FiME

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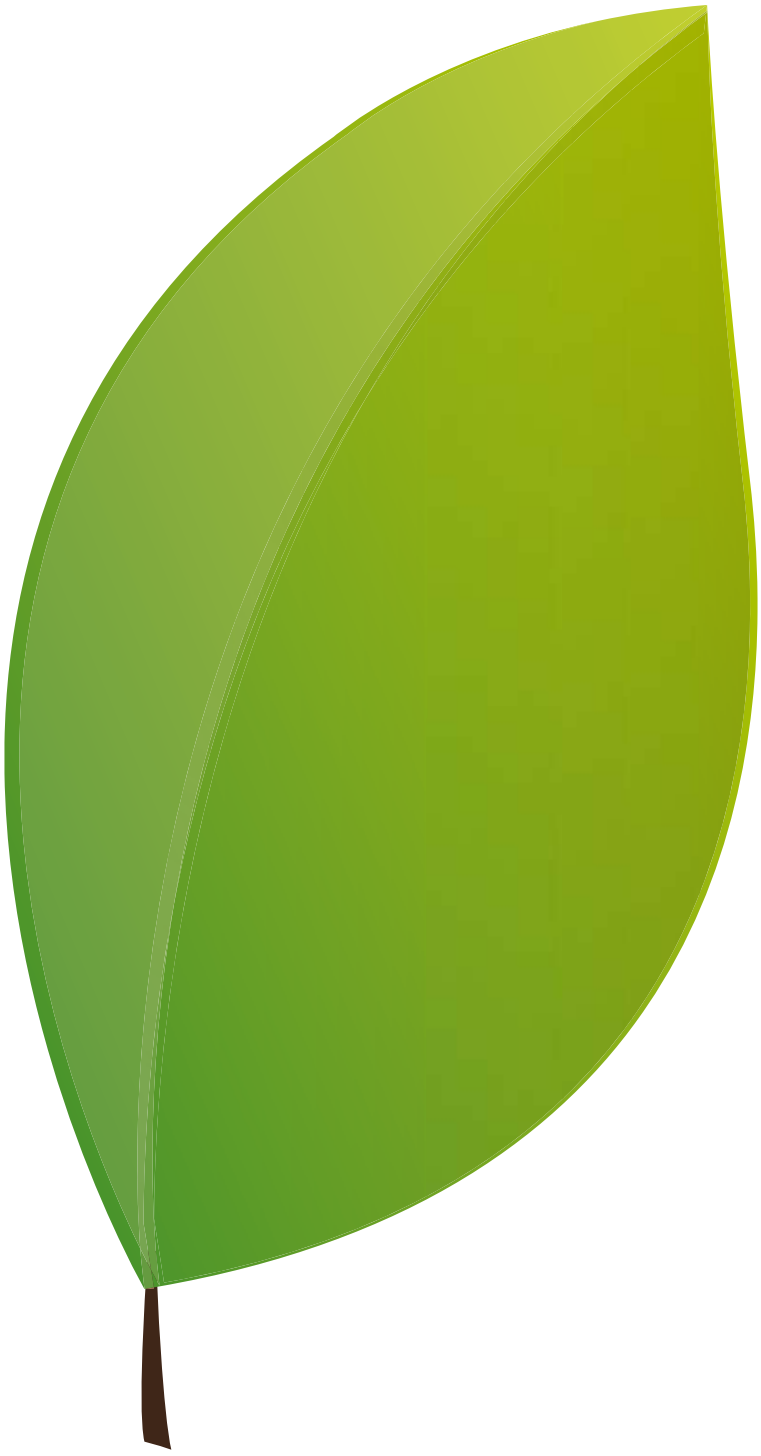

2006/2009

FiNANCE FOR ENERGY MARKET RESEARCH CENTRE

CHAIRE Finance & Développement Durable

DAUPHINE UNIVERSITÉ PARIS

CREST Centre de Recherche en Économie et Statistique

EDF CHANGER L'ENERGIE ENSEMBLE

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Editorial

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René Aïd
Executive Director of the Finance for Energy Market Research Centre

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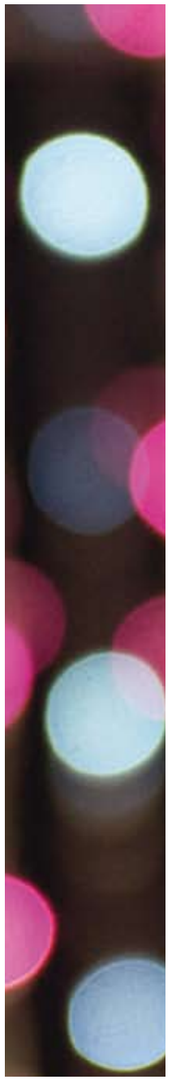
Nizar Touzi
Vice-chairman of the Chair Finance and Sustainable Development

WHAT ROLE CAN RESEARCH play in the huge challenges facing the world of energy and finance? The energy industry is currently undergoing major changes. The wave of deregulation that has swept across the world in the last fifteen years has led electricity markets to develop in line with the standardised commodities markets model. Concerns relating to greenhouse gas reductions aimed at stemming the effects of climate change have led to the creation of a tradable emission allowance market in Europe. While these prices allow producers to manage existing capacities efficiently in the short term, they are still ineffective when it comes to enabling decision-makers to make the technological choices that will commit them for fifty years. Indeed, long-term uncertainty would seem to be at its highest levels ever: fossil fuels, competition and environmental regulations, effects of climate change, and so on. These are all long-term uncertainties that are not reflected in the prices.

Very recently, these difficulties were overshadowed by one of the deepest crises to affect the financial sector and thus the world economy since 1929. Present commentaries show that this is a double crisis of valuation and regulation and that the financial sector will not recover without profound changes. In this ever-changing world, research did not remain passive. In France, it has seen a phase of considerable adaptation: university autonomy, business cluster, campus of excellence, public-private partnership and research patronage, among others. All these mechanisms show a desire to encourage local initiatives and increase exchanges between industry and academia.

The Finance for Energy Market Research Centre works with three fields in constant movement: energy, finance and research. It was founded in October 2006 at the initiative of Paris-Dauphine University, the Economic and Statistical Research Centre of the ENSAE and the R&D division of the EDF group, to complete the chair of "Finance and Sustainable Development" with an operational venue for exchanges. The goal of the Research Centre is to contribute to the development of methods for asset valuation and investment choice as well as to issues concerning energy market regulation using quantitative models. Its resources include openness to scientific networks and exchanges. In this way, its members include professors and engineers, economists and mathematicians. They all work together to improve the methods used for future energy choices. This first operating report contains a sample of the work undertaken by the team of the FiME Research Centre. Regulation of the gas and electricity markets, financial risk management, modelling of electricity and gas prices, interest rate models, methods for solving partial derivative equations and variance reduction, etc. We hope these works will convince the reader that it is possible to contribute to our current challenges by means of useful, innovative, high-quality research, bringing together people from the industrial and academic worlds.



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Seminar of the FiME Research Centre.

The FiME Research Centre

The FiME Research Centre brings together partners and other people who share a common interest in method-related questions. Three years after its creation, these pages offer the founding partners the opportunity to share their opinions: Paris-Dauphine University, CREST, EDF R&D and the Chair Finance and Sustainable Development. They also introduce the people who have made this project a human adventure.

Partners

“The challenge was successfully met, and this is only a start!”

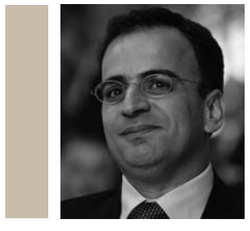
François CARÊME
Director of the Networks and Energy Management Programmes of EDF R&D, member of the Advisory Committee of the Chair of Finance and Sustainable Development and its Steering Committee, as well as of the Advisory Committee of the FiME Research Centre.

One of the main concerns of EDF is to optimise its choices and manage its risks in the long term, which will be dominated by environmental constraints and energy shortages.
These are the themes, developed through the research programmes that I supervise at EDF R&D and that the Research Centre has been working on. The logic behind its creation was to find synergies with the academic world. By opening our research topics to scientific partners, we were pursuing a double goal: on the one hand, to be more efficient in our contacts with top-level scientists working on similar topics and, on the other hand, to benefit from leverage, using the work of researchers from other institutes and taking advantage of their networks. The FiME Research Centre studies in the connections between finance and the energy markets; its scientific interest lies in the effectiveness of research on criteria and methods for optimisation, for asset management and for long-term risk management. The proximity between the Chair and the Research Centre and between top-level economists and mathematicians (Dauphine, CREST, the École Polytechnique, etc.) has allowed research to progress in the desired directions. As an example, we can mention the application of the theory of mean-field games to oil reserve management, a notable development of the mathematical research attributed to Pierre-Louis Lions and his collaborators. Also, the improvement of option value calculation in the electricity market, beyond the Black-Scholes conventional model.
A genuine process is under way, and the entry of the École Polytechnique a year and a half ago has introduced even greater rigour to research supervision. The team has a good level, thanks in part to the synergies and the “network effect”: the challenge was successfully met, and this is only a start!

“With the FiME Research Centre, our efforts have multiplied: it provides true leverage”

Yannick JACQUEMART
Head of the OSIRIS Department (Optimisation, Simulation, Risk and Statistics) at EDF R&D, member of the Advisory Committee of the FiME Research Centre.

Within my department at EDF R&D, we only had half a dozen researchers specialising in financial mathematics. Indeed, this area of specialisation is relatively new in our field, since the concern with covering financial risks was never a factor until the markets were opened up. These researchers were therefore quite isolated. We lacked the critical mass for this emerging field. The Chair of Finance and Sustainable Development and the associated Research Centre offered us a way to interest the financial community in our problems, to adapt financial techniques to the particular features of the energy markets and to offer our researchers a stimulating environment. With the FiME Research Centre, our efforts have multiplied: it provides true leverage. Thanks to this partnership, which can be described as strategic, we have managed to bring this field to life, at a good level and permanently, with a limited internal critical mass. This Research Centre allows us to remain in permanent contact with the scientific community, benefiting from its knowledge and the permanent watch it conducts; the transition time from academic knowledge to applied research has shortened. It is much more efficient, interesting and valuable for our researchers to conduct research in an environment where everything is easy for them. For me as a manager, this provides reassurance of the quality of the work they are performing. The people involved in the Research Centre are among the best discovery researchers. Although they are well recognised by the scientific community, they are not cut off from the department. Internally, they supervise the applied research work carried out by other collaborators. They pass on knowledge, helping young people gain skills more quickly. The link between discovery research and applied research is thus guaranteed.



Paris-Dauphine University

“FiME, virtual research centre, crossroads for meeting and exchange”

Elyes JOUINI
Vice-chairman of Paris Dauphine University in charge of research, director of the Dauphine Finance Institute.

In the world of energy, it is essential to use a long-term approach for considering investment decisions, and the development of derivatives poses unprecedented calculation problems. All this creates an extremely lively field of research, which is also fundamentally multi-disciplinary. The FiME Research Centre and the Chair provide an arena where new ideas are born, offering concrete solutions to these new issues. This is a “virtual research centre”, a crossroads for meeting and exchange between specialists at the pinnacle of their disciplines. An open forum which has broadly succeeded in attracting researchers from other universities, well beyond its initial scope, who come to participate in the task forces that conduct the study, and to attend our seminars and talks. For us, this interaction is the main strength of this partnership. After one year of life, we can report that the “graft” has taken extremely well. As academics, this provides a marvellous opportunity for us to learn how to work specifically and regularly with the business world. EDF R&D offers us the opportunity to work with a group of engineers-teachers with in-depth knowledge of the research world and the skills required to provide long-term reflections. This first experience has proven to be successful, paving the way for other collaborations with EDF or other partners.

“This is a structure that works with great flexibility”

Bertrand VILLENEUVE
Professor of Economics at Paris Dauphine University, researcher at CREST.

As a specialist in energy economics, I was one of the rare researchers to show an interest in the economics of natural gas, using techniques from industrial economics and analysing energy market regulation. I was interested in the FiME Research Centre from the first time I heard about the possibility of its creation. In addition to complementing my activities at CREST, it has allowed me gradually to integrate in Paris Dauphine University. I devote around one day a week to the Research Centre, proposing a new topic of study each year. In this way, I have worked on issues such as transfers of assets linked to restructuring operations, or the economics of natural gas storage. For me, the main advantage of the FiME Research Centre is that it provides a forum for meeting and debate between researchers and industry.
Furthermore, the group effect supports our researchers and guarantees their exposure. Ultimately, the FiME Research Centre allows me to compare the PhD students under my supervision with participants from various fields, validating the relevance of their work. Although our EDF contacts are sometimes subject to constraints that limit their long-term commitment, our meetings are still fruitful. They help me prioritise problems and share their technology watch, while I provide them with methods they can use in their everyday work. In short, this is a structure that works. We enjoy considerable flexibility for management based on projects and financial resources of a policy that provides incentives for publication. The FiME Research Centre offers us the possibility of working at a high level, rallying the best mathematicians and economists around issues that would have been difficult to finance using public funds only.

“A win-win partnership for both sides”

Jean-Michel LASRY
Chairman of the Steering Committee of the Chair for Finance and Sustainable Development, associate professor at Paris Dauphine University, scientific advisor to the managing director of Crédit Agricole CIB.

The FiME Research Centre and the Chair were pioneering institutions when they were created in 2006. At the time, there were no other venues like them for multi-discipline meeting. Thanks to this cooperation between academia and industry, specialists in economy, mathematics, energy, the carbon economy, sustainable development, raw materials, etc. can now combine their skills and their experience to deal with the issues at hand in a cross-disciplinary manner. This initiative created a genuine carrier current, which has gained a considerable following since. We have established very tight scientific collaboration with the Research Centre. The researchers at the FiME Research Centre share their industrial issues with us and we provide them in turn with theoretical elements that contribute to resolving these issues. A dynamic has taken hold within this very large team. Researchers as a whole are benefiting from this global relationship. A concrete example of this fruitful collaboration is the mean field game theory, which offers a new mathematical framework for posing questions regarding long-term investment in production capabilities. Another example: with Roger Guesnerie, tenured Chair of Economics at the Collège de France, we have worked on the theme of “Economic calculation and sustainable development”, in particular studying the discount rates to be used for very long-term projects lasting 50 to 100 years.
Beyond that, this cooperation clearly illustrates the advantages of the public-private partnership, much less developed in France than in the USA: a win-win partnership for both sides, which benefits all the parties involved…

Researchers

Academia

As an open structure, the FiME Research Centre welcomes researchers from its founding partners as well as those from other institutions (École Polytechnique, INRIA and the University of British Columbia). With its flexible structure, researchers only dedicate a part of their time to this project.

JOSEPH FRÉDÉRIC BONNANS

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A graduate of the École Centrale Paris and PhD in Engineering from the University of Technology of Compiègne, **Joseph Frédéric Bonnans** is a lecturing professor at the Centre for Applied Mathematics of the École Polytechnique. He is also senior researcher at the French National Institute for Research in Computer Science and Control (INRIA) and leader of the COMMANDS team, devoted to dynamic optimisation.

GILLES CHEMLA

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Gilles CHEMLA is a civil engineer and PhD in Economics from the London School of Economics. He has an habilitation from Paris-Dauphine University. He is also research director at the CNRS since 2007. He has been involved with the FiME Research Centre since its creation. His main areas of study are corporate finance: mergers and acquisitions, private equity and venture capital, investment and financing policy, privatization and, more recently, pension funds and securitization.

LUCIANO CAMPI

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Luciano CAMPI, PhD in Mathematics from Pierre and Marie Curie University (2003), also associate professor at Paris Dauphine University since 2005. He is a member of the CEREMADE. He is also jointly responsible for the Master's in Statistical and Financial Engineering (ISF) at Dauphine, where he teaches interest rate models and stochastic calculus.
His research topics are: Incomplete markets, transaction costs, insider trading.

ROMUALD ELIE

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Romuald ELIE is associate professor of Applied Mathematics at Paris Dauphine University. He has a PhD in Mathematics. His work deals with financial mathematics, numerical probability, stochastic control and backward stochastic differential equations.

DANIELLE FLORENS

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Danielle FLORENS is a professor at CEREMADE in Paris Dauphine University and a member of the Steering Committee of the Chair of Finance and Sustainable Development. Her work was among the first to deal with the estimation of parameters of diffusion processes based on discrete observations. In addition to her research activities, Danielle Florens is also involved in many programmes for developing university courses in Africa.

ALFRED GALICHON

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Alfred GALICHON is a professor of Economics at the École Polytechnique and Ingénieur en Chef des Mines (Head Engineer of the Corps of Mines). He is an engineering graduate from the École Polytechnique and holds a PhD in Economics from Harvard University. His work relates to economics, microeconomics and quantitative finance. In 2010 he received a distinction from the *Cercle des Économistes* think-tank and *Le Monde* newspaper.

NIZAR TOUZI

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Nizar TOUZI is a professor at the École Polytechnique. He has also taught at the Imperial College, ENSAE, Princeton University and HEC. A specialist in mathematical finance, he is Vice-chairman of the Bachelier Finance Society and editor of multiple mathematical journals specialising in finance and probability. In 2007, he won the Europlace Award for Best Young Researcher in Finance. He was invited speaker at the International Congress of Mathematicians in 2010.

BERTRAND VILLENEUVE

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Bertrand VILLENEUVE is a professor at Paris-Dauphine University. Engineer graduated from the École Centrale Paris, he also holds a PhD in Economics (EHESS, 1996). He is also scientific director of the *La Fondation du Risque* and associate editor of the *Journal of Risk and Insurance*. His main interests include insurance and risk economics, energy markets and industrial organisation.

JEAN-MICHEL ZAKOÏAN

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Jean-Michel ZAKOÏAN is co-director of the LFA at CREST, on leave from the University Lille 3 since 2007, where he was professor of applied mathematics. He teaches at ENSAE and wrote around fifty papers in time series and financial econometrics. In 2009, he co-authored a book entitled "GARCH Model - Structure, estimation and financial applications" (Economica), to be published in English in 2010 (Wiley).

Research-engineers

The first duty of a research-engineer is not to produce academic research, but operational solutions for industry. However, the FiME Research Centre offers research-engineers a way to keep up with the state of the art in techniques for economic and numerical methods, while ensuring that academia are aware of the issues affecting the energy industry. In this way, they split their time between operational projects of the EDF group and research work assessed according to their publications and their relevance.

RENÉ AÏD

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René AÏD is Executive Director of the Finance for Energy Market Research Centre. After leading teams on economic models for power markets and risk management at EDF R&D, he specialised in modelling prices and generation management. His work is dedicated to analysing long-term risk management, investment dynamics and the application of mathematics to corporate finance. He holds a PhD in applied mathematics (INPG, 98) and is an engineer in applied mathematics and computer science (ENSIMAG 92).

CORINNE CHATON

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Corinne CHATON holds a PhD in Economics from the University of Toulouse for her work in "Investment decisions in an uncertain environment with application to the electricity sector". After working at the Research Department of Gaz de France, she joined the Economics Department of EDF R&D in November 2005, in order to study issues with gas and the environment. She is a lecturing professor at Paris 12 University. She is also associate researcher at the CABREE (Centre for Applied Business Research in Energy and the Environment) at Alberta University.

OLIVIER FÉRON

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Olivier FERON is an engineering graduate from the École Supérieure d'Électricité and holds a PhD in Mathematics from the University of Orsay (2006). He joined EDF as an engineer-researcher in statistics and financial mathematics applied, among others, to asset-liability management for the financial department of the EDF group.
He joined the FiME Research Centre in 2009. His interests include electricity price modelling and financial risk management.

NADIA OUDJANE

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Nadia OUDJANE is an engineering graduate from the École Nationale Supérieure d'Aéronautique et de l'Espace (ENSAE) and holds a PhD in Applied Mathematics from the University of Rennes. Her thesis looked into the specific methods applied to non-linear filtering in the context of a partnership with the ONERA. She is an engineering expert at EDF R&D and works on risk management, mathematics applied to finance and numerical probability. She is also an associate professor of applied mathematics at Paris 13 University.

ARNAUD PORCHET

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After graduating from the École Polytechnique in 2004, **Arnaud PORCHET** worked on his thesis at EDF R&D within the FiME Research Centre, obtaining his PhD from Paris Dauphine University in 2008. He has worked as researcher at CREST, and then at Princeton University. His research has focused on issues with organisation and valuation of the energy markets, in particular trading mechanisms for carbon emission rights. He is currently Senior Associate at the Strategic Risk Solutions department of Citigroup.

XAVIER WARIN

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Engineering expert at EDF R&D and a graduate of the École Nationale Supérieure des Techniques Avancées, **Xavier WARIN** has worked in the field of neutron physics for reactor cores, in particular on transport and diffusion equations. A specialist in numerical methods, he has also worked in the field of finance, developing large-scale stochastic control tools as well as decision-making tools for investment projects.

PhD students

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From left to right: Marie Bernhart, Émilie Fabre, Mathilde Bouriga, Adrien Nguyen Huu, Laure Verdier, Laure Durand-Viel and Amélie Mauroux.

The participants at the FiME Research Centre include PhD students from very diverse institutions, as can be seen from the following list. The topics they study also benefit from multi-disciplinary research between economics and applied mathematics.

Marie BERNHART studies methods for valuation of physical or financial assets for gas storage at the Probability and Random Model Research Centre of Paris-Diderot University. Under the direction of Huyên Pham, professor at Paris-Diderot University, Peter Tankov, lecturing professor at the École Polytechnique, and Xavier Warin, she is developing numerical schemes for solving backward stochastic differential equations by modelling the dynamics of these valuation problems.

Mathilde BOURIGA's thesis deals with the problem of estimating diffusion process correlation matrices, an essential goal in problems of risk measurement and asset assignment. A member of the CEREMADE at Dauphine, she is developing a Bayesian estimation approach under the direction of Christian Robert, professor at Paris-Dauphine University, Jean-Michel Marin, professor at Montpellier 2 University, and Olivier Féron.

Laure DURAND-VIEL is currently completing a thesis funded by CREST and directed by Bertrand Villeneuve, on the economics and regulation of the gas market. She will have worked for three years on strategic aspects relating to long-term contracts. She is currently employed by the French Competition Authority (*Autorité de la Concurrence*) as an economist.

Émilie FABRE is writing a thesis in financial mathematics under the direction of Nizar Touzi, professor at the École Polytechnique, at the CMAP. She is studying problems relating to coverage of indivisible assets by a portfolio of financial assets.

Amélie MAUROUX is working under Bertrand Villeneuve at CREST. Her research relates to the analysis of energy markets and, specifically, natural gas. She is examining connections between energy and environmental policies in Europe and, in a regulatory approach, is assessing the levers and economic instruments brought into play.

Adrien NGUYEN HUU's thesis relates to the valuation of derivatives in incomplete markets. Under the direction of Bruno Bouchard, professor at Paris Dauphine University, and Nadia Oudjane, he has developed methods based on optimal stochastic control for calculating optimal strategies for covering derivatives in the electricity market. Like Mathilde, he is a member of the CEREMADE.

Laure VERDIER is working on socially responsible investment and its interactions with corporate environmental policy at Dauphine Research in Management. Her thesis, directed by Gilles Chemla, is currently studying how green, socially responsible investors affect asset prices, the choice of portfolios as well as their consequences for the investment decisions of companies.

New members of the FiME Research Centre

Ivar Ekeland, Philippe Février and Delphine Lautier wanted to participate in the research dynamics created by the Chair Finance and Sustainable Development and the FiME Research Centre dealing with questions of economic modelling, energy and sustainable management.

IVAR EKELAND

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Ivar EKELAND is tenured Chair of Canadian Research in Economic Mathematics at the University of British Columbia (Vancouver). He resumed his post in 2003, after a long stay at Paris Dauphine University, where he was vice-chancellor from 1989 to 1994. He has long enjoyed an international reputation thanks to his leading work in numerous fields: convex and non-linear analysis, control theory, Hamiltonian mechanics, symplectic geometry, mathematical economics and finance. Among his many publications, he received the Jean Rostand and Alembert Awards respectively for his books *Mathematics and the Unexpected* (1984) and *The Broken Dice* (1991), which mainly study the question of a frontier between determinism and chance raised by chaos theory. An influential person in the world of research, Ivar Ekeland is also greatly concerned with disseminating new concepts discovered by science to the largest number of people possible, in particular highlighting the philosophical reach of these concepts. For this purpose, he has published many popular science works, such as Chaos and *The Cat in Numberland*, published in 2006, which met great success in France and abroad.

PHILIPPE FÉVRIER

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Philippe FÉVRIER is director of CREST-LEI and lecturing professor at the École Polytechnique and the ENSAE. A specialist in industrial economics and applied economics, his research covers auction theory, contract theory, incentive theory and competition policy. In 2003 he received an award from the AFSE (French Association of Economic Science) for his work on multi-unit auctions, as well as the prestigious Fulbright grant.
At the FiME Research Centre, Philippe Février hopes to study price formation and the importance of the role played by auctions in the energy market and in the market of pollution rights. Although numerous papers have been published on the topic of auctions, few of them deal with behavioural analysis of firms in the energy market. This subject is of major interest for auction organisers and regulating bodies.
No empirical studies of the market of pollution rights have been conducted to date from a microeconomic point of view. This means considering the decisions taken by firms bound by allocations resulting from the Kyoto Accords. This work should make it possible to anticipate the effects of new policies.

DELPHINE LAUTIER

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Delphine LAUTIER is professor at the University Paris-Dauphine and attached to DRM-Finance (UMR CNRS 7088). She is also associate researcher at the Ecole des Mines ParisTech. Her research focuses on derivatives and risk management, with many applications in energy markets. She is part of the scientific steering committee for the Chair Finance and Sustainable Development.
In the framework of the Chair since 2009, Delphine Lautier has focused her research on the relationship between the physical market and the derivatives market for commodities. Her current projects involve the creation of a general equilibrium model designed on the one hand, to explain the relationship between the cash price and futures price and secondly, to jointly analyze hedging strategy and price discovery. Such models are of interest to all companies that produce, sell or use commodities.

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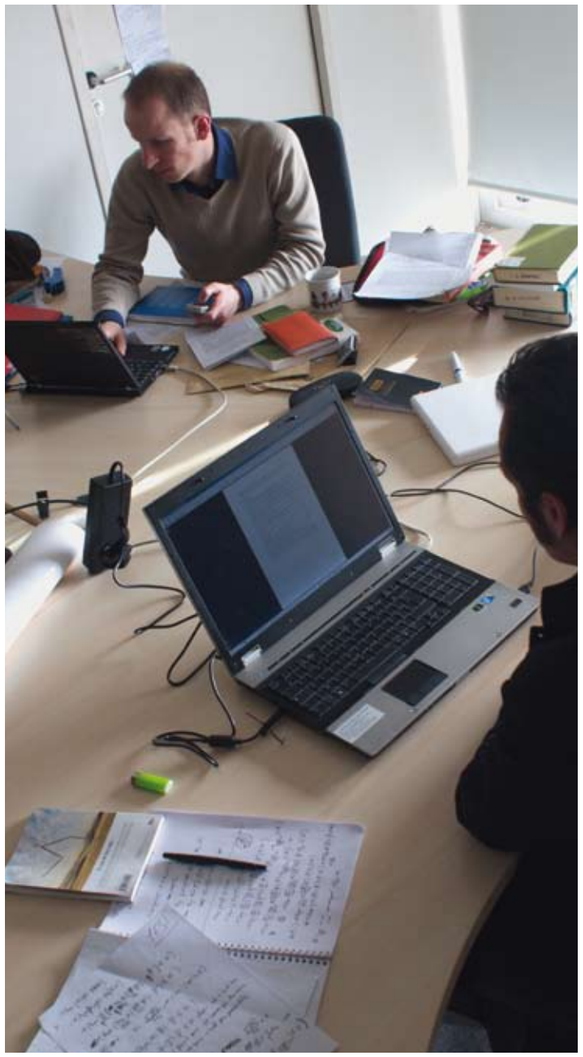
Work of the Research Centre



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Work of the research centre

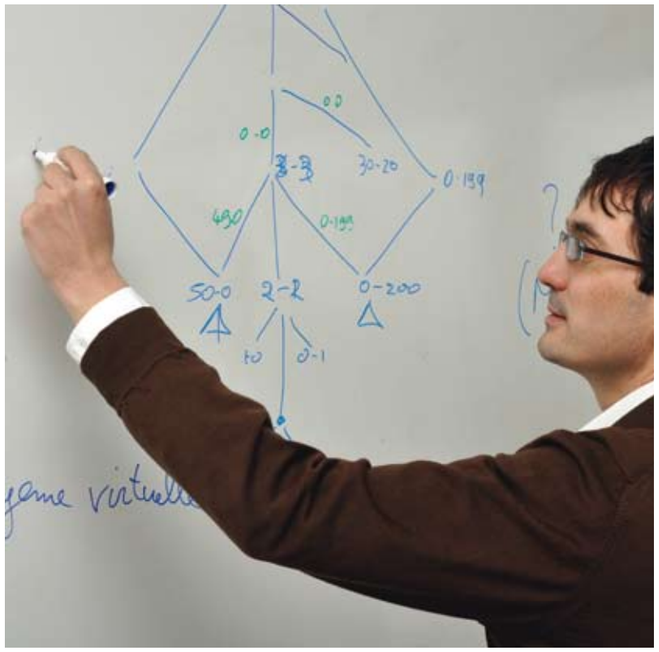
The technique required to ensure scientific rigour may make it difficult to understand research work.
In the following pages, we have tried to make the results of work conducted by the FiME Research Centre accessible to as many people as possible, by means of two-page summaries.

Outline of seasonal gas economics

Based on an interview with **Bertrand Villeneuve** regarding his paper co-authored with **Corinne Chaton** and **Anna Creti** entitled "Some Economics of Seasonal Gas Storage", published in 2008 in *Energy Policy*.

It is no easy task to define the landscape of the modern gas industry. This motivated Bertrand Villeneuve, Corinne Chaton and Anna Creti to analyse the industry in a consistent framework, focussing on the economy of seasonal storage, studying the relationship between stored amounts and price, as well as the impact of external constraints, such as public policy, for example.

THE IDEA EMERGED following the deregulation of USA and European energy markets in the 1990s, and the many papers published as a result; and yet, while some of these papers dealt with gas production or transport, few authors were interested in the economics of its storage, a true headache for conventional analysis tools.
Indeed, it is not enough simply to observe spot markets at a time t, since gas transport and storage allow production to be disconnected from consumption – unlike electricity. Storage is even more difficult to model insofar as a new type of player needs to be added to the equation: pure storers. Prices at a time t therefore depend on instant conditions of supply and demand, price impacts and forecasts. Regardless, researchers view storage as essential for the gas industry as it allows flexibility, lower investment in production and transport infrastructure and buffering of price fluctuations.



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Bertrand Villeneuve explaining an economic model for gas.

METHODOLOGY

Based on a study conducted in Europe and the USA, the researchers established a simple model of the seasonal gas markets in order to understand the link between stored quantities and price. This model makes it possible to determine, first of all, the competitive balance under ideal storage conditions; it is flexible enough to include phenomena such as supply or demand shocks, or even a gradual exhaustion of the resources. Finally, they discussed public policy such as price capping and requisitions.

A simple model of the seasonal gas market

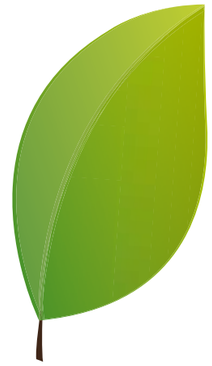
This is why the team have taken a time horizon that is infinite yet based on a seasonal cycle, split between the summer, at the end of which stock levels are at their maximum, and the winter, at the end of which stock levels are empty. The authors have therefore created, for the purpose of clarification, a simple model of the seasonal gas market to understand how storage, a natural source of flexibility for the gas industry, can become an economically viable business. Storage is driven by the considerable difference between future prices and spot prices. In a first stage, Bertrand Villeneuve, Corine Chaton and Anna Creti describe the basic elements of these markets, in order to determine the optimum operating conditions of a storage industry. In a second stage, they look into the possibility of political interference and use of market power.

The limits of arbitrage

Pressure from public opinion or failure to understand the logics of storage can lead to the imposition of regulations that will kill any incentives for storage from the outset. The model shows the limit of seasonal adjustment or price cap policies, even of unique prices, which would eliminate the source of income for the storage industry. And yet, without a free market with storage as a core feature, we would observe operators withdrawing, insufficient market transparency, waves of concentration, etc., with all the eventual difficulties for regulators to understand these companies.

The impact of external constraints

The model has allowed us to compare ideal market performance with the performance that would result from any intervention. If ideal performance is reached when the marginal costs of production and the marginal provisions to be paid are equal, this balance is easily upset by poorly assessed provisions, such as a price cap. The latter can only be justified insofar as it defends the interests of consumers without discouraging the economics of storage. However, capping prices in the winter, for example, would reduce the price gap between the two seasons, and would discourage storage. This same price cap in winter, furthermore, relieves the consumer of his responsibility for using a scarce resource: measures including rationing, waiting lists, priorities, etc. should be implemented, with all associated risks (cronyism, lobbying, etc.). This is why the researchers suggest, in their model, reflecting on an optimal price policy, which would have a more positive impact on storage economics than a "laissez-faire" policy.



APPLICATION

Regulators can use the model to determine the efficiency (or inefficiency) of a policy of seasonal adjustments or price caps. The authors issue a caution to the public powers against any intervention that would discourage the storage industry through an implied lack of income.
On the other hand, they stress how a price cap could help a community of consumers, which could then exercise true power over the producer as soon as it is organised by coordination between states and a true European policy ` in this area.

Quotas or feed-in tariffs: what to choose?

Based on an interview with **Corinne Chaton** regarding the paper entitled "Competition and Environmental Policies in an Electricity Sector", submitted for publication and co-authored with **Marie-Laure Guillerminet**[1].

Two economic mechanisms currently contribute to reducing greenhouse gases: emission quotas, which constrain the electricity sector, and feed-in tariffs, which stimulate investment in renewables. Corinne Chaton and Marie-Laure Guillerminet show the conditions in which these two instruments can create conflicts of interest.

AWARE OF THE IMPACT global greenhouse gas emissions are having on global warming, the European Union ratified the Kyoto Protocol in 1997, establishing targets for industrialised countries with a view to stabilising atmospheric CO_2 concentrations. The researchers based their study on the Climate Energy package adopted by the European Commission in 2008, which set the following targets for 2020: a 20% reduction of greenhouse gases compared with the 1990 level, a 20% increase in renewables and a 20% increase in energy efficiency.
On the one hand, imposing CO_2 quotas seemed to be the most "direct" solution for reducing CO_2 emissions; on the other hand, the promotion of renewables also found a solution in France: feed-in tariffs, subsidies without which the development of renewables would not have been so quick, due to the lack of technological maturity. These two solutions appear to be closely connected and both contribute in theory to the reduction of CO_2 emissions.

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Solar power plant in Narbonne.

What is the best energy policy?

The researchers therefore became interested in the energy mix and the impact of the two environmental policies –quotas and feed-in tariffs– on investment and production decisions in the electricity market. They also studied two market structures: regulated monopoly (maximisation of consumer surplus and producer profit) or duopoly (historical operator + all other producers combined to form a second operator).

- If the choice between the various structures and between the two environmental policies considered is based on maximising collective surplus and minimising CO_2 emissions, the answer is regulated monopoly.
- If the decision is based on competition with the lowest possible CO_2 emissions, the best answer is a duopoly constrained by CO_2 emission quotas. This policy will have a cost for the consumer, whose surplus will be lower than the situation with a social planner: in a duopoly scenario, each firm will maximise its profit and the amounts offered will be lower, situation which will be enhanced by the existence of quotas.
- If the decision is to encourage the entry of competitors, the feed-in tariffs policy is the best solution. However, the only winners in this policy are its beneficiaries. The profits of the historical operator will fall and the consumer surplus will also fall.

Furthermore, the buy-back rate policy will encourage increased investment in wind and solar power which, paradoxically, can lead to an increase in greenhouse gas emissions! These intermittent sources of electricity are often combined with polluting fossil energies (such as fuel-oil turbines, for example). Warning: while investing in renewables may seem counterproductive for the purpose of reducing CO_2 emissions, this depends on the number of production plants installed and the demand specification. In Germany, the situation is reversed: many coal-fired plants are already installed, and they are being coupled with renewable plants!

Is a combination of the two policies optimal?

The model shows that a combination of these two instruments (feed-in tariffs and CO_2 emission quotas) can lead to conflicts of interest. Avoiding these conflicts requires increasing the flexibility of CO_2 emission constraints, which can be done by means of quota exchanges (hypotheses not included in the model, due to poor visibility of future prices), or even setting limits on investments in renewables, or abandoning feed-in tariffs (which should be a temporary measure).
In conclusion, the researchers show that policies should take into account the energy mix and the structure of the market and that an efficient policy in one country can have the opposite effects in another. It seems that, considering the structure of the energy mix in France, feed-in tariffs are effective in promoting renewables, as well as being counterproductive in terms of CO_2 emissions. The next step: to take into account the previously ignored parameter of energy efficiency and to look at the conclusions of the model according to a study contemplating the combination of two markets (Germany and France, for example).

Aerial view of the Porcheville thermal power plant, on the banks of the Seine. Plant subject to a CO_2 emission quota.

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METHODOLOGY

The researchers developed a model which they then used to observe the optimum level of investment in electricity production capabilities, monthly outputs of various technologies, CO_2 emissions, prices, profits and consumer surplus.
For every market structure studied, monopoly or duopoly, two main types of consumers were considered: those who depend on the climate and those who do not.
In a second stage, they looked into the impact of environmental policies (no policy; with feed-in tariffs; with CO2 quotas). The model was applied to a 15-year period, from 2006 to 2021, and uses French data from the DGEMP (French Directorate-General of Energy and Raw Materials).

APPLICATION

This work is useful because it shows conflicts of interest between these two policies for French power plants. It also highlights constraints relating to the feed-in tariff obligation imposed on EDF. These constraints are compounded by the additional obligation to bring forward network expansion. Furthermore, this paper also points to a risk of wasting installed production capacities: investment (by means of feed-in tariffs) in renewables combined with new power plants burning fossil fuels can lead to underuse of the capacities already installed for consumers in the studied country.

1. University of Hamburg.

Compensating for the **windfall profits** of the carbon rights markets

Based on an interview with **Arnaud Porchet** regarding his paper "Market Design for Emission Trading Schemes", co-authored with **René Carmona**[1], **Max Fehr**[2] and **Juri Hinz**[3], to be published in 2010 in *SIAM Review*.

The current system of carbon emission rights has the disadvantage of benefiting certain players and passing on a large part of the costs to the consumers. It is less than optimal, but could be modified to adapt quotas of carbon rights to the demand and make up for the weight supported by the consumers.

TWO SYSTEMS are in place for managing pollution rights: the market of emission rights (*EU Emissions Trading Scheme*) and the cap-and-trade systems (USA, Canada, Australia and Japan). Their aim is to reduce pollution by introducing market mechanisms. In the ETS, a central authority assigns emission rights to producers and participants for a predetermined period with a view to achieving a predetermined global level of emissions.

Market of emission rights and windfall profits

The goal of the ETS is to reduce global pollution at the lowest cost to society. Nevertheless, the system such as designed today implies a transfer of wealth from the consumer to the producer which may exceed the social cost of reducing pollution. One solution consists in redistributing part of the profits of electricity producers to consumers by means of taxes and selling emissions rights at the start of each period. Taxation can be politically complex to implement and implies greater regulatory risks than the trading system.

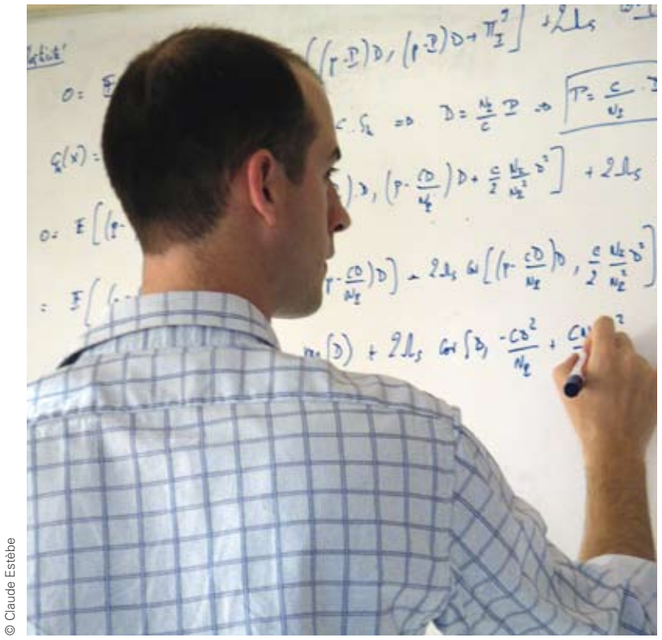
The initial allocation of emission rights is a delicate matter: the regulator needs to find a balance between too many and too few rights. Auctioning all the rights implies a major risk for companies, since they do not know whether the costs will be greater than the income generated later on. However, initial allocation distributes costs within the system. These costs are passed down to the end consumer.

Windfall profits are important for electricity producers: at the start, they receive emission rights free of charge. Then, electricity producers bill each megawatt-hour at the shadow price (including the cost of pollution) regardless of the associated production costs. The cost of pollution is then added to the commodity price.

Relative scheme: a way to optimise the existing system

Taxation makes it difficult to control production. The regulator must adapt taxes to control their impact. In general terms, the prices of emission rights converge towards zero (in the case of excessive emission rights) or towards the penalty price (in the case of insufficient rights). The second phase (2008-2012) of the EU ETS contemplates heavier sanctions for failure to respect targets than the first phase (2005-2008): 40 to 100 Euros plus the spot price of the emission right for the following period.

The implementation of a relative scheme would do away with the initial bargain effect and minimise costs for consumers. Instead of being restricted to the initial allocation of pollution rights, this would require the quotas to be issued in a continuous fashion, proportional to production and consumption. This therefore provided a constant incentive to keep production prices low and to take into consideration variations in electricity demand. This scheme has one main difficulty: reaching the absolute quantity of emission rights. Although particularly difficult to model, auctions could become a useful tool.



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Arnaud Porchet presenting his conclusions.

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METHODOLOGY

For this study, the researchers created a mathematical model for analysing the European Union Emission Trading Scheme (EU ETS). By analysing flaws in the current system, they subsequently drew up a model for relative allocation of rights that responds to certain criticisms of the EU ETS. This model was tested against the benchmark of the EU ETS between 2005 and 2008 (first phase).

APPLICATION

Application for carbon market regulators

Regulators will have difficulties in anticipating the amounts of carbon rights required in order to reduce pollution over a specific period. Regularly releasing quotas makes it possible to adapt quotas to electricity demand (avoiding excessive allocation), as well as to production (avoiding windfall profits). Furthermore, this reduces the windfall profits associated with free initial allocation of rights.

1. René Carmona is a professor of financial engineering at Princeton University.
2. Max Fehr is a postdoctoral researcher at the London School of Economics.
3. Juri Hinz is an assistant professor at the University of Singapore.

Vertical integration or futures markets?

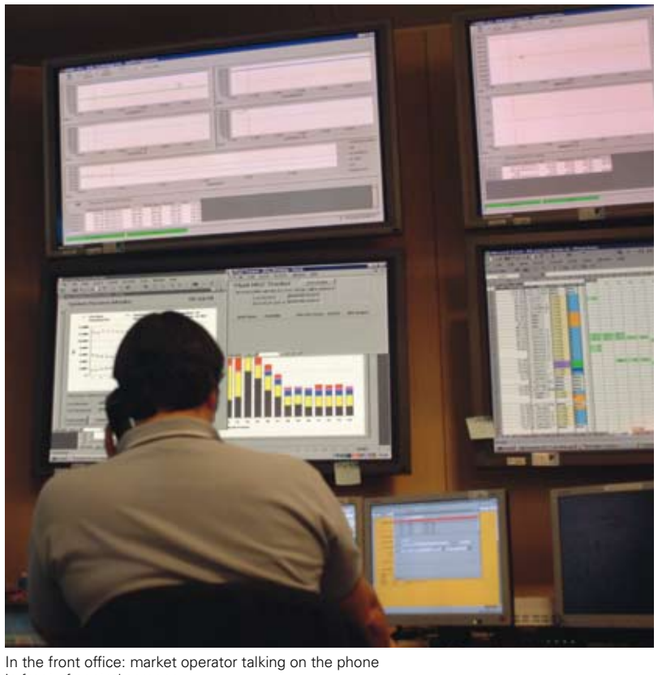
Based on an interview with **Gilles Chemla** author of the paper submitted for publication entitled "Hedging and Vertical Integration in Electricity Markets", co-authored with **René Aïd**, **Arnaud Porchet** and **Nizar Touzi**.

Risk-management mechanisms in the electricity market, vertical integration and futures markets are imperfect substitutes: they guarantee the same effects (reduction of prices in the retail market and increase of the market shares of integrated and non-integrated agents), but with considerable differences in how useful they can be for producers and suppliers.

THERE ARE MANY REASONS why companies in the electricity market are interested in risk management. Gilles Chemla has established two categories: operational risks (risks of penalties imposed by the regulator if they do not satisfy the demand) and more financial risks (such as the interest in smoothing out profits over time). In order to deal with these risks, companies conventionally use two tools: vertical integration and futures markets.

Vertical integration or futures markets?

These questions crop up very frequently in decision-maker processes: to manage risks by means of vertical integration or simply to resort to the financial market?



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In the front office: market operator talking on the phone in front of control screens.

METHODOLOGY

The researchers compared two major tools for financial risk management in the electricity market. These tools are the futures markets on the one hand and the organisation of the company between production, trading and marketing on the other hand. This paper is original in that, for the first time, it provides a balance of three different markets: the spot wholesale market, the retail market and the futures market. The balance model is illustrated by the French electricity market.

And yet, while these two paths for risk management have given rise to abundant academic literature they have, paradoxically, always been the subject of separate studies:

- either these studies have dealt with short-term risk management, with the company resorting to the financial market for this purpose (remember that deep future electricity markets rarely go beyond 3 to 6 months),
- or they have chosen vertical integration as the response to their need for long-term risk management .

The work by Gilles Chemla and his co-authors is original because it shows the existence of a connection between these two risk-management tools and how they interact. Although the angle they have chosen for the study deals with the electricity market, a non-storable commodity, their arguments can be applied more generally to all types of commodities.

Vertical integration and futures markets are substitutes...

The researchers initially proved that vertical integration and futures markets are two substitute mechanisms, insofar as both allow risk diversification. More specifically for downstream companies, in other words suppliers, this diversification allows them to open more customer accounts and increase their business: the supply expands and the retail price drops accordingly. Competition increases in the marketing market, to the detriment of marketing industry profitability but in the benefit of the consumer.

... but imperfect substitutes.

The researchers also highlighted differences between the two mechanisms, considerable differences of interest for pure suppliers and pure producers. Suppliers are involved in a more risky game than producers, since they must first approach customers and then cover their risks. On the other hand, since electricity cannot be stored, producers must know the demand at the time of production.
First of all, these two mechanisms do not offer the same treatment of the asymmetry between production (sensitive to fluctuations of costs or wholesale prices) and marketing (sensitive to fluctuations in demand). Profits made on the cash wholesale market do not depend on retail prices, while the profits of the retail market do depend on the price of the cash wholesale market. For this reason, producers always make a profit from the existence of a futures market, while this is not always the case for suppliers. Vertical integration, when it relates to these two segments, eliminates this asymmetry, unlike the futures markets.
Furthermore, vertical integration is a sturdier risk-management mechanism than futures markets. While vertical integration diversifies operations in the upstream and downstream segments of the industry, the use of futures markets does not entirely cover the risks either of resorting to the spot markets in cases of rising demand, or of paying a higher price than the real cost in cases of falling demand. This flexibility regarding the uncertainty of the demand is possible in the vertical integration scenario, but less likely in the futures market scenario.
The conclusions of this research work are sound. As soon as the market contains non-integrated risk-sensitive agents, futures markets will always be used, although vertical integration has certain advantages in terms of managing risks that are outside the scope of the futures markets.

Saint-Pierre-Cognet dam, France.

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APPLICATION

While companies regularly study the possibility of vertically integrating certain producers or suppliers in order to manage their risks instead of simply resorting to the futures markets, academic literature had not, until now, analysed risk management using these two instruments. This paper intends to clarify the respective qualities of the two, as well as the incentives provided for integrating a supplier or a producer instead of using the futures markets.

Companies, overlooked by the analysis of the opening of the energy market

Based on an interview with **René Aïd** regarding his paper "Long Term Risk Management for Utility Companies: the Next Challenges" to be published in 2010 in the *International Journal of Theoretical & Applied Finance*.

The liberalisation of the market has cast light on the inconsistencies between medium- and long-term risk management and analysis among electricity producers. The tools currently used, which are taken from the financial sector, are not suitable, and those from the monopoly period are outdated. Hence the need, according to the author, to perform new research in this field.

LIBERALISATION of the electricity market has brought about considerable changes. In the USA, some of these consequences include the Californian energy crisis, the Enron scandal, the price spikes and even black-outs. In Europe, the former electricity monopolies experienced a major change from a model which focussed on planning to a model dominated by commercial and competitive strategy, while their management tools had not reached the necessary maturity.

Unsuitable historical models

The theories that underlie economic calculation models from monopoly times (certainties regarding rates, customers and regulation) no longer hold true. Economic and financial risk factors are much more plentiful now than in the past. Historically, the business model of electricity producers consisted of meeting demand at the lowest cost while maintaining a certain level of quality of service (reliability). The principle of specialisation implied that monopolies could only perform the production, transport and distribution of electricity. However, this principle prevented them from asking questions about their business model. The long-term balance between investment and production was determined by planning and the level of obligations for electricity supply (equivalent to a risk-aversion coefficient). Since the price of electricity needed to be stable and uniform for consumers, it was determined in accordance with the marginal costs of production. The parameters that influence production increased in complexity: regulation (environmental and financial) of the market and subsidies for renewables and decentralised production introduced distortions affecting the natural profitability of the various technological fields.

Ensuring the consistency of the adaptations

Faced with these changes, companies performed a large number of adaptations: changing status, transition from the update discount rate according to the plan (8 %) to calculating the cost of capital (10 %) and implementation of financial risk management systems inspired by the banking sector (value at risk and risk limits for all entities).

However, these transformations have led to the coexistence of risk-management parameters whose overall consistency must be assessed. Thus, we should mention the question of the link between the cost of capital and risk limits set using value at risk measurements. Although these two parameters have clearly differentiated fields of action (the selection of investment projects for the former and economic capital management for the latter), they both relate to information on the preferences of companies as regards risk and should be combined. Furthermore, maintaining the loss of load cost, a concept inherited from the monopoly which contains information on the aversion of the company to risk, in decision-making processes also brings up problems for connecting with the preceding parameters.

These difficulties require a research programme that can respond to these needs of the companies. Such a research programme involves the creation of quantitative models. However, major methodological difficulties are encountered. If the models are overly realistic, their complexity leads to numerical calculations which only blur the analysis instead of clarifying it. If they are too poor, they misrepresent the importance of the various decision-making levers of the company. The author believes that the quantitative finance models developed by Rochet and Villeneuve (*Corporate portfolio management, Annals of Finance*, 2005) offer a fair compromise which favours risk-management analysis. The author hopes to see this field of research into corporate financial risk management grow, and to contribute to this growth.

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EPR construction site in Flamanville. A capital-intensive investment with an expected lifetime of forty years.

METHODOLOGY

This study conducts a review of academic literature, its contributions and its gaps as regards analysing how electricity suppliers manage their risks. The author has qualified and compared several analyses in order to identify the fields that are favourable for future research. He points in particular to the deficiencies of current tools and their unsuitability for the needs of the companies in the sector.

APPLICATION

Application for managers

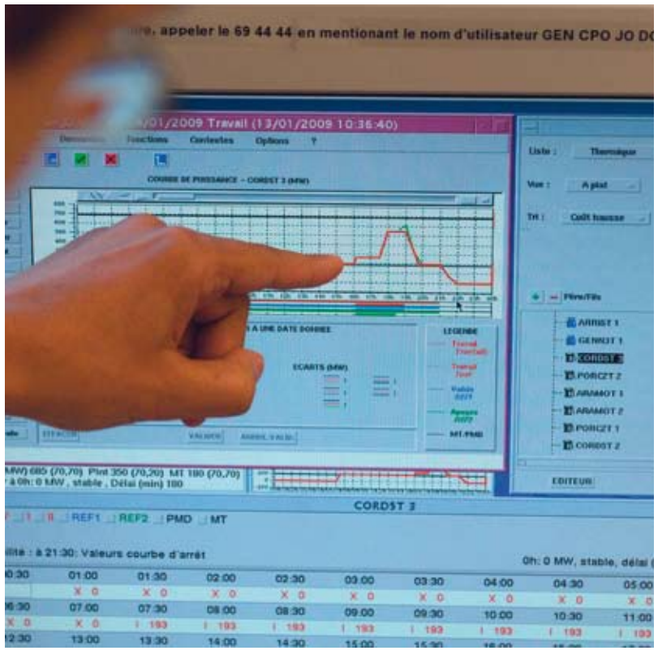
The paper shows the limits of the tools used by the companies in the sector, such as value at risk. And yet, to date, no academic recommendations have been made for managers of electricity producing companies. Specific risk-management models for electricity producers are therefore essential, which implies finding alternatives to the tools currently being used. The research programmes, split among analyses of price dynamics and advice to regulators, should extend to the needs of companies.

Towards a **better assessment** of risk

Based on an interview with **Alfred Galichon** regarding his paper "Comonotonic Measures of Multivariate Risks", co-authored with **Ivar Ekeland** and **Marc Henry**, to be published in 2010 in *Mathematical Finance*.

As a security measure, regulators require financial institutions to deposit funds to match the risks they incur. Decision-makers tend to try to minimise this deposit in order to capitalise as few assets as possible. How then can they select the best risk measurement for more effective regulation?

SINCE THE BASEL II accords of 2004, financial institutions are required to hold a certain amount of capital that depends on the level of risk of their positions. It is therefore essential for companies and regulators to be able to assess the risk of each financial position, including cases of investing in other companies (subsidiaries, for example). On one hand, the regulator wants to penalise the risk taken by imposing an amount to be capitalised; on the other hand, managers seek to minimise this amount, but not necessarily the risk. But what properties should characterise an optimal risk measurement? Is value at risk (VaR), the most commonly used risk-assessment tool in the financial markets, relevant in this case? Does it really encourage companies to engage in more virtuous, less risky behaviour?



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EDF Department of Upstream-Downstream Optimisation & Trading.
Follow-up of the power curve to analyse needs.

METHODOLOGY

The researchers want to show that risk measurements that depend on multiple variables and fulfil the "strong consistency" condition can be represented as maximum correlation functions. They propose examples of "strongly consistent" risk-measurement calculation with multiple variables using conventional algorithms.

The limits of value at risk

The VaR with a level of 99% imposed by the Basel II accords is defined as the smallest amount of capital required to cover losses in 99% of cases. It does not include losses in the remaining 1% of cases. Furthermore, regulators do not find using VaR to assess risk to be entirely satisfactory since "every risk can be split into small parts that are undetectable by VaR", explains Alfred Galichon.
Indeed, if this risk measurement is used to determine the statutory amount that a company must hold, a group can create subsidiaries that separately cover some of these risks, thus considerably reducing (or even cancelling in certain cases) the amount to be capitalised without thereby reducing the risk that weighs over their positions. To avoid this regulatory arbitrage, the researchers recommend using sub-additive risk measurement, in other words a measurement that ensures that diversifying the sources of risk within a single company also makes it possible to reduce overall risk.

Towards balance

"Imposing sub-additive risk measurement would discourage company managers from creating subsidiaries in order to disperse risk", explains Alfred Galichon. However, on the other hand, risk measurement should not systematically benefit conglomerates. To obtain a balance between these two constraints, the researchers explain that the risk measurement used to calculate the amount of capital to be deposited must comply with the so-called "strong-consistency" property.
In other words, regulators should impose on companies the need to deposit an amount that would enable them to deal with the worst-case risk scenarios in order to eliminate the artificial effect of risk reduction when it is split up among several entities. By imposing a risk measurement that complies with this property, companies are no longer encouraged to form conglomerates in order to reduce the amounts to be deposited.

The heterogeneous nature of risk factors

Another problem brought up in this paper is the diversity of risk factors. Can all these risks be reduced to a financial risk? A conventional risk-quantification approach consists of assessing all risk factors in euros, thus relying on the sole factor of financial risk. But is it possible to assign a financial value to environmental or human factors such as river pollution or occupational accidents? Furthermore, setting a price on this type of risk can, in certain cases, encourage companies to act in unethical ways, by only considering the economic cost of this type of risk. Therefore, rather than aggregating all the risks in a financial risk and then quantifying the latter, Ivar Ekeland, Alfred Galichon and Marc Henry suggest considering risk measurement to be a complex function that depends on multiple variables. Underlying idea: the various risk factors can be assessed in different units that do not systematically have to be Euros.

APPLICATION

Applications for the regulator

- With this study, the researchers draw the attention of the regulators to the need to implement mechanisms for risk measurement that drive companies towards ethical behaviour. The issue: better balance of the economy.
- The researchers also raise the question of the validity of converting all types of risk to financial risk, and propose considering risk measurements that depend on several variables by using a complex function.

GARCH model guided by exogenous behaviour

Based on an interview with **Jean-Michel Zakoïan** author of the paper co-authored with **Nazim Regnard** and entitled "A Conditionally Heteroskedastic model with time-varying coefficients for daily gas spot prices" to appear in *Journal of Time Series Analysis*.

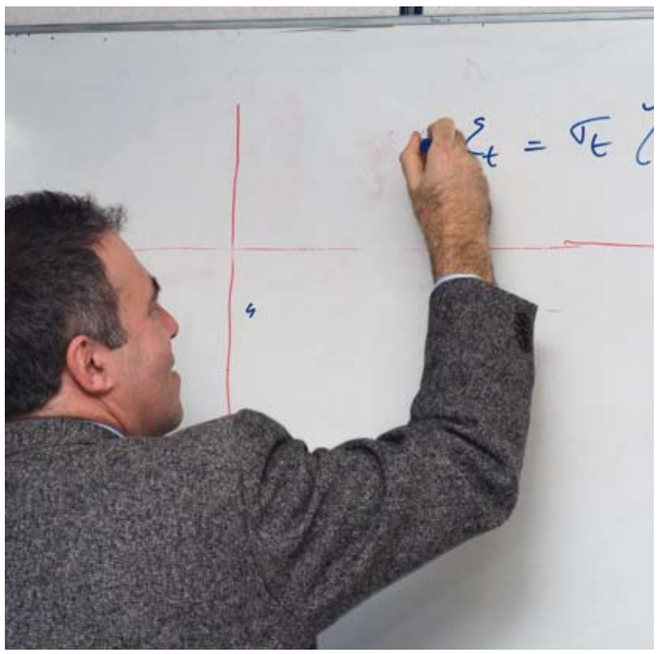
This paper introduces GARCH processes with time-varying coefficients (non-linear stochastic model) for modelling price volatility. In a companion paper it is applied for the gas prices. This choice of method makes it possible to reproduce two important phenomena: volatility clustering and variations in exogenous factors which affect supply and demand and, therefore, model parameterisation.

REPEATING an experiment many times in order to deduce the frequency with which events occur is the main idea behind probability and statistics. In finance, like in every social science, we sometimes notice that consecutive observations of studied variables are the result of a system subject to permanent change. Thus, the conditions for the "experiment" are not identical every day. In order to take into account this variation of the underlying structure of the market, models with dynamic volatility have been introduced. In particular, the GARCH models make it possible to launch high-volatility periods whenever abnormal phenomena, which are capable of destabilising the markets, are observed. These models were introduced by Bollerslev in 1986 based on work by Engle in 1982. They have been improved on constantly since then.

Nazim Regnard and Jean-Michel Zakoïan propose a model that extends the GARCH models, enabling the introduction of additional dependence of volatility on a set of exogenous states. The proposed model improves the consideration of the fluctuating structure of the financial markets. Although extremely general, the method can be applied to studies of the electricity market. Indeed, these markets take into account the effects of seasonality linked to changes in energy requirements, or else to different consumption modes according to the day of the week.
The main difficulty lies in knowing which conditions are required for the proposed model to have meaning and how to estimate its parameters. The parameters of a GARCH(1,1) model correspond to a minimal level of volatility, to a slow rate of return to low volatility and to a destabilisation coefficient whenever an anomaly is observed. These three parameters, which are fixed in a conventional GARCH(1,1) model, here depend on exogenous states of the system. The entire relevance of this type of approach therefore depends on the ability of its user to correctly estimate these parameters. Without this, the result of the simulation can diverge, in which case it can yield arbitrarily large results or a biased view of the phenomenon studied.

The parameters are estimated using the method of maximum likelihood, adapted to the problem. Likelihood is the probability that the observed movements will actually follow the law specified by the model. The parameters are adjusted so that the law is maximal. The authors present and demonstrate several results which enable them to prove that under relatively non-restrictive conditions, the method would work correctly.

The existence of a non-explosive solution is proven, provided that the ergodic hypothesis is fulfilled. This means that the exogenous states must be explored homogeneously over time. The parameters must, in addition, be constrained by inequality that depends on both the characteristics of the volatility and the probabilities of occupying exogenous states. They then explore specific cases in which the exogenous states can be periodic, stationary or represented by a Markov chain.
The analysis of financial temporal series has seen remarkable developments over the last two decades. GARCH models are one of the important tools that enable us better to understand the fluctuating nature of the financial markets. The dependence of the model on exogenous states of nature will enable better modelling of markets and, in particular, of the energy market.



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Jean-Michel Zakoïan explaining the operation of the GARCH processes.

METHODOLOGY

The subject is studied in depth from a theoretical point of view. The paper stresses the probabilistic properties and the methods for estimating parameters of models with variable coefficients. In addition to theoretical formalism, it suggests applying the method to daily gas prices using temperature as an exogenous variable. Various temperature models will be highlighted, with different volatility dynamics.

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Cellino Attanasio gas storage centre, Italy.

APPLICATION

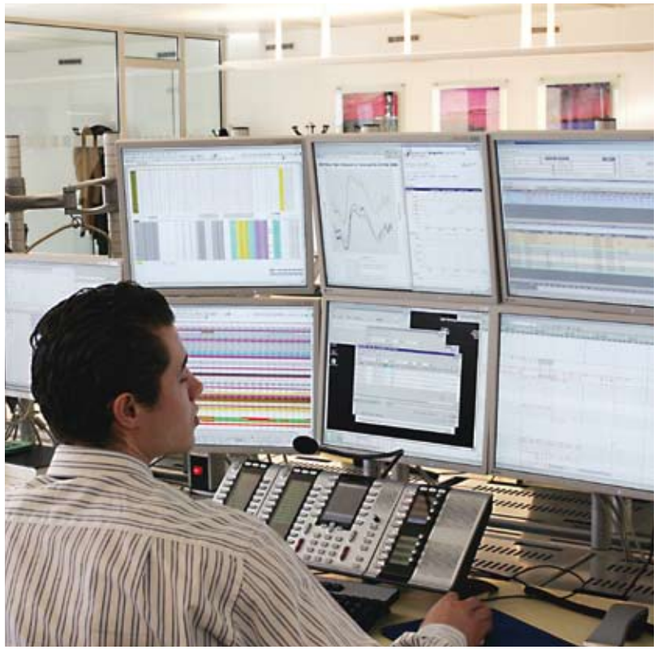
The possibility of conditioning the volatility dynamics of a series of prices by several temperature models will enable us to make forecasts. In a more generic fashion, it would be relevant to be able to predict the dynamics of a temporal series according to a future state of one or more exogenous factors.

Understanding the formation of electricity prices

Based on an interview with Luciano Campi, author of the paper entitled "A Structural Risk-Neutral Model of Electricity Prices", co-authored with **René Aïd**, **Adrien Nguyen Huu** and **Nizar Touzi** and published in 2009 in the *Int. Jour. of Theoretical & Applied Finance*.

Can the electricity market be studied using existing tools in the financial markets? "Yes," says Luciano Campi, "but as long as it can be proven that the constraint of non-storability of this unique product can be overcome". For this purpose, the researchers have developed a model that associates the prices of electricity with the fuels used to produce it.

LUCIANO CAMPI points out that "while many researchers use tools intended for the equities markets to understand the mechanisms in play in the electricity market, the question of the relevance of these tools is rarely studied". In particular, what effect does the non-storable nature of electricity have on price formation? What is the link between the spot and forward prices? The researchers attempt to answer these questions by showing that although electricity cannot be stored, the fuels used for its production can.



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EDF Trading.

METHODOLOGY

The researchers have developed a model which, by overcoming the constraint of non-storability of electricity, aims at establishing a link between spot price and forward price on this market. Their study is based on the hypothesis of an economy in which all electricity is produced by thermal power plants. The spot electricity market is furthermore assumed to be competitive.

Non-storability of electricity: a very specific characteristic

Electricity is a unique commodity which is difficult to compare with the commodities traditionally exchanged on the markets. Its non-storable nature, in particular, means that it must be consumed whenever it is produced. The hypothesis of the lack of arbitrage opportunities (all the players find long-term profit opportunities and want to grasp them, with the result that the price of the asset naturally tends towards its non-arbitrage price) which dominates the financial market models makes no sense in the case of electricity. In other terms, as Luciano Campi explains, "the forward price is not equal to the spot price capitalised at the market interest rate and there is no link between the short- and long-term prices in the field of electricity". A statement that has not however prevented the emergence of mathematical models based solely on the relationship supposed to link the spot and forward prices of electricity (models based mainly on the work of Black and Scholes).

Short- and long-term prices

Luciano Campi invites us to differentiate, as in every market, the short- and medium-term prices that characterise the electricity market.

- **Spot prices:** these are the prices negotiated on one day for the next day, therefore reflecting the short-term balance between supply and demand. The non-storable nature of electricity makes these prices highly volatile, since an increase in demand cannot be immediately compensated by an adjustment of the supply. This phenomenon is even more complex to anticipate insofar as demand variations can be difficult to foresee: they are based on uncontrolled variables (in particular weather conditions).
- **Forward price:** in order to minimise the risks of volatility that affect the spot market, operators sign electricity sale and purchase contracts for periods of one or several months. The price of electricity on the futures market is mostly negotiated upstream from its consumption.

But is there a real link between the spot and futures prices? And can this link be modelled as in the financial markets?

Establishing a link between spot price and forward price

Although electricity cannot be stored, the researchers stress that the fuels used for its production (particularly coal, gas and oil) can. They have therefore designed a model that links the electricity market with the fuels market. In this way, the researchers overcome the constraint of non-storability of electricity, showing that the spot price and the forward price are linked. In other terms, they show that it is valid to use risk-neutral models (based on the hypothesis of no arbitrage opportunities) to understand how electricity prices are formed on the market.

The issue of price peaks

Their model based on fuel energy is even more relevant in that it takes into account price spikes, which are often difficult to model in the electricity markets. These spikes correspond to the time when "sudden shocks in demand (for example during periods of extreme cold) approach the maximum production of the productive system", explains Luciano Campi. Such price spikes are not observed, for example, in the equities markets, where following a sudden shock, the prices generally take a long time to return to their original levels.

Tokyo, Shinjuku ward by night. Electricity is essential for our everyday life.

© Claude Estèbe

APPLICATION

This research is rare in that it establishes a concrete link, based on the fuel market, between spot price and forward price in the electricity market. The model developed, which concludes with the validity of using current financial tools to understand the electricity market, is above all a starting point for future work that will make it possible to improve our analysis of the mechanisms that govern the formation of electricity prices.

Monte-Carlo methods for non-linear PDEs

Based on an interview with **Nizar Touzi** and **Xavier Warin** regarding their paper co-authored with **Arash Fahim**[1]
"A Probabilistic Numerical Method for Fully Nonlinear Parabolic PDEs" to be published in 2010 in
Annals of Applied Probability.

The problems of finance, economics and physics are often modelled using partial derivative equations (PDEs). The most realistic models provide fully non-linear PDEs. The authors have developed a probabilistic method for resolving these PDEs. Various resolution schemes are proposed and a convergence analysis is performed.

Example of the power of numerical calculation.
Simulation of the strength of screws inside a tank.

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THE EVOLUTION OF A SYSTEM, whether financial, economic or physical, is often represented in a more or less simplified manner by a system of partial derivative equations (PDEs). For linear PDEs, such as the option assessment equation by Black and Scholes, the solution can be represented in the form of an average of all the uncertainties foreseen for the future. This representation has major consequences, since it paves the way for probabilistic numerical methods, such as the Monte-Carlo methods, in order to approximate the solution.

The Monte-Carlo methods are highly appreciated in the financial industry, due to their flexibility and their capacity for treating problems on a large scale.

The extension of this method to the non-linear framework responds to an operational requirement. For example, the sound assessment of a position in a case with uncertain knowledge of the volatilities and correlations leads to a considerably non-linear PDE, in other words, one which contains a non-linearity bordering on the second derivative.
Adding market illiquidity to the models that involve the Gamma of the portfolio, as a penalty in the value of the portfolio, also provides considerably non-linear PDEs.

Arash Fahim, Nizar Touzi and Xavier Warin propose a general numerical method that allows the Monte-Carlo methods to be used for these considerably non-linear PDEs. They prove, using the theory of viscosity solutions, that the numerical scheme they propose is convergent, providing a limit for the maximum error committed. They provide formulas which make it possible easily to implement the method.

The numerical scheme proposed by the authors is applied to two problems a simplified problem of propagating the follow-up of the frontier and one problem of optimising the financial portfolio. For both these problems, the method is systematically tested on a low-scale problem with a known solution, and then extended to greater scales. The simplified front propagation problem is known as the "mean curvature flow". It consists of deforming a frontier in a direction that is orthogonal to its gradient with a speed that is proportional to the curvature. This is a non-linear problem to which the method is applied.

In the case of portfolio optimisation, it is a question of resolving the Hamilton-Jacobi-Bellman equations, associated with a dynamic system governed by stochastic differential equations to which constraints are added. In order to manage a portfolio, these constraints are targets to be achieved in terms of profitability and risk minimisation. We should note that, in practice, problems of this type are generally rather delicate to treat. They often lead to numerical instabilities, where we can see that small changes in the variables lead to major shifts in the results. These instabilities are aberrant in relation to actual observations. They are most frequently treated using "numerical tricks" depending on the problem being treated. Having a sufficiently straightforward generic method is a true technical advantage when it comes to effectively treating problems with risk management and assessment for the most complex financial products.

METHODOLOGY

In this paper, the authors show the convergence of the numerical scheme, using the Monte-Carlo methods, for the fully non-linear PDEs before setting the boundaries for the approximation error.
They conclude by implementing numerical experiments for approximating the solution of the mean curvature equations and the Hamilton-Jacobi-Bellman equation.

APPLICATION

The proposed methods can be applied to a very broad range of problems. In this case, the authors only deal with propagating the follow-up of the frontier and a problem of optimising the financial portfolio. In the latter case, where we seek to maximise profitability while minimising risks, the proposed method provides a numerical solution to the Hamilton-Jacobi-Bellman equations in five dimensions, controlling the errors committed by the numerical method.

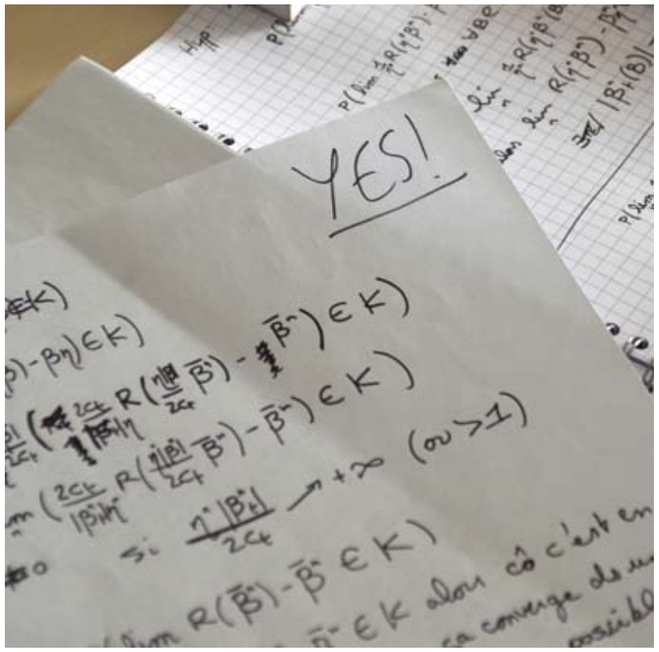
1. Arash Fahim is a postdoctoral researcher at the Fields Institute, Toronto.

Adapting **derivatives** to the needs of companies

Based on an interview with **Romuald Elie** regarding his paper, co-authored with **Bruno Bouchard** and **Cyril Imbert**, entitled "Optimal Control under Stochastic Target Constraints" to be published in 2010 in the *SIAM Journal of Control and Optimization*.

Options are derivatives that are similar to insurance policies. They guarantee a fixed price at a future date for the person purchasing them, despite certain economic uncertainties (raw material price variation, exchange rate fluctuation, etc.). But how can we define the optimum contract that will provide the best protection for the purchaser while also satisfying the seller?

FOLLOWING THE WORK of R. Merton, as well as that of F. Black and M. Scholes in the 1970s, the financial world underwent a true revolution thanks to the use of mathematical advances in the field of probabilities. Since then, many financial products with increasing complexity have appeared, in particular "call" options (purchase options) and "put" options (sale options) which enable companies to cover themselves against fluctuations in raw material prices and exchange rates. These products, which are not directly connected to the economic performance of a company, guarantee that their holder will be able to sell or purchase an asset on a subsequent date at a previously arranged price. But how can the price of these options be determined so that it is advantageous for the purchaser and the seller at the same time?



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METHODOLOGY

The researchers introduced a new method for valuing options in which the price can be defined as the smallest amount of money that makes it possible, on the due date T, to obtain wealth at least equal to the amount to be transferred to the holder in 90%, 95% or 99% of cases. They then show that these prices fulfil a partial derivative equation and can therefore be calculated or, in any case, approximated.

Call options and put options: how and when to activate them?

An option is a deed that gives its holder the right (but not the obligation) to purchase or sell a certain amount of a financial asset on an agreed date T at a previously arranged price known as the exercise price. Let us take the example of a French company whose production costs are in Euros and which sells its products to the USA in dollars, with a delivery and payment date T. The company would like to protect itself against a fall in the value of the dollar and therefore purchases a call option on the euro, enabling it to exchange one dollar for K Euros on the date T, if it so desires. More specifically, two scenarios are possible:

- If on the due date T one dollar is worth less than K Euros then by exercising the call option the company will make a profit equal to the difference between the price of one dollar in Euros and K Euros.
- In the opposite case, if the value of one dollar is greater than K Euros on the date T, the company does not exercise its option.

What value can be assigned to this type of contact?

The problem is knowing the price to assign to these contracts in order to satisfy both the seller and the purchaser. In conventional literature, this price is calculated to be the smallest amount of money that makes it possible, on the due date T, to obtain wealth at least equal to the amount to be transferred to the holder. However, "such a price is generally too high to be of interest to companies, since the imposed constraint is too heavy", explains Romuald Elie. Indeed, this price takes into account all risks in a fixed manner, while companies wants less expensive contracts that will enable them to protect themselves against the most likely risks.

What do companies really want in terms of options?

The researchers studied a type of partial coverage for which the constraint would be lighter and which, therefore, would be less expensive. More specifically, in the case of a call option, they propose that the holder should be guaranteed the possibility of purchasing the asset on the agreed date T at the previously arranged exercise price K in, for example, 90%, 95% or 99% of cases. For the remaining exceptional cases (10%, 5% or 1%) the contract stipulates that the call price for the holder of the option is higher than the exercise price and lower than the price of the asset on the due date. The researchers therefore define the price of the option to be the smallest amount of money that, when correctly invested in the market, makes it possible, on the due date T, to obtain wealth at least equal to the amount to be transferred to the holder in 90%, 95% or 99% of cases. Therefore, unlike in the case of a conventional call option, the company does not have access to a guaranteed price in 100% of cases, only in the vast majority of cases. "The constraint applied to the option is considerably lighter and its price is therefore much lower. The risk coverage is no longer perfect, but it is however more affordable", explains Romuald Elie.

APPLICATION

- With this study, Romuald Elie and his co-authors draw attention to how useful it is for companies to seek protection, at a moderate price, against certain risks even when, in return, they are less well protected in the exceptional cases.
- The approach of the researchers also allows them to propose a method that can be used to approximate or calculate the exact price of this type of financial product according to each case.

Optimising investment decisions

Based on an interview with **Joseph Frédéric Bonnans** author of a paper co-authored with **Dan Tiba**[1] entitled "Control Problems with Mixed Constraints and Application to an Optimal Investment Problem" published in 2009 in *Mathematical Reports of the Romanian Academy of Sciences*.

What are the qualitative characteristics of an investment decision? The initial response of Joseph Frédéric Bonnans and Dan Tiba shows that, for certain capital-formation models and certain optimisation criteria, the decision can only have three optimal values: zero, a maximum value and an equilibrium value.

Investment under constraint

In this paper, the authors mainly studied a problem of optimal investment under constraint. The state variable is the capital, which depends on space (geographical position) as well as time. This capital is subject to linear depreciation as well as geographical distribution, modelling transfers from the richer areas to adjacent poorer areas (according to the model, a poor country has better prospects for development if it is surrounded by rich countries). The decision variable is the investment (creation of capital). The latter cannot exceed a fraction of the capital, which is consistent if we assume that production is proportional to capital, and that investment cannot exceed a fraction of production. The criterion to be minimised is the sum of total investment and the integral of a disutility of capital, showing a preference for the "mean" level of capital at all times. This criterion is perfectly in line with the spirit of sustainable development.

Towards optimal investment decisions

The authors therefore show that, at every point of space and time, the optimal investment decision can only have three values: zero, a maximum value or an optimal critical value, which is obtained in an almost explicit manner. Determining the optimal decision therefore involves identifying the three optimal regions: zero, stationary or critical investment. The article therefore extends the principle known as "generalised bang-bang" to the field of economics.

Frédéric Bonnans presenting his work at a seminar of the FiME Research Centre.

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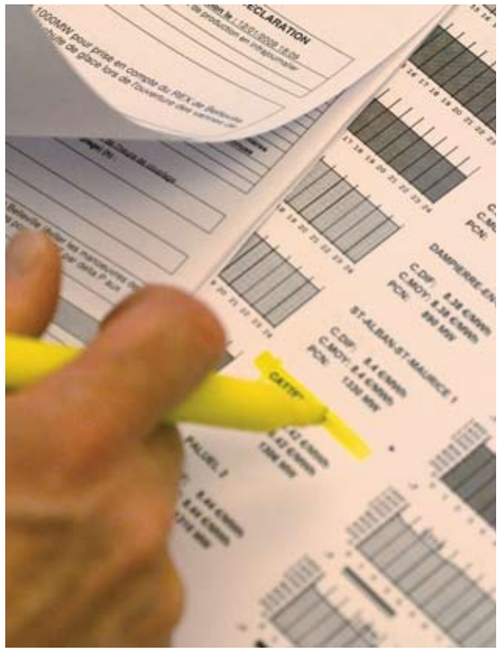
METHODOLOGY

Optimal control problems aim at finding a decision-making law that can be used at all times to optimise a criterion involving the solution of a dynamic system. The issue is to correctly model a system, to define the criteria to be minimised, based for example on a utility function, and then to establish the laws followed by the optimal control. In practice, these models have applications in different industrial fields, in particular in sectors in which control engineers seek to optimise specific processes (aeronautics, aerospace, automobiles, robotics, communication, etc.). In the electricity sector, this type of models can be used, for example, to define the level of investment required to optimise production, taking into account specific features of electricity as a product, such as its non-storable nature.



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EDF Department of Upstream-Downstream Optimisation & Trading (DOAAT).

APPLICATION

The application of the methodology of the paper to problems of sustainable development raises the issue of asymptotic behaviour over long periods. When the horizon is distant, can we guarantee stabilisation of the decision? Does this mean that we would find three possible capital areas: one tending towards zero (zero investment), the other towards infinity (maximum investment) and finally, an area of capital equal to the critical value? This can be interpreted as increasing or reducing social inequalities.

1. Dan Tiba is a researcher at the Institute of Mathematics of the Romanian Academy.

Natural systems to the rescue of algorithmics: application to the Monte-Carlo methods

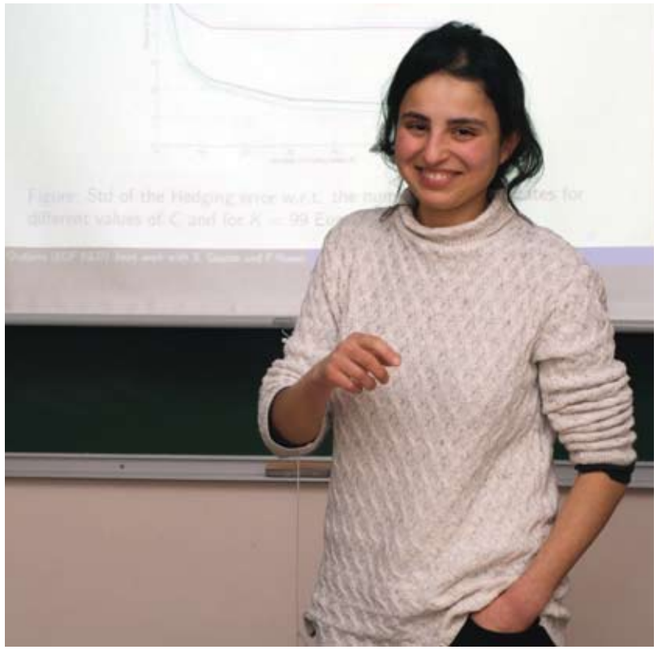
Based on an interview with **Nadia Oudjane** and **François Le Gland** regarding their paper submitted for publication entitled "A New Adaptative Monte-Carlo Method for Variance Reduction: applications to VaR computations and option pricing".

This paper presents an original variance reduction method for calculating expectations using the Monte-Carlo method, inspired by certain mechanisms of the evolution of species to find the optimal importance law. This technique has been applied to calculate the value at risk of a portfolio and the price of a European option outside the currency.

Reducing variance to speed up convergence

The Monte-Carlo methods are very often used in quantitative finance, whether for valuing complex financial products or for calculating risk indicators. These methods make it possible to approximate deterministic quantities in a numerical fashion, estimating them using values obtained by performing a large number of random runs. The accuracy of this approximation depends on the number of simulations and on the variance of the estimator, which we should seek to reduce in order to improve the quality of the approximation without increasing its calculation time. The common idea behind all these so-called variance-reduction techniques is to find a random variable with the same mean value as that sought to be determined but with lower variance. By showing that not every value of the random variable provides the same amount of information, preferential sampling explores the space in a manner that is better suited to the assessed function, selecting the sample used for the calculation and focussing on its most "important" values. The theory then tells us that there is a distribution, the optimal importance law, which explores the space as best as possible and thus minimises the variance of the estimator. However, the characterisation of this law depends on the sought value and is therefore not directly accessible. We are therefore often forced, in practice, to choose an acceptable density "manually", or to resort to limiting parametric hypotheses.
François Le Gland and Nadia Oudjane propose a non-parametric method for constructing an approximation of the optimal importance law.

Nadia Oudjane explaining their variance-reduction method at a seminar of the FiME Research Centre.



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METHODOLOGY

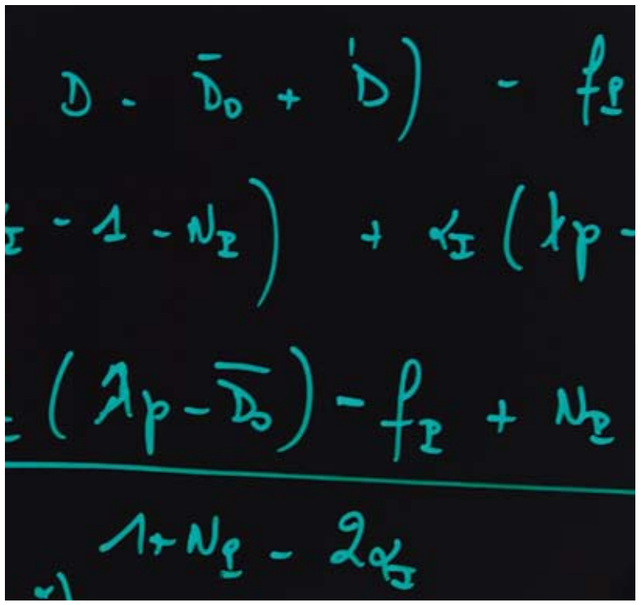
The authors used a new Monte-Carlo simulation method in order to obtain greater accuracy in calculating the VaR of a portfolio. They have developed a so-called particular technique which aims to approximate the new law that makes it possible to reduce the variance. This method consists of introducing particles that will be multiplied in the regions where the law is important while suppressing particles in other regions of the space. In this case, only 1% of simulations are informative for a VaR of 99%.

What if particles did the searching for us?

For this purpose the authors have defined a finite series of importance laws in which the last term is the sought optimal law. Each one of the intermediate terms of this series is therefore approximated by an empirical measurement determined by a sample which in turn is built by recurrence according to a specific method.
A specific method is a process for seeking the solution to a problem in which the space is crossed by "particles" caused to evolve drawing inspiration from the theory of the evolution of species: the characteristics of individuals evolve at random (mutation), but only the best adapted individuals survive and reproduce (selection).
In this case, a system of particles corresponds to a sample of random variables which are caused to evolve by recurrence, applying the steps of mutation and selection in which realisation, in the last iteration, provides a discrete approximation of the optimal importance law. A regularisation step then makes it possible to extract a density of importance approximating the sought value and which can be used for the preferential sampling method.

Application: calculating value at risk (VaR)

VaR is currently the most popular measurement for assessing the financial risk of a portfolio. It is defined as the maximum potential loss that the portfolio can suffer in a given amount of time with a given probability.
Several methods are used to calculate this measurement, including the Monte-Carlo approach. The principle consists of simulating a large number of portfolio trajectories and of deducing from them the maximum loss observed for the desired level of probability. Although it always provides results, even in the most complicated cases, this method has the disadvantage of being potentially more costly in terms of calculation time due to the rarity of the events that contribute to the calculation. The usefulness of the method proposed by François Le Gland and Nadia Oudjane can be clearly seen in this context, in which a large proportion of the simulations conducted by the usual method add little to the accuracy of the result. Experience confirms the value of this algorithm: tests show that the variance reduction is considerable compared with a conventional Monte-Carlo method, while the uncertainty is not too large.



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APPLICATION

The generic nature of the approach presented in this paper provides a tool that can be employed in any calculation using a Monte-Carlo method. This is particularly the case with many problems in quantitative finance, such as the valuation of complex products or the assessment of portfolio risk indicators. It turns out that this method is particularly well suited to calculations involving rare events, including value at risk (VaR) and conditional VaR.

Interest rate model
adapted to long-term asset-liability management

Based on an interview with **Olivier Féron** regarding the paper submitted for publication entitled "An Arbitrage-Free Interest Rate Model Consistent with Economic Constraints for Long-Term Asset-Liability Management", co-authored with **René Aïd**, **Nizar Touzi** and **Christine Vialas**[1].

The researchers propose a Heath-Jarrow-Morton model of the interest rate curve, a model which adapts to the specific demands of long-term asset-liability management. The purpose of their work is to propose models for generating financial uncertainties. In this way they offer help for risk management and decision-making while enabling integration of the economic forecasts of decision-makers.

IN AN UNCERTAIN UNIVERSE, asset-liability management, as a global, coordinated method enabling management of the composition and suitability of all assets and liabilities, is subject to financial uncertainties that influence the yield of the portfolio (asset) and the value of the liabilities, in some cases affecting both. The researchers therefore studied the possibility of simulating financial uncertainties on a large number of possible trajectories. Their goal was to model the values acquired by the assets and the liabilities according to these trajectories, in order eventually to propose the largest number of possible futures.

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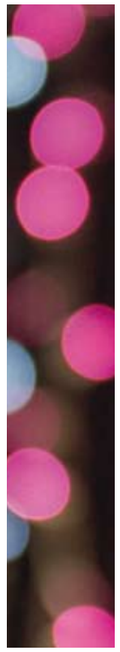
METHODOLOGY

The model created by the researchers, applied in particular to the rate curve, must respect three main constraints: lack of arbitrage opportunities, representation of historical data (statistics) and integration of the future visions of economists. The Heath-Jarrow-Morton model chosen (general rate curve evolution model) respects the first two constraints. The researchers have shown that it also respects the third constraint.



1. Christine Vialas is Director of the Strategic Policy and Asset-Liability Management Division of the Finance Department of the EDF group.

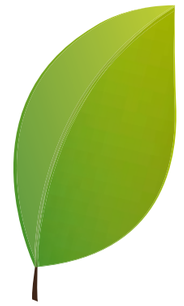
Constraints imposed on the model

The model is subject to one constraint: it must generate realistic futures. Financial uncertainties are not independent from one another; while the influence of each uncertainty on asset-liability management can be easily modelled, the fact that they are independent requires a global model, with the condition of keeping a principle of consistency between them (they cannot evolve independently from one another). The constraint of consistency between financial uncertainties has led the researchers to fix one of the three hypotheses that govern the model: the lack of arbitrage opportunities. Indeed, one of the fundamental hypotheses of the usual models is that no financial strategy makes it possible, with an initial cost of zero, to acquire certain wealth at a future date. This hypothesis is called the lack of arbitrage opportunities. It is theoretically justified by the uniqueness of the prices that characterise a market with pure and perfect competition.
Generating realistic futures imposes not only the need to respect the lack of arbitrage opportunities, but also to know how to represent what has happened in the past (past statistics) as well as to be capable of integrating the vision of economists regarding possible futures (economic expert reports). Conventional models are required to respect the first two constraints; the addition of the third is the methodological contribution of this paper.

Focus on interest rates

One of the most heavily studied uncertainties is the interest rate curve, of great importance in asset-liability management. While the global model looks at other uncertainties, the rate curve is one of the most difficult ones to model because it is a continuous function. The researchers based their study on an existing model, the Heath-Jarrow-Morton model which, by definition, respects the lack of arbitrage opportunities and, in the form chosen by the authors, can be calibrated easily using historical data. Their work has shown that it can also be calibrated using the vision of the experts and they have described how to determine the parameters of the model that will provide the expected characteristics. This is the main contribution of this paper. The choice of model was also influenced by three other endogenous constraints:

- the realism of the future structure: modelling the rate curve involves this consistency between the rates (consistency that can realistically be assumed due to the lack of arbitrage opportunities), as well as consistency in the variation of this curve over time.



- Integration capacity: the correlation between the rate curve and the other financial uncertainties (using a correlation matrix) must be easy to perform.
- Simplicity: the problems come out in the long term (around one hundred years) and the simulations can relate to one million trajectories; the more complicated the chosen model, the longer the calculation times; hence the need for the model to be simple in order to guarantee acceptable calculation times.

Why calibration using expert visions?

Conventionally, models are calibrated using historical data. This assumes that the futures simulated by the model will have the same characteristics as those observed historically. This is relatively true for the near future (less than one year). For very long-term studies, this hypothesis is generally reappraised and management committees want to be able to integrate the vision of the experts in the characteristics of possible futures.
In practice, the capacity for calibrating the model using the visions of experts is therefore essential for long-term studies. Moreover, this makes it easier to study several different visions of the future (crisis, post-crisis, etc.).

APPLICATION

This model can be used to manage pension funds. The management committees of these funds involve various stakeholders. They can agree on macroeconomic visions of the future (inflation level etc.). The model can then include these visions while guaranteeing that the simulations produce a rate of return on assets that is compatible with market constraints.

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SUBMITTED

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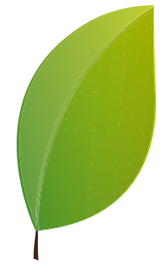

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Paris-Dauphine University
Place du Maréchal de Lattre de Tassigny
75 775 Paris Cedex 16

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