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A reconsideration of the theory of social predictions

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A RECONSIDERATION OF THE THEORY OF SOCIAL PREDICTIONS

Abstract:

We study whether the fact that social predictions may be *self-altering* prevents the formulation of correct public predictions. We build a dynamic model inhabited by two types of actors: 'hermits' and "trackers". The former act *opposite* to what they expect other actors to do whereas the latter act the *same way* they expect others to act. We assume that individual actors revise expectations in the aftermath of forecast errors. We obtain the following results: First, when the proportion of 'hermits' in the referential group is significant a correct public prediction is possible if a correct private prediction is possible even if forecasters don't know the extent to which public predictions are believed. Second, when all actors in the referential group are 'trackers' and forecasters are *fully* believed a correct public prediction is possible even if a correct private prediction isn't. Our results extend and qualify the 'classical' results in Grunberg & Modigliani (1954) and Simon (1954) in a more general theoretical framework.

Keywords: Equilibrium; Expectations; Self-defeating Predictions; Self-fulfilling Predictions.

UNA RECONSIDERACIÓN DE LA TEORÍA DE LAS PREDICCIONES SOCIALES

Resumen:

En este trabajo abordamos el problema teórico de si la naturaleza auto-alterable de las predicciones sociales puede impedir la formulación de predicciones públicas correctas. Para ello construimos un modelo dinámico habitado por dos tipos de individuos: 'eremitas' y 'rastreadores'. Mientras que los primeros actúan de forma opuesta a como esperan que el resto de los individuos actúe, los segundos actúan de forma similar a como esperan que actúen los demás. También suponemos que los individuos revisan sus expectativas a la luz de los errores de predicción cometidos. Los dos principales resultados que obtenemos son los siguientes. En primer lugar, cuando la proporción de 'eremitas' en el grupo referencial es significativo es posible formular predicciones públicas que sean correctas siempre y cuando la predicción privada correspondiente también sea correcta. En segundo lugar, cuando todos los actores en el grupo referencial son 'rastreadores' y las predicciones públicas tienen total credibilidad entonces es posible formular predicciones públicas correctas incluso cuando la predicción privada asociada es incorrecta. Estos resultados extienden y matizan los resultados en los estudios 'clásicos' de Grunberg y Modigliani (1954) y Simon (1954) en el contexto de un marco teórico más general.

Palabras clave: Predicciones autocumplidas; Predicciones autoincumplidas; Equilibrio; Expectativas.

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1. Introduction

Prediction is important for science for two reasons. First, every human being has a practical interest in knowing the future. Science may help to satisfy this need by formulating theories which can be used as a basis for expectations. Second, the standard way of testing theories is to subject their predictions to empirical tests. However, philosophers and social scientists recognize that social predictions pose specific methodological problems owing to: (i) the complexity of social phenomena makes it virtually impossible to formulate law-like generalizations about them, (ii) free will, and (iii) the fact that social predictions may be *self-altering* thus making themselves true or untrue.[1] The announcement of a prediction (falsely or otherwise) may set off a sequence of events in reaction to prediction of a future state such that the reaction alters what would otherwise have occurred. Starting with Merton (1948), a long list of social scientists and philosophers have recognized that the *self-altering* nature of predictions is a feature of the social world that creates a philosophical and methodological problem for the social sciences (Popper 1957; Henshel 1982; Kopec 2011). First, if social phenomena can be altered by public predictions (i.e., predictions that are announced) then the interpretation of the results of empirical tests becomes problematic. A 'false' prediction may be confirmed if expectations are self-fulfilling while a 'correct' one may be falsified if they are self-defeating. Second, the impact of predictions on expectations raises the issue whether a correct public prediction is feasible. This issue was originally studied by Grunberg and Modigliani (1954) (hereafter G&M) and Simon (1954).[2] These studies use Brouwer's 'Fixed-Point' theorem in topology to refute the thesis that social scientists cannot predict publicly and correctly. The study in G&M are more general than the one in Simon where the discussion focusses on the impact of election polls on election outcomes. Both studies are premised on the notion that a public prediction may alter social outcomes so that the goal is to ascertain whether a correct public prediction exists. Similarly, both studies use the above-mentioned theorem to show that the *boundedness* of the variables of the system and their *continuity* over the relevant intervals of the functions that relate the variables to each other are sufficient conditions for the existence of a correct public prediction. In light of it, G&M (*op. cit*., 478) conclude that 'the major difficulties of predicting in the domain of social phenomena turn out to be those of private predictions'.

In retrospect these studies were an attempt to respond to the literature on *self-altering* predictions triggered off by Merton's above-alluded work on self-fulfilling prophecies. They sought to show that it is possible to have a correct theory, formulate a public prediction based on it that changes the expectations and behavior of actors, and still have the prediction turn out to be correct. Although the economic model used in G&M seeks to capture the working of the market for a typical commodity it exhibits a peculiar feature. It consists of a system of simultaneous equations whose (non-trivial) solution constitutes the correct private prediction p^*. If the system of equations can be solved (i.e., if it is determined) then the model can be represented by equation $p=R(P)$ where P denotes the public prediction, p denotes the value of the predicted variable, and R is a continuous non-linear function. Since function R implies that p is affected by P then the exercise consists of finding out whether there exists a correct public prediction P^* such that $p^*=R(P^*)=P^*$. The main formal result is that P^* exists if R is *continuous* and *bounded*. Equation $p=R(P)$ implies that the equilibrium market price depends on suppliers' price expectations which, in turn, depend on P. This implies, for instance, that the equilibrium market price that obtains if P is *fully* believed differs from the one that obtains if P is *less-than-fully* believed. As a result of it there is a different P^* and p^* for every possible specification of suppliers' expectations equation. Furthermore, the formulation of P^* requires that forecasters know R which requires *knowing all the equations all the model including the extent to which P will be believed by suppliers*. These information requirements are stringent and imply that, even if P^* exists, public forecasters may never get to know it! However, the main attractiveness of a decentralized market economy resides in the notion that the existence of competitive markets may ensure that an efficient allocation of society's resources obtains without public authorities having to collect and process large amounts of information. In fact, market equilibrium in G&M differs markedly from market equilibrium in standard demand-supply analysis where market participants' expectations may affect the adjustment path that market prices follow before market equilibrium is attained but do not affect the latter. The implications of the assumptions made in G&M may be better appreciated by inspecting an extension of their work in Rothschild (1964) who employs the 'cobweb' model of agricultural commodities to study the dynamics of the market price of a commodity in a theoretical setting similar to G&M's. Rothschild (op. cit.) shows that, if local stability conditions are satisfied and the public prediction is perfect ($P=P^*$), the market price will exhibits dampened cyclical oscillations as it converges to stationary equilibrium. Yet he finds that if public forecasting is less-than-perfect ($P \neq P^*$) and P is fully or less-than-fully believed the market price *never* attains equilibrium!

Although the importance of the pioneering studies in G&M and Simon (1954) can hardly be overrated we believe that the feasibility of correct public predictions can and should also be studied in the context of a theoretical framework where (i) equilibrium may or may not be affected by actors' expectations, and (ii) equilibrium may be attained regardless of the correctness of public predictions. In contrast to the model used in G&M our model is dynamic and disaggregated: it is inhabited by a very large number of microscopic actors who face a dichotomous choice-problem and revise expectations in the aftermath of last period' forecast errors. The revision of expectations constitutes a notable difference with respect to previous works and implies that following the announcement of a public prediction individual actors revise expectations in the aftermath of forecast errors. We evaluate the feasibility of correct private and public predictions using sequential and graphical analysis. An important feature of the model is the distinction between two different types of actors: 'hermits' and 'trackers'. The former act *opposite* to what they expect other actors to do whereas the latter act the *same way* they expect others to act. There is a long tradition in the social sciences of study of binary or dichotomous choices. The list of works is too long to cite here. A source of inspiration for us is the conceptual framework and examples discussed in Schelling (1971, 1978), however. We believe the theoretical distinction between 'hermits' and 'trackers' is relevant for, at least, three reasons. First, it allows us to identify the formal requirements for the emergence of self-defeating and self-fulfilling expectations. Second, it allows us to identify the circumstances under which equilibria may be either stationary or bootstrapped. Last, the dynamic behavior of the system is driven by the interaction between actors' forecast revision and the pattern of behavior of 'hermits' and 'trackers'.

Our main findings may be summarized as follows. First, and foremost, we show that the results in G&M are valid only if the proportion of 'hermits' in the referential social group is significant. In such circumstances equilibrium is *stationary* and locally stable and a correct public prediction is possible if a correct private prediction is possible. Yet there is a notable difference between our results and G&M's. While G&M assume that public forecasters know how expectations are formed including the extent to which public predictions are believed, we assume the opposite. Second, we find that if all or the vast majority of members of the referential social group are 'trackers' equilibrium is *bootstrapped* and expectations are self-fulfilling. This implies that, if public predictions are *fully* believed, a correct public prediction is possible even if a correct private one isn't. Furthermore, this finding suggests that if public forecasters knew precisely the extent to which a public prediction is believed — which is an assumption made in G&M — they could simultaneously formulate a false public prediction and a correct private one. All in all these findings imply that when the referential social group includes a significant proportion of 'hermits' the main obstacle to the formulation of a correct public prediction is the possibility of formulating a correct private prediction whereas, when all or the vast majority of members of the group are 'trackers', the obstacle to the formulation of a correct public prediction is forecaster's credibility. Last, our results also suggest that the formulation of correct public predictions is largely circumscribed to social situations where equilibrium is stationary and locally stable, namely, to situations where the referential social group includes a significant proportion of 'hermits'.

The content of this study is as follows. In the following section we expound a model of a social system composed of a large number of microscopic actors who face a dichotomous choice problem and act strategically. In section 3 we make a distinction between 'hermits' and 'trackers' and identify the conditions for the emergence of 'self-defeating expectations' (SDE) and 'self-fulfilling expectations' (SFE). In section 4 we use an abridged version of the model to illustrate a typical social event in which all actors are either 'hermits' (i.e., traffic jams) or 'trackers' (i.e., bank runs). In section 5 we address the issue whether a correct public prediction exists when individual actors do not revise expectations. In section 6 we discuss the same issue when individual actors revise expectations in an adaptive fashion. Last, section 7 summarizes and concludes.

2. The general model

In this section we expound a general model which can be used to study a broad range of social situations. The model seeks to capture typical social situations characterized by the presence of a large number of microscopic actors who act strategically. By *microscopic* we mean that the social impact of the action of any individual actor is negligible. An important feature of the model is that the choice-problem an actor faces is *dichotomous*: cooperate or defect. By cooperation we mean that an actor contributes to the provision of a common good, or helps avert or mitigate a social bad, or complies with certain norms, etc. By defection we mean the opposite. Another feature of the model is that the *motives* behind the behavior of an individual may consist of pecuniary and non-pecuniary ones like moral, quasi-moral, and social norms. Following Elster (2007, 104), the difference between, on the one hand, moral norms and, on the other hand, both quasi-moral and social norms is that while the former are *unconditional* and *pro-active* the latter are *conditional* and *reactive*. Social norms resemble quasi-moral norms in that they are triggered by the presence or behavior of other people yet they differ in another way: while the former are triggered only when other people can observe what the actor is doing, quasi-moral norms are triggered solely when the actor can observe what other people are doing (*op. cit*.). An example of a moral norm is the Kantian principle of action according to duty known as the ‘Categorical Imperative’. An actor who adheres to it will act in a way that is compatible with its fulfilment regardless of what other actors do and of what she expects other actors to do. For this reason, we denote the actors who follow the Kantian principle as *unconditional* co-operators.

Let's now describe the functions that characterize the behavior of individual actors. TB_i and TC_i denote respectively the total pecuniary benefits an individual actor *i* obtains and the total non-pecuniary costs she incurs *if she defects*. Thus an actor *i* cooperates if $TB_i < TC_i$ and defects otherwise. Non-pecuniary costs (e.g., shame, guilt, etc.) stem from the violation of moral, quasi-moral, and social norms. A (rational) actor *i* decides whether to cooperate or defect after *comparing* TB_i and TC_i albeit such decision may not necessarily be the result of deliberation. As we noted above, a feature of the model is that every actor is microscopic relative to the social group she belongs to. This implies that she doesn't consider the impact of her action upon other actors' expectations and actions. Another feature of the model is that the value of functions TB_i and TC_i depends on the proportion of actors an actor *i expects* to cooperate $0<Z_i<1$. If an actor *i* expects all other actors to cooperate then $Z_i=1$ whereas, if she expects all other actors to defect, then $Z_i=0$. We denote by Z_i^* the value of Z_i at which $TB_i = TC_i$ for actor *i*. Thus, Z_i^* is a *critical* value in the sense that, if $Z_i = Z_i^*$, an actor is indifferent between cooperating and defecting. We depict functions TB_i and TC_i in Figure 1 below. We measure Z_i on the abscissa and both TB_i and TC_i on the ordinate. The value of Z_i^* on the abscissa depends on all the factors that affect the position and slope of TB_i and TC_i which we may denote, for convenience, as the incentive structure actor *i* faces. To simplify matters, we assume that (i) the schedule of TB_i does not depend on Z_i (i.e., it is horizontal), and (ii) both schedules are *linear*. The linearity of TB_i and TC_i implies that every individual actor has only one Z_i^* and that, if a stable stationary equilibrium exists when the choices of all members of a social group are aggregated, it is *unique*. It follows that, when TC_i cuts TB_i, *ceteris paribus*, an upward shift of TC_i or a downward shift of TB_i reduces the likelihood of defection and vice-versa.

Next, we postulate the existence of four different scenarios regarding the position and slope of TC_i: (A) *i* is an unconditional defector, (B) *i* is an unconditional co-operator, (C) *i* is a conditional co-operator who follows quasi-moral norm ‘cooperate if the “commons” is in peril; otherwise not’, and (D) *i* is a conditional co-operator who follows quasi-moral norm ‘cooperate if others do; otherwise not’.[3] Hereafter we denote the conditional co-operators associated to scenarios (C) and (D) as ‘hermits’ and ‘trackers’ respectively. More generally, ‘hermits’ act *contrary* to what they expect most other actors to do whereas ‘trackers’ act the *same way* they expect most other actors to act. We also assume that TB_i is the same in all four scenarios identified above. We depict TC_i^A and TC_i^B by horizontal dashed lines lying respectively *below* and *above* TB_i. It follows that, in Figure 1 below, $TC_i^A < TB_i$ and $TC_i^B > TB_i$ for any value of Z_i so that Z_i^* cannot be computed in scenarios A and B above. Thus, unconditional defectors (co-operators) will defect (cooperate) regardless of what they expect others to do. From an analytical viewpoint there is little we can say about these two types of actors except that their proportion in a social group may affect the behavior of conditional co-operators *via* the impact on the latter’s expectations. Throughout we focus on the study of the behavior of ‘hermits’ and ‘trackers’.

< Insert Figure 1 here >

In scenario (C) in Figure 1 above TC_i^C cuts TB_i from *above* whereas in scenario (D) TC_i^D cuts TB_i from *below*. The decision whether to cooperate or defect by an individual actor *i* in scenarios (C) and (D) thus depends on (i) her incentive structure as captured by Z_i^*, and (ii) her expectations about other actors' behavior Z_i. A 'hermit' (scenario C) cooperates if $Z_i < Z_i^*$ and defects otherwise ($Z_i > Z_i^*$) whereas a 'tracker' (scenario D) cooperates if $Z_i > Z_i^*$ and defects otherwise ($Z_i < Z_i^*$). For example, in Figure 1 above a 'hermit' cooperates if $Z_i = Z_{i,1}$ and defects if $Z_i = Z_{i,2}$ while a 'tracker' cooperates if $Z_i = Z_{i,2}$ and defects if $Z_i = Z_{i,1}$. Changes in the incentive structure an actor faces are captured by shifts in TB_i or TC_i, or both, and may result in either vertical shifts of these schedules or changes in their slopes, or both. When TC_i cuts TB_i then, if TB_i shifts upwards or TC_i shifts downwards there will be a rise in the likelihood that, for a given Z_i, an actor *i* chooses to defect regardless of whether she is a 'hermit' or 'tracker' and vice-versa. In turn, this means that if TC_i is sufficiently low and/or TB_i is sufficiently high both 'hermits' and 'trackers' may become unconditional defectors. Similarly, when TC_i cuts TB_i, if TC_i is sufficiently high and/or TB_i is sufficiently low then both types of actors may become unconditional co-operators.

3. The micro-foundations of social phenomena: 'Hermits' *versus* 'trackers'

For readers familiar with game theory it shouldn't come as a surprise that the type of behavior we have associated above to 'hermits' resembles the behavior of players in 'Chicken Game' whereas the behavior we have associated above to 'trackers' resembles that of players in 'Assurance Game'. In the 2x2 version of 'Assurance Game' (two players each one facing a dichotomous choice-problem) there are two equilibria: one where both players cooperate and another one where both players defect. In the 2x2 version of 'Chicken Game' there are two pure equilibria and a single mixed equilibrium that depends on the payoffs.[4] By contrast, in the games shown below there is a *continuum* of outcomes exhibiting different proportions of co-operators and defectors. For any aggregate outcome the expectations of an individual actor may or may not be fulfilled and, if unfulfilled, she will revise expectations in the next period. Particularly relevant for this study is the fact that the pattern of behavior of 'hermits' and 'trackers' may lead respectively to the emergence of SDE and SFE.

From our presentation of the basic features of the general model above there follows that, for a given Z_i^*, the decision whether to cooperate or defect by actor *i* will depend on (i) whether she is a 'hermit' or a 'tracker', and (ii) her expectations about the behavior of others, Z_i. The relative proportion of actors who cooperate and defect is determined by the proportion of 'hermits' and 'trackers' in the referential social group and the distribution of Z_i^* and Z_i across actors. Throughout we assume that Z_i^* is given and seek to find out how the joint distribution of Z_i^* and Z_i across actors affects the proportion of co-operators and defectors. To facilitate the exposition we denote by *n* the total number of individual actors in a group and represent the *joint* distribution of actors' expectations and incentives *X* as follows:

$$X = \frac{\sum_{i=0}^{i=n} F(Z_i - Z_i^*)}{n} \quad \text{where } F = \begin{cases} -1 \ \ if \ \ Z_i < Z_i^* \\ 0 \ \ if \ \ Z_i = Z_i^* \\ 1 \ \ if \ \ Z_i > Z_i^* \end{cases}$$

If $Z_i - Z_i^* > 0$ actor *i* will cooperate if she is a 'tracker' and defect if she is a 'hermit'. If $Z_i - Z_i^* < 0$, she will cooperate if she is a 'hermit' and defect if she is a 'tracker'. For the sake of simplicity we assume that the probability distributions of Z_i and Z_i^* are normal. In

Figures 2 and 3 below we assume that all actors are ‘hermits’ and ‘trackers’ respectively. Let us consider three scenarios in Figure 2 below. In scenario (1) we have that X < 0 so that the proportion of ‘hermits’ who cooperate exceeds the proportion of them who defect. In scenario (2) we have that X > 0 so that the proportion of ‘hermits’ who defect exceeds the proportion of them who cooperate. This scenario may be interpreted as a coordination failure. In scenario (3) we have that X = 0 so that half the ‘hermits’ defect while the other half cooperate. If we assume (i) that there are no minimum thresholds in the actual proportion of actors who need to cooperate or defect for a social event to occur and (ii) the probability of the occurrence of social events is directly proportional to the proportion of actors who cooperate or defect, then the larger $|X|$ is the more likely it is that the event will occur when all or the vast majority of actors are ‘hermits’.[5]

< Insert Figure 2 here >

Let us consider Figure 3 below where all actors are ‘trackers’. In scenario (4) we have that X < 0 so that the proportion of ‘trackers’ who defect exceeds the proportion of them who cooperate. This scenario may be interpreted as a coordination failure. In scenario (5) we have instead that X > 0 so that the proportion of ‘trackers’ who cooperate exceeds the proportion of them who defect. In scenario (6) we have that X = 0 so that half the ‘trackers’ defect while the other half cooperate. If we assume that (i) there are no minimum thresholds, and (ii) the probability of a social event is directly proportional to the proportion of actors who cooperate or defect then, the larger $|X|$ is the more likely it is that the event will occur when all or the vast majority of actors are ‘trackers’. Last, we are now in a position to identify the formal requirements for the emergence of SDE and SFE. For expectations to be either self-defeating or self-fulfilling it is necessary that a large enough proportion of actors in the referential social group be ‘hermits’ or ‘trackers’ respectively and $|X|$ be large enough.

< Insert Figure 3 here >

4. The *Homo Economicus* version of the model

There are some phenomena in which non-pecuniary motives don’t play a significant role. Thus, it may be useful to use a simpler version of our model where actors’ behavior is driven solely by pecuniary motives. Let us denote it as the *Homo Economicus* version of the model. Let us replace functions TB_i and TC_i in the model sketched out above by a function we denote by NB_i which captures the ‘net total pecuniary benefits’ associated to an action. In particular, NB_i includes all those factors an individual actor perceives as the opportunity cost of an action like lost income and wealth, foregone leisure, etc. In Figures 4 and 5 below we measure NB_i on the ordinate and measure Z_i on the abscissa. Since non-pecuniary motives (e.g., guilt, shame, pride) do not affect behavior in the examples discussed in this section we cannot define the choice-problem an individual actor *i* faces as one between cooperation and defection. The dichotomous choice-problem actor *i* faces implies following a course of action if $NB_i > 0$ or following the *opposite* one if $NB_i < 0$. The slope of NB_i in Figures 4 and 5 below will depend on the type of social event. We use the *Homo Economicus* version of the model to illustrate the choice-problem of actor *i* in two typical events: Traffic jams and bank runs.

4.1. Traffic jams

We depict the problem-situation facing a typical driver in Figure 4 below. A driver *i* is a 'hermit': she tends to act the *opposite* way she expects other drivers to act. Let's consider an example where *i* must choose one of two possible routes (A or B) to reach her destination. We measure the proportion of drivers that *i expects* to choose route A, Z_i, on the abscissa and measure *NBi* on the ordinate. If *i* expects most other drivers to take route A she will choose route B instead to avoid getting stuck in a traffic jam. By contrast, if she expects most other drivers to take route B she will choose route A. This decision rule is shown in Figure 4 below. The schedule of *NBi* is downward-sloping. The value of Z_i^* is determined by the intersection of *NBi* and the abscissa, i.e., the value of Z_i when *NBi = 0*. It follows that, if the proportion of drivers that *i* expects to take route A is equal to $Z_{i,1} < Z_i^*$ in Figure 4, she will take choose route A whereas, if the proportion of drivers she expects to take route A is equal to $Z_{i,2} > Z_i^*$, she will choose route B. Thus, Z_i^* is a *critical* value of the proportion of drivers that *i* expects to take route A. If both routes are equally preferred in terms of road quality, dangerousness, distance, etc., then $Z_i^* = 1/2$. If the routes are not equally preferred Z_i^* will take a value that differs from 1/2. For example, if driver *i* has a higher preference for route A the schedule of *NBi* will shift *upwards* thus making $Z_i^* > 1/2$ and vice-versa. What are the factors that may explain the occurrence of a traffic jam? The likelihood that a traffic jam occurs will depend on the probability distribution of $Z_i - Z_i^*$ across drivers. If most drivers *expect* most other drivers to take route A then the most likely outcome is a traffic jam in route B and vice-versa. If half the drivers *expect* most other drivers to take route A and the other half *expects* most drivers to take route B then half the drivers will take route A whereas the other half will take route B thus making the likelihood that a traffic jam occurs in any of the routes much lower.

In short, traffic jams are an example of social situation where all actors act like ‘hermits’ and expectations may be self-defeating.

< Insert Figure 4 here >

4.2. Bank runs

Let us inspect a classical example of social event associated to SFE: the behavior of depositors. Bank depositors seek to outguess the behavior of other depositors to avoid losing their deposits. This phenomenon is used by Merton (1948) to illustrate the notion of SFE. A typical depositor *i* is a ‘tracker’: she acts *the same way* she expects other depositors to act in the aftermath of rumors about the liquidity position of her bank. In particular, she will keep her deposits if she expects other depositors to do so and will withdraw them otherwise. Thus, the choice-problem a depositor *i* faces is dichotomous. Let’s denote as ‘remainers’ those depositors who prefer to keep their funds in the form of deposits and ‘leavers’ those who prefer to withdraw them. We measure on the abscissa the proportion of depositors that *i* *expects* to keep their funds in the bank, Z_i, and measure *NBi* on the ordinate of Figure 5 below. The schedule of *NBi* is *upward-sloping* in the corresponding space. The interpretation of Z_i^* in Figure 5 is that of a *critical* value of Z_i for *i*: it is the minimum *expected* proportion of ‘remainers’ at which she chooses to keep her deposits; for any value of $Z_i < Z_i^*$ say, $Z_{i,1}$, she withdraws them. The value of Z_i^* will depend on the convenience for *i* of keeping her funds in the bank *vis-à-vis* purchasing other financial assets.[6] This suggests that changes in the net benefits of keeping funds in the bank will cause a change in Z_i^*. For example, if bank deposits become more attractive for *i* than alternative financial assets (including cash) then the schedule of *NBi* will shift *upwards* and, thus, Z_i^* will *decrease* accordingly in Figure 5. The occurrence of a bank run will depend on the joint behavior of depositors as captured by the probability distribution of $Z_i - Z_i^*$ across them.

< Insert Figure 5 here >

5. Private and public predictions when individual actors do not revise expectations

Let's return to the general model discussed in sections 2 and 3 above. The next issue we want to discuss is the feasibility of correct private and public predictions when individual actors cannot revise expectations so that we can compare our results to those in G&M. We noted above that a central assumption in G&M is that forecasters know the extent to which a public prediction *P* will be believed and use this information along with public forecaster's full knowledge of the equations of the model to formulate both correct private and public predictions. By contrast, our model is based on the premise that forecasters do not know how expectations are formed, let alone, the extent to which public predictions will be believed. *All they know is the probability distribution of* Z_i^* *across actors*. Since forecasters don't know the probability distribution of Z_i across actors they don't know the probability distribution of $Z_i - Z_i^*$ and *X* either. Furthermore, they don't know the proportion of the four types of actors we identified above either. In such circumstances neither a correct private prediction nor a correct public prediction is possible. However, there is an exception to this rule. When all or the vast majority of actors are 'trackers' expectations are self-fulfilling and a correct public prediction is possible if it is *fully* believed even though a correct private prediction is not.[7] Let's illustrate this idea by means of Figure 3 above. Suppose that X = 0 initially so that the probability distribution of Z_i and Z_i^* exhibit the same central or average value. Suppose also that a forecaster predicts that Y < $\bar{Z}_0$ where $\bar{Z}_0$ denotes the average value of the probability distribution of Z_i across actors *before* the prediction is released. If the public prediction is *fully* believed the probability distribution of Z_i will shift leftwards (i.e., its central value will decrease in absolute terms) so that X < 0 in Figure 3 above. Notably, if all actors are 'trackers' then Y = $\bar{Z}_1$ where $\bar{Z}_1 < \bar{Z}_0$ denotes the central value of the probability distribution of Z_i *after* the announcement of the prediction so that the latter will turn out to be correct. Thus, unlike G&M, and with the exception of the highly restrictive scenario illustrated above, we have that the formulation of correct public predictions in our model is largely circumscribed to social situations in which (i) a significant proportion of the members of the referential social group are 'hermits', and (ii) actors can revise expectations. These results are summarized in Table 1 below.

< Insert Table 1 here >

6. Private and public predictions when individual actors revise expectations

The analysis has been restricted so far to social situations where actors cannot revise expectations. In this section we seek to investigate the feasibility of correct private and public predictions when actors revise expectations in the wake of forecast errors. If we denote the proportion of co-operators by Y (and the proportion of defectors by 1-Y) the issue we need to ascertain is whether Y converges to a stationary equilibrium, namely, an equilibrium that is *independent* of expectations. The dynamics of a system characterized by a large number of actors who act strategically may be quite complex. To explore this issue we use sequential and graphical analysis. We assume that (i) Z_i^* varies randomly across actors regardless of whether they are 'hermits' or 'trackers' and (ii) Z_i^* follows a normal probability distribution. The dynamics of the model are driven by the interaction of schedules XY and XZ. The former yields the value of Y on the ordinate for every value of X on the abscissa. Its slope is equal to -1 and 1 when all actors are 'hermits' and 'trackers' respectively. When the group consists of a combination of 'hermits' and 'trackers' the slope of XY will take a value between -1 and 1. The schedule of XZ captures the process whereby actors *revise* expectations following last period's forecast error. To simplify matters we assume that every actor revises expectations according to the rule: $Z_{t+1} = Z_t + \alpha(Y_t - Z_t)$ where $0 < \alpha \leq 1$.[8] If actors *fully* revise last period's forecast error then $\alpha = 1$. Yet some actors may be unable to do so. A more realistic scenario is that in which, on average, they *partly* revise last period's forecast error or $\alpha < 1$.[9] The slope of schedule XZ is equal to $1/\alpha$. Thus, the slope of XZ is equal to 1 when $\alpha = 1$ and higher than 1 when $\alpha < 1$.

A stationary equilibrium in our model above corresponds to a situation in which X = 0. Some actors may not have their expectations fulfilled even when a stationary equilibrium is attained, however. This means that attainment of equilibrium does not imply that all actors will stop revising expectations; it only means that the forecast errors of some actors will be fully offset by the forecast errors of others so that forecast errors cancel each other out at the aggregate level. When equilibrium is finally attained the proportion of co-operators *Y* remains constant albeit some actors in the social group may switch from being co-operators to being defectors and vice-versa after equilibrium has been attained as they revise expectations. The purpose of the six graphical analysis exercises shown below is to ascertain: (i) whether and, if so, how expectations converge to a stationary equilibrium determined by actors' incentive structure Z_i^*, (ii) how changes in the proportion of 'hermits' and 'trackers' affect outcomes, and (iii) whether and, if so, how the value of α affects dynamics.

6.1. Dynamics when all individual actors are 'hermits'

Let's start with the case in which all actors are 'hermits' and α = 1. This case is shown in Figure 6 below. The upper panel shows the probability distribution of Z_i^* across actors. Let's identify three different scenarios we denote respectively by A, B, and C. In scenario A (which is the one we discuss in detail throughout) the distribution of Z_i^* is skewed to the right of Z_i^*= 1/2. In scenario B the probability distribution of Z_i^* is centered on Z_i^* = 1/2. Last, in scenario C the probability distribution of Z_i^* is skewed to the left of Z_i^* = 1/2.[10] The final proportion of co-operators if equilibrium is attained in scenarios A, B, and C are $Y^*(A) > 1/2$, $Y^*(B) = 1/2$, and $Y^*(C) < 1/2$ respectively. In all examples discussed below except the one where all actors are 'trackers' we focus on scenario A where equilibrium yields $Y^*(A) > 1/2$. We show the dynamics of X and Y in the lower panel of Figures 6 and 7 below. We assume that the system is initially (in period t_o) at point 0 so that $X = 0$ and $Y = Y^*(A)$. Since the group consists only of 'hermits' the slope of XY is equal to -1. This means that, as the value of $Z_i - Z_i^*$ moves from left to right along the abscissa, Y will decrease *pari passu* and vice-versa. If α = 1 actors revise expectations according to $Z_{t+1} = Y_t$ and the slope of XZ is equal to 1. As we show in Figure 6 below, if α = 1 the system exhibits *self-sustained* cyclical oscillations around point 0. In Figure 7 below we depict the more realistic case where

$\alpha < 1$ and cyclical oscillations are dampened. These two cases are reminiscent of the 'Cobweb theorem' originally formulated by Kaldor (1934) and developed by Ezequiel (1938) to study the behavior of the market prices of agricultural commodities. The prediction of the theorem is that the behavior of the market price depends on the values of the slopes of the demand and supply schedules of the commodity. Likewise, the prediction of our situational model is that equilibrium $Y = Y^*(A)$ is attained *only* if $\alpha < 1$ so that the slope of XZ is higher than 1.[11]

Let us now explain the content of Figures 6 and 7. In both cases the system is initially at point 0. We assume that a forecaster formulates in t_0 a correct public prediction $P*$ that is *less-than-fully* believed so that the system moves leftwards along the abscissa up to point 1 in both Figures with the result that $X = -1/2$ in t_1.[12] The arrows in the lower panel of Figure 6 show the trajectory of the system through t_1, t_2, t_3, and t_n. The emergence of *self-sustained* cyclical oscillations is a consequence of the fact that the slopes of schedules XY and XZ have the same absolute value but opposite sign. Thus the dynamics of the system resemble that of a *perfect* pendulum: if equilibrium is disrupted by a shock self-sustained cyclical oscillations will emerge since the pattern of behavior of 'hermits' and their revisions of expectations are two mutually reinforcing negative feedback mechanisms when $\alpha = 1$. This scenario is a limit case where *expectations determine the behavior of the system both in the short- and the long run*. The amplitude of the oscillations of Y will depend on the initial discrepancy of Z_i from Z_i^*; the larger the initial discrepancy is, the larger the amplitude of oscillations will be. Thus, when all actors are 'hermits' and $\alpha = 1$ expectations matter. Last, a correct private prediction is not feasible in this scenario since the system never converges to equilibrium and prediction $Y = Y^*(A) > 1/2$ will be falsified. So will the equivalent public prediction unless it is *fully* believed. In this latter case the system would remain at equilibrium point 0 after t_0.

< Insert Figure 6 here >

By contrast, as we show in Figure 7 below, expectations become mere *epiphenomena* if α < 1. As in Figure 6 above, we assume that a public forecaster announces $Y = Y^*(A)$ and the latter is *less-than-fully* believed so that the system moves, for instance, from point 0 in t_0 to point 1 in t_1 where X = -1/2. The size of the forecast error in t_1 is captured by the vertical distance between points 1 and 2. Since we have assumed that α < 1 actors' forecast revision in t_2 (measured by the horizontal distance between points 2 and 3) is *less* than proportional to last period's forecast error. In particular, the revision of expectations in t_2 takes the system to point 3 where X > 0 which, if projected onto schedule XY (at point 4) in t_2, yields a proportion of co-operators equal to $Y = Y^*(B)$. Since this value of Y is lower than the one forecast in the previous period there will be a new revision of expectations in t_3. The system will follow the path shown by the arrows in the lower panel of Figure 7, the size of forecast errors will decrease in subsequent periods, and equilibrium at $Y = Y^*(A)$ will be eventually attained. As the system approaches equilibrium it will exhibit *dampened* cyclical oscillations around equilibrium point 0. The only difference between this case and the cases discussed in Figures 9, 10, and 11 below where the group consists of a mix of 'hermits' and 'trackers' is the path the system follows before equilibrium is attained. In all four cases expectations are mere *epiphenomena*. Last, since the system eventually converges to equilibrium it follows that the correct private prediction $Y^*(A) > 1/2$ is confirmed and so will the public prediction $Y = Y^*(A)$ even if it is *less-than-fully* believed. Any false private prediction (i.e., a prediction other than $Y^*(A)$) will be falsified.

< Insert Figure 7 here >

6.2. Dynamics when all individual actors are 'trackers'

We illustrate the case where all actors are 'trackers' in Figure 8 below. The slope of XY is equal to +1. This implies that as we move from left to right along the abscissa in the lower panel *Y* increases *pari passu* and vice-versa. The reason is that when all or the vast majority of individual actors are 'trackers' *equilibria are bootstrapped and expectations are self-fulfilling*. The latter implies that expectations are *unbiased* on average; forecast errors cancel each other out at the aggregate level for any set of expectations. Thus, when all or the vast majority of actors are 'trackers' (i) there is no forecast revision at the aggregate level thus making schedule XZ redundant, and (ii) there is a *continuum* of equilibria so that the selection of a particular equilibrium depends on expectations. Although there is no forecast revision at the aggregate level after equilibrium has been attained some actors will continue making forecast errors and, hence, revising expectations; the forecast errors of individual actors will cancel each other out. Let us explain this. In Figure 8 below we assume that the system moves down along schedule XY(A) from point 0 at t_0 to point 1 in t_1 following the announcement of prediction $Y = Y^*(C) < 1/2$.[13] Thus, we have that X = -1/2 at point 1. Since the slope of XY is equal to 1 the decrease in *Y* has the same magnitude as the decrease in *X*. Likewise, if expectations change from X = -1/2 to X = 1/2 in t_2 then *Y* increases from $Y = Y^*(C)$ to $Y = Y^*(A)$ and the system settles at point 2. Thus, any shift in *X* is followed by *equivalent changes in Y in the same direction* and equilibrium shifts around as expectations shift. In short, if equilibria are bootstrapped expectations 'rule the roost' in the short- and the long run.[14] Now, a correct private prediction is not generally possible since equilibrium is determined by expectations and the latter may shift unpredictably and abruptly. By contrast, a correct public prediction is possible provided it is *fully* believed. For example, if a forecaster announces $Y = Y^*(A)$ and this prediction is *fully* believed the system will jump *ipso facto* to point 2. Likewise, if she announces that $Y = Y^*(C)$ the system will jump *ipso facto* to point 1. Last, a correct public prediction is not possible in the realistic case in which the prediction is *less-than-fully* believed yet a correct private prediction may be possible in such scenario. In particular, when expectations are self-fulfilling and — as G&M assume in their model — public forecasters know the *extent* to which a public prediction will be believed then a correct public prediction is not possible but a correct private prediction is possible even if forecasters don't know the probability distribution of Z_i^* across individual actors. Suppose a forecaster publicly predicts that $Y = Y^*(A) = 7/8$ and knows for certain that Y will turn out to be equal to *half* its publicly predicted value so it privately predicts that $Y^*= 7/16$. When the prediction is publicly announced Y becomes equal to $Y^*= 7/16$. Thus, the public prediction turns out to be false but the private prediction turns out to be correct.

< Insert Figure 8 here >

6.3. Dynamics when there is a combination of 'hermits' and 'trackers'

The three scenarios we discuss below consist of situations where the referential group consists of a combination of 'hermits' and 'trackers'. These three scenarios are qualitatively similar to the one depicted in Figure 7 above; the system eventually converges to a stationary equilibrium determined by actors' incentive structure. In Figures 9, 10 and 11 below the only difference with respect to Figure 7 resides in the *slope* of XY. Starting from a situation where all actors are 'hermits' and the slope of XY is equal to -1 the latter decreases in absolute value as the proportion of 'trackers' increases and may become positive (but still lower than 1 in absolute value) if the proportion of 'trackers' exceeds that of 'hermits'. In Figure 9 below we represent the scenario in which the proportion of 'hermits' exceeds that of 'trackers'. The slope of XY is negative but lower than $|1|$. The value of the slope depends on the proportion of 'trackers'; as the latter increases the slope decreases *pari passu* in absolute value. In Figure 10 below we depict the scenario where the proportion of 'hermits' and 'trackers' is similar. The slope of schedule XY is zero. Equilibrium will be attained after one round of revision of expectations without the system exhibiting oscillations around equilibrium point 0. The main intuition behind this result is that, when the proportion of 'hermits' and 'trackers' is equal, the actions of the former group is *fully* offset by those of the latter group. The behavior of 'hermits' consists of a *negative* or stabilizing feedback mechanism while that of 'trackers' consists of a *positive* or destabilizing one. Thus, volatility is minimized when the number of 'hermits' and 'trackers' is the same since the two opposite feedback mechanisms cancel each other out. Last, in Figure 11 we show the case in which the proportion of 'hermits' is lower than that of 'trackers'. The slope of XY is positive and equilibrium is attained after a few rounds of revisions of expectations. As the proportion of 'trackers' increases the slope of XY increases *pari passu* but remains lower than $|1|$ if there are some 'hermits' in the group. This scenario converges in the limit to the one shown in Figure 8 when all actors are 'trackers'. In the three Figures shown below we assume that the system is initially at equilibrium point 0 where $Y = Y^*(A) > 1/2$ and $\alpha < 1$. As in previous sections we assume that there is a shift in expectations in period t_0 following a public prediction that is *less-than-fully* believed so that expectations shift and the system moves to point 1 in t_1. In all three cases the disequilibrium sets off forecast revisions. In Figure 9 below Y exhibits *dampened* cyclical fluctuations as it converges to equilibrium. In Figure 10 convergence to equilibrium is rapid and smooth for the reasons we explained above. Last, convergence to equilibrium in Figure 11 is similar to that in Figure 10 albeit more gradual. Thus, in all three cases the system eventually converges to a stationary and locally stable equilibrium where Y is determined by the incentive structure actors face as captured by Z_i^*.

< Insert Figure 9 here >

< Insert Figure 10 here >

< Insert Figure 11 here >

Last, the existence of a locally stable stationary equilibrium in the scenarios depicted in Figures 9, 10, and 11 above implies that a correct private and public prediction $Y^*(A) > 1/2$ is possible regardless of the extent to which the latter is believed. Any other prediction will be falsified. This shows that the typical pattern of behavior of 'hermits' added to actors' revision of expectations guarantees the existence of a locally stable stationary equilibrium which can be used, in principle, to formulate predictions which turn out to be correct provided equilibrium is eventually attained.[15] The feasibility of correct private predictions is uncertain, however. Three requirements must be satisfied for a correct private prediction to be possible. First, equilibrium must be stochastically stable (Bicchieri 1987). Second, equilibrium must be *unique*. The unicity of equilibrium (which is satisfied in our model since we imposed the condition that functions *TBi* and *TCi* are linear) guarantees that, if the former is locally stable, it will also be globally stable provided it is stochastically stationary or stable. Last, the pace of convergence of the system to equilibrium must be rapid enough to guarantee that the latter is attained before it shifts (Sen 1986, 10). These formal requirements are stringent and their fulfilment is uncertain, to say the least. All these results were summarized in Table 1 above.

7. Summary and conclusions

We started this study by positing the idea that prediction is important for science and that philosophers and social scientists recognize that predictions pose specific philosophical and methodological problems in the theoretical social sciences associated to the impossibility of formulating law-like generalizations, free will, and the fact that social predictions may be *self-altering*. Two problems have attracted the most attention among philosophers of science and social scientists. First, if social phenomena can be altered by public predictions then the interpretation of empirical tests becomes problematic thereby raising concerns about the role of empirical testing in the theoretical social sciences. Second, the impact of public predictions on expectations raises the issue whether a correct public prediction is possible. This second issue was originally studied in G&M and Simon (1954). The main conclusion of these studies and related ones is that a correct public prediction is possible if a correct private prediction is possible provided forecasters know how expectations are formed including the extent to which a public prediction will be believed. Although these studies address the same issue and use a similar approach our discussion focused on G&M due to its higher level of generality. In this respect we argued that, although the model used in G&M is rather general, it implies that the equilibrium market price (and quantity) of a commodity depends on suppliers' price expectations which depend, in turn, on the extent to which public predictions are believed.

In light of these considerations we set off to explore the feasibility of both private and public predictions in a disaggregated dynamic model characterized by the presence of a large number of microscopic individual actors who act strategically and revise expectations in the aftermath of forecast errors. A central feature of the model was the existence of two types of individual actors: ‘hermits’ and ‘trackers’. Our findings may be summarized as follows. First, and foremost, we found that the results in G&M are valid only if the proportion of ‘hermits’ in the referential social group is significant. The reason is that, in such setting, equilibrium is stationary and locally stable so that a correct public prediction is possible if a correct private prediction is possible even if forecasters don’t know how expectations are formed. Second, we found that when all or the vast majority of members of the group are ‘trackers’ equilibrium is *bootstrapped* and expectations are self-fulfilling. Unlike G&M this means that a correct public prediction is possible even if a correct private prediction isn’t possible provided the former is *fully* believed. In general terms these findings do suggest that when the referential social group includes a significant proportion of ‘hermits’ the obstacle to the formulation of a correct public prediction is the possibility of formulating a correct private prediction while, when all or the vast majority of members of the referential social group are ‘trackers’, the obstacle to the formulation of a correct public prediction is forecaster’s credibility.

We believe our results extend and qualify the results in G&M’s for the following four reasons. First, our results suggest that, in normal circumstances, social prediction is possible only when the referential social group includes a significant proportion of ‘hermits’. Second, our results suggest that, when this requirement is fulfilled, a correct public prediction may be possible even if forecasters don’t know how expectations are formed including the extent to which public predictions are believed. Third, our results also suggest that, when the former requirement is not satisfied (i.e., if all or the vast majority of actors are 'trackers') and public forecasters know, as G&M assume, the extent to which public predictions are believed they can simultaneously issue a false public prediction and a correct private one. Last, our results are obtained using a more general theoretical framework. While G&M use an aggregate static economic model in which forecasters know how expectations are formed including the extent to which public predictions will be believed we used instead a dynamic disaggregated model in which (i) there are different types of individual actors who revise expectations in the wake of forecast errors, (ii) forecasters don't know how actors' expectations are formed, and (iii) equilibrium may be either stationary or bootstrapped depending on the actual composition of the referential social group. That said, the relevance of our findings hinges on the significance of the distinction between 'hermits' and 'trackers' and a number of modelling assumptions like the linearity of actors' behavioral functions, the absence of thresholds effects, and the adaptive nature of expectations. Hopefully, these are issues which may be addressed in future works.

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Appendix

Revision of expectations	Type of prediction	Composition of the social group	Prediction
No	Private	Only ‘trackers’ (Bootstrapped equilibria)	Unfeasible
		Significant proportion of ‘hermits’	Unfeasible
	Public	Only ‘trackers’ (Bootstrapped equilibria)	?
		Significant proportion of ‘hermits’	Unfeasible
Yes	Private	Only ‘trackers’ (Bootstrapped equilibria)	Unfeasible
		Significant proportion of ‘hermits’ (Locally stable stationary equilibrium)	??
	Public	Only ‘trackers’ (Bootstrapped equilibria)	?
		Significant proportion of ‘hermits’ (Locally stable stationary equilibrium)	???

(?) means that a correct public prediction is possible only if it is *fully* believed.
(??) means that a correct private prediction may be possible if several formal requirements are fulfilled.
(???) means that a correct public prediction may be possible if a correct private prediction is possible.

Table 1. The feasibility of private and public predictions

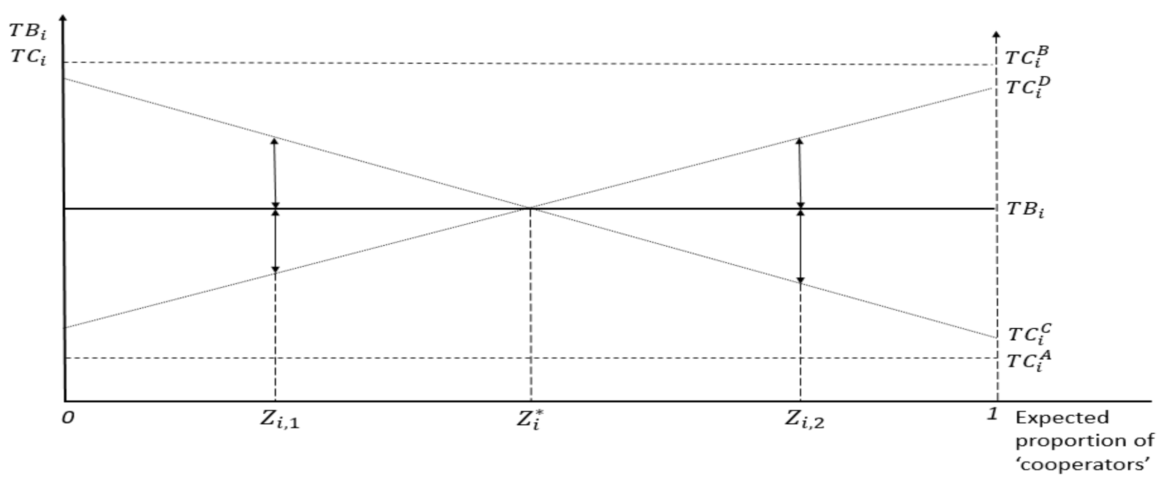

Fig. 1 The general model

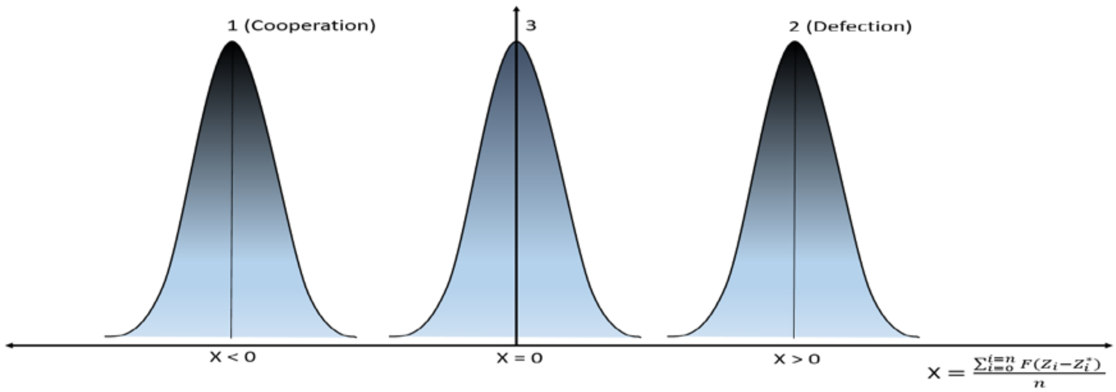

Fig. 2 Joint distribution of Z_i and Z_i^* when all individual actors are ‘hermits’

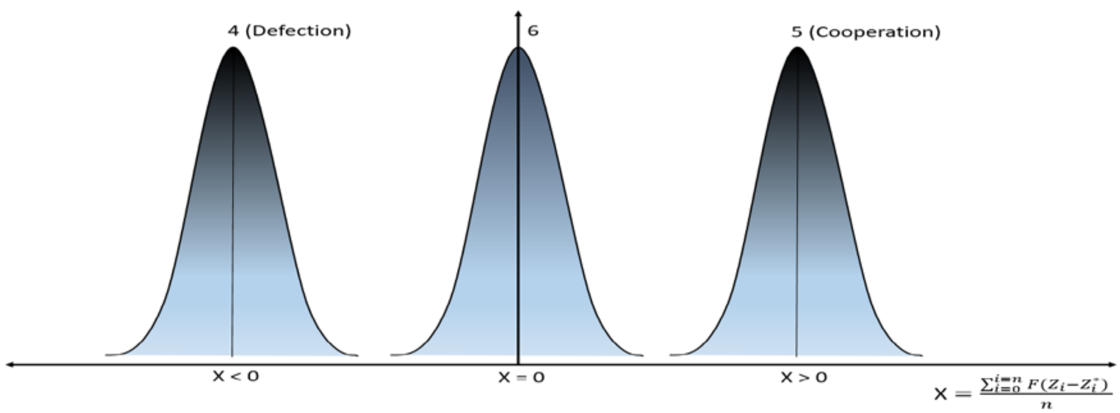

Fig 3. Joint distribution of Z_i and Z_i^* when all individual actors are ‘trackers’

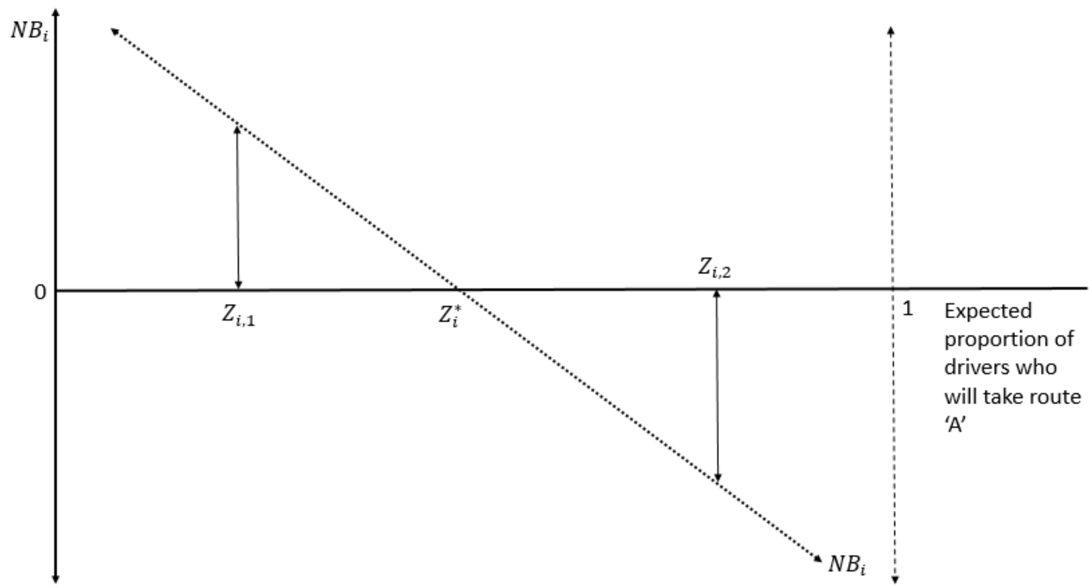

Fig. 4. Traffic jams

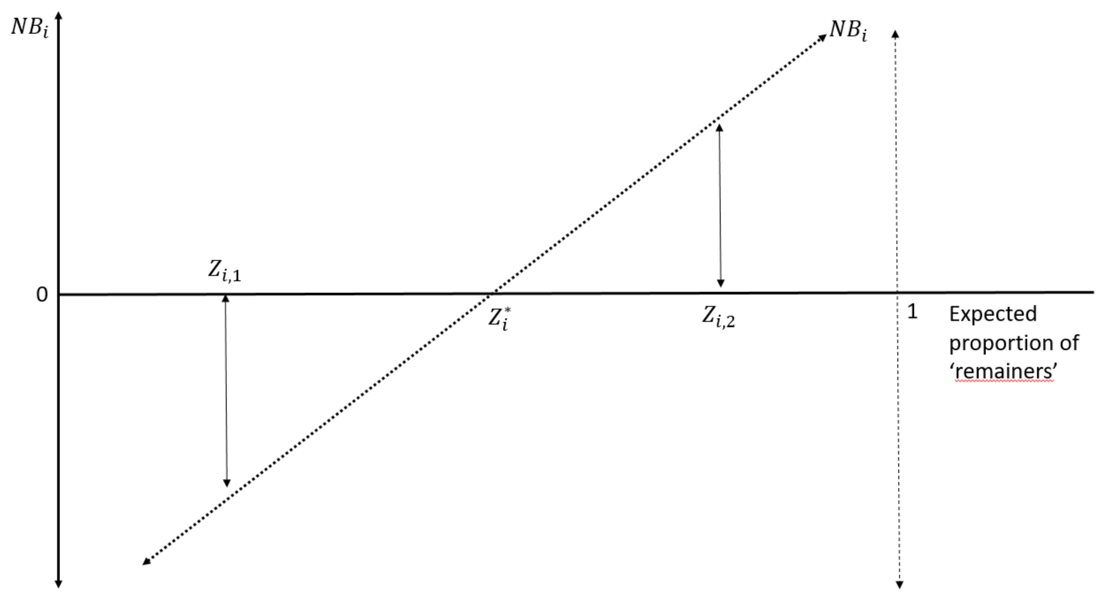

Fig. 5. Bank runs

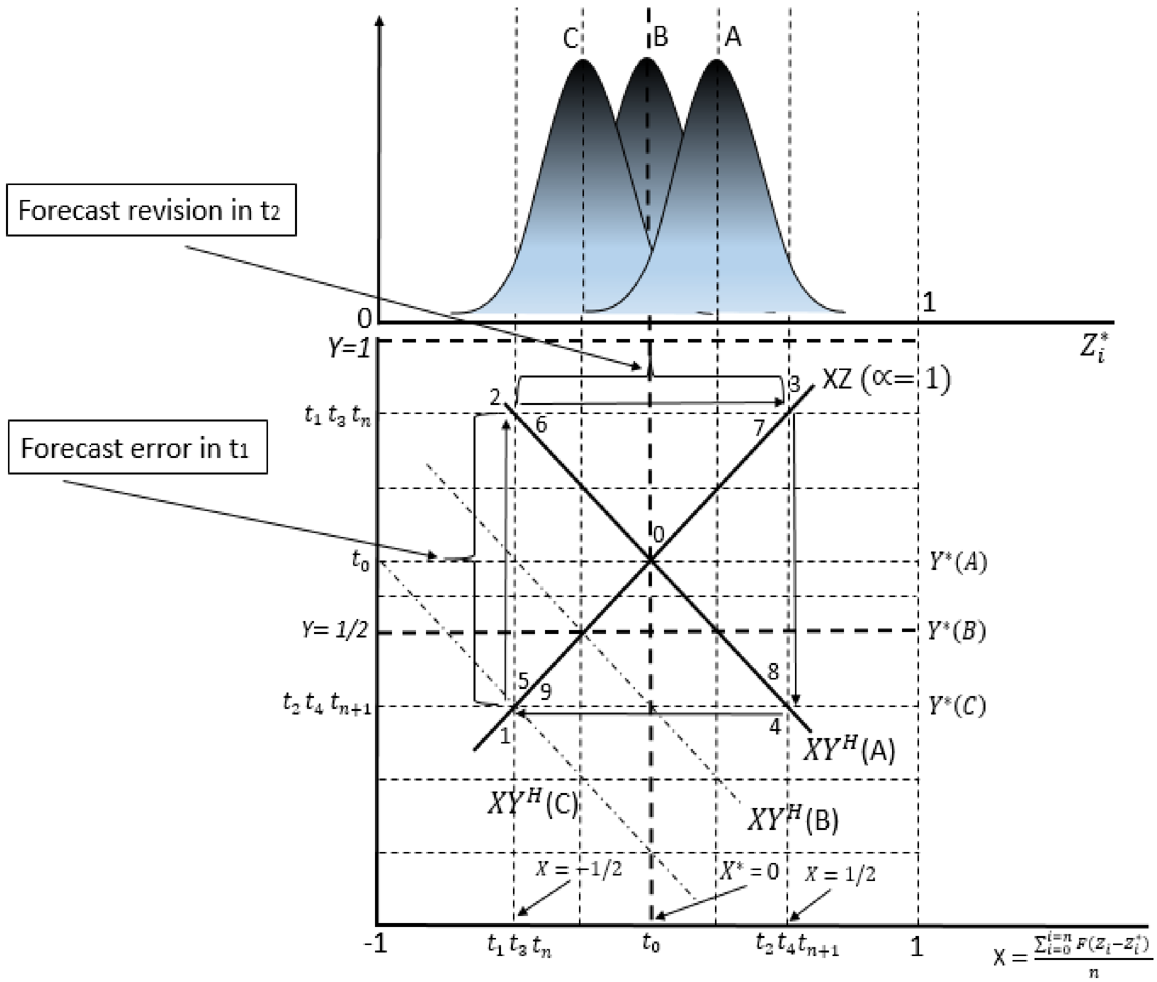

Fig. 6 Dynamics when all actors are 'hermits' and α = 1

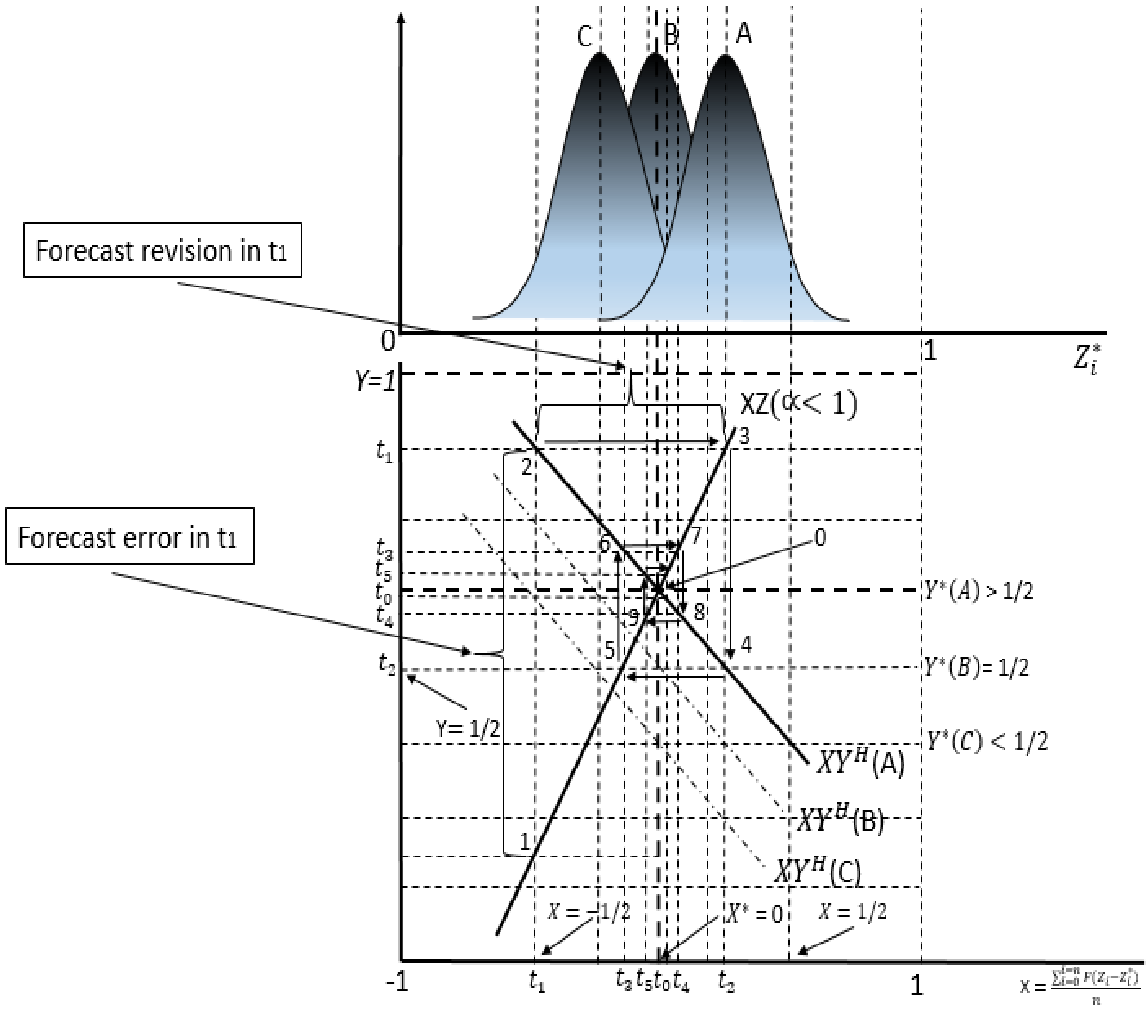

Fig. 7 Dynamics when all actors are 'hermits' and α < 1

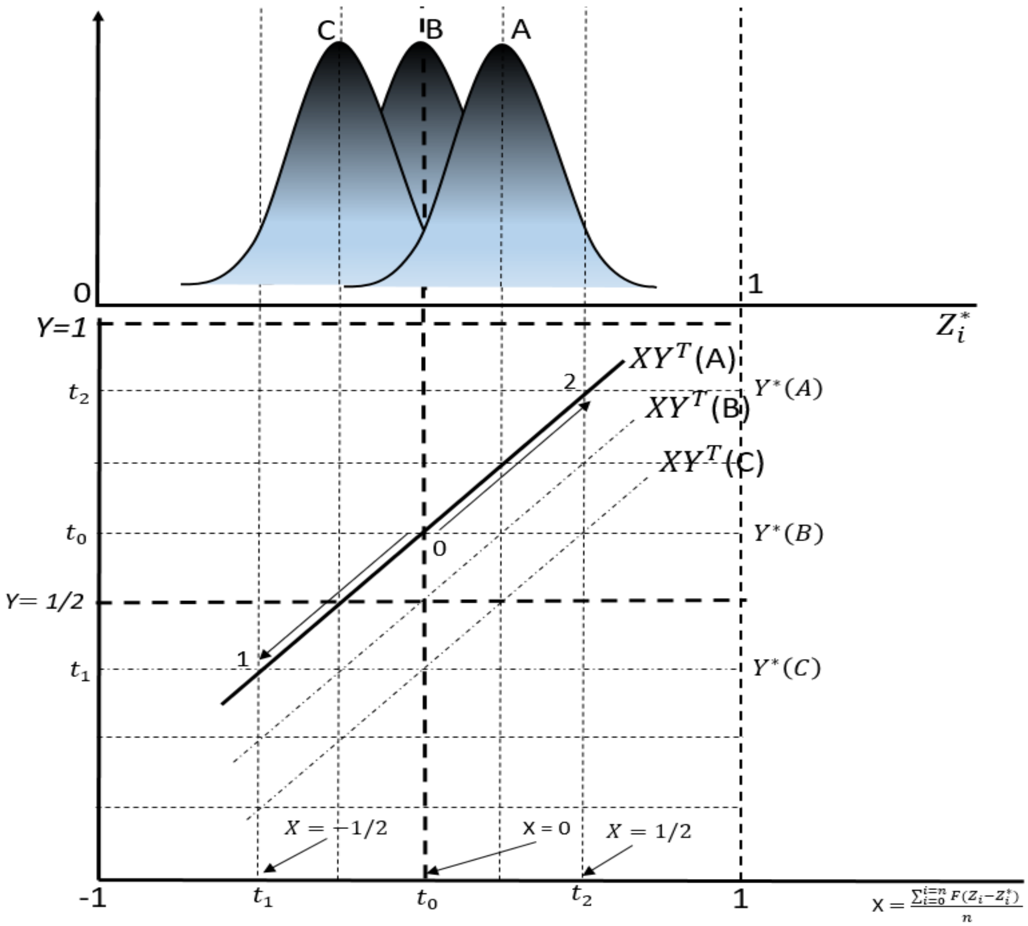

Fig. 8 Dynamics when all actors are 'trackers'

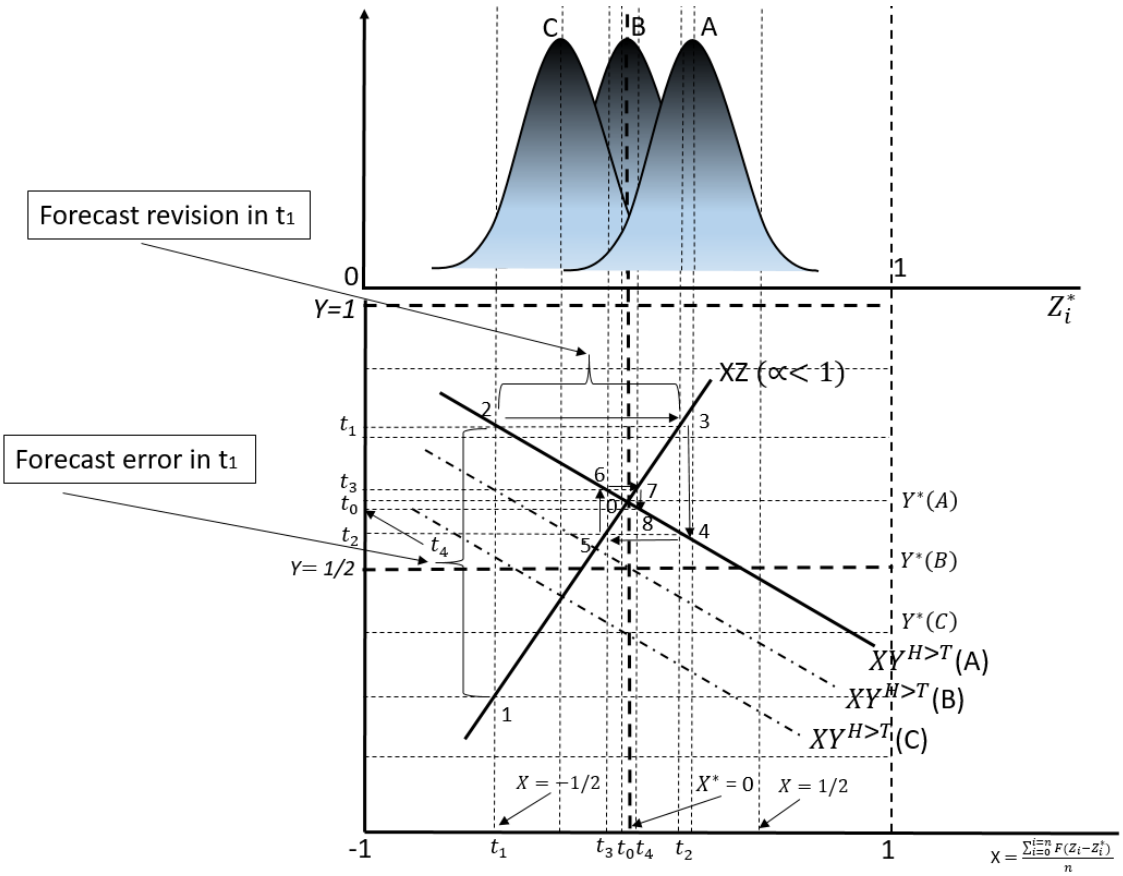

Fig. 9 Dynamics when the proportion of 'hermits' *exceeds* that of 'trackers'

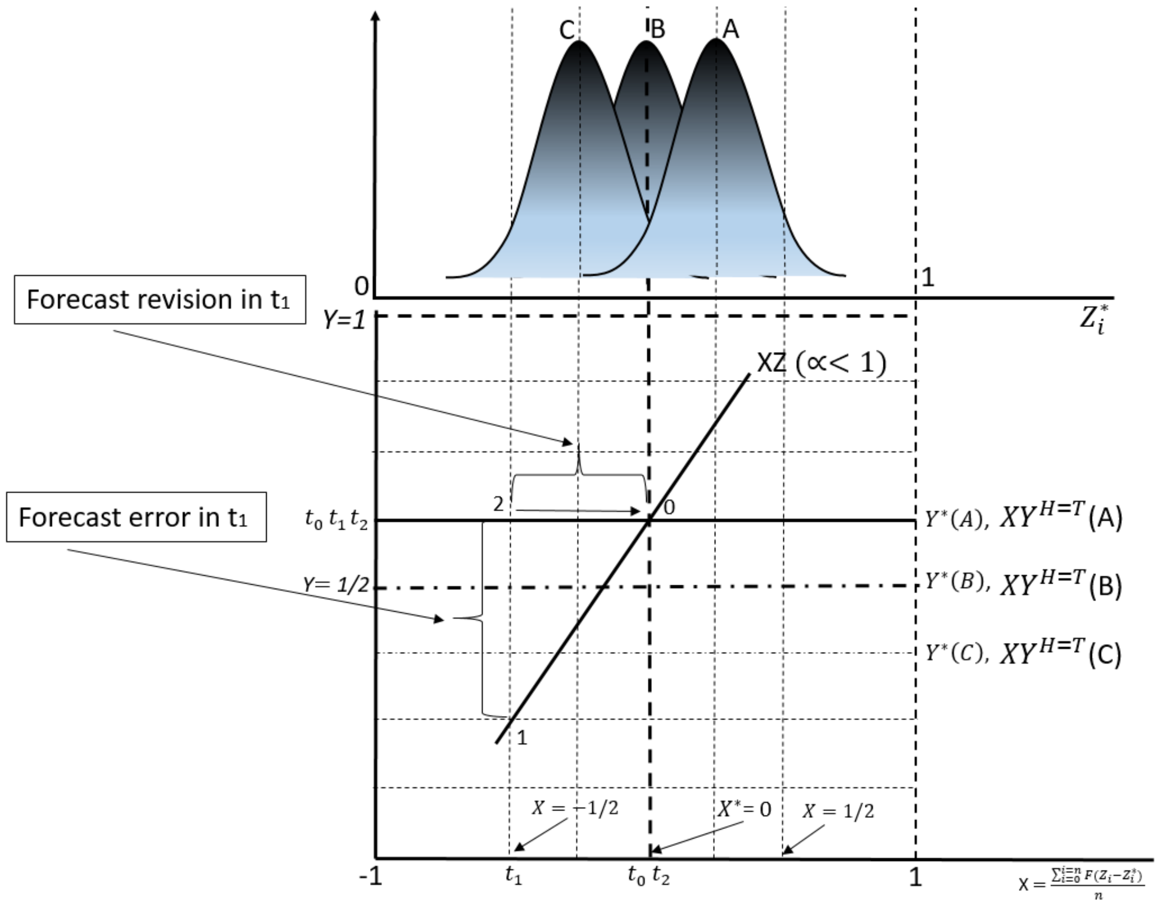

Fig. 10 Dynamics when the proportion of 'hermits' and 'trackers' is similar

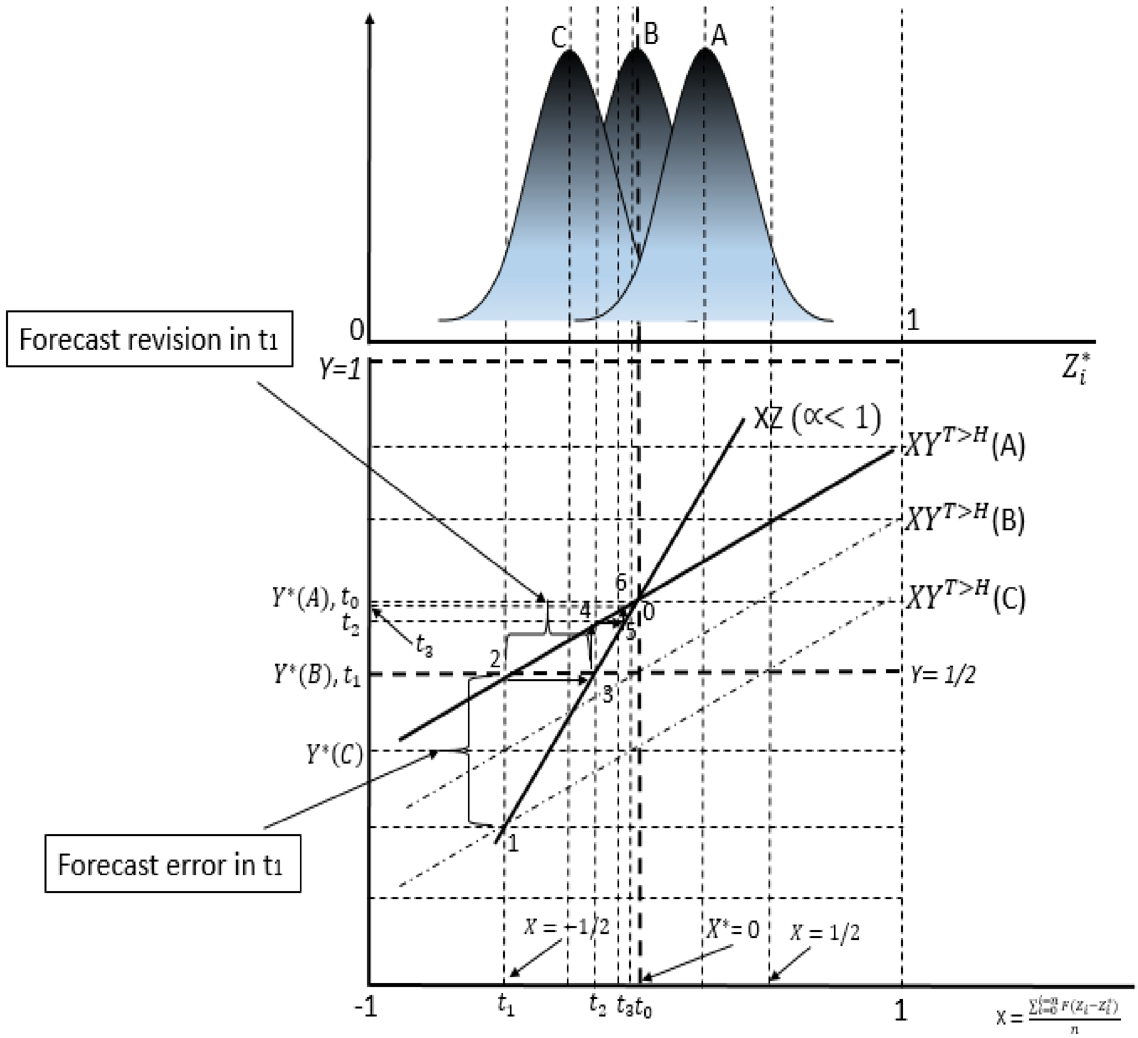

Fig. 11 Dynamics when the proportion of 'trackers' *exceeds* that of 'hermits'

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[1] Self-altering predictions are often referred to as *reflexive* predictions. However, reflexivity is a much wider phenomenon. Thus, we will stick to the former notion throughout.

[2] The problem was subsequently studied, among others, by Devletoglou (1961) and Rothschild (1964).

[3] Bicchieri and Xiao (2009) report empirical results based on 'Dictator Game' experiments which suggest that the pattern of behaviour we have associated above to 'trackers' is very important in practice.

[4] Accessible presentations of 'Chicken Game' and 'Assurance Game' (also known as 'Stag-Hunt Game') may be found in Tuomela (1992) and Elster (2007, ch. 19).

[5] By minimum threshold we mean a *minimum* proportion of co-operators (defectors) which must be exceeded by the actual proportion of co-operators (defectors) if a certain social phenomenon is to occur.

[6] Implicit in this argument is the assumption that keeping a large part of our wealth in cash is inconvenient and that it may be preferable to keep a certain proportion of our wealth in the form of bank deposits.

[7] This scenario is discussed in detail in section 6.2 below.

[8] As Sen (1986, 12) notes, the assumption that individual actors form their expectations in an adaptive fashion is fully consistent with rationality when knowledge is limited.

[9] With the exception of the scenario represented in Figure 6 below where local stability of equilibrium requires that $\alpha < 1$, equilibrium is locally stable in the scenarios represented in Figures 7, 9, 10, and 11 below if $\alpha \leq 1$.

[10] To facilitate the graphical exposition we show the schedule of XY corresponding to $Y^*(A)$, $Y^*(B)$ and $Y^*(C)$ but we only show the schedule of XZ corresponding to $Y^*(A)$. The intersection of schedules XY and XZ must always yield X=0 on the abscissa and the corresponding value of Y^*on the ordinate with the exception of the specific case in which all actors are 'trackers'.

[11] When there is a significant proportion of 'hermits' in the group a stationary equilibrium will be locally stable only if XZ is *steeper* than XY.

[12] If $P*$ were *fully* believed the system would remain at equilibrium point 0.

[13] For the purpose of illustrating this particular case it doesn't matter whether a public prediction is correct or whether it is fully or less-than-fully believed. All we need to assume is that it is, at least partly, believed.

[14] Social situations in which all actors are 'trackers' are inherently *unstable*. Some typical examples of them are bank runs, asset price bubbles, and currency crises. Bootstrapped equilibria may also help describe institutions like social norms (e.g., norms of fairness and reciprocity), descriptive norms (e.g., fads and fashions), and conventions. In fact, Bicchieri (2006, x) defines descriptive norms, social norms, and conventions as *clusters of SFE* or complex systems of self-sustaining beliefs.

[15] The only exception to this rule is the highly unlikely scenario shown in Figure 6 where all individual actors are 'hermits', $\alpha = 1$, and equilibrium is stationary yet the system exhibits self-sustained oscillations around it.