Choosing between low- and high-quality information when the latter is potentially biased. An example with recommendations from the financial analysts.*

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ABSTRACT

Suppose a financial decision-maker having two sources of information. One is an internal, low-quality information. The other is an external information which quality is comparatively high, but being potentially biased. The bias is possible because the external financial adviser is interested in the trading decision taken on the basis of his advice. However, the decision-maker can not observe the thruthfullness of the adviser's message, because he can not verify the relative weights of issuing correct advices vs generating trade in the adviser's utility function. Using a principal-agent model, this paper shows that there exists equilibria under which the decision-maker can deviate from high-quality information and follow the low-quality information instead. This situation is more likely to occur when: the precision of the two informations are close; the amount at stake decreases; the advisers' precision decreases; correct advices are more rewarded. We base ourselves on the example of stock recommendations from financial analysts to develop the model.

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1 Introduction

In many finance contexts, a decision-maker is confronted to financial recommendations from an adviser who is an intermediary interested in the advice he gives. It is mostly the case when the advice is about whether to trade or not a given asset, as long as the adviser receives a commission fee based on the volume traded. A financial analysts from a brokerage house can be compensated upon the volume of trade he convinced fund managers to trade. A bank teller can drive households towards mutual funds pertaining to the institutions he belongs to, etc.

In the contexts we are talking about, the advice is given for free, as a complement to the underlying trading relationship between the decision-maker and the adviser. Both are already in contact at the occasion of a trade, and the intermediary freely gives the advice about the trade. The information cost is then supported by the commission on the volume traded. That is why such intermediaires are often called being on the "sell-side" (as financial analysts from brokers). As they both intermediate trade and advise investors, they should be called "intermediary-advisors".

However, although these situations characterizes conflicts of interests, it does not mean that the advices given are automatically adverse to the decision-maker's interest. For example the adviser can consider that ethics are important and may refuse to give a biased advice. The conflict of interest is only potentially harmful to the decision-maker. It will be acually harmful if a biased advice is given.

Why listening to potentially biased advices? It is probably the case because advisers are experts in their fields.

Then the question is: has the decision-maker the ability to "de-bias" the advice? Most theoretical models focus on the sources of the conflict of interest and do not let the possibility for the decision maker to deviate from the advice given.

In this paper, we use a simple principal-agent framework to study situations when deviation from the high-quality information is possible, namely, for example, when the decision-maker decides to sell when the expert adviser recommands to buy. An original contribution of this paper is to introduce a second, "in-house", advice to the decision-maker, that cannot be suspected of being biased. This signal has a weaker precision. We show that when both signals are contradictory, the decision-maker nevertheless follow its own signal against the potentially biased expert advice. We use comparative static to show the conditions under which this situation is more plausible.

The remaining sections will proceed as follows: the second section presents the environment, the third section shows the equilibrium situation and its properties. The fourth section highlights the cases when the decsion-maker can deviate from the expert's recommendation.

2 The environment

We consider an decision-maker who has to buy or sell a risky asset and receives two signals about this asset's price. The first one is a recommendation to buy (r_H) or sell (r_L) the asset, given by a market intermediary (hereafter the "adviser"). The second one is a private, in-house signal, to buy (y_H) or sell (y_L) the asset. Updating his beliefs on the basis of these two signals, the decision-maker trades a positive volumes ($V > 0$, i.e. purchase) or a negative volume ($V < 0$, i.e. sale). The realized price is then observed: x_H when price rises, x_L when price decreases. A device exists that threatens *ex-ante* the adviser: a reward R, conditional to the comparison between the advice given and the price that will occur. More precisely, if the recommendation turns out to be , ex post, wrong, the relationship ends, and no future trade will take place ($R = 0$). If the recommendation is right, the future trading prospects have a positive present value ($R > 0$). The game is not repeated, provided that R is a reduced form of reputation constrainst as it would take place in a repeated game.

2.1 Information structure

Both individuals have a common prior $\Pr(x_H) = \Pr(x_L) = 1/2$. The adviser privately observes a signal s, such that $\Pr(s_H \mid x_H) = \Pr(s_L \mid x_L) = p$. The decision-maker privately observes a signal y such that $\Pr(y_H \mid x_H) = \Pr(y_L \mid x_L) = q$. We will hereafter refer to p and q as to the "precision" or "quality of information" of the respective signals [1]. In the financial information context that we study, this can represent the record of past recommendations: $\Pr(s_H \mid x_H) = 0.6$ means that, on the last ten observations of price increase, the private signal of the adviser was right six times out of ten.

Assumption 1 *The adviser recommendation is an expert signal in the sense that the quality of his information is higher than the quality of the information of the decision-maker. Nevertheless, y has value in the sense that it exceeds the prior precision of* $1/2$. *That is:* $1/2 < q < p \leq 1$

[1] For notational convenience, we follow the subsequent device. When two variables are indexed by the binary states H and L and when the four cases are considered, the index is not mentioned. For example, mentioning (s, r) refers to: (s_H, r_H), (s_H, r_L), (s_L, r_H), and (s_L, r_L). Mentioning $(s = r)$ refers to the two subcases where indexes are the same, i.e. (s_H, r_H) and (s_L, r_L). Hence $(s \neq r)$ refers to the two subcases where indexes are different, i.e. (s_H, r_L) and (s_L, r_H).

The two signals are independant. We suppose that they result from a personal effort of data interpretation that is possibly differing, or from the private acquisition of distinct informations[2]. They are private in the sense that no Court could prove which signal is observed. Finally, note that all advisers in the population have the same precision p: the only difference between them is their type. We define the preferences and types in the next subsection.

2.2 Preferences

2.2.1 Decision-maker

In this subsection we closely follow the models of Hayes (1998) and Jackson (2005), which build on a standard framework of a risk-adverse agent with a CRRA utility function. Therefore we only mention the result. See details in appendix A1, p.14.

The maximization of the expected utility yields an optimal quantity γ_0^* of asset to trade on the basis of the prior $\Pr(x)$. Then the decision-maker receives the two signals: the recommendation r and the internal signal y. He updates his beliefs, and computes the new optimal quantity γ_1^* of asset to trade on the basis of the revised beliefs $\Pr(x \mid r, y)$. The decision takes the form of the difference $\gamma_1^* - \gamma_0^*$ which we define as the volume traded V.

$$
\begin{aligned}
V &\equiv \gamma_1^* - \gamma_0^* = [\Pr(x_H \mid r, y) - \Pr(x_H)].\alpha \\
V &= [\Pr(x_H \mid r, y) - 1/2].\alpha \qquad (1)
\end{aligned}
$$

with α a positive amount scaled by the wealth of the decision-maker and by the asset prices level; $\alpha > 0$.

2.2.2 Adviser

The preferences of the adviser depend on the expected volume of trade V; and on the expected relationship value, R. For simplicity we retain a binary measure for R. It is defined as follows:

$$
\begin{cases}
\text{if } r \neq x \text{ then } R = 0 \\
\text{if } r = x \text{ then } R = R
\end{cases} \qquad (2)
$$

[2] Suppose for example that the analyst uses a bottom-up approach and the fund manager a top-down approach.

with $R > 0$. The decision-maker records the recommendation r, and ex-post observes the realized price x. If the recommendation turns out to be wrong ($r \neq x$), the relationship ends. The present value of future trading relationship is positive if the recommendation is correct ($r = s$).Hereafter we will refer to R as to the relationship value. As such, it depends on the market structure, the expected level of competition on the financial markets, the frequency of trades, the economies of scale by adressing to the same intermediary,... Hence it is an exogenous parameter. But not only future trades, R may also reflects all forms of compensation indexed on some reputation indicator: the broker review for financial analysts, publications of performance rankings, ratings based on the history of past recommendations, and so on [3]. In that sense R also represents the reward from being seen as independent from trading incentives, which may attract new clients to the adviser. In short, R is a reputational incentive that can outweight the trading generation incentive.

The adviser is risk-neutral. The weight of volume in the utility function is represented by the parameter θ, with θ randomly sorted from $\theta \in [0, 1]$. This constitutes the size of the conflict of interest. The higher θ, the higher the volume is important, in utility terms, to the adviser. For example this can reflect the brokerage commissions of an intermediary (with the adviser being an employee of the intermediary), or any form of compensation being a percentage of the volume traded with the help of the intermediary.

The weight of the expected reward for a correct advice is then $1 - \theta$. This represents the degree of attachment of the adviser to reputation, and to the long-term relationship. This also encompasses attachment to make correct predictions, or to moral or ethical principles. Professional codes of ethics, academic formation, regulatory authorities commonly promote principles such as truthfulness due to clients, and independence from trading incentives.

The expected utility function of the adviser is then:

$$\theta E(V \mid s, r) + (1 - \theta) E(R \mid s, r)$$

The adviser tries to anticipate what will be the volume traded by the decision-maker conditionnal on his recommendation r. But he ignores the belief of the decision-maker about the future price of the asset (y). Hence he uses his own signal s as a proxy.

It is then necessary to assume some uncertainty about the type of adviser to generate non-trivial results. In Sobel (1985), Scharfstein and Stein (1990), Graham (1999) and Jackson (2005) for instance, there exists a "dumb" and a "smart" type of analyst, with

[3]Note that such reputation indicators are clearly distinct from the precision p. The latter relates to $Pr(s \mid x)$ wheras the former relates to comparing x to r, instead of s.

respectively a non-informative signal or a precise signal. A new device in this paper is to assume a high signal precision for all advisers, but to posit a "loyal" type of adviser (which is not subject to a conflict of interest), and a "potentially biased" type of adviser (which is). The decision-maker cannot observe the type of the adviser.

Assumption 2 *A population of advisers bears $\pi\%$ individuals of the "loyal" type (L), and $(1-\pi)\%$ being "potentially biased" (PB). When type L receives the favorable signal s_H, he recommands to buy (r_H); and with the unfavorable signal s_L, recommands to sell (r_L). When type PB receives the favorable signal s_H, he recommands to buy (r_H), but with the unfavorable signal s_L, recommands to buy (r_H).*

3 Equilibrium characterization and properties

The perfect Bayesian equilibrium is the solution concept used to identify an equilibrium in the game. The agents decisions are sequentially rational given their beliefs, and the beliefs are revised using Bayes' rules. The sequences are as follows: α, p, R,and q are known, exogenous parameters. The decision-maker computes an amount to trade based on his initial beliefs, and randomly picks an intermediary-advisor. The decision maker ignores θ, hence ignores the type of the agent selected. The adviser sends r, the decision-maker privately observes y, and fixes a revised amount to trade V. Then price x is observed and R is paid.

Definition 1 *The recommendation r of the adviser which maximizes his expected utility function, and the corresponding trading volume V chosen by the decision-maker, are forming an equilibrium.*

In this section we study the equilibrium by analyzing the optimal choice of the adviser. We then show that the probability of the type, π, is determined at equilibrium. Finally we propose a probability distribution for π in order to analyze the different equilibrium outcomes.

3.1 Optimal choice of the adviser.

As the choice is binary, the maximization consists in comparing the expected utility depending on the recommendation made. The analyst will choose r_L if:

$$\theta E(V \mid r_L, s) + (1-\theta)E(R \mid r_L, s) > \theta E(V \mid r_H, s) + (1-\theta)E(R \mid r_H, s) \quad (3)$$

and r_H in the contrary. See appendix A2 p.15, for computation of expected volumes and expected relationship value.

We rewrite the above equation as:

$$(1-\theta)[E(R \mid r_L, s) - E(R \mid r_H, s)] > \theta[E(V \mid r_H, s) - E(V \mid r_L, s)] \quad (4)$$

We now study the signs of the differences.

- Conditionnal on s_H received

To assess the expected volume traded by the decision-maker on the basis of his advice r and on signal y (equation 1), the adviser must consider the cases y_H and y_L. We obtain $\underset{y}{E}(V \mid r_H, s_H) = \frac{\alpha}{2}[2(\frac{p\pi+1-\pi}{2-\pi}) - 1]$ and $\underset{y}{E}(V \mid r_L, s_H) = \frac{\alpha}{2}[1-2p]$. Thus,

$$\underset{y}{E}(V \mid r_H, s_H) - \underset{y}{E}(V \mid r_L, s_H) = \alpha[\frac{p\pi+1-\pi}{2-\pi} + p] \quad (5)$$

Now with $\alpha > 0$, $p \in]1/2;1]$ and $\pi \in [0;1]$ we derive that $(p\pi+1-\pi)/(2-\pi) \in [1/2;p]$ Thus, (5) is strictly positive.

Turning to expected relationship value, we have $E(R \mid r_L, s_H) = (1-p)R$ and $E(R \mid r_H, s_H) = pR$. By then,

$$E(R \mid r_L, s_H) - E(R \mid r_H, s_H) = R(1-2p) \quad (6)$$

Since $R > 0$ and $p \in]1/2;1]$; then $(1-2p) < 0$ and (6) is strictly negative.

- Conditionnal on s_L received

In this case, we obtain $\underset{y}{E}(V \mid r_H, s_L) = \frac{\alpha}{2}[2(\frac{p\pi+1-\pi}{2-\pi}) - 1]$ and $\underset{y}{E}(V \mid r_L, s_L) = \frac{\alpha}{2}[1-2p]$ We immediatly make the following remark.

Remark 1 *Due to symmetric binary signals and a prior $Pr(x) = 1/2$; $\underset{y}{E}(V \mid r_H, s_L)$ is equal to $\underset{y}{E}(V \mid r_H, s_H)$ and $\underset{y}{E}(V \mid r_L, s_L)$ is equal to $\underset{y}{E}(V \mid r_L, s_H)$.*

On the basis of this remark we derive that the sign of $\underset{y}{E}(V \mid r_H, s_L) - \underset{y}{E}(V \mid r_L, s_L)$ is strictly positive too.

Concerning expected relationship value, we have $E(R \mid r_L, s_L) = pR$ and $E(R \mid r_L, s_H) = (1-p)R$. Then,

$$E(R \mid r_L, s_L) - E(R \mid r_H, s_L) = R(2p-1) \quad (7)$$

As $p \in]1/2;1]$ we conclude that (7) is strictly positive. Conditionnal on s_L, (3) rewrites:

$$\frac{1-\theta}{\theta} > \frac{E(V \mid r_H, s) - E(V \mid r_L, s)}{E(R \mid r_L, s) - E(R \mid r_H, s)} \tag{8}$$

As $\theta \in [0,1]$ we remark that $(1-\theta)/\theta$ belongs to $]0;\infty[$. Now we can state the following propositions.

Proposition 1 *As (7) is positive and (6) is negative, we state that a truthfull advice ($s = r$) always yields a higher rating than a biased advice ($s \neq r$).*

As the relationship value R is greater with correct advices, and knowing that as $p > 1/2$ the advice has more chance being correct when truthfull ($s = r$), then $(1-\theta).E(R \mid r, s)$ is always higher with a truthfull advice rather than with a biased advice.

Proposition 2 *Whatever the signal s received by the adviser, the favorable recommendation r_H always yields a higher compensation to the adviser than recommendation r_L*
Proof. *The results comes from (5) being strictly positive and remark 1, and from $\theta.E(V \mid r, s)$ being the compensation for the volume traded at the adviser's financial intermediary.* ■

Proposition 3 *Whatever the type of the adviser, playing r_L when s_H is received is not an equilibrium strategy.*

Proof. As (6) is negative, equation (4) rewrites:

$$\frac{1-\theta}{\theta} < \frac{E(V \mid r_H, s) - E(V \mid r_L, s)}{E(R \mid r_L, s) - E(R \mid r_H, s)} \tag{9}$$

with the right-hand side being strictly negative. As $(1-\theta)/\theta$ belongs to $]0;\infty[$ the inequation is never true. ■

This means that, playing r_L when s_H is received, the adviser would loose both from a reputational point of view (prop.1) and from the volume commission point of view (prop.2).

3.2 Equilibrium determination of π

As proposition 3 shows, the case when s_H is received cannot help us dicriminate between the two types of advisers. However, the type of the adviser can be determinated at equilibrium when s_L is received. If (8) is true, then the choice is (s_L, r_L), and we can state that the adviser is of type L. If 9) is true, the choice is (s_L, r_H) and we know that the adviser is of type PB. We can elicit a threshold for which both terms are equal:

$$\left[\frac{1-\theta}{\theta}\right]^* = \frac{E(V \mid r_H, s) - E(V \mid r_L, s)}{E(R \mid r_L, s) - E(R \mid r_H, s)} \tag{10}$$

Then, when s_L is received:

$$\begin{cases} \text{if } \frac{1-\theta}{\theta} \leq \left[\frac{1-\theta}{\theta}\right]^* \text{ then adviser is of type } PB \\ \text{if } \frac{1-\theta}{\theta} > \left[\frac{1-\theta}{\theta}\right]^* \text{ then adviser is of type } L \end{cases} \tag{11}$$

Now recall that the decision-maker does not observes θ hence ignores the type. The best the decision-maker can do is to assume a probability distribution for $(1-\theta)/\theta$. Consider $(1-\theta)/\theta$ as a random variable. For simplicity, assume a uniform distribution function with boundaries 0 and 100. We define the cdf as:

$$\begin{aligned} F(\tfrac{1-\theta}{\theta}) &= \Pr(\tfrac{1-\theta}{\theta} \leq \left[\tfrac{1-\theta}{\theta}\right]^*) = 1 \text{ if } \left[\tfrac{1-\theta}{\theta}\right]^* \geq 100 \\ F(\tfrac{1-\theta}{\theta}) &= \Pr(\tfrac{1-\theta}{\theta} \leq \left[\tfrac{1-\theta}{\theta}\right]^*) = \tfrac{1}{100}\left[\tfrac{1-\theta}{\theta}\right]^* \text{ if } 0 \leq \left[\tfrac{1-\theta}{\theta}\right]^* < 100 \\ F(\tfrac{1-\theta}{\theta}) &= \Pr(\tfrac{1-\theta}{\theta} \leq \left[\tfrac{1-\theta}{\theta}\right]^*) = 0 \text{ if } \left[\tfrac{1-\theta}{\theta}\right]^* < 0 \end{aligned} \tag{12}$$

Thus, the probability of type L (resp. PB) defined in (11) is the exact equilibrium expression of π (resp. $1-\pi$) . The numerical values of π and $1-\pi$ are given by (12).

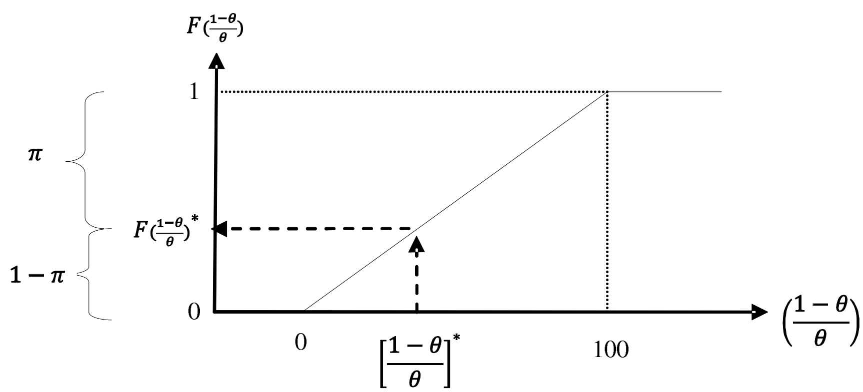

Figure 1: Cumulative density function of k

We now study the determination of the threshold $\left[\frac{1-\theta}{\theta}\right]^*$, i.e. the right-hand side of (10). With the expressions of expected trading volumes and ratings, we obtain:

$$\left[\frac{1-\theta}{\theta}\right]^* = \frac{\alpha\left[\frac{p\pi+1-\pi}{2-\pi} + p\right]}{R(2p-1)} \tag{13}$$

With our expression of the cdf we can express π:

$$\pi = 1 - \frac{1}{100}.\left[\frac{1-\theta}{\theta}\right]^{*} \tag{14}$$

Replacing this expression of π in (13), we solve a fix point and obtain our threshold:

$$\left[\frac{1-\theta}{\theta}\right]^{*} = \frac{\alpha - 100R(2p-1) + \sqrt{[100R(2p-1)-\alpha]^{2} + 800R(2p-1)\alpha p}}{2R(2p-1)} \tag{15}$$

For details see appendix A3 p.17

3.3 The factors of the probability of the type

The above equation shows that, when the decision-maker assesses the probability of the type of the adviser, he uses R (the value of the relationship, seen as the reward if the advice turns out to be correct), α (the amount of trade at stake), and p (the precision of the adviser's information). It is interesting to know how this probability is affected by shocks upon parameters level. A comparative static study of how (15) reacts to increases in R, α, and p, (see appendix A4 p.18 for computation details) shows the following lemmas.

Lemma 1 $\left[\frac{1-\theta}{\theta}\right]^{*}$ *decreases(i.e. Loyal type more probable) when p increases*

When $((1-\theta)/(\theta))^{*}$ decreases, it is less likely to pick some θ such that the adviser is of type PB (see (11) and figure 1). Thus, the more precise is the adviser, the more type L is probable. This is one of the main conclusions of herding models applied to finance, where biased behaviors are held by the less precise, "dumb", or low-ability, less experienced analysts (in particular Jackson, 2005). The proposition also illustrates tests showing a negative relation between analysts' forecast bias and several proxies for precision: analysts in the top ranking (Graham 1999), or analysts with upward career paths (Hong, Kubik & Solomon, 2003) or more experienced analysts (Clement 1999, Lim 2001).

Lemma 2 $\left[\frac{1-\theta}{\theta}\right]^{*}$ *increases (i.e. Loyal type less probable) when α increases*

The greater is the amount traded at stake, the higher the probability to pick an adviser who is of the PB type, i.e. the conflict of interest is more important. This is similar to Hayes (1998) main result, according to which the trading commission incentives strengthen when the size of the trade is high.

Lemma 3 $\left[\frac{1-\theta}{\theta}\right]^{*}$ *decreases (i.e. Loyal type more probable) when R increases*

In the model, the level of R is common knowledge before the adviser reveals his recommendation. The greater the reward for the correct advice, the more the adviser has to loose with a biased advice, all else equal. Formally, the decreasing threshold make it less likely to pick an adviser with a θ such that he would be of type PB. In a given market, if trades are frequent, if there exists large econmis of scale by using the same intermediary, then probably R is high. In this context, less advisors will be prone to bias their advice. This result support the claim for devoting ressources to track the quality of advices. For example, McNamee (2002) states that rating is "the only cure" to analysts' bias. Firms like Bureau van Dijk, ThomsonReuters or Bloomberg sell softwares which timely rate the analysts. Many Investment Funds also build their in-house rating, called "broker review" by the fund managers. Used as a criterion for the ongoing of the future relationship, the *ex-post* supervision of the quality of advice has a *rationale*: it upfront deters advisers from releasing biased recommendations.

4 The decision-maker deviates from high-quality information

We now expose the frontier between deviating or following the adviser recommendation when it is conflicting with the decision-maker personal information, and then study how parameters may move this frontier.

4.1 Deviate or follow

We saw that the decision-maker buys if $V > 0$ ans sells if $V < 0$. If both information y and advice r go in the same direction, the decision-maker always follow those informations. A first case of conflicting information is (r_L, y_H). We derive from proposition 3 that if the adviser tells "r_L", he is necessarily of the loyal type L. In this case, the decision-maker always follow the most precise information, i.e. the adviser, i.e. he sells: $V < 0$ (see proofs in appendix A5, p.20). The second case of conflicting information is (r_H, y_L). Here the decision-maker follows the less precise information if $V < 0$. Applying the definition of V in eq.(1) ; it happens if:

$$\Pr(x_H \mid r_H, y_L) < 1/2 \tag{16}$$

and using the expression of the revised belief $\Pr(x_H \mid r_H, y_L)$, there is deviation if:

$$2(1-q)\Big(\frac{p\pi + 1 - \pi}{2 - \pi}\Big) < 1/2 \tag{17}$$

and there is following in the contrary. Now consider that both sides are equal and isolate q. We obtain the frontier between deviating and following, expressed as a function of p : $q(p)$. Rearranging the equation gives

$$q(p) = 1 - \frac{1}{4}\Big(\frac{2-\pi}{1-(1-p)\pi}\Big) \tag{18}$$

For any given p and π, if $q > q(p)$, then $V < 0$, meaning that the decision-maker deviates. We interpret it as a sufficient trust in his own information. If $q < q(p)$, then $V > 0$, meaning that the decision-maker follows the expert. The precision q is too weak to trust his own information.

To study $q(p)$, recall that π is determined at equilibrium by the value of parameters p, α, R. In equation (18), π must be replaced by its equilibrium value defined in (13) and (14). Therefore, to assess the shape of $q(p)$, we first have to consider π as a function of p, and then to study the sign of $q'(p)$. We demonstrate that $q(p)$ is strictly increasing (see Appendix A6, p.21 for details.)

We plot this function in the following figure, in the case when $R = 2$ and $\alpha = 30$.

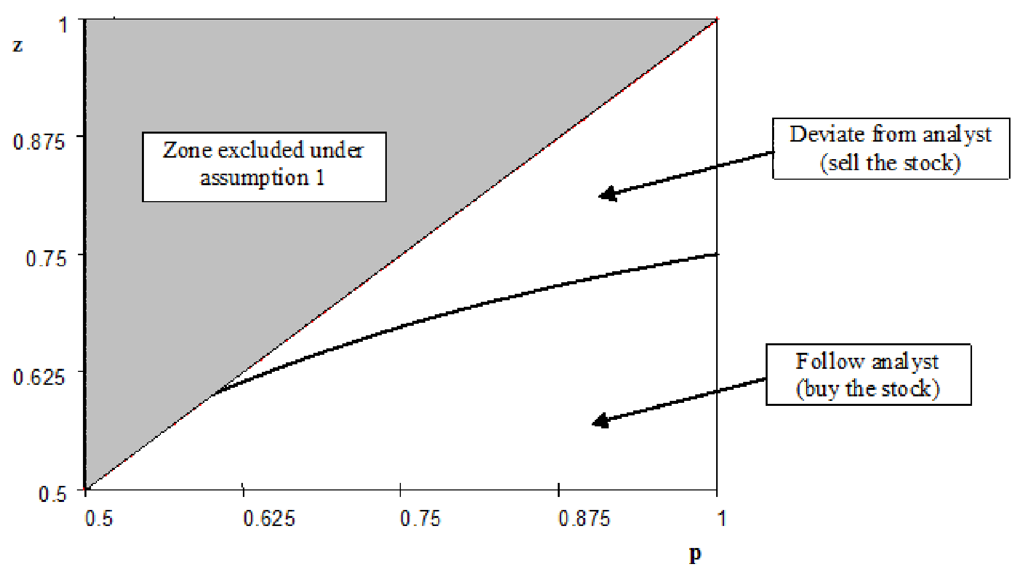

Figure 2: Trading decision and signal's precision

On figure 2, the 45° line is where $q = p$, representing assumption (1). Under this line, we remark that the "deviation" zone (described by the area between the 45° line and the frontier) represents cases when the decision-maker has an information y with a precision q that is "not too inferior" to the precision p of the recommendation r of the adviser. The decision-maker follows the expert in the area below the frontier. We can now state the following proposition.

Proposition 4 *The lower the precision p of the adviser' information, the lower or equal the level of precision q above which the decision-maker deviates (i.e. sells, despites a recommendation to buy), and reciprocally.*

For any given p, there exist a level $q(p)$ above which the decision-maker deviates. This result matters in the financial context, as it encourages decision-makers to improve in-house research about future asset prices evolution. The greater q, the more the decision-maker can "de-bias" potentially misleading advices.

In fact, "information y of precision q" reprensents any kind of advice that is independant from conflicts of interests. Setting aside the question of its cost, we want to emphasize here that, when contradicting the expert advice, *an independant information can have value, even though its precision is lower.*

4.2 Environments in which the decision-maker deviates

We saw that the deviation is possible only if the decision-maker has an information to sell and the adviser recommands to buy (r_H, y_L). Whithin this case, we now study the shocks on parameters α and R and their effects on the frontier. In (18), we have π that is depending on α, R, and p.

If we consider π, in (18), as a function of α, we can endeavour a comparative static study of the impact of α on $q(p)$. We can show that when α increases, the function moves downward, therefore increasing the space of $(q;p)$ points for which the decision-maker deviates (see details in Appendix A6, p.21). We interpret it as the fact that, everything else equal, it is more likely that the decion-maker deviates when α increases, and reciprocically.

Proposition 5 *The higher the amount of the trade, the more the decision-maker is likely to deviate (i.e. to sell despites a recommendation to buy), and reciprocically.*

It is as if the decision-maker was driven to take a much closer look and finally deviate when there is a greater amount at stake, than when the volume traded is low. It is consistent with the lemma 2 according to which the adviser has less chance being of the Loyal type when α is high.

(FIGURE PSTRICKS)

Now considering π as a function of R, we can assess the impact of R on the frontier. Is is shown that when R is increasing, the function $q(p)$ moves upward, thereby reducing the chances that the decision-maker will deviate (see details in Appendix A6, p.21).

Proposition 6 *The higher the long term relationship value R, the less the decision-maker is likely to deviate (i.e. to sell despites a recommendation to buy), and reciprocally.*

As R represents the value of the future relationship as a reward for the correct recommandation, the decision-maker infers that a higher R makes it more likely to pick an adviser of the Loyal type. He is then more confident in following the recommendation.

(FIGURE PSTRICKS)

4.3 Chances of deviating

Finally, figure 2 illustrates the chances of deviating, given a certain expert precision p. Imagine, for a given p, the ratio of the distance between the 45° line and the frontier, in proportion to the total distance between the 45° line and the horizontal axis $q = 1/2$. This ratio would give an idea of the % of chances to deviate for this given p. Appendix A6 shows that the ratio's variation is undetermined, i.e., it can decrease or increase in p, depending on the values of α and R. This subsection illustrates that point. (IN PROGRESS...)

5 Discussion

Implications : decision-maker should favor 1/ multiple trades with a low amount and diversify advisers, rather than a single and massive trade (this provides rational for fractionned stock orders when the intermediary is payed on a commission basis) 2/ is better off with high ability advisers 3/ offer a high value for future relationships 4/ invest in independant information (in-house information production or subscription to an adviser not compensated on the trade generated by the recommendation).

Regulators interested in promoting loyal information should: 1/ promote regulation of trading-commission-like forms of compensations (reduce θ) 2/ promote ethics in finance, and/or favor long-term contracts to enhance relationship value (increase $1-\theta$)

Limits : information production is costly. Credibility of the long term relationship value (extension to reputation problems on the side of the decision-maker) Endogenize reputation on the analyst's side : increase or decrease of p ?

Appendix

Appendix A1. Decision-Maker maximization

As in Hirshleifer (1971) and Jackson (2005), the CRRA utility function is logarithmic, $U = \ln(W+$ net gain$)$ where W is the the wealth of the fund manager apart from the risky asset. With P_0 the price of the stock at t_0, such that $x_L < P_0 < x_H$ and γ_0 the quantity owned at t_0, if the agent invested γ_0 stocks and that the price becomes x_H, his net gain is $\gamma_0(x_H - P_0)$. If the price becomes x_L, the net gain is $\gamma_0(x_L - P_0)$. At t_0 the fund manager must choose the optimal level of quantity to hold, γ_0^*.

Thus he must maximize expected utility:

$$E(U) = \Pr(x_H).\ln(W + \gamma_0(x_H - P_0)) + \Pr(x_L).\ln(W + \gamma_0(x_L - P_0)) \tag{19}$$

with respect to γ, which yields γ_0^* :

$$\gamma_0^* = \frac{-W[\Pr(x_H)(x_H - P_0) + (1 - \Pr(x_H))(x_L - P_0)]}{(x_H - P_0)(x_L - P_0)} \tag{20}$$

Now consider γ_0^* as the fund manager's initial endowment. At t_1, he has to modify this quantity, using the revised beliefs $\Pr(x_H \mid y, r)$ and $\Pr(x_L \mid y, r)$. By analogy we can compute γ_1^*, which gives the same result as (20) but with $\Pr(x_H \mid y, r)$ instead of $\Pr(x_H)$. Then defining the volume traded as the difference $\gamma_1^* - \gamma_0^*$ obtains:

$$V \equiv \gamma_1^* - \gamma_0^* = (\Pr(x_H \mid y, r) - \Pr(x_H)) * \frac{W[(x_L - P_0) - (x_H - P_0)]}{(x_L - P_0)(x_H - P_0)} \tag{21}$$

From what we define the positive amount α:

$$\alpha \equiv \frac{W[(x_L - P_0) - (x_H - P_0)]}{(x_L - P_0)(x_H - P_0)}$$

Appendix A2. Expected trading volume and relationship value

- Revised beliefs

First, remark that y being a symmetric binary signal, we use Bayes rules to verify that $\Pr(y_H) = \Pr(y_L) = 1/2$.

The adviser ignores y and infers what is the revised belief of the decision-maker confronted with r. As y and r are independant, we use:

$$\Pr(x \mid y, r) = \frac{\Pr(y \mid x)\Pr(x \mid r)}{\Pr(y)}$$

Thus we need to assess $\Pr(x \mid r)$.

$$\Pr(x_H \mid r_H) = \frac{\Pr(x_H, r_H)}{\Pr(r_H)} = \frac{\Pr(r_H \mid x_H).\Pr(x_H)}{\Pr(r_H \mid x_H).\Pr(x_H) + \Pr(r_H \mid x_L).\Pr(x_L)}$$

The states in which we obtain r_H conditionnal on x_H are : the adviser is of type L, and as such, tells r_H only if s_H is received (see assumption 2), and it is received with precision p ; or, the adviser is of type PB, and tells r_H either with signal s_L or with s_H. Formally:

$$\Pr(r_H \mid x_H) = \pi p + (1-\pi)(1-p+p) = \pi p + 1 - \pi$$

Using the same reasoning we find:

$$\Pr(r_H \mid x_L) = \pi(1-p) + 1 - \pi$$

Then

$$\Pr(x_H \mid r_H) = \frac{(\pi p + 1 - \pi)1/2}{(\pi p + 1 - \pi)1/2 + (\pi(1-p) + 1 - \pi)1/2} = \frac{(\pi p + 1 - \pi)1/2}{1 - \frac{1}{2}\pi} = \frac{p\pi + 1 - \pi}{2 - \pi}$$

Remark that $\Pr(r_H) = 1 - \frac{1}{2}\pi$, and thus $\Pr(r_L) = \frac{1}{2}\pi$.

Using the same steps we find:

$$\Pr(x_H \mid r_L) = 1 - p$$

Observing r_L, the decision-maker infers that the type is L (see assumption 2), then the precision of the recommendation is exactly the precision of his signal s_L conditionnal to x_H.

Back to the revised beliefs, we can define:

$$\begin{array}{l} \Pr(x_H \mid r_H, y_H) = 2q\left[\frac{p\pi+1-\pi}{2-\pi}\right] \\ \Pr(x_H \mid r_H, y_L) = 2(1-q)\left[\frac{p\pi+1-\pi}{2-\pi}\right] \\ \Pr(x_H \mid r_L, y_H) = 2q(1-p) \\ \Pr(x_H \mid r_L, y_L) = 2(1-q)(1-p) \end{array} \tag{22}$$

- Expected volume

Back to the expected volume, the adviser evaluates the average volume traded conditional on y received by the decision-maker:

$$\underset{y}{E}(V \mid r, s) = \Pr(y_H)(\alpha\left[\Pr(x_H \mid y_H, r) - 1/2\right]) + \Pr(y_L)(\alpha\left[\Pr(x_H \mid y_L, r) - 1/2\right])$$

Using $\Pr(y) = 1/2$, this rewrites:

$$\underset{y}{E}(V \mid r, s) = \frac{\alpha}{2}\left[\Pr(x_H \mid y_H, r) + \Pr(x_H \mid y_L, r) - 1\right]$$

Using the above equation with (22) for each cases yields:

$$\underset{y}{E}(V \mid r_H, s_H) = \frac{\alpha}{2}(2\left[\frac{p\pi+1-\pi}{2-\pi}\right] - 1) = \underset{y}{E}(V \mid r_H, s_L)$$
$$\underset{y}{E}(V \mid r_L, s_H) = \frac{\alpha}{2}(1-2p) = \underset{y}{E}(V \mid r_L, s_L) \tag{23}$$

- Expected value of the relationship

The adviser tries to assess what would be the response of the decision maker to his recommendation. The four possible cases are the following:
- The adviser receives s_H and considers sending r_H. With probability $\Pr(x_H \mid s_H)$ he is right and obtains R, and with probability$\Pr(x_L \mid s_H)$ the recommendation is not correct and this yields zero. Then $E(R \mid r_H, s_H) = pR$. Remark that both types of adviser consider this case.
- The adviser receives s_H and considers sending r_L. With probability $\Pr(x_H \mid s_H)$ he is wrong and obtains zero, and with probability $\Pr(x_L \mid s_H)$ the recommendation is correct and this yields R. Then $E(R \mid r_L, s_H) = (1-p)R$. However this choice is not an equilibrium strategy (see proposition 3, p.8).
- The adviser receives s_L and considers sending r_H. With probability $\Pr(x_H \mid s_L)$ he is right and obtains R, and with probability$\Pr(x_L \mid s_L)$ the recommendation is not correct and this yields zero. Then $E(R \mid r_H, s_L) = (1-p)R$. Remark that, by assumption 2, only the *potentially biased* (PB) type is susceptible of making this choice.
- The adviser receives s_L and considers sending r_L. With probability $\Pr(x_L \mid s_L)$ he is right and obtains R, and with probability$\Pr(x_H \mid s_L)$ the recommendation is not correct and this yields zero. Then $E(R \mid r_L, s_L) = pR$. Remark that, by assumption 2, only the *loyal* (L) type is susceptible of making this choice.

Appendix A3.Equilibrium determination of π

To ease notations, rewrite (13) with some change of variables. Let X be $\frac{1}{100}(\frac{1-\theta}{\theta})^*$, i.e., from (14), the probability of being of the PB type; and $\gamma = R(2p-1)$. Then (13) rewrites:

$$100X = \frac{\alpha p + \frac{\alpha p + X(\alpha - \alpha p)}{1+X}}{\gamma} \tag{24}$$

Rearranging terms to isolate X, we find a polynomial equation of the second degree:

$$(100\gamma)X^2 + (100\gamma - \alpha)X - 2\alpha p = 0 \tag{25}$$

Using the quadratic formula we identify a positive discriminant. Indeed, as $1/2 < p \leq 1$, γ is strictly positive, just as R and α. There are two distinct real roots for X:

$$
\begin{aligned}
x_1 &= \tfrac{\alpha-100\gamma-\sqrt{[100\gamma-\alpha]^2+800\alpha\gamma p}}{200\gamma} \\
x_2 &= \tfrac{\alpha-100\gamma+\sqrt{[100\gamma-\alpha]^2+800\alpha\gamma p}}{200\gamma}
\end{aligned} \tag{26}
$$

Recall that this threshold is used to assess a probability. Now, studying x_1, and developping the square term under the square root, it appears from the equation above that $x_1 > 0$ if:

$$\alpha > 100\gamma + \sqrt{10000\gamma^2 - 200\alpha\gamma + \alpha^2 + 800\alpha\gamma p} \tag{27}$$

First make the following remark:

Remark 2 *We verify that the term under the square root in (27) is strictly positive: factorizing* $\alpha\gamma$ *yields* $800p - 200$*, which is always positive as* $1/2 < p \leq 1$*. Others terms are square terms.*

Now remark that α^2 appears in the square root of (27) and that the rest is positive. It follows that α being stricly positive, it cannot be strictly superior to itself, hence (27) is never true and x_1 is always negative. Hence the adviser would always be of type L. It is not the case for x_2, as the sign before the square root term would be negative in equation (27).
That is why we only retain x_2 in the paper. From the second line in (26), replacing variables γ and X yields the threshold given in equation (15), p.10.

Appendix A4. Factors of type probability

- Reaction to an increase in α

Consider the right-hand side of (15) as a function $f(\alpha)$, with given R and p. We study the sign of the derivative $df/d\alpha$. It appears that this sign depends on the derivative of the square root term. Denoting by $g(\alpha)$ the term under the square root and by $h(.)$ the square root function, the derivative becomes $(h \circ g)'g'$. First, $(h \circ g)' = \frac{1}{2\sqrt{g(\alpha)}}$. From remark 2 in appendix A3, we know that $g(\alpha)$ is positive. Now with $g'(\alpha) = 2\alpha + 800R(2p - 1) - 200R(2p - 1)p$, we use the same reasoning as in remark 2 to assess that it is strictly positive.
Finally, $df/d\alpha$ equals a positive constant *times* 1 + something positive. Hence $df/d\alpha$ is strictly positive and this prooves lemma 2.

- Reaction to an increase in R.

Consider the right-hand side of (15) as a function $f(R)$, with given α and p. We study the sign of the derivative df/dR. Denoting by $u(R)$ the numerator and by $v(R)$ the denominator, the sign depends on the sign of $u'v - uv'$. Note that $v(R)$ is strictly positive. Turning to $u'(R)$, we use again $g(R)$ as the term under the square root in (15) and $h(.)$ as the square root function. From remark 2, $g(R)$ is positive, and so is $(h \circ g)'$. Now $g'(R) = 2R100^2(2p-1)^2 - 200(2p-1)\alpha + 800(2p-1)\alpha p$. Then $u'v - uv'$ is equal to:

$$\left[-100(2p-1) + \frac{g'(R)}{2\sqrt{g(R)}}\right] 200R(2p-1) - \left[\alpha - 100R(2p-1) + \sqrt{g(R)}\right] 200(2p-1)$$

Let us distribute R over the left-hand term, in order to factor the whole expression by $200(2p-1)$, which simplifies with the denominator. The denominator becomes $200(2p-1)R^2$, which is positive. Now call B the expression $B = 2.100^2\left[R(2p-1)\right]^2 - 200R(2p-1)\alpha + 800R(2p-1)\alpha p$. As in remark 2 factorizing by $R(2p-1)\alpha$ shows that B is positive. Then $u'v - uv'$ becomes:

$$-\alpha - \sqrt{g(R)} + \frac{B}{2\sqrt{g(R)}}$$

which we rewrite:

$$-\alpha - \sqrt{g(R)}\left(1 - \frac{B}{2g(R)}\right)$$

The sign of this expression is negative only if $(1 - B/2g(R))$ is; and this is the case only if $B < 2g(R)$. After some computations, $B < 2g(R)$ becomes:

$$0 < -200R(2p-1)\alpha + 800R(2p-1)\alpha p + \alpha^2$$

which is always true (as $1/2 < p \leq 1$, $p800 > 200$). Hence the numerator is always negative, hence df/dR is strictly negative, which prooves lemma 3.

- Reaction to an increase in p

Consider the right-hand side of (15) as a function $f(p)$, with given α and R. We study the sign of the derivative df/dp. Denoting by $u(p)$ the numerator and by $v(p)$ the denominator, the sign depends on the sign of $u'v - uv'$. $v(p)$ is strictly positive. Note $g(p)$ the term under the square root. By remark 2 $g(p)$ is positive.
Now $g'(p) = 100^2 4R^2(2p-1) - 400R\alpha + 800R\alpha(4p-1)$. Then $u'v - uv'$ is:

$$200R(2p-1)\left(\frac{g'(p)}{2\sqrt{g(p)}} - 200R\right) - 400R(\alpha + \sqrt{g(p)} - 100R(2p-1)) \qquad (28)$$

Dividing by $200R$, factorizing by $(2p-1)$ yields:

$$(2p-1)\Big(\frac{g'(p)}{2\sqrt{g(p)}}\Big) - 2(\alpha + \sqrt{g(p)})$$

This expression is negative if:

$$(2p-1)g'(p) < 4\alpha\sqrt{g(p)} + 4g(p)$$

As $\sqrt{g(p)} > 0$, it is sufficient to proove that $(2p-1)g'(p) < 4g(p)$. Replacing $g'(p)$ and $g(p)$ in this expression gives, after some computations:

$$(3200p - 1200)(2p-1) < (3200p - 800)(2p-1) + \frac{4\alpha}{R}$$

which is always true. By then, the numerator $u'v - uv'$ is negative, thus df/dp is alsways negative. This prooves lemma 1.

Appendix A5. When the Decision-maker follows

We assess to what extent the decision-maker will participate to the market by following or deviating from some information. Equation (1) shows that we must compare the revised beliefs (22) to the prior :1/2.

- Convergent favorable informations: r_H, y_H

In this case we expect a purhcase, i.e. $V > 0$:

$$2q\Big(\frac{p\pi + 1 - \pi}{2 - \pi}\Big) > 1/2$$

Studying the fraction in parenthesis, with π in $[0, 1]$ and p in $]1/2; 1]$, we derive that this fraction : *a)* converges to 1/2 when $\pi \to 0$, or, when $\pi \to 1$ if $p \to 1/2$, and *b)* has 1 as upper bound, when $\pi \to 1$ and $p \to 1$. Now as $q \in]1/2; 1[$, then $2q \in]1; 2[$. Therefore the left term of the inequation is in $]1/2; 2[$. Hence it is strictly superior to 1/2, thus the inequation is always true.

- Convergent unfavorable informations: r_L, y_L

We expect a sale: $V < 0$, i.e.:

$$2(1-p)(1-q) < 1/2$$

Under assumption (1), $(1-p) < (1-q) < 1/2$, then $(1-p)(1-q) < 1/4$, and thus the inequation is always true.

- Conflicting informations: r_L, y_H

The decision-maker will follow the expert against his own information, i.e. will sell, if $V < 0$:

$$2q(1-p) < 1/2$$

By assumption (1), $1/2 < q < p \leq 1$. If $q \to \frac{1}{2}^+$, there is a wide range for which $p \in]q; 1]$, but in the case when $q \to 1^-$, p is necessarily very close or equal to 1. Besides, the product $q(1-p)$ is strictly under $1/4$: as $1-p < 1-q$, we could write $1-p = 1-q-\varepsilon$ with $\varepsilon \to 0$, and verify that the function $q(1-q-\varepsilon)$ has a maximum approaching $1/4$ from below. Finally, the left term of the inequation vary between 0 (when p approaches 1) and $1/2$ from below (when $q \to \frac{1}{2}^+$ and $p \to q$). Thus, the inequation is always true.

- Conflicting informations: r_H, y_L

The decision-maker will buy and follow the expert against his own information if $V > 0$, that is:

$$2(1-q)\Big(\frac{p\pi + 1 - \pi}{2-\pi}\Big) > 1/2$$

We saw above that the fraction in parenthesis is in $[1/2; 1]$. Besides, $2(1-q) \in]0; 1[$. The the left term vary between 0 and 1: the choice of following or deviating from the expert depends on the respective values of p and q.

A6. The frontier between deviating and following

- Proposition 4 : $q(p)$ increases with p

  Proof.

  First interpret lemma 1 as $\pi'(p) > 0$ (proof in Appendix A4). Then $q'(p)$ is $-(1/4)(u/v)'$ with $u = 2 - \pi(p)$, $v = 1 - (1-p)\pi(p)$, $u' = -\pi'(p)$, and $v' = \pi(p) - (1-p)\pi'(p)$. Then study the sign of the numerator $u'v - uv'$:

  $$\pi'(p)[(1-p)\pi(p) - 1] - (2 - \pi(p))[\pi(p) - (1-p)\pi'(p)]$$

  Expanding and simplifying yields:

  $$(\pi(p))^2 - 2\pi(p) + 2\pi'(p)(1-p) - \pi'(p)$$

  The terms implicating π are $\in [-1; 0]$. We rewrite the terms implicating π' as $\pi'(p)(1-2p)$. With $(1-2p) \in [-1; 0[$ and recalling that $\pi'(p) > 0$ from lemma 1, we show that the whole numerator is strictly negative. As it is multiplied by $-(1/4)$, then $q'(p) > 0$. ■

- Proposition 5 : deviation more likely when α is high

  Proof.

  As π depends on α, then $q(p)$ is indirectly impacted by α. Considering q as a function of α, then $q'(\alpha) = -1/4(u/v)'$. We study the sign of $u'v - uv'$, which is negative if:

  $$\pi'(\alpha)[1-(1-p)\pi(\alpha)] < (2-\pi(\alpha))(1-p)\pi'(\alpha)$$

  Factorizing with $\pi'(\alpha)$ gives:

  $$\pi'(\alpha)[1-(1-p)\pi(\alpha)-(2-\pi(\alpha))(1-p)] < 0$$

  As $\pi'(\alpha)$ is negative (see lemma 2, proof in appendix A4), the whole expression is true if the term into brakets is positive. When distributing with $(2-\pi(\alpha))$, this latter expression simplifies into: $1-2(1-p)$, which is strictly positive by definition of p. Then the whole expression is negative: when α increases, the function $q(p)$ moves downward, hence, all else equal, the "deviation" zone is greater. ∎

- Proposition 6 : deviation more likely when R is low

  Proof.

  Again $q(p)$ depends on π which depends on R. Considering q as a function of R gives $q'(R) = -1/4(u/v)'$. The numerator $u'v - uv'$ is positive if: $\pi'(R)(1-(1-p)\pi(R) - (2-\pi(R))(1-p)\pi'(R) > 0$. Factorizing by $\pi'(R)$ and distributing with $(2-\pi(R))$ yields: $\pi'(R)[1-2(1-p)]$. As $\pi'(R)$ is positive (see lemma 3, proof in appendix A4), and also $1-2(1-p)$, then the whole expression is positive: when R increases, the function $q(p)$ moves upward, i.e. all else equal, the "deviation" zone is smaller. ∎

- Chances of deviating: indetermination of the ratio $[p-q(p)]/[p-1/2]$

  Consider the ratio as a function of p. Denote q' the derivative $q'(p)$ analyzed in the first item of this appendix. Then the ratio varies according to the sign of $(1-q')(p-1/2)-(p-q)$. Suppose for example that the sign is negative, it yields:

  $$q - q'p - \frac{1}{2} + \frac{1}{2}q' < 0$$

  Or else

  $$q'(\frac{1}{2}-p) < \frac{1}{2} - q$$

  From the definitions of p and q we have $0 < q-\frac{1}{2} < p-\frac{1}{2}$. Further, $(p-1/2) \in]0;1/2]$, but for a given p, $(q-1/2) \in]0;p-1/2[$, as q is smaller than p. Putting it differently,

$p - 1/2 > q - 1/2$, but $p - 1/2$ is multiplied by $q'(p)$. We know from above that $q'(p) > 0$, hence we are never sure that the inequality holds, unless we could proove that $q'(p) > 1$. Back to the first item of appendix A6, we analyze that, once multiplied by $-1/4$, the numerator of $q'(p)$ is $\in]0; 1]$, whereas the denominator is $\in [1/4; 1/2]$, which means that $q'(p)$ values are $\in]0; 4]$. Thus we cannot be sure that $q' > 1$. It depends on how α and R impact π. Therefore we state that how the chances of deviating depend on p is undetermined.

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