Research Assessment Exercise 2020
Impact Case Study
University: The Chinese University of Hong Kong
Unit of Assessment (UoA): 11 Mathematical Sciences
Title of case study: Big data and statistical learning for portfolio risk management

(1) Summary of the impact (indicative maximum 100 words)

The massive growth of the financial market creates a challenge to the portfolio risk measurement and investment decisions. Prof. Hoi Ying WONG's research on statistical learning and big data methods has delivered considerable economic impacts on financial technology which has been adopted by [text removed for publication], to construct portfolio selection strategies and calculate risk in the mutual fund, resulting in enhanced investment performance (e.g. projected annualised return of a fund increased by [text removed for publication]) and effective [text removed for publication] signals to the corporation. Wong's approach was also featured in media coverage and online open-access materials for risk calculation of certain popular derivatives.

(2) Underpinning research (indicative maximum 500 words)

Conventional investment and risk management strategies based on modern portfolio theory (MPT), or mean-variance analysis, encounter two fundamental challenges: (i) progressively growing number of financial instruments to select and (ii) positions in derivatives, which may result in highly unstable risk measure estimates, hence distorted decisions on risk management and/or investment. This underpinning research consists of work since 2011, carried out by Prof. Wong (Department of Statistics, CUHK [2001-]) and his team, which employed and operated numerous big data and statistical learning techniques. These contributions are the fruits of Wong's long-term focus on financial mathematics and high-dimensional statistics which have been adopted by an international asset management firm (detailed in [4]).

Conventional MPT is a formalization and extension of diversification to optimally allocate one's investment among different assets by considering the trade-off between risk and return. However, there is an inevitable limitation – estimation errors for MPT on large size portfolio. The first underpinning research contribution by Wong's team in 2011 invented a novel stochastic optimal control solution to the trading with cointegrated risky assets by developing the continuous-time MPT trading strategy for cointegration (a statistical technique in time series analysis to detect common equilibrium), and showed the empirical relevancy in [3.1].

In an effort to capture parameter ambiguity effects in portfolio optimization, Wong's team made substantial theoretical advances in showing the advantages of sparse portfolios. The ambiguity in the correct estimate resulted in a prudential investment strategy on a sparse portfolio instead of diversification [3.2]. This finding also enables portfolio managers to combine forward-looking information from the volatility surfaces of options to optimize investment among various assets.

The consequence of sparse portfolio stimulated Wong to invent a new portfolio optimisation strategy with statistical learning techniques. Specifically, his research directly estimates and select effective factors amongst high-dimensional candidates simultaneously [3.3, 3.4], instead of separating the estimation and optimization procedures. Consequently, this approach helped selecting valuable assets and financial instruments for decision-making. These models have been adopted by [text removed for publication] into its own proprietary estimation method (detailed in [4]).

Regulatory capital is a requirement to be fulfilled by financial institutions, is closely related to the risk measure "Value-at-Risk (VaR)". Wong, jointly with his CUHK colleague, Tony Sit revisited the estimation problem of risk measures using big data techniques. For portfolios that consist of financial derivatives, conventional approaches often miscalculate the corresponding risk measures. Wong's research reveals the problem of "large p and small n" issue in the classic approaches and proposed the use of LASSO regression in the multi-level backward computation for VaR. This greatly enhances

the accuracy of risk measurement and capital retention after intensive backtesting of VaR for the company's portfolios. [3.5]

Wong's team further investigated the calibration of stochastic volatility model for insurance product pricing in [3.6]. Interestingly, as the practical implementation of the framework of [3.3] and [3.4] was found to be sensitive to the market volatility. The firm found that the stochastic volatility calibration in [3.1] was helpful to stabilize the learning (detailed in [4]).

(3) References to the research (indicative maximum of 6 references)

[3.1] M.C. Chiu and **H.Y. Wong** (2011). Mean-variance portfolio selection of cointegrated assets. *Journal of Economic Dynamics and Control* 35(8), 1369-1385.
[3.2] J.-P. Fouque, C.S. Pun and **H.Y. Wong** (2016). Portfolio optimization with ambiguous correlation and stochastic volatilities. *SIAM Journal on Control and Optimization* 54, 2309-2338.
[3.3] M.C. Chiu, C.S. Pun and **H.Y. Wong** (2017). Big data challenges of high-dimensional continuous-time mean-variance portfolio selection and a remedy. *Risk Analysis* 37, 1532-1549.
[3.4] C.S. Pun and **H.Y. Wong** (2019). A linear programming model for selection of sparse high-dimensional multiperiod portfolios. *European Journal of Operational Research* 273, 754-771.
[3.5] J. Chen, T. Sit and **H.Y. Wong** (2019). Simulation-based value-at-risk for nonlinear portfolios. *Quantitative Finance* 19, 1639–1658.
[3.6] **H.Y. Wong** and C.M. Chan (2007). Lookback options and dynamic fund protection under multiscale stochastic volatility, *Insurance: Mathematics and Economics* 40, 357-385.

(4) Details of the impact (indicative maximum 750 words)

Asset classes and amount nowadays rapidly increased. The estimation of parameters to capture correlations among the traded assets for fund operation encountered the curse of dimensionality. Wong's big data and statistical learning approach for portfolio risk management has delivered significant impacts on the financial industrial environment and social impact since 2017.

From research to impact

Wong's research team has invented a novel statistical learning approach to estimate the asset allocation policy. In particular, his PhD student Chi Seng PUN (currently Assistant Professor at Nanyang Technological University) won the 2015 INFORMS Financial Services Best Student Paper Award (the first place) and the 2016 Nicola Bruti Liberati Prize conferred by BFS with media coverage in 2015 [5.1], attracting great attention from overseas and local financial firms including [text removed for publication] [5.2], [text removed for publication] [5.3], [text removed for publication] [5.4] for industrial collaboration invitations. Wong has been invited to join several industrial projects and speak at Ortec Finance Seminar as the keynote speaker in **2018** [5.5]. Since early 2019, [text removed for publication] has adopted Wong's research [3.6] into the development of the Risk Neutral models [5.3]. Among several completed and on-going industrial projects, the collaboration with [text removed for publication] was selected to exemplify the impacts from Wong's research for its fundamental contribution in portfolio selection and risk measurement using modern statistical learning techniques.

Nature and extent of the impact:

Like other hedge funds, [text removed for publication], had its own proprietary estimation method for the model. However, the estimates were found to be highly unstable with respect to sampling windows, events and missing data resulting in contradictory trading and risk signals. Based on Wong's previous works in [3.1, 3.3-3.6], several key statistical learning methodologies were implemented in the development of the algorithmic trading and risk management platform, which helps the integration of estimation and optimization procedures together. The target became estimating the resulting stock allocation policy. This framework named as [text removed for publication] has been implemented under a systemic risk parity strategy, [text removed for publication] and significantly enhanced the quantitative asset allocation efficiency and calculation of risk to ensure reasonable exposure to the financial markets. The novelty originates from the intricate

application of statistical learning on the [text removed for publication] directly. This allows the fund to avoid over investing into an [text removed for publication] hence enjoy better control on the [text removed for publication]. Wong's methodology has been approved and implemented [text removed for publication] as of March, 2019. The investors of [text removed for publication] includes [text removed for publication] [5.6].

The new methodology improves substantially the investment performance and risk management at the firm in the ways described by the COO of [text removed for publication] as follows, *"*[text removed for publication] *originally* ***managed its equity book in*** [text removed for publication]*……with the introduction of the* [text removed for publication] *now feasible to* ***combine the*** [text removed for publication] *resulting a much* ***meaningful and manageable portfolio*** *upon which our effective investment strategies can be applied."* [5.6]

The accuracy in measuring of risk-adjusted return of a financial portfolio was also enhanced and expanded to other products. *"During the back-testing period of 2006-18, the Sharpe ratio of S&P500 was* [text removed for publication]*, whereas the micro-managed* [text removed for publication] *can achieve a Sharpe ratio of* [text removed for publication] ***almost two-fold*** [text removed for publication] *…****we are actively carrying out extensive testing and implementation on*** [text removed for publication]*"* The risk adjusted return over capital of the fund was improved and outperformed the fund's competitors in the market even during the very difficult year of 2018 [5.6]. Apart from linear securities like stock and futures, the fund took position in derivatives. The contribution of Wong's research proposed the use of LASSO in the multi-level backward computation for VaR which greatly enhanced the accuracy of risk measure estimation and capital reserve calculation.

Wong and Sit would like to make their risk calculation framework a public good after gaining practical experience from the fund. With the fund's consent, a simplified version of the risk calculator for some selected popular derivatives was launched as an online open-access educational platform for practitioners and public to understand and appreciate statistical learning theory for portfolio risk management through the Department of Statistics, CUHK. This platform revealed Wong's research in portfolio risk measurement has aroused public awareness about the investment of financial derivatives [5.7].

(5) Sources to corroborate the impact (indicative maximum of 10 references)

[5.1] News report from *Wen Wei Po* for Chi Seng PUN won the INFORMS Financial Services Best Student Paper Award (the first place) (2015)
[5.2] Acknowledge letter from [text removed for publication] for collaboration (2019) (nondisclosure)
[5.3] Invitation from [text removed for publication] for collaboration (2017) (nondisclosure)
[5.4] Invitation from [text removed for publication] for collaboration (2019) (nondisclosure)
[5.5] Ortec Finance Seminar brochure with Prof. Wong as the keynote speaker (2018)
[5.6] Acknowledge letter from [text removed for publication] (2019) (nondisclosure)
[5.7] The online open-access educational platform, Department of Statistics, CUHK (2019): http://www3.sta.cuhk.edu.hk/webapp/2019lmm/