Environment template (REF5)

Institution: London Metropolitan University

Unit of assessment: Mathematical Sciences

a. Overview

At London Metropolitan University, research in the mathematical sciences is mainly conducted in the areas of Pure Mathematics and Statistics. This research is carried out within STORM, the Statistics, Operational Research and Mathematics Research Centre, (established in 1992) that has five research active members of staff. STORM complements the extensive teaching programme of the Mathematical Sciences Group of the Faculty of Life Science and Computing, where there are a number of other staff teaching maths and stats and carrying out pedagogic research and other activities. The Mathematical Sciences Group has a robust financial base, with healthy student recruitment. The group will continue high quality research in mathematics and statistics. As well as pursuing individual projects, members of STORM have enjoyed and benefited from collaboration with colleagues and users in the UK and abroad. The mathematics projects involve: i) operadic and simplicial methods, with applications in K-theory, cohomology of categories and mathematical physics; ii) Lie and Banach Lie algebras and the theory of operator Lipschitz functions; iii) mathematical biology and dynamical systems. In the statistics area the group has continued to build on the GAMLSS models with new methodology and new applications of the models.

b. Research strategy

STORM maintains five active researchers producing high quality research and a thriving research culture, evidenced by the 44 articles published in peer-reviewed journals during the REF period, and successful achievement of the majority of the targets set in RAE2008. In both mathematics and statistics areas we have expanded our national and international collaborations. Dr Tonks, for example, benefited from a two month stay at the Newton Institute from which a number of further research collaborations and ideas emerged. In the stats area we are expanding research in statistical modeling, widening our interdisciplinary base, and augmenting the facilities of the R implementation of GAMLSS. With the worldwide use of the GAMLSS models in different applied scientific fields, our international profile has increased during the current period and we expect to continue this increase. During last year the GAMLSS website had over 9000 hits, the GAMLSS original paper (in Applied Statistics) had100 new citations in google scholar, and we had the opportunity to give many invited and keynote talks and international short courses as detailed in section e. An issue of the 'Statistical Modelling' journal (2013, **4**, pp 275-385) devoted solely to "Beyond mean regression" focuses on GAMLSS as one of three modelling approaches. During the REF period we had four PhD completions and currently we have five full time and two part time PhD students. We aim to continue and expand our short courses aimed at academics, users and schools.

The medium term aim of STORM is to continue to develop high quality research which is financially sustainable. This includes blending research with teaching and also the development of areas where high impact will be visible (as for example in the area of statistical modelling). We will aim to recruit and retain early career research staff. We aim to continue to recruit PhD students, provide them with a good environment and ensure timely completion. We will also continue to seek funding

opportunities. The Faculty of Life Science and Computing, where STORM belongs, provides an excellent research environment encouraging internal and external collaboration. We aim to expand our international activities including conferences and courses, which are a catalyst for new original ideas and lead to research collaboration and publications with colleagues from many countries. We also aim to continue to contribute to the larger scientific community and take part in various professional activities such as organizing and participating in workshops and conferences (such as the International Workshop on Statistical Modelling), peer reviewing, scientific committees and editorial boards (the Journal of Mathematical Research and Applications and the Eurasian Mathematical Journal). We plan to capitalize on the use of the GAMLSS model to strengthen collaborations with industry, especially with sectors such as risk management.

c. People, including:

i Staffing strategy and staff development

The mathematics group of STORM consists of Professor Kissin, Dr Hou and Dr Tonks. Professor Kissin works closely with Professor Shulman, a former full-time member of STORM who returned to Russia. He has also published joint papers with mathematicians from Australia, Azerbaijan and Slovenia. Dr Tonks works closely with a former member of STORM, Dr I. Galvez, and with other colleagues, in Spain, France, Germany, Switzerland, Argentina and the UK.
The statistics group of STORM consists of Professor Stasinopoulos, Dr Rigby and Emeritus Professor Gilchrist. They have also collaborated productively with numerous colleagues in, e.g. Holland, Germany, Australia, Portugal, Brazil, Argentina, Italy and Japan.
STORM has hosted numerous international visitors from Australia, Azerbaijan, Brazil, Netherlands, Russia and Japan. Their visits were funded or part-funded by the University and have resulted in the establishment of fruitful joint research projects. The informal STORM seminar often involves our international visitors.
STORM is integrated within the Faculty of Life Sciences and Computing (FLSC) a recent merger of two former faculties that took place on 1st August 2012. STORM contributes to faculty research by providing mathematical and statistical advice to faculty members. Members of STORM are given sufficient time off their teaching and administrative duties to allow them to continue their research activities. Typically 30% of their time is devoted to research. Members are encouraged to apply for external funding to support research and they are given the relevant administrative support. The Faculty has funded a research fellowship in statistics for one year. Funding is available that enables staff to attend international conferences, etc.; moreover, staff also receive externally funded staff development opportunities. For example, Dr Tonks spends extensive periods with colleagues in Barcelona, and in 2013 spent two months at the Isaac Newton Institute. Professor Stasinopoulos was funded to give courses in Brazil and Argentina, with excellent interaction with local and international statisticians.

ii Research students

The mathematics and statistics research students are part of a much wider group of research students within the Faculty of Life Sciences and Computing. All research students have a Leading Supervisor (LS) and a second supervisor. They have a room with desk and IT facilities, an extensive library, and good access to online resources. There is a well developed research training programme for research students, providing a range of development opportunities. Courses are

available for all levels of research experience, including new researchers. The courses are designed to support researchers in developing a full range of transferable professional, personal, research, and career skills and knowledge. The students are also encouraged to attend courses and seminars (e.g. RSS, LMS and IMA talks).

The Research Student Progress Group meets each semester for formal monitoring of student progress, with written reports by the supervisory team and the student. Generic training and personal development requirements of the research students are monitored, and research students are required to present their research at the weekly Faculty research seminars.

The University has a VC Scholarship Scheme. Five of these were awarded in the Mathematics and Statistics area. All are on track to complete by the end of 2014. The first mathematics student (LS Kissin) is due to complete in June 2013, the second (LS Hou) is intermitting for accepted reasons but should complete in early 2014 and the third (LS Calay) expected to complete in early 2014. For the stats students (LS Stasinopoulos) the first will complete by the end of 2013 while the second will complete by the summer of 2014.

There are also other PhD students not within this University funded programme. Four of them already completed, two in 2009 (LS Gilchrist and Hou respectively), one in 2010 (LS Gilchrist) and one in 2012 (LS Tonks) and one of them (LS Stasinopoulos) will complete by the end of 2013.

There are in addition one part time student in maths enrolled in 2013 (LS Dr Tonks) and two part time distance learning research in stats (LS Prof Stasinopoulos), who enrolled in 2011.

d. Income, infrastructure and facilities

Members of staff in STORM receive a substantial time allocation for research, consultancy and staff development and are expected to generate income through research funding applications, short courses and consultancy. Income earned from the RAE 2008 has been mainly used for research studentships, allocated through the VC Scholarship Scheme and to fund a research fellowship in statistics that contributed to the development of the discrete distribution aspects of the GAMLSS programs. Members of staff are located in close proximity, with 4 adjacent rooms with space for informal meetings. All rooms have modern computing facilities, with fast printing and copying facilities nearby. The STORM suite has desk space, which allows us to welcome academic visitors for productive short or longer term visits. The FLSC provides an administrative structure, this includes 3 administrators and appropriate committees e.g. the Faculty Research and Enterprise committee. There is a bookable well-equipped large staff seminar room within 20 yards. During the submission period the university has comprehensively redeveloped the library and information centre. The University provides excellent library facilities, a comprehensive information system and computing services The University has a well-established series of 'traditional' journals and are receptive to the acquisition of new journals and research texts. Online journal access is also available through the library's OPAC system.

e. Collaboration and contribution to the discipline or research base

Z. Hou

Hou has been doing collaborative research since 2010 with Dr Stephen Baigent (UCL), who specializes in mathematical biology and dynamical systems. They have published three joint papers [6, 9, 11]. This collaboration of research will continue in the immediate and longer term, to produce high quality outputs and external funding.

One of Hou's research directions is in the simple case of dynamical systems when the system is dissipative and has a single fixed point as a global attractor or repellor. He published results and developed an "ultimate contracting cells" method for a single point global attractor in autonomous competitive LV systems before 2008. As a continuation, in his recent publications, he has obtained new criteria for a fixed point to be a global attractor or repellor. More importantly, in Hou's joint papers with Baigent [6, 9], the split Lyapunov method originally used by Zeeman and others for Competitive LV systems has been further developed for global stability and global repellor of general LV systems. Four more papers [1-3, 7] have been published in this area since 2009. The other two directions are in permanence [4, 5, 10, 12, 13] and limit cycles [8, 11].
Hou has been a member of Editorial Board of **Journal of Mathematical Research and Applications,** and refereeing papers since 2008 for many journals including Nonlinear Analysis, Mathematical Analysis and Applications, Applied Math. Comp. etc. He is a regular reviewer for Math. Rev. and Zentralblatt Math.

[1] Z. Hou, Global attractor in competitive Lotka-Volterra systems, *Math. Nach.*, **282,** No. 7, (2009) 995 – 1008.
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[5] Z. Hou, Permanence and extinction in competitive Lotka–Volterra systems with delays *Nonlin. Anal.:* **12** (2011) 2130–2141.
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[8] Z. Hou, Oscillations and limit cycles in Lotka-Volterra systems with delays*Nonlin. Anal.* **75** (2012) 358–370.
[9] S. Baigent and Z. Hou, Global stability of interior and boundary fixed points for Lotka-Volterra systems, Dif. Eq. Dyn. Syst., **20** (2012), 53–66.
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[12] Z. Hou, Permanence criteria for Kolmogorov systems with delays, Proc. Roy. Soc. Edin. A, (url: http://arxiv.org/abs/1303.1668v1).

E. Kissin

E. Kissin specializes in the field of operator theory, the theory of Banach algebras and invariant subspace theory and the theory of algebra and group representations.
In a series of joint articles [1] – [3] Bresar (Slovenia), Kissin and Shulman (Russia), studied the structure of Lie and Jordan ideals of Banach and C*-algebras. Another extensive collaboration with Shulman and Turovskii (Azerbaijan) led, so far, to three publications. In papers [4] and [5] they investigated the structure of Banach Lie algebras that contain Lie subalgebras of finite codimension, their invariant spaces and Lie ideals. In particular, it was proved that such Banach Lie algebras always have Lie ideals of finite codimension. In [8] they developed the theory of topological radicals and Frattini theory of Banach Lie algebras.
In a joint paper [9] with his PhD student Formisano, Kissin investigated minimax conditions for Schatten ideals of compact operators. In another paper, recently submitted for publication, they study the structure of l_p-spaces of operators from Schatten ideals and obtain analogues of Clarkson-McCarthy inequalities for these spaces.
Another collaborative project with Potapov (Australia), Shulman (Russia) and Sukochev (Australia) led to publication of two papers [6], [7]. They investigated operator smoothness in Schatten norms for functions of several variables: Lipschitz conditions for these functions, their differentiability and

application to the theory of unbounded derivations on Schatten ideals.
Since 2010, Kissin has been a member of Editorial Board of Eurasian Mathematical Journal. He was an invited lecturer at Gotheburg conference on operator theory in 2011 and has given talks at various British Universities and abroad. Kissin has been a peer review assessor of articles submitted to leading mathematical journals (e.g. Journ. and Proc. of the Lond. Math. Soc., Journ. of Functional Analysis, Trans. of the Amer. Math. Soc., Indiana Univ. Math. Journ., Proc. of the Edinburgh Mat. Soc., etc.) and for many years has been refereeing numerous papers for Mathematical Reviews.
[1] M. Bresar, E. Kissin, V.S. Shulman, *Journal of Functional Analysis and its Applications*, **42:3**(2008), 71-75.
[2] M. Bresar, E. Kissin, V.S. Shulman, modules, *Quarterly Journal of Mathematics Oxford*, **59(4)** (2008), 409-440, doi:10.1093/qmath/ham053
[3] M. Bresar, E. Kissin, V.S. Shulman, *Journal fur die reine und angew. Math.* (*Crelle*), **623**(2008), 73-121.
[4] E. Kissin, V.S. Shulman, Yu. Turovskii, *Journal of Functional Analysis*, **256** (2009), 323-351, doi: 10.1016/j.jfa.2008.10.012.
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[8] E. Kissin, V.S. Shulman and Yu. Turovskii, *Journal of Integral Equations and Operator Theory*, No 1, **74**(2012), 51-121, doi:10.1007/s00020-012-1990-8
[9] T. Formisano, E. Kissin, *Eurasian Mathematical Journal*, **3**(1), (2012), 29-40.

A. Tonks:
Tonks, in collaboration with Dr F. Muro (Seville), published in [1] a small algebraic model for the truncation (to dimensions 0 and 1) of Waldhausen K theory. The collaboration has continued to be fruitful and lead to an explicit calculation of the K_1 group [2], and to application of these ideas to universal determinant functors as introduced by Deligne. The clean algebraic formalism of these papers noted and used by Witte as an essential part of his thesis [3]. The preprint [4], as well as giving a unified framework for determinant functors, settles conjectures of Maltsiniotis and of Neeman, and a question of Grothendieck to Knudsen.

Another extensive joint research collaboration with Dr I. Gálvez and Dr F. Neumann (Leicestser) has, so far, led to two publications [5,6] where a very general simplicial framework for the cohomology and homology of categories is considered. The main objective here will be to find new ways of constructing Serre spectral sequences for a more general framework of fibrations then the classical one in algebraic topology, and to provide new computational tools for stack cohomology, crucial for computing invariants in the theory of moduli in algebraic geometry and mathematical physics.

Much of the work of Tonks is in the area of operads, and recent collaborations with I. Gálvez, V. Gorbounov (Aberdeen), F. Muro, and B. Vallette (Nice), have led to the following important results:

-The description of a topological operad, generalising Stasheff's polytopes, whose cellular chain complex governs the homotopy unital associative algebras used by Fukaya-Oh-Ohta-Ono in Lagrangian intersection Floer theory. [7]
- The resolution of a conjecture of Lian-Zuckerman in mathematical physics, showing that certain vertex algebras have an explicit up-to-homotopy Gerstenhaber algebra structure. [8]
- The development of a theory of Koszul duality and quasi-free resolutions of non-quadratic operads, leading to the correct notion of homotopy Batalin-Vilkovisky algebras. The relation of BV algebras to Gerstenhaber algebras parallels that of the framed little discs operad and the cyclic Deligne conjecture to the more classical versions. [9]

Tonks enjoyed a 2 month visit to the Newton Institute in 2013. He was the external examiner for PhD theses in Barcelona (2012), Lausanne (2010) and Southampton (2008)

[1] F Muro, A Tonks. The 1-type of a Waldhausen K-theory spectrum, Adv Math 216 (2007), 178-211
[2] F Muro, A Tonks. On K1 of a Waldhausen category. In: K-Theory and Noncommutative Geometry, Cortiñas et.al.(Eds) EMS Series (2008) 91-116
[3] M Witte. Noncommutative Iwasawa main conjectures for varieties over finite fields, PhD thesis, Fakultät für Mathematik und Informatik der Universität Leipzig, 2008
[4] F Muro, A Tonks, M Witte. On determinant functors and K-theory. arXiv:1006.5399
[5] I Gálvez, F Neumann, A Tonks. Thomason cohomology of categories, Jour Pure Appl Algebra. 217 (2013) 2163-2179.
[6] I Gálvez, F Neumann, A. Tonks. André spectral sequences for Baues–Wirsching cohomology of categories, Jour Pure Appl Algebra 216 (2012) 2549-2561.
[7] F. Muro, A. Tonks. Unital Associahedra, Forum Mathematicum. doi:10.1515/forum-2011-0130
[8] I. Gálvez, V. Gorbounov, A. Tonks. Homotopy Gerstenhaber structures and vertex algebras, Appl. Categ. Struct. 18 (2010) 1-15.
[9] I Gálvez, B Vallette, A Tonks. Homotopy Batalin-Vilkovisky Algebras. Journal of Noncommutative Geometry 6 (2012) 539–602
[10] K Hess, A Tonks. The loop group and the cobar construction, Proc of the American Mathematical Society 138 (2010) 1861-1876

R. Gilchrist (retired)
Gilchrist collaborated [1] with van den Hout (Cambridge) and van der Heijden (Utrecht) on randomized response models and with [2] Rudge (Londonmet) on the modelling of fuel poverty and poor housing. Gilchrist was an assessor for the ESRC Research Fellowship Scheme from 2005 to 2010.

[1] A. van den Hout, P. van der Heijden, R.Gilchrist. The randomised response loglinear model as a composite link. *Statistical Modelling(2013).* 10,1,57-67. doi: 10.1177/1471082X0801000104
[2] R.Gilchrist, A. Kamara and J. Rudge. An insurance type model for the health cost of cold housing..*Revstat*, 2009,7,1, 55-66.
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R. Rigby and D. Stasinopoulos
Rigby and Stasinopoulos work closely together on the development of the theory and application of generalized additive models for scale, location and shape (GAMLSS) and on the associated GAMLSS, R software. The Statistics Group in STORM has regularly provided on-line consultancy throughout the REF period on the world-wide used R GAMLSS software. There is a dedicated GAMLSS website www.gamlss.org managed by STORM.
They have collaborated [1] with Prof. Van Buuren, Department of Mathematics and Statistics, (University of Utrecht, The Netherlands), and Dr. D. J. Hayes, Dr. F. O. Ter Keile and Dr. D. J. Terlouw (Child and Reproductive Health Group, Liverpool School of Tropical Medicine, Liverpool, UK), on estimating regional centile curves from mixed data sources and countries. Further collaboration [2] has been with Graciela-Muniz Terrera and Ardo van den Hout (MRC Biostatistics Unit, Institute of Public Health, Robinson Way, Cambridge CB2 OSR, UK) on non-parametric random effects and [3],[4] with Carlo Di Maio (Deutsche Bank SpA, P.za del Calendario 3, 20126 Milano, Italy) and Matsumoto K (Kyoto University Japan) on agent-based computational economics of the global energy system, ACEGES). In the area of long-range forecasting of intermittent streamflow, Rigby and Stasinopoulos have worked [5] with F. F. van Ogtrop and R. W. Vervoort, (Hydrology Research Laboratory Faculty of Agriculture, Food and Natural Resources, University of Sydney, Sydney, NSW, Australia) and G. Z. Heller, (Department of Statistics, Macquarie University, Sydney, NSW, Australia). Professor Stasinopoulos has collaborated on interdisciplinary research in health and nutrition [6],[7], health and biology [8],[9] and sport science [10].
The following short courses were given:

- July 2008 : One day short course on GAMLSS, given at the 23rd International Workshop of Statistical Modelling at the University of Utrecht, Netherlands.
- September 2008 One day short course on GAMLSS, given on the 23th of September at the Macquarie University, Sydney, Australia.
- November-December 2009 : Introduction To Modern Smoothing Methods: GAMLSS and P-Splines In Action, a three day short course, given at Lancaster University, UK.
- June 2010 : A 12 hours short course on GAMLSS, given as part of the MSc Biostatistics course, University of Athens , Greece.
- October 2012 : A 12 hours short course on GAMLSS, Cordoba University, Argentina.
- July 2013: A 6 hours short course on GAMLSS, Brazil.

Prof Stasinopoulos gave the following invited lectures.

- March 2009 : Centile estimation using GAMLSS, invited talk to the Symposium of the Analysis of Growth Curves Erasmus Medical University, Rotterdam, Netherlands
- April 2010 A flexible regression approach using GAMLSS. This talk was given in the one day meeting on statistical modelling celebrating Murray Aitkin's 70th birthday at the Royal Statistical Society
- April 2010 : A flexible regression approach using GAMLSS. The talk was given at the MRC Biostatistics, University of Cambridge.
- June 2012 : Invited speaker at the Brazilian Meeting on Probability and Statistics (SINAPE) organised by the Brazilian Statistical Association (ABE) (Keynote speaker).
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[1] S. van Buuren, D. J. Hayes, D. M. Stasinopoulos, R. A. Rigby, F. O. ter Kuile and D. J. Terlouw. (2008) Estimating regional centile curves from mixed data sources and countries. Statistics in Medicine 2009. 28; 23: 2891-911.
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[3] V. Voudouris , D. Stasinopoulos, R. Rigby , C. Di Maio The ACEGES laboratory for energy policy: Exploring the production of crude oil. Energy Policy 39 (2011) 5480–5489
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[9] Freitas D., Malina R. M., Maia J., Lefevre J., Stasinopoulos D. M., Gou- veia E., Claessens A. L., Thomis M. and Lausen B (2012) Short-term secular change in Tanner-Whitehouse 3 skeletal maturity of Portuguese children. Annals of Human Biology. Vol. 39, No. 3 , Pages 195-205 (doi:10.3109/03014460.2012.674155)
[10] Sandercock G., Voss C., Cohen D., Taylor M., and Stasinopoulos D. M. (2012) Centile curves and normative values for the twenty metre shuttle-run test in English schoolchildren. Journal of Sports Sciences, DOI:10.1080/02640414.2012.660185
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