Institution: Lancaster University

Unit of Assessment: 19, Business and Management Studies

Title of case study: Using Derivative Prices to Make Better Stock Market, Exchange Rate and Interest Rate Forecasts.

1. Summary of the impact

Research led by Stephen Taylor has resulted in the development of forecasting methods for financial market prices and [TEXT REMOVED FOR PUBLICATION] analytical tool at the Macro-Financial Analysis Division of the Bank of England. These methods have been cited in papers by employees of the European Central Bank, the Central Banks of Brazil, Norway and Mexico and the Italian Securities and Exchange Commission. The ability to manage risk by making more accurate predictions about financial market prices has been particularly important since the onset of the economic and financial crisis in 2008. Taylor has developed forecasting methods to make the best use of information recorded about recent asset and derivative prices, providing more precise expectations about future stock index levels, exchange rates and interest rates. Taylor's 2005 text on 'Asset Price Dynamics, Volatility and Prediction' has also had significant and far-reaching impact on students learning about Finance and Economics worldwide.

2. Underpinning research

More than 30 years of research into forecasting at Lancaster has explored the areas of volatility and density forecasts, emphasising the value of information provided by derivative securities. The published research which underpins the developments, described in the impact section of this case, is primarily into UK and US stock market indices, but also into exchange rates and stock prices.

<u>The development of new forecasting methods:</u>
There are many methods which can be used to make predictions about the probabilities of future market prices for financial assets. The Lancaster programme of research developed new forecasting methods that incorporated new information sources (high-frequency prices and volatility indices) and made applications to new problems (density forecasting). It has also made several comparisons between the predictive value of the two major sources of relevant public information, firstly historical information contained in past asset prices and secondly the current prices of derivative securities.

The programme shows that historical information provides the best predictions over short horizons (such as one day and one week) if intraday prices (typically sampled every five minutes) are used. In contrast, derivative prices can be used to obtain the best predictions over longer horizons from one to three months.

The research has innovated by evaluating new information sources (such as intraday price information) and by developing new methods to extract relevant information (such as transformations which control for market risk premia). Initially the focus was on predicting price volatility, a measure of risk often associated with the standard deviation of price changes. More recently, effort has been concentrated on producing the first research into density forecasts, which provide the probability that a future asset price falls within a stated range.

Research outputs comparing historical and derivative forecasts of volatility have been published between 1995 and 2010. The research into comparisons between density forecasts started around 2004 and is ongoing. A recent paper on densities evaluates information about the future prospects of US banks during the subprime/liquidity crisis in 2008, and shows that option prices anticipated the collapse of Lehman Brothers and provided useful information about other fragile institutions. The paper, entitled 'Bankruptcy probabilities inferred from option

prices' (Taylor, Tzeng and Widdicks, 2013), has been presented on several occasions during 2013, nationally and internationally.

The Lancaster research team:
The research programme has been led throughout by Stephen Taylor, Professor of Finance at LUMS since 1993. Several contributions have been made by Professor Mark Shackleton, employed by LU since 1997, and by former LU staff including Professor Xinzhong Xu and Professor Ser-Huang Poon. Important contributions have been made in PhD theses by Lancaster research students including Bevan Blair, Shiuyan Pong, Xiaoquan Liu, Peng Yu, Yuanyuan Zhang and Chi-Feng Tzeng. The research has been made possible by the purchase of several large datasets of asset prices by LUMS.

3. References to the research

Volatility models and forecasts, and preliminary methods for density estimation and forecasting, are covered in Chapters 8 to 16 inclusive of:

1. Taylor, S.J. (2005) 'Asset Price Dynamics, Volatility, and Prediction'. Princeton University Press.

Evidence of the quality of the book is provided by its recommendation as a course text worldwide (see Section 4 below). The research has also been published in the following international peer-reviewed journals.

Comparisons of volatility forecasts have appeared in seven journal articles, including:

2. Taylor, S.J. and Xu, X. (1997) 'The incremental volatility information in one million foreign exchange quotations', *Journal of Empirical Finance* 4(4): 317-340.
3. Blair, B.J., Poon, S. and Taylor, S.J. (2001) 'Forecasting S&P 100 volatility: the incremental information content of implied volatilities and high frequency index returns', *Journal of Econometrics* 105(1): 5-26.
4. Pong, S., Shackleton, M.B., Taylor, S.J. and Xu, X. (2004) 'Forecasting currency volatility: a comparison of implied volatilities and AR(FI)MA models', *Journal of Banking and Finance* 28(10): 2541-2563.

Detailed comparisons of density forecasts have been published in:

5. Liu, X., Shackleton, M.B., Taylor, S.J. and Xu, X. (2007) 'Closed-form transformations from risk-neutral to real-world densities', *Journal of Banking and Finance* 31(5): 1501-1520.
6. Shackleton, M.B., Taylor, S.J. and Yu, P. (2010) 'A multi-horizon comparison of density forecasts for the S&P 500 using index returns and option prices', *Journal of Banking and Finance* (34): 2678-2693.

4. Details of the impact

The research has had a documented and significant impact nationally at the Bank of England and internationally, upon researchers at banks worldwide who have cited the underpinning research conducted at Lancaster and its application by the BoE.

Impact on the financial sector:
The research has provided a solution to a problem faced by the Macro-Financial Analysis Division at the Bank of England. [TEXT REMOVED FOR PUBLICATION]. The methods developed in Liu et. al (2007) provide practical risk transformations which lead to more accurate density predictions. These methods were explained by Professor Taylor at a Bank seminar in London and subsequent meetings. The Bank accepted the solution proposed and used it in their calculations, which were published in a publicly available Bank working paper in 2012.

[TEXT REMOVED FOR PUBLICATION]

International impact:
The methods proposed in the research papers in Section 3 and the Bank of England report (which included real-world forecasting and risk adjustments) have been adopted in papers by banks worldwide:

European Central Bank:
In Ivanova and Gutiérrez (2013), employees of the European Central Bank cited two Lancaster papers on density methods listed in Section 3, and directly applied the Lancaster risk transformation methods. An earlier paper with De Vincent-Humphreys et. al (2010) also cited Liu et al (2007) as providing a risk transformation methodology.

Banco Central do Brasil:
The work was referenced in two papers by employees of the Central Bank of Brazil. The first paper on recovering risk-neutral densities (2011) discusses the market expectations based on the research conducted by Liu et.al (2007). A follow up paper in 2012 on Risk Aversion, Risk Neutral and Real World Densities uses the specific calculations that Taylor used with the Bank of England to produce their report.

Commissione Nazionale per le Società e la Borsa:
CONSOB (the Italian Securities and Exchange Commission), is the government authority responsible for regulating the Italian securities market. Giordano and Siciliano (2013), employees at CONSOB, refer to a need for risk adjustments and suggest the methods provided in Liu et. al (2007) and the Bank of England report.

Mexican Central Bank:
Several employees at the Mexican Central Bank have been publishing papers for several years based on Lancaster's research for example Benavides and Mora (2006), Benavides and Capistrán (2007) and Ysusi (2006a, 2006b, 2007a, 2007b). A recent paper by Benavides (2011) applies density methods to Mexico during the financial crisis and cites Taylor (2005) and Liu et al (2007).

Dagfinn Rime, an employee at Norges Bank (the Central Bank of Norway) has recommended several of Taylor's papers in a 'Bibliography of Microstructure of Foreign Exchange Markets' (2012, see pages 15, 19 and 27). The work has also been used in research done in conjunction with banks and stock markets for example The National Stock Exchange of India.

The impact upon risk managers and other practitioners within the financial sector is hard to measure; although it is notable that riskbook.com recommended 'Asset Price Dynamics, Volatility, and Prediction' as a Top Ten Book in 2005.

Impact on higher education:
In addition to impact on the banking industry, research into price predictions has also had significant impact on the teaching and learning of students worldwide. They have been taught the best known methods to make predictions about the probabilities of future market prices for financial assets.

More than 2,600 copies of Taylor's 2005 book were sold between January 2008 and June 2013, of which only 300 are estimated to have been bought by Lancaster students. The book is often included in reading lists for courses about Financial Econometrics, making a global impact on the education of students. In 2011, for example, it was a core, main or recommended text for the following courses:

- Time Series and Financial Econometrics, Cambridge University
- Advanced Empirical Finance, University of Manchester
- Financial Econometrics, Birkbeck College, London University
- Quantitative Financial Risk, UniversitLibre de Bruxelles
- Financial Econometrics, Humboldt-Universität zu Berlin

- Financial Time Series Analysis, University of Vaasa
- Financial Econometrics, University of Washington
- Time Series Analysis and Statistical Arbitrage, New York University
- Empirical Finance, Chinese University of Hong Kong
- Stock Prices and Volatility Modelling, Victoria University of Wellington

The contents of the book have been taught by Stephen Taylor to students at National Taiwan University, Taipei (2009), Norwegian University of Science and Technology, Trondheim (2011), the University of Auckland (2013) and the University of Queensland (2013).

5. Sources to corroborate the impact

Impact on the UK financial sector:

1. De Vincent-Humphreys, R. and Noss, J. (2012) 'Estimating probability distributions of future asset prices: empirical transformations from option-implied risk-neutral to real-world density functions', Bank of England Working Paper 455.
2. [TEXT REMOVED FOR PUBLICATION]

Impact on the international financial sector:

CONSOB:

3. Giordano, L. and Siliciano, G. (2013) 'Real-world and risk-neutral probabilities in the regulation on the transparency of structured products' CONSOB Working Paper No. 74.

European Central Bank:

4. Ivanova, V.; Gutiérrez, J.M.P. (2013) 'Getting real forecasts, state price densities and risk premium from Euribor options' http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2178428
5. De Vincent Humprehys, R. and Gutiérrez, J.M.P. (2010) 'A Quantitative Mirror on the Euribor Market Using Implied Probability Density Functions' Working Paper No. 1281 http://www.ecb.europa.eu/pub/pdf/scpwps/ecbwp1281.pdf

Central Bank of Brazil:

6. Ornelas, J.R.H. and Takami, M.Y. (2011) 'Recovering risk-neutral densities from Brazilian interest rate options', *Revista Brasileira de Financas* 9(1): 9-26.
7. Ornelas, J.R.H.; Barbachan, J.S.F. and de Farias, A.R. (2012) 'Estimating Relative Risk Aversion, Risk-Neutral and Real-World Densities using Brazilian Real Currency Options.' Working Paper Series 269.

Mexican Central Bank:

8. Benavides, G. (2011) 'Central Bank Exchange Rate Interventions and Market Expectations: The Case of Mexico during the Financial Crisis 2008-2009': http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1923101

Impact on higher education:

9. Sales information provided by Princeton University Press.
10. Web pages for course outlines at several universities [TEXT REMOVED FOR PUBLICATION].