cultural evolution can promote either functional or dysfunctional traits

Darwinian selection in biology is about differential success of gene lineages. It frequently promotes organismal *adaptation*, wherein organisms function well in some environment. Selection and adaptation are among the key premises of what Lo (Lo, 2017) calls *the adaptive markets hypothesis*. In cultural evolution, too, adaptation is about differential reproductive success of *cultural traits*. Such adaptation can sometimes, but not always promote the success of the vehicles that bear them (such as investors or managers), either in terms of welfare or reproduction. Even fallacious folk financial models often persist in the population of amateurs and professionals.

There are myriad examples of cultural traits that spread owing to a benefit they confer upon the bearer. Financial examples include belief in stock market participation, and various quantitative methodologies used by investment professionals. Crucially, the benefits that cultural traits confer upon their bearers do not have to be correctly understood by the bearer (Henrich, 2015).

A possible financial example is the almost universal advice of popular books and websites that borrowers refinance their fixed rate mortgages as soon as the present value of doing so turns positive. The simplicity of this rule of thumb makes it highly transmissible, but it prescribes refinancing too early, thereby ensuring that borrowers extract near-zero gains from refinancing. However, this rule 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 investors do not correctly understand (Brennan et al., 2005).

Financial beliefs that are detrimental to their bearers can also be highly transmissible. For example, (Rantala, 2019) provides evidence that participation in a major Finnish Ponzi scheme was mediated by social interaction between participants. The payback criterion for discounting investment projects is fallacious and pernicious, 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, diminishing returns and congestion effects in investing strategies are ubiquitous. These result in what economists call strategic complementarities or anticomplementarities—taking an action affects the incentives of other agents to engage in it. So security trading is an ecological interaction between different investor types whose activities influence each other's profitability via market price (Farmer, 2002). 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, often fitting into distinct ecological niches. In financial markets these are filled by retail investors and various financial institutions and players. Indeed, Lo (Lo, 2017) refers to the panoply of specialized adaptations of hedge funds as the "Galapagos islands of finance."

Strategic complementarities can also induce multiple equilibria, an example being either liquid or illiquid financial markets. So societies can pass through critical transitions between very different financial equilibria. Historically, some societies have evolved to thriving financial 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.

3.3 Financial traits evolve cumulatively

Culture evolution can take the form of shifts in a single unidimensional trait (Henrich et al., 2008), or of consolidation of *assemblies* of traits that complement each other to promote their joint success. In biology, such interaction between units of inheritance in determining fitness is called *epistasis*.

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. For example, if stock mispricing fluctuates, then investing in the most underpriced stocks is in conflict with buying and holding. But these ideas are emotionally complementary.

Assemblies of financial traits are often connected by shallow arguments, and motivated by emotions, including moral attitudes (Hirshleifer, 2008; Shiller, 2017). For example, the value philosophy emphasizes the personal virtues of thrift, long-term planning, and independence of thought. However, logic is also an important source of linkage, as in sophisticated quantitative models popular among academics and 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 (Mace and Holden, 2005). 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 through textual analysis of investment discussions.

3.4 Cultural evolution operates at multiple time-scales

Cultural evolutionary dynamics play out at multiple time-scales in finance. 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 (either 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 (such as risk preference, time preference, and general understandings about how the world works) are influenced by slow-moving traits such as religious, ethnic and national culture (Guiso et al., 2006). Cumulative evolution elaborates and reshapes 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 (Barnea et al., 2010).

Most models of cultural evolution have been at the fastest and slowest of the time-scales described above. At the highest frequency, a large body of theory illuminates how the spread of a behavior can be facilitated or hindered by transmission biases or social network structure (Jackson, 2009).

At lower frequencies, cultural evolutionary models of intergenerational behavioral change have modeled the interplay between cultural and genetic selection (Richerson and Boyd, 1978; Bisin and Verdier, 2001; Aguilar and Akçay, 2018). There is an opening for greater study of the intermediate time scales mentioned above in evolutionary finance.

4 Models of cultural evolutionary dynamics in finance

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

4.1 Biased transmission of financial traits

In settings with either rational or imperfectly rational investors, biased social transmission of financial traits shapes the evolution of trading strategies and market prices. We review models of these biases, with emphasis on emerging approaches.

4.1.1 Effects of payoff-biased trait transmission

Some early models in evolutionary finance focus on the effects of mechanistic rules of investors for changing their beliefs and choosing trades, and of market price setting. Such models generate interesting system dynamics such as bubbles and cycles, autoregressive second return moments (Lux, 1997), and power laws in returns and volatility (Alfarano and Lux, 2007). Several papers examine settings in which investors choose between different heuristic belief updating functions based upon the past performance of each heuristic (Brock and Hommes, 1997; Chiarella et al., 2013). 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 (Heimer and Simon, 2015; Escobar and Pedraza, 2019; Lane et al., 2020)—*self-enhancing transmission bias*. This is a specific kind of payoff-biased transmission in which the payoffs reports are subject to selection bias.

In (Han et al., 2020), investors adopt one of two strategies: A ("Active") or P ("Passive"), 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 that operates more strongly on the returns of 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 investor nondiversification and the puzzle of active retail investing, and some well-known return 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, 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 the allocation by investors from safe to risky assets is increasing in fund returns (Chevalier and Ellison, 1997; Kaustia and Knüpfer, 2012).

4.1.2 Bet hedging

Multiperiod evolutionary dynamics can induce selection for low risk strategies, a phenomenon known as *bet hedging* (Gillespie, 1973). Brennan and Lo (Brennan and Lo, 2011) find that such dynamics can explain a range of psychological effects, such as loss aversion, risk aversion, and probability matching. Bet hedging effects in cultural evolution can potentially moderate the evolutionary attraction of investors to risky strategies discussed earlier.

4.1.3 Salience-biased trait transmission

To be influenced by a behavior, an agent usually needs to observe it and pay attention to it. So behaviors that are more visible and salient to others have an evolutionary advantage in spreading. Han et al. (Han et al., 2019) 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 non-event of not consuming.

In their model, people neglect this observation selection bias, and therefore perceive that others are consuming heavily. Observers infer that others have information favoring high consumption. In consequence, 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 (Laibson, 1997)). In consequence, the cultural evolutionary approach has different empirical and policy implications 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 (D'Acunto et al., 2019).

In the model of Hirshleifer and Plotkin 2020, 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 in the event of success.

4.1.4 Private information, trait modification and intensification

Financial agents often acquire information signals from others to update their beliefs and select actions. Until recently, there has been very little study of the consequences of investors talking to each other and exchanging ideas. This research has usually focused on the special case of rational Bayesian agents (Duffie and Manso, 2007; Özsöylev and Walden, 2011).

In the evolutionary approach, an agent's information signals and/or beliefs are cultural traits that are transmitted from person to person, often with modification. Beliefs are subject to mutation pressure even under rational Bayesians updating. When agents acquire information signals from others, owing for example to transmission noise or skepticism, the belief of the receiver may be a weakened version of the belief of the sender. Imperfect rationality induces further transmission bias, and can cause populations to evolve to systematically mistaken assessments (Bohren, 2016).

Turning to actions, research on *information cascades* (also called 'herding') studies how agents learn from the actions of others (Banerjee, 1992; Bikhchandani et al., 1992), inducing conformist transmission bias. Such observation transmits beliefs and behaviors across agents. 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 (Chamley and Gale, 1994). In several other models, information cascades and related phenomena induce failures of information aggregation and sudden crashes (Lee, 1998)

Several models examine the rational diffusion of private information through social networks of investors in securities markets, and how network position and network structure affects investment performance, liquidity, volume, investor welfare, and the informativeness of market prices (Özsöylev and Walden, 2011; Walden, 2019). 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 (Duffie and Manso, 2007).

In application to financial markets (Andrei and Cujean, 2017), 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 places a beneficial mutation pressure on beliefs. Imperfect rationality and distortion of signals in the transmission process induce a different form of mutation pressure. In either case, mutation pressure in social learning models can potentially be captured by the nonselection term in the Price Equation (Price, 1970; Hirshleifer and Plotkin, 2020).

Biased information transmission and mutation pressure can also cause market bubbles and crashes. In the biased percolation model of (Hirshleifer, 2020), 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 investors grows exponentially, and bias compounds recursively. Naive receivers fail to discount for signal bias. As biases accumulate, price bubbles start to grow. On average these start slowly, and then accelerate, because the effects of bias at first grow exponentially. However, at each discrete date, public signals of growing informativeness arrive, which eventually correct the action boom or price bubble.

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.

There is growing evidence of contagion via social interaction for a wide array of economic behaviors (e.g. Glaeser and Scheinkman, 2003). This includes contagion of the beliefs and behaviors of retail and professional investors (see the review of Hirshleifer and Teoh, 2009). Such behaviors include retirement saving, market participation and selection of individual stocks (Kelly and O'Grada, 2000; Duflo and Saez, 2002; Hong et al., 2004; Brown et al., 2008; Shive, 2010; Massa and Simonov, 2011).

The interplay between continuous information percolation (with a continuum of investors in continuous time) and the discrete arrival of public information (such as earning news) generates oscillatory dynamics. On each of the public information release dates, overoptimism is on average partially corrected, inducing discrete price drops. Such oscillations grow and then diminish—there is *peak oscillation*. This may potentially help explain the empirical puzzle of short term negative return autocorrelations (Jegadeesh, 1990). Owing to the 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 (DeBondt and Thaler, 1985; Jegadeesh and Titman, 1993).

4.2 Contagion and compartmental models of trait transmission

Most of this literature has focused on specific investment behaviors. However, general trading strategies also spread from person to person, such as the tendency of investors to sell winners more often than losers (Heimer, 2016).

The sheer existence of contagion says little, in itself, about the direction in which the population is evolving. It also says little, per se, about the sources of evolution in terms of selection, mutation pressure, or drift. It is systematic *asymmetry* in the contagion of competing traits, that induces a directional selection effect.

Biased transmission of discrete cultural traits can be captured using epidemiological models of disease transmission (Kermack and McKendrick, 1927). In such models, agents can be 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 'recovery' from infection with the cultural trait. In the most famous of these compartmental models, the SIR model, there are susceptibles ($\mathcal{S}$) who can become infected, infectious agents ($\mathcal{I}$) who can recover, and recovered or "removed" agents ($\mathcal{R}$) who never change.

Shiller (Shiller, 2017) 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 (Shive, 2010) empirically tests whether a SIR model explains the trading behavior of investors in Finland. Consistent with the compartmental approach, the product of the number of owners in a municipality and the number of investors who do not own a stock is associated with increased trading.

The rise-and-fall epidemic curve in SIR-related models can induce price overshooting and bubbles. Burnside, Eichenbaum and Rebelo (Burnside et al., 2016) 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 (Hirshleifer, 2020) describes a modified SIRS setting (where recovered agents can become susceptible again) in which "buzz," the degree of excitement about the folk model, makes the folk model more contagious. In the model, 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," so that a meeting with a Bitcoin adopter is more persuasive. When the popularity of the folk model is declining, there is *negative* buzz, so that meetings tend to cause investors to abandon Bitcoin—an endogenously negative contagion parameter. Buzz effects can exacerbate the boom/crash pattern in prices.

As in the standard SIRS model, the epidemic curve overshoots. When a bubble collapses, the infected fraction falls below its long-run equilibrium value, and tends to fluctuate cyclically thereafter. So the compartmental approach is potentially consistent with a rich serial correlation pattern in asset returns at different lags. Chinco (Chinco, 2020) estimates a compartmental model in which social interaction induces stock market bubbles. He reports that industries with a high level of his proxy for the 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 (Shiller, 2000). Such theories are cultural traits which 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.

4.3 Empirical avenues in new evolutionary finance

New evolutionary finance models offer distinctive empirical hypotheses about both familiar and novel test variables. A distinctive implication of the cultural evolutionary approach is that outcomes depend on the transmissibility of different strategies. Empirically, factors that influence transmissibility include 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). We give examples of each of these factors, although they are not completely separable.

Characteristics of the financial trait include whether it is easily observable to others, whether it is vivid or fun to talk about, whether it is simple to observe or communicate, whether external cues relating to the trait are prevalent, and whether potential senders or receivers have an incentive to communicate it. Textual analysis of folk 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 network position. 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 how skeptical they are of the reports of others, and in their propensity to adjust for selection biases. Datasets from social media, as well as survey evidence, have been used to estimate individual social network position and sociability (Hong et al., 2004; Bailey et al., 2018). 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 (tendency for investors with similar traits to be linked), and how intensely investors tend to communicate about their investment strategies or performance.

In many cultural evolutionary models, a cross-sectional implication is that the predicted effects will be stronger for more socially active agents and those who are more central in the social network. Similarly, the effects of transmission bias on market outcomes are predicted to be stronger in networks that are more connected. In sharp contrast, in rational information sharing models (Duffie and Manso, 2007; Özsöylev and Walden, 2011; Walden, 2019), more intense social interaction causes the system to evolve more rapidly toward greater market efficiency.

In (Han et al., 2020), sociability and connectedness are associated with more active investing, as measured by variance and skewness. Consistent with this, Heimer (Heimer, 2014) documents that social interaction is more prevalent amongst active investors (who buy and/or sell stocks) than passive investors who hold U.S. savings bonds. Furthermore, proxies for sociability or connectedness are associated with greater stock market participation (Hong et al., 2004; Kaustia and Knüpfer, 2012; Georgarakos and Pasini, 2011) and investment in more volatile or skewed stocks (Kumar, 2009). The model also implies that convexity of investment flows derives from *social interaction*, consistent with evidence on social influence of stock market investment in Finland (Kaustia and Knüpfer, 2012).

5 Policy and regulation

Regulatory systems evolve through a process in which observers learn what regulations work and which do not. Greater heterogeneity in regulatory systems across countries or principalities can promote the evolution of more effective regulation via greater experimentation and selection of superior outcomes (Romano, 2014). Sunsetting of existing regulations can also promote greater experimentation and avoid regulatory drift owing to large mutations at the time of rare crises (Romano and

Levin, 2020). Both heterogeneity and sunsetting can potentially help regulators adapt to rapidly changing environments, avoid extinction of beneficial policies via random drift, and help them compete more effectively in the evolutionary arms race with investors (whose traits evolve quickly).

The cultural evolutionary approach also suggests new directions for promoting financial literacy and prudent investor behavior. This approach suggests using *evolutionary design* to increase the transmissibility of accurate or functional investor beliefs and behaviors.

For example, psychological research has found that ideas that are cued more heavily by the environment tend to spread more readily (Berger and Heath, 2005). One reason why people find it hard to save is that there are many daily cues (such as social media posts) about new purchases of others. This suggests that to help people who want to save more, it can be helpful to increase cues about saving (or low spending) by others (D'Acunto et al., 2019).

6 Conclusion and new directions for new evolutionary finance

In both classical and behavioral finance, as agents learn from others, financial traits are transmitted between agents. So these fields fall under the purview of evolutionary finance. However, a cultural evolutionary perspective offers new insights for these approaches by clarifying the nature of transmission biases and the evolution of trait populations.

More generally, the coevolution of cultural traits and financial outcomes, as studied in *new* evolutionary finance, is 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. New evolutionary finance studies these issues with a broadened set of financial traits, transmission biases, and focal applications.

New evolutionary finance has promise to help explain important facts about financial markets, such as bubbles and stock return predictability anomalies at different time horizons. Given the efficiencies of fund investing, the slowness of its rise over decades is a natural further topic to be addressed.

Finance scholars have devoted vastly greater attention to how investors learn from market price than on 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 new 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 promising, relatively unexplored direction in new evolutionary finance is to model how coadapted assemblies of folk models, such as the value investing or growth investing philosophies, evolve.

There are different possible sources of complementarity between financial ideas. The ideas underlying portfolio theory are highly transmissible among sophisticated investors owing to compelling logic and usefulness. Other financial ideas combine effectively by appealing to similar moralistic emotions, as in our discussion of the value philosophy. Moral intuitions also offer a possible explanation for why macrocultural traits such as religion are correlated with financial behaviors (Guiso et al., 2006).

The cultural evolutionary approach suggests a program for social economic and finance research. Commentators have long argued that market bubbles crashes, and swings in market sentiment are social in nature, and reflect contagion of emotions as well as ideas. A rich area for future research is to study how emotions bias the transmission of different kinds of investment narratives and behaviors (Lo, 2017; Shiller, 2017). 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 provide an attractive proving ground for refining evolutionary concepts. Financial markets generate 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.

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