

<p><b>Institution: Birkbeck, University of London</b></p>
<p><b>Unit of Assessment: 18 Economics and Econometrics</b></p>
<p><b>Title of case study: Advances in Stochastic Modelling for Complex Option Pricing and Commodity Forward Curves, and Applications in Corporate Trading and Hedging</b></p>
<p><b>1. Summary of the impact</b></p> <p>Geman’s research has made contributions to exotic option pricing, insurance and catastrophic risk, high frequency trading, and the whole spectrum of commodities, from crude oil and electricity to metals and agricultural commodities. Her research identified complex options and derivatives for commodities, and their applications for risk management and the valuation of physical assets for energy and mining companies, as a relatively under-researched and neglected field, and has made several scientific contributions to it (detailed in section 2).</p> <p>There are four impacts detailed in this case study:</p> <ol style="list-style-type: none"> <li>1. Geman’s discoveries are used to determine the composition of the UBS-Bloomberg commodities index.</li> <li>2. Geman has used her results to construct leading indicators of volatility spikes in agricultural prices for developing countries. These leading indicators are used by the European Commission.</li> <li>3. Geman’s results have caused fertilizer manufacturers and investors to increase their use of fertilizer-industry financial assets (and fertilizer-based derivatives) in their investment portfolios.</li> <li>4. Geman’s results have modified the investment strategies used by EdFT (Electricité de France Trading).</li> </ol>
<p><b>2. Underpinning research</b></p> <p>Geman’s research in mathematical finance has employed theoretical probabilistic tools (as opposed to partial differential equations or numerical methods) to determine exact valuations of complex options, such as multi-asset options or path-dependent options. The Black-Scholes-Merton model, which provides a closed-form solution for the price of a plain option, relies crucially on Einstein’s solution of the heat equation. This formula has been incorporated into the software of all banks for decades. Its ease of use allows ordinary corporations to benefit from it in their daily hedging activities. But the heat equation cannot be used to determine prices of complex options that are widespread in commodities markets. In the case of Asian options on the average value of the underlying asset, which appeared in 1990, and which are crucially useful in the world of currencies and commodities, an equation analogous to Black-Scholes can be derived but its solution is far from obvious. Geman introduced the tool of stochastic time-changes in order to obtain the exact prices, sensitivities and convexity, of multi-asset, Asian and double-barrier options.</p> <p>Commodities (electricity, natural gas, metals, corn) naturally lend themselves to models with jumps in the price trajectories because of inelasticity of supply, or even squeezes. Moreover, crude oil and commodity indexes in general are defined as averages, to reflect the time to delivery and avoid price manipulation within a single day. So called plain-vanilla options are essentially non-existent. Geman shows that by using exact formulas for the price, only the volatility parameter needs to be estimated (3.4). This leads, in turn, to exact formulas for the <i>Greeks</i> (viz., <math>\alpha</math>, <math>\beta</math>, and the other parameters that are used in the Black-Scholes and other formulae for pricing options) and allows traders to price and hedge in a consistent manner, which is crucial (3.2).</p>

In (3.4) Geman and Roncoroni show that electricity spot prices display not only mean reversion, in common with other commodities, but also spikes. They introduce a class of discontinuous processes exhibiting a “*jump-reversion*” component to properly represent these movements. Their model captures both the trajectorial and the statistical properties of electricity pool prices.

In (3.3) Geman and Ohana show that, when one explores the relationship between inventory and price volatility, the slope of the forward curve of oil and natural gas prices can be used as a proxy for inventory. They find that there is a globally significant negative correlation between price volatility and inventory for crude oil, which prevails only during those periods of scarcity when the inventory is below the historical average and increases importantly during the winter periods for natural gas. Their results are illustrated by the analysis of a 15 year-database of US oil and natural gas prices and inventory.

Geman and Eleuterio show in (3.1) that investing in fertilizer–mining companies is a valid strategy, from the perspective of both market returns and hedging. The shares of an exhaustive sample of listed fertilizer producing companies between January 2004 and December 2012 generated good returns over the whole period and extremely high ones between January 2004 and December 2007. In addition, these returns are much more sensitive to major agricultural indexes than to the World Bank Fertilizer Index, underpinning the hedging argument.

### 3. References to the research

- 3.1 Geman, Hélyette, and Pedro Vergel Eleuterio, “Investing in fertilizer–mining companies in times of food scarcity”, *Resources Policy*, Volume 38, Issue 4, December 2013, Pages 470-480, ISSN 0301-4207, <http://dx.doi.org/10.1016/j.resourpol.2013.07.004>.
- 3.2 Geman, Hélyette, and William O. Smith, “Theory of storage, inventory and volatility in the LME base metals”, *Resources Policy*, Volume 38, Issue 1, March 2013, Pages 18-28, ISSN 0301-4207, <http://dx.doi.org/10.1016/j.resourpol.2012.06.014>.
- 3.3 Geman, Hélyette, and Steven Ohana, 2009 , “Forward Curves, Scarcity and Price Volatility in Oil and Natural Gas Markets”, *Energy Economics*, vol 31 issue 4, July, pp 576-585.
- 3.4 Geman, Hélyette and Andrea Roncoroni, 2006, “Understanding the Fine Structure of Electricity Prices: A Jump- Reversion Model”, *Journal of Business*, Vol. 79, No. 3, May, pp. 1225-1261. Article Stable URL: <http://www.jstor.org/stable/10.1086/500675>.
- 3.5 Geman, Hélyette, 2005, *Commodities and Commodity Derivatives: Modeling and Pricing for Agriculturals, Metals, and Energy (The Wiley Finance Series)*, John Wiley and Sons Ltd: Chichester.

### 4. Details of the impact

Geman has served as a scientific advisor to major banks, energy and mining companies and commodity trading houses. Her articles and books are the references used in trading rooms, Commodity Exchanges and in prominent court cases, e.g., one in 2011 between the State of California and a major agrifood company (the name of which is covered by a non-disclosure agreement) on the subject of the use of futures contracts for tax purposes.

The following are four specific impacts:

1. The results obtained by Geman (3.2, 3.3, 3.5) are used in the periodic rebalancing of the composition of the UBS–Bloomberg commodity index. As a result of the importance of her scientific contributions, and their recognition by practitioners, Geman joined the Board of the UBS-Bloomberg Commodity Index as the only academic member in 2008 (5.3). She remains in this position and by occupying this role she is able to make a direct input into the construction of the index. The rebalancing of the composition of the index in terms of the commodity prices

makes use of her results on the shape of the forward curve, since the rolling futures position has a key impact on the performance of the index. References (3.2) and (3.3) above analyse the forward curves for crude oil, natural gas and all base metals (copper, nickel, tin).

2. The level and volatility of agricultural commodity prices represent crucial issues for governments of developing countries where they may create severe problems as witnessed in the last few years. Since 2010, Geman has been a Scientific Advisor to the European Commission, and she has defined early indicators of price and volatility spikes. The usual explanation given for these spikes in volatility is the somewhat populist one that it is due to speculation in futures contracts. However, Geman has demonstrated, through a series of empirical examples, that scarcity of the physical commodity is the key factor driving the spikes. She has shown that useful indicators need to use data that reveal scarcity and can measure it continuously. She has shown that data on inventories is crucial for this (3.3, 3.5, 5.5, 5.6). These results are used in the European Commission's indicators.
3. In a world of food scarcity, limited arable land and soil erosion, fertilizers represent a crucial asset class. In 2011 and 2012 Geman delivered a series of talks in Casablanca for the Office Chérifien des Phosphates, the gigantic phosphate producing company and the major source of revenues for Morocco. In reference (3.1) (which was circulated as a working paper in 2011), she explains, first why fertilizers can represent a desirable investment for financial institutions and crucial working capital for the industry; second how the use of phosphate derivatives, such as forward contracts and swaps, can be integrated with the 'old' activity of the physical export of phosphate rock, allowing the company itself, as opposed to the banks who advise it, to optimize its revenues over a larger feasible set, by combining physical and financial trading in a consistent manner. These findings are now used in the strategic decisions of the Office Chérifien des Phosphates all along the supply chain of the phosphates and at the corporate level. Geman explained this combined physical/financial optimization in the production of phosphates in private sessions with the President of the company (5.2).
4. Geman's research on electricity, crude oil and natural gas (3.3, 3.4, 3.5, 5.1) is implemented at EDF Trading, the trading arm of the giant utility Electricite de France (which owns London Energy). Geman was Head of Research at EdFT during the years 2001 and 2002 when the company was built. The new developments of her research, including the analysis of the WTI/Brent spread according to the methodology of her 2009 paper (3.3) make a key contribution to the trading and investment strategies implemented by EdFT. Her papers are quoted in the EdFT's technical reports which explain their strategies (5.4).

Geman's book *Commodities and Commodity Derivatives*, published by Wiley Finance in 2005 (3.5) has become the standard reference book in trading rooms and commodity companies. In 2006, it was endorsed by Robert Merton, MIT, Nobel Prize winner and his comment that it is destined to be a "must have" supports the argument for influence and impact post 2008:

*In Commodities and Commodity Derivatives, Hélyette Geman shows her powerful command of the subject by combining a rigorous development of its mathematical modelling with a compact institutional presentation of the arcane characteristics of commodities that makes the complex analysis of commodities derivative securities accessible to both the academic and practitioner who wants a deep foundation and a breadth of different market applications. It is destined to be a "must have" on the subject.*

<http://www.amazon.com/Commodities-Commodity-Derivatives-Modelling-Agriculturals/dp/0470012188>

Geman has disseminated her work through more than 100 peer-reviewed academic publications in top finance Journals. She has been (since 2005) the Keynote Speaker in a large number of conferences, both academic like the Heidelberg Academy of Sciences conference on Energy in 2009, and organized by practitioners, like the annual World Mining Association conference or *Euromoney*.

**Impact case study (REF3b)**

In the case of the US court case, mentioned at the beginning of Section 4, trading in futures by a corporation to hedge its revenues (a so called 'commercial activity') has a social utility recognized by governments, and it benefits from tax advantages. However, an entity labelled as 'commercial' may also engage in speculative activities which should not generate the same tax shield. The frontier between two activities is very difficult to identify. Geman was appointed by the Government of California to identify this frontier because of her research on the use of futures contracts for 'hedging' versus 'trading' purposes. The case was subsequently won by the Government of California.

**5. Sources to corroborate the impact****Practitioners**

5.1 Head of Oil Structured Products, BP.

5.2 General Director, OCP, Paris.

5.3 Head of Quantitative Research, Bloomberg, New York.

5.4 Head of Electricity Regulation and Price Design, Innogy/ RWE (London).

5.5 Director, European Commission, Joint Research Centre, Seville.

5.6 Report for the European Commission:

Some Elements on Agricultural Commodity Price Volatility (draft version) – H Ott and H Geman (2012 – Revised 2013). Report available on request.