Informational cascades in financial markets: review and synthesis

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Abstract

Purpose – The purpose of this paper is to review recent contributions to the theoretical and empirical literature on informational cascades.

Design/methodology/approach – This paper reviews and synthesises the existing literature, methodologies and evidence on informational cascades.

Findings – Many financial settings foster situations where informational cascades and herding are likely. Cascades remain mainly an area of experimental research, leaving the empirical evidence inconclusive. Existing measures have limitations that do not allow for a direct test of cascading behaviour. More accurate models and methods for empirical testing of informational cascades could provide more conclusive evidence on the matter.

Practical implications – Outlined findings have implications for designing policies and regulatory requirements, as well as for the design of collective decisions processes.

Originality/value – The paper reviews and critiques existing theory; it summarises the recent laboratory and empirical evidence and identifies issues for future research. Most of other theoretical work reviews informational cascades as a subsection of herding. This paper focusses on informational cascades specifically. It distinguishes between informational cascade and herding. The paper also reviews most recent empirical evidence on cascades, presents review and synthesis of the theoretical and empirical development on information cascades up to date, and reviews the model of informational cascades with model criticism.

Keywords Herding, Social learning, Bayesian updating, Informational cascades, IPO markets

Paper type Literature review

When people are free to do as they please, they usually imitate each other (Eric Hoffer, 1955).

1. Introduction

There are several means by which the thoughts, feelings and actions of an individual can be influenced by others. Man is a "social animal" (Aronson, 2008). These influences occur through words, observing decisions and consequences of these decisions, and include different learning processes; rational, quasi-rational, or even an updating of beliefs that does not improve decision-making at all. This social influence leads to behavioural convergence or divergence. Convergence begins with infants "mirroring" the facial expressions of their mother. There are different sources of convergence (herding/dispersing, observational influence, rational observational learning, informational cascade (cascade)). Hirshleifer and Teoh (2003) describe these sources. The most inclusive category is herding/dispersing, defined as similarities/dissimilarities in behaviour caused by social interactions between individuals. The last category, informational cascades, depicts a condition in which imitation is inevitable (Hirshleifer and Teoh, 2003).

In this context, informational cascades (disregarding private information) are a subset of herding (behavioural convergence). Examples of "herding" (behavioural convergence) or "cascading" (disregarding private information) amongst market participants are numerous.

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Investors may herd in their decisions to participate or not in the market, in their choices of securities to trade, and in their buy and sell decisions. Market analysts herd in the choice of securities that they follow and in their offered forecasts. Firms herd in their finance and investment decisions, timing of new issues, implementation of new projects, and reporting formats of their earnings. Very often, firms make decisions that protect against or help to profit from herding and cascading tendencies and behaviours of investors and analysts (Hirshleifer and Teoh, 2003). As argued by Scharfstein and Stein (1990), the IPO setting fosters many plausible scenarios that could be associated with cascades and herding.

From a social perspective, cascades can lead to inefficient and sometimes detrimental outcomes for a society (Welch, 2001). According to Kuran (1997), people often have reasons to falsify their preferences (to misrepresent their wants under the perceived social pressure). This preference falsification is ubiquitous and has serious social and political consequences, such as the retention of widely disliked structures and policies and the preservation of structures vulnerable to sudden collapses.

On the other hand, the presence of overconfident entrepreneurs who irrationally attribute lesser importance to the information in the herd and act on their own informational signal may be very useful for social development. Unknowingly or knowingly, they behave altruistically, making irrational choices to their own detriment. Their actions, however, broadcast valuable private information to the rest of the group. This information can potentially inform others about the drawbacks of existing arrangements, merits of alternatives, and the advantages of change (Kuran, 1997; Welch, 2001).

Market participants combined hold very accurate information about the market and its products. However, communication between market participants is often restricted. Information disclosures, therefore, should serve as a means to fill the informational gaps, creating perfect information for all the market participants and leading to "correct" choices where incorrect cascades do not form.

The reasons behind behavioural convergence can be diverse; for a comprehensive review of herding see Spyrou (2013). The focus of this paper is narrower; it addresses the modelling device of cascades and the role of information in financial markets.

The aim of this paper is to provide a brief review of the theory and empirical evidence on cascades and identify open issues and limitations in the literature. Many issues emerge from the discussion. First, there is a substantial amount of research on herding as a more general form of behavioural convergence, while theoretical and empirical literature on cascades is relatively scarce. Second, predictions of laboratory experiments differ from the empirical evidence, and the evidence itself remains inconclusive. Third, the main empirical methodologies on cascades are divided in two main groups based on the supposed rationality/irrationality of investors. These methodologies have limitations in relation to their applicability to real-life settings[1].

The remainder of the paper is organised as follows. Section 2 describes cascades and their characteristics; Section 3 presents an overview of cascades in IPO markets; Section 4 introduces cascade models and their criticisms; Section 5 depicts laboratory and empirical evidence of cascades; and Section 6 concludes.

2. Informational cascades

An individual is perceived to be in a cascade[2], if, through the observation of others' actions, his decisions are not dependent on his own privately held information and his action choice provides no further information to later decision-makers (Hirshleifer and Teoh, 2003).

Due to informational inefficiencies, economic and financial environments often display settings where it may be more rational to base decisions on public signals and ignore private information (Alevy *et al.*, 2007). Studies of chaos theory in financial markets for example demonstrate that meta-knowledge, knowing the limits of one's ability to predict, is much more important than the predictions themselves. Highly complex systems exhibit chaotic behaviour only some of the time (Mandelbrot, 1971). The system will behave quite predictably, but then suddenly shift into a mode of behaviour following a different set of rules. Concerning the stock market, chaos emerges as the result of the psychology of trading, which is never purely rational, as people react with different emotional intensities to gains and losses, and tend to become biased (Levy, 1994; Mandelbrot *et al.*, 1997).

When decisions are made in a sequence and the action choices of earlier investors are publicly known, individuals may rationally choose to imitate the actions of predecessors despite different private information that they might hold. However, cascades are very fragile and display sudden shifts and reversals in behaviour with the arrival of new information. This is because the limited amount of information revealed early in the sequence has a disproportionally large impact on the social welfare (Bikhchandani *et al.*, 1992, 1998; Gale, 1996; Goree and Rogers, 2007).

Cascades can often lead to a complete information blockage (Hirshleifer and Teoh, 2003). These information blockages are an integral part of a cascade and are associated with an informational externality, i.e. the individual decision-maker decides upon an action choice for private reasons and needs with little consideration for the informational benefit of his decision to others. After individual i starts a cascade, individual i+1 obtains no information by observing his choice. By induction, all individuals i+1 find themselves informationally in the position identical to i and make the same choice independently of private information.

Hirshleifer and Teoh (2003) identify behavioural coarsening as a generalisation of the cascade concept, where an individual makes identical choices for numerous signal values and his information is not fully transferred to his observers through his actions. This situation causes partial information blockage, while a cascade is viewed as an extreme case of behavioural coarsening where all possible signals are blocked.

The correct choice could in principle be identified with certainty if the information held by different individuals could be combined; however, since information aggregation is poor in cascades (we largely observe actions, but not the information of others), decisions will also be poor. Nonetheless, individuals perfectly understand that they are in a cascade and rationally assume the poor quality of available information. As a result, even a small public shock can lead to a switch in popular and established behaviour (Hirshleifer and Teoh, 2003).

Kuran and Sunstein (1999) identify availability cascades mediated by the availability heuristic that occurs in societies via public disclosure or over social networks. They emphasise the role of availability entrepreneurs, social agents who seek to exploit the dynamics of availability cascades in order to gain some personal benefits. The availability cascades may improve social welfare but sometimes they bring harm.

Decisions can be improved with the arrival of sufficient public information; yet, the arrival of a single public disclosure may incite the formation of a cascade sooner (Bikhchandani *et al.*, 1992). Similarly, Cao *et al.* (2002) and Hirshleifer and Teoh (2009) argue that decisions are worse on average when past actions are observed with low noise rather than high noise and when individuals observe payoff outcomes in addition to predecessors' actions.

It is unrealistic to assume that the timing and order of choices is exogenous in real investment contexts. When market participants have a choice of postponing their decisions, there can be long periods of inactivity followed by sudden outbursts triggered by project adoption by one firm.

The concepts described above are applicable to models of social learning in which cascades do not occur. As decisions made by individuals have private optimisation as their base and seldom take into account their value for the public information pool, information aggregation is limited even when information blockage is not complete. The sensitivity of action in relation to private signals is very high when the public pool of information is very uninformative.

As the public pool of information grows, sensitivity to private signals is reduced. This loss of sensitivity can arise gradually or abruptly with sudden switches from one extreme to the other, with partial, complete informational blockage or never reach that point (Hirshleifer and Teoh, 2003).

Hirshleifer and Teoh (2003) summarise the general implications of cascades and other rational learning models. They identify idiosyncrasy (poor information aggregation), fragility (fads), simultaneity (delay followed by sudden joint action), paradoxicality (greater public information or higher observability of actions does not improve decisions), and path dependence (the effect of the order of moves and information arrival on the outcomes) as their main characteristics. As demonstrated by Bebchuk and Roe (1999), path dependence in particular plays an important role in the development of the broader social structures and can explain the existing differences in societies.

2.1 Characteristics of a cascades

Information and the aggregation of information play vital roles in the formation and dislodgement of a cascade. In reality, the informativeness of past actions is often reduced to the summary statistics of the predecessors' actions and information keeps accumulating until it is significant enough to outweigh one individual's private signal. At this stage, privately held information is disregarded and a cascade forms (Bikhchandani *et al.*, 1998). Similar development occurs when individuals do not have the opportunity to observe the whole chain but only a few predecessors, such as neighbours, or when only two action alternatives are possible.

According to Lee (1993), as the set of alternatives becomes larger and richer, cascades take longer to form. With a continuous set of action alternatives individual followers, even late in the chain, adjust their actions based on their private signals, and cascades do not form. This suggests that cascades pertain to the situations with choices that are characterised by the elements of discreteness or finiteness. However, individuals tend to divide up actions into discrete choices, moreover, cascades do not require discreteness in informational signals received by individuals. For a cascade to arise signals must be inconclusive (Bikhchandani *et al.*, 1998).

Social psychologists report that people imitate the actions of those who appear to have expertise. It is argued that these behavioural patterns underlie the success of product endorsements and ensure more informed decisions in simultaneous balloting. In financial markets, investors follow the same principle; they imitate the investment decisions of market "celebrities", individuals or firms, who are perceived to be better informed (Hirshleifer and Teoh, 2003).

Individuals differ in many dimensions, including the precision of the received information, preferences and payoffs. Such differences can either exaggerate or moderate cascading behaviour. When each individual's type is observable, his action together with his type communicates information about the signal he received to his follower. If the type of each individual is only privately known and the preferences are downright opposing, followers may have difficulties in inferring the information they receive from the signals of their predecessors. Therefore, even when the actions of individuals are noisy, as long as they are not continuous and unbounded, cascades still form when public information outweighs an individual's private signal in determining his choice (Bikhchandani *et al.*, 1998).

Often, when making a decision can be delayed, there is a cost per unit of time of postponing the decision. Experts or higher-precision individuals gain less from waiting to see the actions of lesser-informed individuals and tend to act fast. When signal accuracy is not public knowledge, the followers learn about the accuracy of their predecessors' signals from the delay before action. Thus, all actions are delayed until one individual triggers an explosion of simultaneous cascading activity. Since the best informed individual acts first, extreme idiosyncrasy occurs where all actions are based on a single individual's information.

In the context of IPOs, the delay before action can act as a signal about the quality of an issue on its own (Bikhchandani *et al.*, 1998). From the issuers'/underwriters' point of view, the shorter this delay is the better. There is a higher chance of inducing a cascade if an "expert" investor acts fast.

Cascades form instantly when individuals have to pay a fixed cost to obtain private information. It is argued that additional information sources can prevent cascades by improving information aggregation. Even when all past actions and outcomes are observable, cascades can still form. A cascade upon a choice with payoffs visible to all may be formed by a number of early joiners, yet an alternative choice may be superior but have hidden payoffs (Bikhchandani *et al.*, 1998). However, according to Fudenberg and Banerjee (2004), the ability to observe a random sample of predecessors' choices and outcomes leads to convergence upon correct actions.

In many realistic settings uniformity is likely in the presence of positive consumption or production externalities because joining a network benefits both the joiner and those who have already joined. According to Choi (1997), in a situation with positive network externalities and imperfect information about outcomes, observational learning determines fixed behaviours and strengthens the path dependence of the outcome.

When only the actions of predecessors are visible, favourable informational externality is weakened and outcomes are relatively inefficient. These informational inefficiencies are due to the limited nature of possible actions and discrete filters of information transmission between individuals. These inefficiencies could be potentially solved through trade in information. The gathering and dissemination of information could possibly be organised through the intervention of an independent third party, such as government, rating agency, or through improvement of the institutions and technologies used for communication by individuals facing similar choices. However, improved communication can also help individuals to observe the actions of others and thus reduce incentives to collect information. This could trigger cascades sooner and extend them further (Bikhchandani *et al.*, 1998).

2.2 Informational Eddy

Besides learning from the public pool of information or personal experiences, agents could base their decisions on observing the actions of their neighbours. However, people tend to exaggerate the degree of the representativeness of a small sample. Tversky and Kahneman (1971) labelled that belief "law of small numbers". Following Tversky and Kahneman (1971), Rabin (2002) and Rabin and Vayanos (2010) model this inaccuracy and demonstrate the differences in inferences made by Bayesians and believers in the representativeness of small samples. Their model demonstrates the over-inference tendency that leads to assumptions of non-existing variations and examines the link between the gambler's fallacy and the hot-hand fallacy.

Benjamin *et al.* (2013) extend the work of Rabin (2002) and Rabin and Vayanos (2010) and develop a model of "non-belief in the Law of Large Numbers". The paper compares beliefs and actions of a non-believer to a purely Bayesian information processor and introduces the notion of "eddy" (informational eddy), where agents follow their own private signal independently of the informativeness of public information. An "informational eddy" can occur for a non-believer, but not for a Bayesian. An "eddy" forms when beliefs are not too extreme initially and the true state has a relatively low weight. If early signals are mixed, the probability of a cascade falls, as for non-believers even a strong signal does not alter their beliefs. Although in an "eddy" it is impossible for all agents to take wrong actions as in an incorrect cascade (because agents apply their non-belief to the inferred signals), "eddies" are on average less efficient than herds as the average payoff is higher in a cascade than in a herd.

3. Informational cascades in IPO markets

Clustering of IPOs has attracted much attention. Studies show that IPOs tend to cluster because of prior underpricing (Lowry and Schwert, 2002) and underwriters' ability to bundle IPOs (Benveniste *et al.*, 2002). Benveniste *et al.* (2003) find evidence that indirect learning from a prior IPO influences a firm's decision to complete or withdraw its own IPO and determines how the offer is priced relative to prior expectations.

Shleifer and Vishny (2003), in their study of clusters in merger and acquisition (M&A) markets, demonstrate that firms have a powerful incentive to get their equity overvalued as firms with undervalued equity become takeover targets. Managers understand stock market inefficiencies and take advantage of them. Following this line of argument, founders have high incentive to use the pricing of their issue to manipulate investment activity, and similarly to M&A markets, founders will tend to rush into an IPO in periods of booms and avoid post-crash periods.

The pricing of new offers is the point of contact between investors and issuers that can provide an insight into the behaviour of market participants and explain existing anomalies (Alti, 2005). In the context of IPOs two types of cascades are possible; firms cascading in their decisions to go public (or remain private) and investors cascading in their decisions to invest into a new issue (or abstain).

A cascade is viewed as a consequence of informational externalities. Each potential issuer holds private information on the expected value of the IPO. However, due to the information spillovers, issuers update their expectation and re-evaluate the IPO decision. Cascades are formed when this spillover information dominates the private information, i.e. after observing a few successful IPOs potential issuers believe that IPOs produce positive value and go public themselves, irrespective of their initial expectations. When this happens, IPO clusters form and with the start of a cascade consecutive issuers blindly follow the herd and no new learning occurs in the market (Draho, 2000; Alti, 2005).

Welch (1992) discusses the role of information through the role of underwriters in an IPO. The information about the value of this IPO may be undetermined by individual investors; however, in combination, investors hold very accurate information about the value of the stock. This scenario predicts success for underpriced IPOs and failure for the overpriced IPOs as potential investors are numerous and a small number of them jointly via deliberation can easily determine the correct value of an IPO.

However, according to Welch (1992), when underwriters have limited distribution channels the situation is reversed, i.e. underpriced stocks fail and overpriced stocks succeed.

This is because with limited distribution underwriters require time to approach interested parties. Due to this time gap, later investors can observe the success of an IPO up to some date and/or its progress relative to the previous offerings of the same underwriter(s). The initial success of an IPO can indicate that early investors had private information favouring the offering and, thus, provide additional incentives for others to invest. On the other hand, slow initial investment can reduce the demand for shares and result in IPO failure.

Therefore, the proceeds of an IPO are conditional on the order in which investors make decisions and receive information. Holding combined information unchanged, an issuer will generally receive higher proceeds if initial investors favour the IPO. The value of an IPO inferred by a relatively late investor does not often reflect its true value.

The inferred value would reflect the true value if later investors could observe signals held by their predecessors. In reality, however, investors are forced to infer information based only on the actions of earlier investors. In that situation, investors base their investment decisions on previously high or low demand. As a result, early investors' beliefs about the value of an IPO can doom the offering to fail, or generate an unlimited demand for the shares. Welch (1992) refers to this effect as a "cascade".

Cascades can be quite beneficial for an issuer. When later investors disregard their private information and act as their predecessors, their decisions provide no further information to later investors. This leaves the issuer at a greater informational advantage and increases the issuer's expected wealth. According to Welch (1992), issuers deliberately prevent communication among investors and hire underwriters to act "as an institution that distributes an offering widely, i.e., to investors who find it more difficult to communicate among themselves" (Welch, 1992, p. 697).

When subscriptions to an IPO are not pro-rata based but are served in a sequential order, IPO underpricing can be explained through path dependence and cascades. The demand curve of the cascade model determines the success or failure of an IPO by the time the first investor who could be rationed is approached, and, as a result, the pricing of an IPO is aimed at convincing earlier investors. When private signals about a firm's aftermarket value distribution are observed by both the issuer and investors, internal and external information is correlated. Under these circumstances, an issuer can set a high price if high future cash flows are expected. This pricing is risky because when many outsiders have negative information, a high price increases the probability of IPO failure. This marginal cost of higher pricing is especially high for a lower-quality issuer.

4. Cascade models

There are a number of papers focussing on different models of herd behaviour, however, herding phenomenon is outside of the scope of this paper. A comprehensive review of recent theoretical developments on the models of herding is presented in Hirshleifer and Teoh (2003), Bowden (2013), and Spyrou (2013). I begin by describing the characteristics of a basic model of informational cascades introduced in the seminal papers by Banerjee (1992), Bikhchandani *et al.* (1992), and Bikhchandani *et al.* (1998). The model introduced by Bikhchandani *et al.* (1992) and Banerjee (1992) is the basic model of informational cascades, later models are extensions of the original model focussing on relaxing the general assumptions of the model. The models that deviate mostly from the original model are the ones focussed on the criticism relating to the rationality of the market participants (Bayesian updating of beliefs, see Section 4.4).

The first drafts of Banerjee (1992) and Welch (1992) were both independent and contemporaneous. Banerjee (1992) and Bikhchandani *et al.* (1992) independently show in different settings that informational cascades (or "herding", in Banerjee's terminology) will eventually occur with certainty. Welch (1992) and Bikhchandani *et al.* (1992) assume discrete actions. Banerjee (1992) assumes continuous actions, but discontinuous preferences. Bikhchandani *et al.* (1992) prove the generality of informational cascades, their fragility, and discuss their applications.

By the argument of the law of large numbers, the accurate reporting of information held by each individual is a sufficient natural condition for information aggregation. A number of papers, most notably Welch (1992) and Bikhchandani *et al.* (1992, 1998), explain how the information fails to aggregate under the conditions of perfect Bayesian learning.

Bikhchandani *et al.* (1992) propose a model explaining conformity in social behaviour and also rapid and short-lived fluctuations, such as fads, fashion, booms and crashes, while Welch (1992) develops the model and applies it to IPO settings.

4.1 Model settings

The model assumes a number of decision-makers facing a choice of adoption or rejection of a certain behaviour. The actions of all predecessors are visible to all and decisions are made in sequence. The cost of adoption, C, is set at 1/2 and is the same for all, as well as the gain from adoption, V, that is either 1 or 0 (with equal prior probability of 1/2). Each decision-maker observes a private signal, X, indicating the value. Signal X_i

(for an individual i) is H or L, probability of H is $p_i > 1/2$ if $V = 1$, and $1 - p_i$ if $V = 0$. The signals are distributed identically ($p_{i=}p$ for all i).

A H signal induces an individual to adopt and an L signal to reject. His follower can make inferences about the value of the signal according to his decision. Adoption by the first individual causes the second individual to adopt if his signal is H. An L signal, however, results in inferred HL signal ordering and reduces the expected value of adoption for the second individual to 1/2. He becomes indifferent between choices and with probability 1/2 he adopts. The reasoning is similar when the first individual rejects. In the case of the third individual three scenarios are possible: adoption by both first and second individual (causing him to disregard his own signal and adopt creating and UP cascade); rejection by both predecessors (inducing further rejection and causing a DOWN cascade even if his signal was H); or one adoption and one rejection, in which case his situation is similar to that of the first. In that case, the fourth individual faces the same choices as the second, the fifth as the third, etc.

An unconditional *ex ante* probability of an UP, DOWN, or no cascade can be determined after the first two individuals. The reduction in p towards 1/2 delays the formation of a cascade and is equivalent to adding noise to the signal. Cao *et al.* (2002) and Hirshleifer and Teoh (2009) correlate this signal precision to higher/lower level of noise and higher/lower sensitivity to private signals.

When only the actions of the predecessors are observed, outcomes are more uniform and, once a cascade starts, information stops accumulating. However, in a situation where the signals of predecessors are also visible, even if a signal is disregarded by an individual, the information is still gathered in the common pool of knowledge and it can improve later decisions.

4.2 Model scenarios

Under the model of observational learning (MOL) two scenarios are distinguished: the observable actions scenario and the observable signals (and actions) scenario. In both scenarios, individuals start with some private information, obtain some information from predecessors, and then make a choice between alternative decisions. Figure 1 presents the basic MOL.

In the observable signals scenario an individual can observe both the actions and signals of his predecessor. All signals are publicly observed, the pool of public information builds gradually, and individuals eventually settle on the correct choice and act in a similar manner. The scenario is summarised in Figure 2.

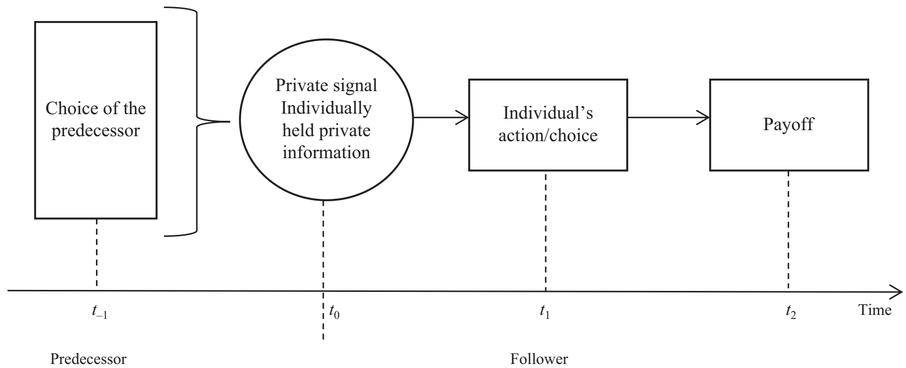

Figure 1. Model of observational learning (MOL)

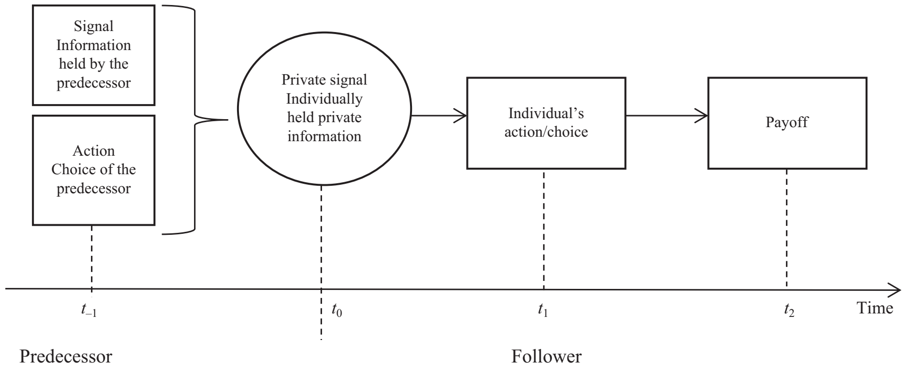

Figure 2.
MOL: observable signals (and actions) scenario

In the situations when only the actions of predecessors are observed the choices of the first few individuals determine the choices of all followers. The behaviour of individuals becomes idiosyncratic and an UP or DOWN cascade is formed. The scenario is presented in Figure 3.

As summarised by Bikhchandani *et al.* (1998), the optimal decision for an individual in the observable action scenario is determined by the difference between the number of predecessors who adopted and the number who rejected.

The outcome of the scenario with observable actions is fundamentally different from the scenario with observable signals. Once the cascade starts, public information stops accumulating and individual followers herd towards the same choice regardless of their private signals that never join the public pool of knowledge.

4.3 Model of informational cascade in IPO markets

The MOL has been applied to the IPO markets by Welch (1992). His model assumes n investors, who are rational, risk-neutral, expected wealth-maximisers. V is the efficient aftermarket value of a share of an IPO and it is unknown to both an issuer and investors. A share is purchased by an investor only if the expected aftermarket value, is equal to or higher than the offer price. The issuer can offer an investor one share, and has a sufficient amount of shares to service each individual investor. The shares are offered to the public once and at a fixed price. Each investor decides to buy or to abstain.

The model assumes that the number of investors approached by the issuer (or his underwriter) is publicly known. The aftermarket value of a firm could be determined

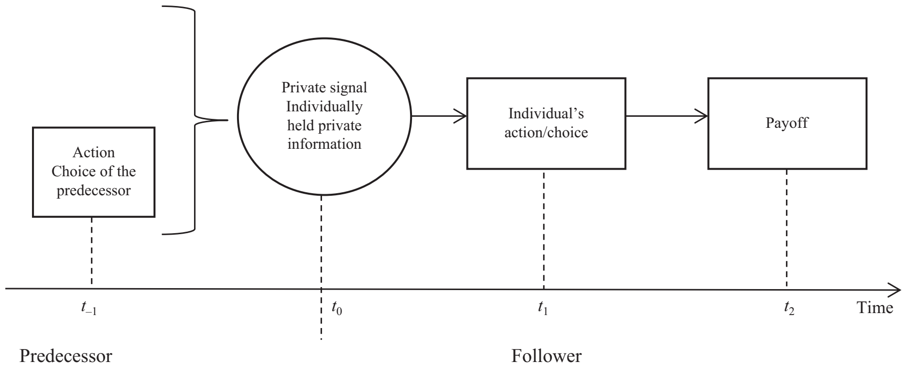

Figure 3.
MOL: observable actions (only) scenario

arbitrarily precisely if investors could communicate with each other. The model could be interpreted to allow for either endogenous or exogenous aftermarket valuation: the large number of signals among investors, when perfectly aggregated, could be the efficient aftermarket value of the offering; or, signals could be informative about an underlying true value that is revealed soon after the IPO.

Welch (1992) identifies three scenarios of investor communication in the IPO market: the perfect communication, the simple path dependence, and the cascade scenarios.

The perfect communication scenario denotes the case where investors can communicate with each other freely and readily. The issuer's goal, expected utility maximisation, can be expressed in terms of price optimisation against the total number of investors with H signals (i.e. the investor guesses the number of investors with H signals and sets the offering price in accordance with that number).

The simple path dependence scenario assumes perfect communication only from early to late investors and implies that each market participant observes only his signal and the privately held information of investors approached earlier. It is important to note that the issuer's proceeds are path dependent

As the number of investors increases to infinitely many (identified as "large market" by Welch, 1992), an issuer's expected outcome becomes the same as in the scenario of perfect communication. In a large market an issuer prices his offering in the similar manner as to when investors have perfect communication. Even for a small number of investors, the issuer is best off pricing as under the perfect communication condition. His proceeds, however, could be higher, because with small n the initial few investors, that make the larger portion of the market, are at a higher informational disadvantage against the issuer (Welch, 1992).

The cascade scenario assumes no communication among investors. When an investor, M, with a H signal finds it optimal not to invest, his followers will conform to the same decision. Even though M's decision to abstain, given previous investment choices, should not be directly interpreted as a received L signal, investor $M+1$ does not learn from his predecessor's action. He will also abstain regardless of his private signal, inducing all the later investors not to invest.

A well-informed market does not accumulate information well and market efficiency does not necessarily prevent the failure of underpriced offerings or guarantee the failure of overpriced offerings. However, the success of an offering can be ensured through setting price at 1/3 and inducing investors to disregard information. Also, when the aftermarket price reflects accumulated information perfectly, both underpriced and overpriced (relative to the aftermarket price) offerings can be successful. This is a distinguishing feature of cascades as overpriced offerings are unsuccessful in other scenarios.

Welch (1992) derives the issuer's optimal price ($\theta = 1/3$) and expected underpricing (0 to 50 per cent). The reasoning behind his theorem is that the price reduction in order to convince market participants to invest is secondary to the risk of a complete failure for any price above the full-subscription price. At optimum price, cascades ensure demand elasticity. This is especially the case with a risk-averse issuer as full-subscription price assures safe proceeds (compared to the uncertainty of proceeds in the simple path-dependent scenario).

Welch (1992) derives the expected proceeds per investor under the three information scenarios as a function of a price. He shows that the optimal price is 1/2 for the perfect communication and the simple path-dependence scenarios. For the cascade scenario it is 1/3, with a sharp decline in proceeds when prices are raised. Expected proceeds in a perfect communication scenario are regular, while a simple path-dependence scenario displays irregular proceeds. Cascade proceeds are chaotic with irregular drops.

A risk-neutral issuer may choose to vary the price in order to induce only investors with H signals to buy, and then create a cascade to induce all subsequent investors to purchase the issue at the price arbitrarily close to the aftermarket value. However, issuers are risk-averse and prefer to price an offering sufficiently low (at the full-subscription price) to create a cascade immediately, forgoing the path-dependent pricing. Therefore, according to Welch's (1992), the issuer is best off in a cascade scenario. The cascade model supports the documented positive relationship between IPO underpricing and *ex ante* risk.

4.4 Model criticisms

A substantial number of papers followed the seminal work of Bikhchandani *et al.* (1992), Banerjee (1992) and Welch (1992). For a comprehensive review see Bikhchandani and Sharma (2001) and Hirshleifer and Teoh (2003).

There are a number of criticisms of the original model of social learning. Bowden (2013) identifies the main four that relate to: the action space, the externally determined sequence of decision-makers, Bayesian updating of beliefs, and the fixed price.

Cascades can arise only in a situation where information is discrete, bounded or with gaps. If a signal is continuous, unbounded, and without gaps, then an individual remains sensitive to his private signal and a cascade does not form (Smith and Sørensen, 2000; Hirshleifer and Teoh, 2003; Çelen and Kariv, 2004; Goeree *et al.*, 2006)[3].

The assumption of the exogenously determined sequence of decision-makers in the observational learning model can be relaxed. Research shows that if market participants have a choice of postponing their decisions, there can be long periods of inactivity followed by sudden outbursts triggered by project adoption by one firm (Beaudry and González, 2003; Chari and Kehoe, 2004; Chamley, 2004; Banerjee and Fudenberg, 2004)[4].

A number of researchers relax the assumption of sequential decision-making through the introduction of the concept of a social network, where market participants observe decisions and payoffs of the investors to which they are connected. Some decisions are inherently social and in such circumstances agents base their decisions on the subset of society; for example the Royal Family, in Bala and Goyal (1998). Information gathering in finite-agent societies is generally incomplete and cascades within a network can lead to clustering (Gale and Kariv, 2003; Acemoglu *et al.*, 2011).

The assumption of Bayesian updating of beliefs does not hold in more complex decision-making scenarios. Recent research shows that market participants are more likely to deviate from Bayes' rule and follow their own private signal when signals have varying precision or the framework for decision-making is more complex than under Bikhchandani *et al.* (1992). Perceptions about the quality of the previous signals, as well as the overconfidence heuristic are found to be the likely causes of the deviant behaviour (Çelen and Kariv, 2005; Guarino *et al.*, 2006; Drehmann *et al.*, 2005; Goree and Rogers, 2007; Spiwoks *et al.*, 2008; Grebe *et al.*, 2008)[5].

Cascade behaviour may emerge even when the fixed price assumption is relaxed. Avery and Zemsky (1998) extend the Bikhchandani *et al.* (1992) model and introduce multiple dimensions of uncertainty. The assumption of "event uncertainty" – uncertainty over whether the received signal is an informative one – gives additional informational advantage to informed traders over market-makers (who adjust prices sluggishly as a result of their ignorance over the signal informativeness). As a result, insiders adjust their expected value quicker than the market-maker, while the price adjustment remains slow. In the extreme scenario where event uncertainty is a complete surprise, the market-maker recreates the scenario of Bikhchandani *et al.* (1992) by completely ignoring the event and fixing the price. Hirshleifer and Teoh (2003) characterise the behaviour described by Avery and Zemsky (1998) as pseudo-cascading that can, nonetheless, lead to partial information blockages.

5. Informational cascades: empirical evidence

Informational cascades are defined as one of the sources of herding as the most inclusive category of behavioural convergence (Hirshleifer and Teoh, 2003). Herding in general has been studied by many researchers, while cascades remain an area of predominantly experimental literature. For a critical review of the early methodology and empirical studies on herding in financial markets, see Bikhchandani and Sharma (2001). For a comprehensive review of the later empirical evidence on herding see Spyrou (2013).

Following Anderson and Holt (1996, 1997), several laboratory and controlled experiments offering more decisive evidence on the validity of the rational view of cascades have been conducted (Holt and Anderson, 1996; Anderson and Holt, 1996, 1997; Noeth *et al.*, 1999; Drehmann *et al.*, 2005; Alevy *et al.*, 2007)[6].

Anderson and Holt (1996, 1997) and Holt and Anderson (1996) confirm the predictions of the model by Bikhchandani *et al.* (1992). They find that cascades form in approximately 80 per cent of the cases where the possibility arises. They also find that the "reverse cascades" that form with the first few misrepresentative signals are not broken by the correct signals received later in the sequence.

Willinger and Ziegelmeyer (1998) replicate the experiment of Anderson and Holt (1996, 1997), with an attempt to shatter potential cascades through raising the amount of agents' private information. Ziegelmeyer *et al.* (2005) attempt to reduce information inefficiency by changing the order of participation to endogenous, i.e. agents are able to choose the moment that they step into the sequence (the agents in the influential subset become endogenously determined, according to the quality of their private information). Their results confirm the findings of Anderson and Holt (1996, 1997) and demonstrate that additional private information increases the agents' sensitivity to privately held information and is sufficient to stop wrong cascades and improve economic efficiency. Hung and Plott (2001) extend the study of Anderson and Holt (1996, 1997) and examine information production and gathering under three different scenarios of institutional organisation: individualistic institution – agents rewarded according to the right or wrong decision, as in Anderson and Holt (1996, 1997); the majority rule institution – agents rewarded if the majority of announced decisions are right; and the conformity-rewarding institution – where agents have an incentive to be right, but are rewarded more if they do not deviate from others' decisions. They find that individual decisions change with the change of an institution. Agents place significantly higher weight on public information rather than on private information in the conformity-rewarding scenario. Under the majority rule scenario the situation is reversed and private information has much higher value relative to the public information. The findings of Hung and Plott (2001) indicate that the choices of others carry important information that needs to be incorporated with agents' "own decisions", and following the crowd reflects an element of wisdom. On the other hand, the rules of the institutions make a difference and great care should be exercised when designing collective decisions processes.

A number of laboratory experiments address the deviation from Bayes' rule in decision-making. Huck and Oechssler (2000) find that subjects deviate from Bayesian updating of beliefs when faced with more complex decision-making frameworks. Anderson (2001) changes the payoff structure and finds that most deviant decisions are based on a private signal. Guarino *et al.* (2006) suggest that individuals can relate only to their own experiences; they are unaware of the experiences of the previous decision-makers and, therefore, tend to follow their own signal. However, according to Da *et al.* (2014), the deviation from the rational decision-making can be affected by how the information arrives. Investors are less attentive to gradual changes and tend to underreact to information that arrives on a continuous basis in small amounts compared to sudden dramatic informational shocks. Therefore, the slow partial release of information will not generate the same reaction in investors as the arrival of large amounts of information released at discrete time points.

Goeree and Palfrey (2007) conduct laboratory experiments with very long sequences of varying signal informativeness. Their findings are different to the short horizon experiments of Anderson and Holt (1996, 1997). While standard cascade theory predicts that information stops aggregating after a few initial decisions, Goeree and Palfrey (2007) show that learning is continuous and for long sequences public beliefs tend to be correct.

Kübler and Weizsäcker (2004) introduce a cost for obtaining a signal. According to their results, early investors attribute a high error rate to the preceding signals and overinvest in obtaining information, while later investors ignore the possibility of being in a cascade, spend less on buying the signals and end up in a cascade. Grebe *et al.* (2008) provide an explanation as to why decision-makers deviate in early stages, but follow the predecessor once the cascade sets in. They find that overconfidence results in a higher chance of agents assuming that the action of their predecessor reveals his signal; they ignore the possibility of being in a cascade and follow the predecessors' choice.

The general lessons of laboratory experiments have implications for policy and law. They show that errors are most likely when people are rewarded for conforming and least likely when people are rewarded for helping groups and institutions to decide correctly.

6. Concluding remarks

This paper presents an overview of the theoretical and empirical developments relating to the area of informational cascades in financial markets. The main issues that emanate from the discussion are as follows.

First, theoretical developments in the area of social learning and behavioural convergence reveal that what often seems irrational is actually a natural reaction in a certain context. Seminal work by Bikhchandani *et al.* (1992) shows that cascades form very quickly, often on the wrong decision, and are very fragile and easily dislodged. Many financial settings foster situations where cascades and herding are possible. Following Welch (1992, p. 697), issuers/underwriters operate in an informational environment where cascades form quickly, generating higher short-term proceeds. The pricing of an IPO is aimed at convincing earlier investors and is often manipulated in order to induce early investors to disregard their private information. Thus, issues are underpriced to reward early investors. Underpricing is used by the issuers reflecting their risk-averse preferences.

Second, the empirical evidence on cascades remains inconclusive; perhaps due to the fact that while herding in general has attracted substantial attention in empirical literature, cascades remain an area of largely experimental research. Several lessons, however, emerge from the existing evidence. These lessons indicate that the role of information in financial markets has huge significance for policy and law. Thus, rewarding conformity leads to more errors, while helping groups and institutions decide correctly reduces the number of errors and cascades.

Third, existing measures of cascades in financial markets have limitations that do not allow for a direct test of cascading behaviour. The main theoretical models of cascades assume sequential or simultaneous trading and examine the development of cascades and the role of information in their formation and dislodgement. There are a number of criticisms of the original model of social learning relating to the discreteness/boundedness of the action space, externally determined sequential decision making, Bayesian rationality, and fixed price. Fourth, inconsistencies between the theoretical developments and suitable data sets make it problematic to test many of the theoretical predictions and issues. This leads to the indirect application of empirical tests and development of proxies.

In conclusion, there are a number of issues for future research. For example, designing more accurate models and methods for empirical testing for cascades could provide more conclusive evidence on the matter. Studies that deal with cascades could differentiate between different industries and types of investors. More close attention should be paid to the communication and information exchange between market participants, such as different types of investors and/or different financial agents. Furthermore, more profound research is needed on the role of information in financial markets. If information releases are manipulated in order to induce cascades and create short-term profits or are misrepresented or falsified under perceived social pressure, then there is a greater need for clearer policies on information disclosure, information gathering, and dissemination.

Notes

1. Note that it is beyond the scope of this paper to discuss informational cascades in contexts other than those related to financial markets and that the review aims to cover some of the most important breakthrough results and significant issues.
2. Herding, as specified in Section 1, is a more general phenomenon than an informational cascade though both result in behavioural conformity. The homogeneity of a herd may arise through means other than informational cascades, such as payoff externalities, preferences for conformity, or sanctions.
3. See also Lee (1993) and Vives (1993).
4. See also Chamley and Gale (1994) and Zhang (1997).
5. See also Huck and Oechssler (2000), Anderson (2001) and Kübler and Weizsäcker (2004).
6. See also, e.g. Goidel and Shields (1994), Bounmy *et al.* (1998), Sadiraj *et al.* (1999), Allsopp and Hey (2000), Huck and Oechssler (2000), Ashiya and Doi (2001), Hung and Plott (2001), Oberhammer and Stiehler (2001), Nöth and Weber (2003), Plott *et al.* (2003), Kübler and Weizsäcker (2004), Kraemer *et al.* (2006), Cipriani and Guarino (2005), and Drehmann *et al.* (2005).

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