TOULOUSE ECONOMISTS ON
RISK-SHARING MECHANISMS

JANUARY 2017

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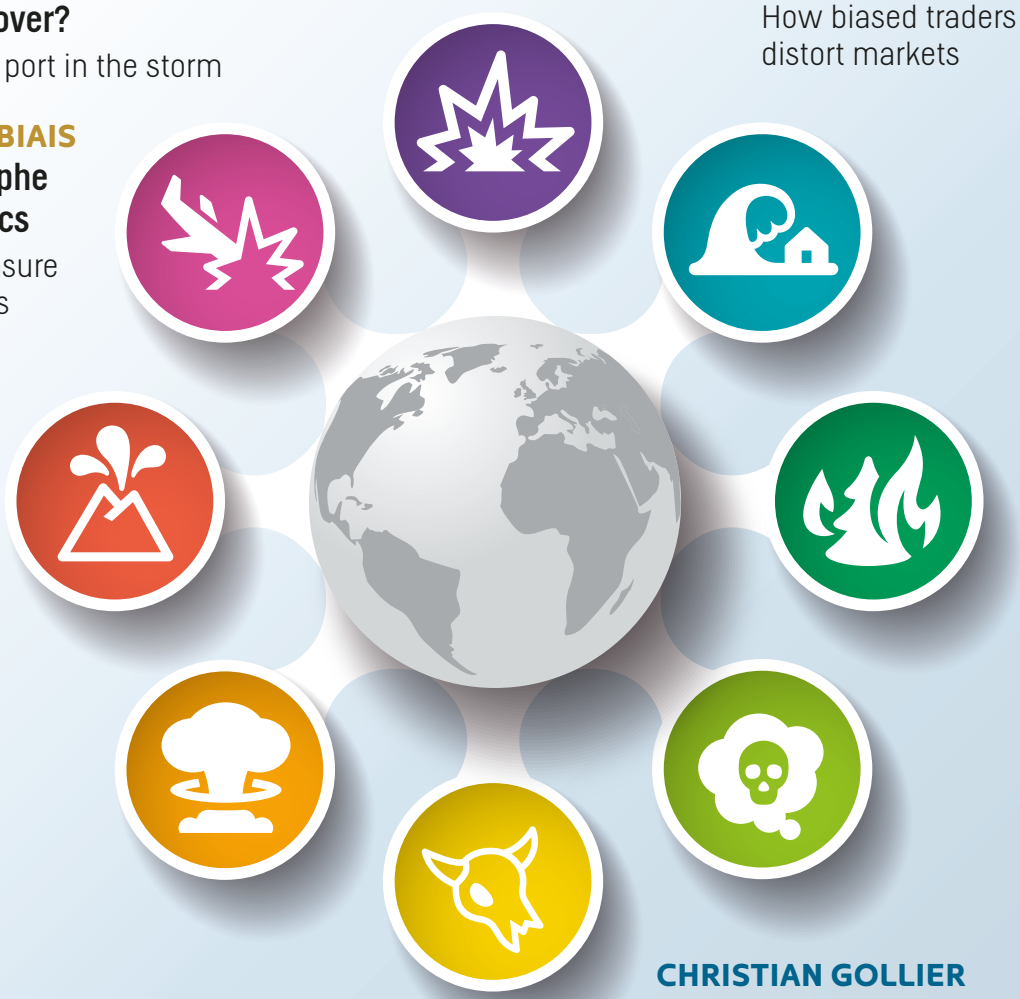

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SCOR The Art & Science of Risk

IDEI Institut d'économie industrielle

Toulouse School of Economics

A TRULY **extraordinary** RECORD

Celebrating productive partnership

The Institute of Industrial Economics (IDEI) is a partnership-based research centre which offers businesses and administrations an interface between their activities and the world-class economic research at Toulouse School of Economics.

With a balance sheet of €41.6bn and more than 2,500 employees, SCOR is a giant of the global reinsurance industry and a highly valued TSE partner. Here, the company's chief economist Philippe Trainar explains why this partnership has been of such value to both sides, stimulating cutting-edge research and providing the tools to address the latest developments.

"SCOR is extremely satisfied with this long-standing partnership," says Trainar. *"It has brought us great rewards. The research deals with the economy of risk, an area to which French economists have contributed enormously. As a reinsurer, we at SCOR are very interested in this question, but above all, we want to understand how risk transforms and influences economic decision-making."*

The IDEI-SCOR partnership has already gone above and beyond its original goals, says Trainar. *"There has been excellent, extremely precise research at the international level. This research is also very enriching for SCOR because it allows us to address direct questions to the TSE team. These may sometimes seem a bit 'clumsy', but the researchers have a great capacity to listen, to reformulate the questions in a general framework and, above all, to provide answers. To what extent are risk premiums insurable or re insurable? What are the optimal ways of sharing very high risks? How should risk-based profitability evolve?"*

The support of TSE economists on these issues, says Trainar, has helped to reshape SCOR's business strategy. *"With Christian Gollier, Stéphane Villeneuve, and the rest of the Toulouse team, we have already made a lot of progress. What is being written today is completely different from what we wrote 10 years ago and for that we are extremely grateful to the Toulouse researchers. They have brought us solutions on issues that transcend everyday activities. These are often questions that will influence our long-term strategy. Today, we can celebrate a truly extraordinary record and a very fruitful partnership."*

CUTTING-EDGE RESEARCH

Since 2008, the SCOR Chair "Risk Markets and Value Creation" has supported theoretical and applied research at TSE on regulation of insurance markets and risk management, combining methods from financial economics, industrial organization and econometrics. The contract was renewed in 2012 for five years. Key topics include:

- *Longevity risk, long-term care and (social) insurance*
- *Risk management of large environmental risks*
- *Methodology of credit risk models*
- *Regulation, liquidity and solvency risks*
- *Risk attitude*

DYNAMIC INTERACTION

SCOR teams are in constant contact with TSE researchers. At regular intervals and minimum once a year, a steering committee meeting allows researchers to present their results, and SCOR representatives to express their research needs. It also determines the orientation of applied research to meet the needs of SCOR management. Monitoring is done through the delivery of research papers and the development of internal seminars.

CONTENTS

WORLD-CLASS TALENT

In the fast-changing landscape of today's reinsurance market, SCOR representatives can draw directly on the knowledge networks, nuanced advice and latest discoveries of TSE's research teams. Here, we present some of the leading TSE economists whose work is featured in the following pages.

BRUNO BIAIS

Professor at TSE, he is also a senior researcher at the Centre for Research in Management (CNRS). His work has been published in Econometrica, the JPE, the AER, the Review of Economic Studies, the Journal of Finance and the RFS.

He has taught at HEC, CMU, LBS, Oxford and LSE. He has been a scientific adviser to Euronext and the NYSE. He received the CNRS bronze medal and is a fellow of the Econometric Society. He has been editor of the ***Review of Economic Studies*** and is co-editor of the ***Journal of Finance***.

RESEARCH INTERESTS

- Market microstructure
- Corporate finance
- Financial contracting
- Political economy
- Psychology and economics
- Experimental economics

FRÉDÉRIC CHERBONNIER

Professor at Sciences Po in Toulouse since 2010 and a TSE researcher since 2007, Frédéric Cherbonnier won a prestigious IEF grant in 2014 for his research project *'Informational Rents and Real Estate Markets'*.

He has a PhD in mathematics from Paris and extensive professional experience in providing economic analysis and strategic advice to France Telecom and the French government. He has published in leading journals including the ***Journal of Economic Theory.***

RESEARCH INTERESTS

- Business administration
- Risk management and insurance
- Financial economics

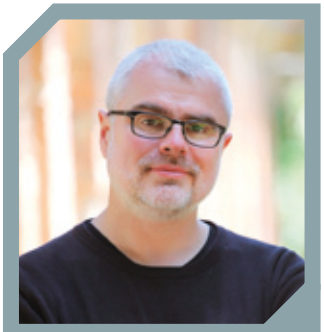
CHRISTIAN GOLLIER

Alongside Jean Tirole, he was one of TSE's founders. He subsequently served as deputy director (2007-2009) then director (2009-2015).

His current fields of interest extend from decision theory under uncertainty to environmental economics through finance, investment, consumption theory, insurance economics and cost-benefit analysis, with a special interest in long-term (sustainable) effects. He has published seven books on risk including ***The Economics of Risk and Time***, winner of the 2001 Paul A. Samuelson Award.

RESEARCH INTERESTS

- Economics of uncertainty
- Finance
- Insurance
- Environmental economics



THOMAS MARIOTTI

Senior researcher at the Centre for Research in Management (CNRS), he has also taught economics at LSE. Since earning his PhD in Toulouse, he has become co-editor of ***Theoretical Economics and Mathematics*** and ***Financial Economics,*** and associate editor of ***Econometrica*** and the ***Journal of the European Economic Association.***

In 2009 he won the IEF prize for the best young researcher in finance. He has held visiting positions at Princeton, Yale and many other prestigious institutions.

RESEARCH INTERESTS

- Economic theory
- Finance

LEADING LIGHTS

Key figures in the partnership

SÉBASTIEN POUGET

Professor of finance at University of Toulouse Capitole and a TSE member, he was a visiting professor of economics at Princeton. He studies financial markets using a multidisciplinary approach that combines insights from economics, psychology and history.

His research has been published in international academic journals such as the *Journal of Finance, Econometrica*. He is co-director of the research centre on Sustainable Finance and Responsible Investment (FDIR chair).

RESEARCH INTERESTS

- Financial markets
- Psychology of finance
- History of finance
- Experimental economics

JEAN-CHARLES ROCHET

SFI professor of banking at Zurich University, he is also a TSE associate researcher. He became president of the Econometric Society in 2012.

He has advised the IMF, the Federal Reserve and the European Central Bank. He has also been council member of the European Economic Association, and associate editor of *Econometrica*. He has published more than 80 articles in international scientific journals and seven books, including *Microeconomics of Banking* and *Why Are There So Many Banking Crises?* (2008).

RESEARCH INTERESTS

- Financial stability
- Industrial organization of financial markets
- Risk management
- Contract theory
- Solvency regulations for financial institutions

PHILIPPE TRAINAR

One of the driving forces of the IDEI-SCOR project, he is SCOR group's chief economist and its chairman's senior global advisor. He is a TSE board member, a lecturer at Paris-Dauphine University and chairman of the Risk Commission of the Association des Professionnels de la Réassurance en France (APREF).

He is also editor-in-chief of the *Revue Française d'Économie*, and member of the editorial committees of the magazines *Commentaire, Risques and Sociétal,* as well as the *Revue d'Économie Financière*.

AREAS OF EXPERTISE

- Macroeconomics
- Risk and insurance
- Tax, pensions and social security
- Finance
- International economics

STÉPHANE VILLENEUVE

Professor of applied mathematics and dean of the mathematics department at University of Toulouse Capitole, Stéphane Villeneuve is also affiliated with the Centre for Research in Management (CNRS) and TSE.

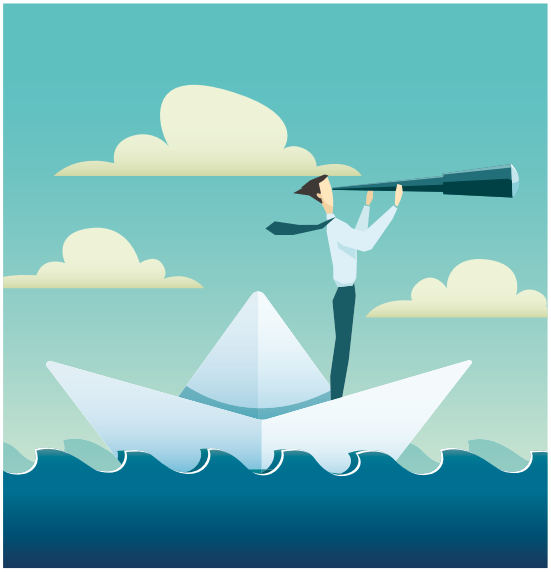
He coordinates the Market Risk and Value Creation Chair, sponsored by SCOR under the aegis of the Fondation du Risque. His research focuses on stochastic methods in finance and more recently on their applications in dynamic contracting.

RESEARCH INTERESTS

- Optimal stopping and stochastic control
- Mathematical and computational finance
- Contract theory in continuous time

WHERE DO INSURERS RUN FOR COVER?

Finding a port in the storm



Philippe Trainar
Stéphane Villeneuve

Terrorism and solar storms are among the many new risks that must be faced by 21st-century society. The size and complexity of such risks in a globalized world demand big ideas and complex solutions. This is the stage set for reinsurance companies like SCOR, which cover the risks of direct insurers. Here, SCOR's chief economist Philippe Trainar and TSE's Stéphane Villeneuve outline some of the new challenges facing the industry.

The big news in insurance, says Villeneuve, is the globalization of risks: *"The event that woke everyone up to this was the terrorist attack on the World Trade Center in 2001, which had a global financial impact. Another example is the risks of drought in Ukraine which led to a spike in agricultural prices that sparked a revolution in Tunisia."*

The complexity of such multi-dimensional phenomena is daunting, but Villeneuve emphasizes that taking risks can also be very positive, and coverage offers opportunities for growth and cooperation: *"An investor must take risks. The role of an insurer or reinsurer is to share risks, to accompany economic actors and find the mechanisms which mitigate catastrophes."*

The reinsurance industry is in excellent health, says Trainar, and it will continue to grow and diversify as the sources of risk become increasingly complex: *"The proof is that today all investors are turning to the reinsurance market. We are now witnessing a kind of equalization of profits because when you increase the capacity of a market, prices tend to drop. But this market benefits from the expansion of the universe of risks, especially extreme risks."*

The growth and enrichment of the world population has multiplied the risks faced by humans, Trainar explains: *"When you are richer, you have more things to lose; when you have more interactions, some will be negative and require coverage. Climate change also contributes to the growth of risks – Toulouse has already worked hard on this issue. People often congregate in dangerous areas, along coastlines and rivers, probably because this is where contacts are made more easily. This also increases the need for reinsurance. So this is a market that has a great future."*

Digitalization is another revolutionary force in the reinsurance industry, and a key focus of TSE research. *"Whether we like it or not, our insurance contracts in future will be increasingly individualized,"* explains Villeneuve. *"Machines will measure the way we drive, eat and exercise. This will considerably alter the relationship between insurers and policyholders, raising new ethical and legal issues."*

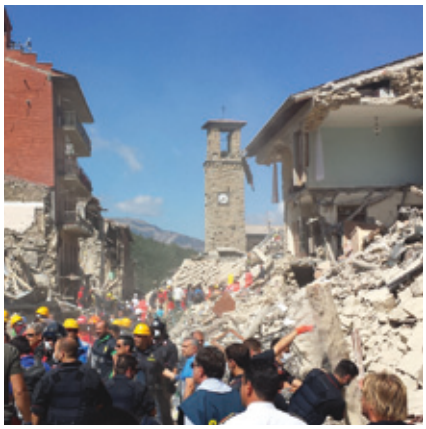
The role of reinsurers

Reinsurance provides direct insurers with three crucial benefits:

- **Greater security**
  Reinsurance protects the equity and solvency of direct insurers, offering stability when unusual and major events occur.
- **Increased capacity**
  Reinsurers enable insurers to underwrite policies covering a larger number of risks, or larger risks, without excessively raising their administrative costs or their need to cover their solvency margin and, therefore, their shareholders' equity.
- **Liquidity**
  Substantial liquid assets can be made available to insurers in the event of exceptional losses.

Reinsurers also provide advisory services to ceding companies:

- Defining reinsurance needs and devising the most effective programme for their capital needs and solvency margin.
- Supplying a wide array of support services, including technical training, organisation, accounting and information technology.
- Providing expertise in highly specialised areas such as the analysis of complex risks and risk pricing.
- Enabling under-capitalised firms to build up their business, particularly when new products require heavy investment.



August 24, 2016: Corso Umberto in the historic centre in Amatrice, Italy, reduced to a pile of rubble.

March 11, 2011: A magnitude-9 earthquake hit northeastern Japan which spawned a tsunami that left about 18,500 dead or missing.

January 18, 2014: Residents cross flooded streets of Jakarta, Indonesia.

CATASTROPHE ECONOMICS

How to insure large risks

Bruno Biais
Thomas Mariotti
Jean-Charles Rochet
Stéphane Villeneuve

Industrial accidents, such as the explosion at the BP Texas refinery in 2005, are often blamed on inadequate attention to safety procedures. Similarly, the huge losses suffered by financial firms during the 2008 financial crisis were partly due to insufficient risk control. Recent research on the prevention of such large, infrequent risks by TSE's Bruno Biais, Thomas Mariotti, Jean-Charles Rochet and Stéphane Villeneuve is particularly relevant in the context of globalization, climate change and new political uncertainties. Their timely paper, 'Large Risks, Limited Liability and Dynamic Moral Hazard', studies the design of incentives to mitigate catastrophic events.

The risk of catastrophe, while mercifully rare, presents a unique challenge to firms, investors and society. One way to stimulate the prevention of large risks would be to make managers and firms bear the social costs that they generate. This is often impossible in practice, because total damages can exceed the wealth of managers and even the net worth of firms, while the former are protected by limited liability and the latter by bankruptcy laws. This curbs managers' incentives to reduce the risk of losses that exceed the value of their own assets. If managers' efforts to prevent risk were observable, compensation schemes could easily be designed. However, these activities are often unobservable by external parties, and this creates moral hazard.

Modelling model hazard

Biais and his colleagues study a dynamic setup, where the timing of losses differs from that of operations. They examine the optimal contract between a principal and an agent that provides the latter with appropriate incentives to reduce the risk of losses under dynamic moral hazard. Both players in their model are risk-neutral. The agent, who can be thought of as an entrepreneur or a manager running a business, is protected by limited liability. The principal, who can be thought of as a financier, an insurance company or society, has unlimited liability. The project run by the agent can expand, through investment, or shrink, through downsizing. Assets can be instantaneously liquidated, but the pace of investment is limited by adjustment costs. The model assumes constant returns to scale.

What's the ideal contract?

The optimal contract relies on two instruments: positive payments to the agent and project size management through downsizing and investment. The evolution of the agent's continuation utility mirrors the dynamics of losses and thus serves as a track record of the agent's performance.

- **Compensation policy:** The agent is motivated by the prospect of payments after good performance and reductions in continuation utility after losses. When the track record of the agent is relatively poor, there is a probation phase during which he or she does not receive any payment. As long as no loss occurs, the size-adjusted continuation utility of the agent increases until it reaches a threshold

at which he or she receives a constant wage per unit of time and size of the project, such that her size-adjusted continuation utility remains constant. As soon as a loss occurs, the continuation utility of the agent is sharply reduced and the contract reverts to the probation phase. The more severe the moral hazard problem and the larger the project, the greater the punishment.

➨ **Firm size:** In the best scenario, there is no need for downsizing: investment occurs at the highest feasible rate to maximize project size. In the second-best case, project size is lower. The researchers' intuition is that the agent is partly motivated by the threat of reductions in continuation utility in case of bad performance. But when the agent's continuation utility is low, the threat to reduce it further has limited bite, because of limited liability. To counter the agent's temptation to shirk, the scale of operations can be reduced after losses. In addition to downsizing, moral hazard also affects project size through its impact on investment. Since increases in project size raise the temptation to shirk, investment takes place only when the agent's track record is good enough to reach a given threshold. The total size of the pie grows with investment, which makes delaying compensation of the agent less costly. This means it is efficient to invest before compensating the agent. But as the agent is more impatient than the principal, all compensation ideally occurs before investment.

> ***"In the optimal contract, investment takes place only if enough time elapses without losses"***

Results and implications

The researchers obtain an explicit formula that maps the path of the agent's size-adjusted continuation utility into the size of the project. If one interprets the latter as firm size, this formula exactly spells out how firm size grows, stays constant, or declines over time. In the best scenario, firm size goes to infinity at a constant rate. In the second-best case, this trend in firm size is reduced by downsizing and possibly lower investment rates. When the adjustment costs are high, firm size eventually goes to zero. By contrast, when both the adjustment costs and the frequency of losses are low, firm size eventually goes to infinity, although more slowly than in the best scenario.

- In the best case, firms should always invest. In the second-best case, firms should invest only after a long record of good performance, when the cost of investment is not too low. After good performance, agents will be compensated, while after bad performance, the firm will be partially liquidated.
- Small firms in this model tend to be exposed to financial constraints on investment. They are also more fragile, since a few negative shocks are enough to require downsizing. Conversely, large firms that have enjoyed sustained investment are more likely to have long records of good performance, which makes them more secure. Overall, the probability of downsizing decreases with firm size.
- This logic implies that large firms should have higher growth rates than smaller ones, while data suggest that on average the opposite is true. Interestingly, Dunne, Roberts, and Samuelson (1989) found that growth rates for plants owned by multi-plant firms tend to increase with size, because of a substantial fall in failure rates. This evidence suggests that this TSE analysis is particularly relevant for multi-plant firms.
- A further testable implication is that downsizing decisions should be followed by relatively long periods with no investment.
- Firm size and agent compensation ought to be positively correlated: after a long period of good performance, the scale of operations is large and so are the payments to the agent. This suggests that explanations based on size should not be divorced from explanations based on incentives, and that investment and managerial compensation are complementary incentive instruments.

Summing up

In the optimal contract, investment takes place only if enough time elapses without losses. If good performance continues, the agent is paid. As soon as a loss occurs, payments to the agent are suspended, and so is investment if further losses occur. Accumulated bad performance leads to downsizing. As well as characterizing the optimal policies, the TSE researchers provide explicit formulae for the dynamics of firm size and growth.

Their analysis generates important policy and managerial implications:

→ This research provides a rationale for prudential regulations that require that a firm's size ought to be proportionate to its capital. In the context of financial institutions, downsizing and investment decisions should be made contingent on accumulated performance.

→ Capital requirements should also be complemented by regulation of managerial compensation. This should be based on long-term track records, and reduced after large losses by an amount that increases with the private benefits from shirking and the extent to which shirking is difficult to detect.

CLOSED MINDS

How biased traders distort markets

> ***A mind is a terrible thing to change... you believe stocks are going to outperform other assets, and all you can hear are warnings of the bloodbath to come in the bond and commodity markets. In short, your own mind acts like a compulsive yes-man who echoes whatever you want to believe***
>
> Jason ZWEIG, *Wall Street Journal*
> November 19, 2009

Sébastien Pouget
Julien Sauvagnat
Stéphane Villeneuve

The human tendency to select and use information in ways that confirm our own preconceptions has been well documented by psychologists. This confirmatory bias can be extremely costly for traders and investors, and has huge implications for price formation. In a unique new paper titled 'A Mind is a Terrible Thing to Change: Confirmatory Bias in Financial Markets', TSE's Sébastien Pouget, Julien Sauvagnat and Stéphane Villeneuve offer the first study of how confirmatory bias affects beliefs and asset pricing in financial markets.

Confirmatory bias – or *"the seeking or interpreting of evidence in ways that are partial to existing beliefs"* (Nickerson, 1998) - is intimately related to the dynamics of belief formation. As such, it is particularly relevant to traders and investors.

To understand how this bias affects financial markets, consider that traders initially hold positive views about an asset's future cashflow. If subsequent information is also positive, then all traders interpret it correctly. However, if this information is negative, biased traders have a given probability to ignore the negative information.

These differences of opinion give rise to trading. Speculators take opposite positions with respect to biased traders and thus have a corrective impact on prices. However, transaction costs limit the effectiveness of corrective strategies, causing the views of both speculators and biased traders to be incorporated into asset prices.

Mind your own beliefs

The TSE researchers propose a simple dynamic model of financial markets in which some traders are prone to the confirmatory bias: biased traders may ignore information when it is inconsistent with their prior views. This bias creates differences of opinion between rational speculators and biased traders over the interpretation of public information.

The researchers consider a pure exchange economy with one risky asset in fixed supply and a riskless asset in perfectly elastic supply. There are two groups of agents: speculators and biased traders. Each trader is endowed with one unit of the risky asset and no cash. The researchers introduce an uninformative signal, so that traders who neglect the informational content of news cannot realize that they are biased. To focus on the informational aspects of financial markets, traders are assumed to be risk neutral.

Market mysteries: a new explanation

The TSE researchers' theoretical analysis shows that the confirmatory bias provides a unified explanation for various phenomena that have been documented in actual financial markets, including excess volume, excess volatility, momentum, bubbles and crashes. Several behavioral finance theories have been proposed to account for these stylized facts. For instance, overconfidence may explain excess volume, excess volatility and even momentum when coupled with self-attribution bias. Representativeness heuristics may also rationalize momentum. Sticky expectations can also be invoked to explain momentum, as well as other asset pricing phenomena such as the quality anomaly. Finally, gradual information flow and limited attention may explain excess volume and momentum.

The TSE researchers' model offers a complementary explanation to these long-standing puzzles and has the following distinctive features:

- It provides a novel mechanism for differences of opinion, the confirmatory bias, which is theoretically and empirically well-grounded in the psychology literature
- It is parsimonious in the sense that departures from perfect rationality are driven by only one parameter
- It offers novel predictions that the researchers are able to test empirically

First impressions matter

To show the unique impact of confirmatory bias, the TSE researchers make the following novel theoretical predictions.

At the individual level:

- After initial positive or negative signals, some traders tend to ignore subsequent signals in the other direction
- Traders that have previously updated their beliefs upward or downward are more likely to ignore subsequent signals in the other direction

At the stock level:

- As conflicting signals open opportunities for biased traders to misinterpret information, this creates differences of opinion
- In the presence of biased traders, differences of opinion should be larger when past signals exhibit changes in sign

Empirical analysis

The researchers tested their predictions using data on US firms' earnings announcements and financial analysts' earnings forecasts over the period 1982 to 2014. Their results suggest that the confirmatory bias is at work in financial markets:

- First, consistent with the basic prediction of the model, they find that analysts are less likely to revise their forecasts upward (respectively, downward) after good (respectively, bad) earnings surprises when one of the previous earnings surprises was negative (respectively, positive).
- Using previous analysts' forecast revisions as a proxy for their bearish or bullish prior beliefs about an asset, the researchers also find that analysts are less likely to revise their forecasts after earnings surprises of a different sign to their prior beliefs.
- To test the last prediction, the researchers use dispersion in analysts' annual earnings forecasts as a proxy for differences of opinion. They find that forecasts dispersion is significantly larger when news revealed by earnings announcements over the previous quarters have different signs. Their findings hold when they consider changes in the sign of earnings surprises over either the previous two or previous three quarters.

This empirical investigation provides new stylized facts on the link between the sign of public signals, on the one hand, and analysts' forecast dispersion and revisions. The researchers also find heterogeneous effects across analysts in their forecast behavior in the direction predicted by the model. These stylized facts are consistent with the confirmatory bias affecting analysts' perception of information.

Summing up

This research proposes a theory of financial markets based on the premise that some traders are prone to confirmatory bias. In the TSE researchers' model, biased traders tend to misperceive public signals that are inconsistent with their prior views. The researchers show that this bias provides a rationale for various phenomena observed on financial markets, including excess volume, excess volatility, and momentum.

This research also delivers novel predictions: at the individual level, traders' belief updating depends on the sign of past signals and previous beliefs, and, at the stock level, differences of opinion should be larger when past subsequent signals have different signs. The researchers find strong empirical support for their predictions, suggesting that the confirmatory bias is at work in financial markets.

Overall, the contribution of this research is threefold:

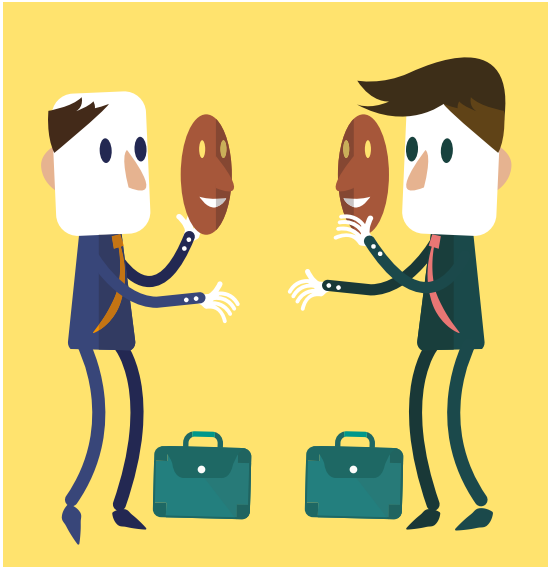
- The TSE researchers propose a parsimonious and tractable model in which departure from perfect rationality is well-grounded in psychology and driven by only one parameter.
- They show that confirmatory bias alone offers a unified rationale for several existing stylized facts, complementing previous explanations offered in the behavioral finance literature.
- They deliver and find support in the data for novel empirical predictions that follow from confirmatory bias.

Future research

The researchers believe it would be interesting to estimate the parameters of their model and, in particular, the proportion of biased traders on financial markets and the magnitude of confirmatory bias. This could be useful to evaluate the performance of a strategy designed to profit from the mistakes of biased traders. Their model could also be used to study optimal corporate communication. Firms that are confronted with financial markets populated by investors prone to the confirmatory bias might have an interest in appropriately choosing the timing of information releases.

AMBIGUOUS RISKS

What's the best contract?



Christian Gollier

Sharing risk is essential to the health of modern societies. Continuing his award-winning work in this field, TSE's Christian Gollier has made another invaluable contribution with his paper, 'Optimal Insurance Design of Ambiguous Risks'. Here, he examines the characteristics of the ideal insurance contract when transaction costs are linear and the distribution of losses is ambiguous. He also explores the effect of ambiguity aversion on the intensity of demand for insurance.

The ability to share risk among different agents facing imperfectly correlated risks is a crucial element in the functioning of our economies. The recent financial crisis demonstrates the catastrophic consequences of the inefficiencies that plague risk-sharing markets. In this context, insurance markets play an important role in mutualizing individual risks. In an ideal world, full insurance would wash out these risks by pooling them in financial markets.

However, because of asymmetric information, monitoring individual risk transfers usually entails high transaction costs. In some insurance lines, these costs can be as high as 30% to 50% of the policy's actuarial value. When insurance entails such large dead-weight losses, it is intuitive that partial insurance is optimal. Various forms of partial coverage can be considered, including insurance clauses such as a proportional retention rate, a straight deductible, or an upper limit of coverage.

Optimal insurance: Arrow on target

Kenneth Arrow (1963) was the first to examine the optimal design of the insurance contract. When transaction costs are proportional to the indemnity, he showed that the optimal contract is one with a straight deductible. For losses below the deductible, the insurer pays no indemnity. For losses above the deductible, the indemnity equals the loss minus the deductible. The intuition of this result is simple: the deductible insurance contract is the best compromise between the willingness to reduce risk and the need to limit the deadweight cost. Any increment of indemnification opportunity should be used to cover the largest uncovered loss. This is because, under risk aversion, the marginal utility of wealth is decreasing.

Gollier has previously shown that any contract without a straight deductible is dominated in the sense of second-order stochastic dominance (SSD) by a straight deductible contract with the same premium. This suggests that risk-averse agents should always prefer such a contract. It also implies that Arrow's result holds in all decision-theoretic frameworks in which the preference functional exhibits the SSD property.

Following Arrow: A quiver full of ideas

Arrow's result has also been extended in other directions. Raviv (1979) and Blazenko (1985) showed that the optimal insurance contains a coinsurance rule above the deductible when the insurer is risk-averse: in other words, when individual risk cannot be washed out through mutualisation. Raviv (1979) and Huberman, Mayers and Smith (1983) explored the case of nonlinear transaction costs. A convex relationship between the indemnity and the cost can also explain why coinsurance may be optimal above the deductible.

Comparative statics analyses have also been performed in the literature. Mossin (1968) showed that the optimal deductible is positive and decreasing with the degree of risk aversion of the policyholder. Eeckhoudt, Gollier and Schlesinger (1991) examined the impact of a change in the distribution of losses observed by the two parties on the optimal deductible.

Gollier's model: Ambiguous risks

Gollier extends these analyses by characterizing the optimal insurance contract when the distribution of losses is ambiguous and the policyholder is ambiguity-averse. There is little doubt that most people face some uncertainty about the distribution of their potential future losses. The estimation of individual probabilities associated with health hazards often differs from observed frequencies. Ambiguous probabilities are also often found for low-probability events.

Three models of ambiguity aversion have attracted much attention: the maxmin expected utility model of Gilboa and Schmeidler (1989), the α-maxmin expected utility model of Ghirardato, Maccheroni, and Marinacci (2004), and the smooth ambiguity aversion model of Klibanoff, Marinacci and Mukerji (KMM, 2005). Gollier uses the KMM model for its ability to define the notion of ambiguity neutrality, and for its simple way to perform the comparative statics of a change in ambiguity aversion.

> ***"The effect of ambiguity aversion on decisions is similar to the effect of pessimism"***

Results: Ambiguity's impact

Building on his own and others' research, Gollier shows that the effect of the policyholder's ambiguity aversion on the optimal contract is observationally equivalent to a change in his or her beliefs. This change is endogenous to the choice of insurance contract. The ambiguity aversion puts more weight on priors which yield a smaller conditional expected utility. This pessimism may have various effects on the optimal insurance coverage. Intuitively, it should increase demand for insurance, but Gollier shows this is not true in general. In particular, demand for insurance will be reduced by ambiguity aversion if the ambiguity is concentrated on the probability of small losses.

Gollier has shown that a policyholder's ambiguity aversion may have a very different impact on the optimal insurance contract depending upon the structure of the ambiguity.

- Under ambiguity neutrality, the insurance contract with a straight deductible is optimal.
- If the ambiguity is entirely concentrated on high losses, this contract has the additional advantage to fully eliminate the ambiguity of the distribution of the retained loss. In that case, ambiguity aversion has no effect on the optimal design of the contract and on the global insurance demand.
- When the ambiguity is concentrated on losses below the deductible, the optimal contract is still with a straight deductible if the degree of ambiguity aversion is small enough, and the demand for insurance is negatively affected by ambiguity aversion.
- Gollier has also exhibited ambiguity structures that affect a contract's optimal design. In particular, he has shown that the optimal contract has a disappearing deductible if the multiple priors that characterize the ambiguity can be ranked by the monotone likelihood ratio order.

Summing up

The optimal contract depends upon the structure of the ambiguity. For example, if the set of possible priors can be ranked according to the monotone likelihood ratio order, the optimal contract contains a disappearing deductible. Gollier also shows that the policyholder's ambiguity aversion can reduce the optimal insurance coverage. More ambiguity aversion yields more pessimism rather than more risk aversion. Contrary to the comparative statics of more risk aversion in the insurance problem, the comparative statics of more pessimism is in general ambiguous.

This paper provides a new illustration of the richness and complexity of decision problems under ambiguity aversion. The effect of ambiguity aversion on decisions is similar to the effect of pessimism. The nature of pessimism entailed by ambiguous probabilities is very sensitive to its structure. Moreover, the ambiguous probability in one state affects the optimal demand for insurance in all other states, contrary to the expected utility framework. This generates new insights to explain actual behaviours.

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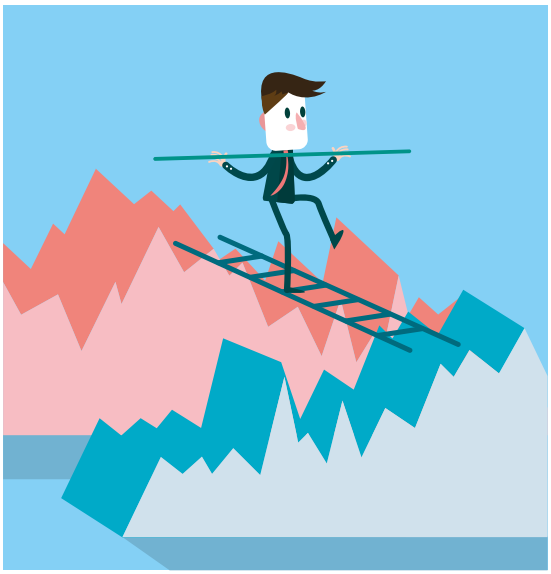
FEAR OF THE UNKNOWN

Do the rich embrace uncertainty?



Frédéric Cherbonnier
Christian Gollier

How do attitudes towards risk evolve as we become wealthier? In their insightful paper 'Decreasing aversion under ambiguity', TSE's Frédéric Cherbonnier and Christian Gollier investigate the conditions under which the set of desirable uncertain prospects expand when wealth increases. They test prevailing hypotheses about ambiguity aversion, with results that demonstrate the opportunities for significantly improving decision-theory models.

One of the most ubiquitous assumptions in the economics of risk is that wealthier people are less risk-averse. Various definitions of the concept of decreasing aversion exist. For example, an agent is said to have decreasing aversion if any risk that is undesirable at some specific wealth level is also undesirable at all smaller wealth levels. Another definition of decreasing aversion is that in the one-risk-free-one-risky-asset portfolio choice problem, the demand for the risky asset is an increasing function of the initially sure wealth of the agent.

In the classical expected utility model, these two definitions of decreasing aversion are equivalent, and the necessary and sufficient condition is expressed by the decreasing nature of the Arrow-Pratt index of absolute risk aversion (DARA). DARA just means that the utility function u exhibits decreasing concavity à la Arrow-Pratt. This universally accepted property of individual risk preferences plays a crucial role in many applications of the expected utility theory, as previously illustrated by Gollier.

Ellsberg's paradox

In this research, Cherbonnier and Gollier explore the concept of decreasing aversion in the context of ambiguity and ambiguity aversion. In most cases, the probability distribution of the risk is not perfectly known – in other words, it is ambiguous. Examining a simple thought experiment, Ellsberg (1961) suggested that economic agents do not behave according to the subjective expected utility model. Under ambiguity, they do not use a subjectively chosen probability distribution to compute the expected utility of the set of possible acts to determine their optimal strategy.

Many experiments have confirmed Ellsberg's hypothesis that in the absence of an objective probability distribution, individuals tend to favour a relatively pessimistic plausible distribution to measure their welfare. Gilboa and Schmeidler (1989) were the first to propose a decision criteria compatible with Ellsberg's hypothesis, and that generalizes the expected utility model. In short, agents are assumed to have multiple priors whose formation is a characteristic of the preferences of the agent. The agent's welfare before an act is the smallest expected utility generated by this act over the different possible priors.

A tale of two models

More recently, two models have been proposed to account for ambiguity attitude. Ghirardato, Maccheroni and Marinacci (2004) have proposed the α-maxmin expected utility (α-MEU) family of preferences in which the agent's ex ante welfare is measured by a α-weighted average of the smallest and the largest expected utility levels among a convex, compact set of probability distributions. The alternative approach provided by Klibanoff, Marinacci and Mukerji (2005) represents the agent's welfare under uncertainty by the certainty equivalent

of the different prior-dependent expected utility levels. This certainty equivalent is computed by using a function ϕ that is increasing and concave, and whose degree of concavity is an index of ambiguity aversion.

For these two decision criteria under ambiguity, Cherbonnier and Gollier determine the conditions under which wealthier people are less averse to risk, under the two standard definitions for this concept. Consider first the definition of decreasing aversion based on the shrinkage of the set of desirable lotteries when wealth is reduced. In the α-MEU family of preferences, this property is obtained under the necessary and sufficient condition that the utility function exhibits DARA. In the case of smooth ambiguity aversion, the shrinkage of the set of desirable lotteries when wealth decreases prevails if and only if both u and $\phi \circ u$ exhibit decreasing concavity à la Arrow-Pratt. This condition is weaker than the sufficient condition that u and ϕ are decreasingly concave.

The definition of decreasing aversion based on the increasing demand for the risky asset when wealth increases is more complex to characterize. In the maxmin model, which is a special case of the α-MEU criterion, Cherbonnier and Gollier show that the decreasing concavity of the utility function is not enough to guarantee the desired comparative statics property, except in the small. Different sufficient conditions are derived. For example, a sufficient condition is that the utility function belongs to the HARA class with decreasing aversion. Another sufficient condition is that all priors can be ranked according to Jewitt's order, and relative prudence is smaller than relative risk aversion plus one. A similar condition is obtained in the KMM's smooth ambiguity aversion model, under the additional condition that ϕ is decreasingly concave. The condition relating relative prudence and relative risk aversion may be removed at the cost of replacing Jewitt's order by the monotone likelihood ratio order, which is stronger.

> ***"One of the most ubiquitous assumptions in the economics of risk is that wealthier people are less risk-averse"***

Key results

Two basic hypotheses prevail in decision theory with a large consensus in the profession:

1] Human beings are averse to uncertainty;

2] They are decreasingly averse to uncertainty. In the classical expected utility model, these properties of human behaviour prevail respectively if the utility function u is concave, and if it is decreasingly concave in the sense that - u''/u' is decreasing.

Cherbonnier and Gollier's key findings are as follows:

- In the α-maxmin expected utility model, the decreasing concavity of the utility function u is necessary and sufficient.
- In the smooth ambiguity aversion model with the ambiguity valuation function ϕ, the decreasing concavity of the utility function u and of $\phi \circ u$ is necessary and sufficient.
- The alternative hypothesis – that investment in a risky asset increases with wealth - does not generally hold under ambiguity aversion.

The structure of ambiguity also needs to be constrained to obtain unambiguous results of an increase in wealth in this portfolio-choice problem.

Summing up

For this research, Cherbonnier and Gollier focused their attention on the concept of decreasing aversion, by examining two different decision problems when the decision-maker is not ambiguity-neutral. They first define decreasing aversion by the property that the set of desirable uncertain prospects expands when wealth increases. In the smooth ambiguity aversion model, they show that the classical conditions of decreasing risk aversion and of decreasing ambiguity aversion imply this property, and that an intuitive weaker condition is necessary and sufficient. In the α-maxmin expected utility model, the standard DARA condition is necessary and sufficient.

Another definition of decreasing aversion is that the demand for a risky asset is increasing with wealth. The introduction of ambiguity-sensitive preferences implies much more complexity than in the above discrete-choice problem. Even with the simpler maxmin criterion, the decreasing concavity of u is not sufficient to get this result, except in the case of small risks. As in the smooth ambiguity aversion model with a decreasingly concave ambiguity-related function ϕ, the unambiguous comparative static result requires some assumptions on the structure of ambiguity.

This research illustrates once again the fact that even the most intuitive departures from the classical subjective expected utility model introduce much richness to decision models. This is at the cost of a non-marginal increment in the complexity of the analysis.

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TOULOUSE ECONOMISTS ON
RISK-SHARING MECHANISMS

JANUARY 2017

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