

Proposal for a  
**Master of Science Program in Quantitative Finance**  
conducted by the Department of Economics

### 1. Rationale for the program

The Department of Economics proposes a Master of Science in Quantitative Finance (**MSQF**) program. This proposal is being submitted to the Graduate School for consideration in fall 2013, for implementation in fall 2015 for a 3- or 4- semester program.

The Economics department already has a very strong Masters in Economics program with tracks in both Financial Economics and Applied Financial Economics. So the natural question is why should we create an entirely new program in Quantitative Finance, rather than subsuming this into the existing Economics Master's program? There are several reasons for a new, stand-alone program.

- As the market for strong Masters in Economics programs becomes more crowded, offering a stand-alone Master of Science (MS) program focused on quantitative finance (rather than just a track within the overall MA in Economics program) further differentiate our offerings relative to our competitors, in a field that is perennially popular for both aspiring academics and those interested in working in the private sector. We will address the specific needs of both these “academic” and “professional” tracks within this Proposal.
- We will set our program apart by explicitly highlighting the responsibility of “financial engineers” to consider the broader societal implications of the complex financial instruments they develop and utilize. History shows us the increasing power of financial engineering to wreak economic havoc: from institutional damage (e.g., the Savings and Loans crisis of the late 1980s and the corporate and municipal bankruptcies of the 1990s), to global economic meltdown (the 2008 credit crisis). With this increased power comes an increasing need for ethical responsibility on the part of those who develop and market these products. To ensure this, the program curriculum will include both qualitative and quantitative approaches to the risks of credit misallocation; the dangers of concentrating rather than sharing risk, and also of placing excessive risk-taking capability in the hands of insufficiently trained financial agents. (See Sections 3 (a) & (b) and Section 4.)
- Within our program, students will also be expected to reflect on the larger question of how to assess the longer-run systemic-level risks posed by complex strategies that offer opportunities for short term gain. Furthermore, they will address the (potentially more difficult) problem of determining when to be a minority voice of caution with colleagues in the face of enthusiasm for immediate positive returns. (See Sections 7(a) & (c)).
- The core components of a Quantitative Finance program differ from those in the existing Economics Masters Programs. In Section 3(b) we list the core courses required for the MSQF program, and note that some of these would not be accessible to many incoming Economics Masters students. By implication, the quantitative pre-requisites for students entering the MSQF will be higher than those required for the regular MA program. We

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expect that Economics Masters students who would currently select the Financial Economics track as their concentration within the existing Econ Masters program will therefore be better served by the MSQF program.

- Additionally, we anticipate that the MSQF program will be attractive to a new set of candidates seeking careers in the ever more complex financial markets, where strong quantitative skills and training are highly prized. We will therefore need a more directed career advising component for these students, who will be seeking jobs in areas where the quantitative finance training provided by the MSQF is an essential component. See our discussion in Section 2(c) about career-oriented staff for this program.
- Meanwhile, MSQF students who wish to participate in the program as a stepping stone to applying to PhD programs in finance, especially within business schools, will also improve their candidacy by studying quantitative finance with this program. (The existing infrastructure for advising such students already exists within the economics department.)
- We anticipate that students who select the career track for the MSQF may complete the program within 3 semesters, especially if they have secured a full time position for January after their third semester (as has been the case with some of the Applied Financial Economics track MA students in our current program). However, candidates for PhD programs in finance will more likely need 4 semesters, so that they can have an opportunity to take higher level finance classes (including PhD-level classes in Economics and at Fuqua) before moving to a PhD program. The Economics department offers an 80% tuition waiver to most MA students in their 4<sup>th</sup> semester (subject to their funding needs), and the majority of MA students avail themselves of this benefit. We will adopt this practice for the MSQF as well; we expect this will be particularly valuable to PhD program candidates who will want to take advanced level courses in their 4<sup>th</sup> semester.

The current Economics master's program has tracks in Financial Economics and Applied Financial Economics, but the stand-alone quantitative finance degree proposed here will replace these tracks and provide the greater depth and rigor that are increasingly demanded by advanced academic programs and in the private sector. Thus it is expected to attract among others, candidates who would previously have selected one of the existing finance tracks in the current MA program.

As noted above, we believe that the candidate pool will also expand to include applicants who recognize that there is an increasing need for rigorous quantitative training as preparation for both finance PhD programs and the private sector. Previously these candidates would have applied to existing programs in Mathematical Finance, Quantitative Finance and/or Financial Engineering at schools that already offer these at the Master's level. Among our peer group, there are a handful of such programs, including Princeton's Master's in Finance, Columbia's MS in Financial Engineering, and NYU's MS in Mathematical Finance. Some business schools also offer "specialized" Master's programs in finance that are distinct from their MBA offerings. However, we believe that this is not yet a crowded marketplace, and that worldwide demand for graduates of quantitatively rigorous Master's programs will continue to grow, both in higher level academic programs and in the financial markets.

**2. Statement of resources needed for the program:**

**2(a) business plan indicating the program expenses and how they will be covered**

Please also refer to the Budget in Addendum 1.

- We anticipate that the new MSQF program will share some fixed administrative costs with the existing MA program, especially those provided by the Ecoteach Center, which handles teaching administration at all levels in Economics.
- Part of this additional workload will also be assumed by the Duke Financial Economics Center, whose Research, Teaching and Executive Directors (Professors Bollerslev & Rasiel and John Caccavale respectively) will also take an active role in this new Masters Program.
- The program will require faculty to assume advisory roles on Masters committees for students selecting the academic track within the MSQF program, who will write theses as part of their program requirements (see Section 5 for relevant faculty).
- The program will also require career-related advising for students selecting the professional track within the MSQF program (see below).
- We propose that additional revenue from the new program will be included within the existing revenue sharing agreement already in place between the Graduate School and the Economics department.
- We anticipate providing financial aid for up to 25% of total tuition across all students, with a cap of 80% waiver for any individual student. Each student's individual financial aid package will be determined on an as-needed basis, with a goal of attracting high caliber candidates and a diverse student pool. We note that both PhD programs and financial market firms are eager to recruit diverse candidates, and our existing MA program has been quite successful in recruiting under-represented minorities (between 10 – 15% of the MA class has been from this cohort in each of the last few years). We anticipate that the MSQF will continue this trend, and that our financial aid policies will facilitate this trend.
- *Periodic Re-evaluation*  
Every three years after the completion of the first year of study by the first class admitted, the department will conduct a review of the program to establish whether it shall be continued for an additional three-year period.

**2(b) Review of resources available (personnel, finances, space, library, etc.)**

The Economics Center for Teaching (Ecoteach) is the instructional division of the Department of Economics, supporting the three economics degree programs: Undergraduate, M.A. and Ph.D. Established in 2001, the EcoTeach office provides student services and offers assistance with the many aspects of pursuing a degree in Economics, whether as an undergraduate, M.A. or Ph.D. student. With Ecoteach's assistance, the Economics department continually updates the curriculum at both undergraduate and graduate levels, introducing new and relevant coursework to stay up-to-date with the latest research in the field.

***Finance MS Program Key Administrative faculty and staff:***

Dr. Tim Bollerslev & Dr. Emma Rasiel: Program Directors

Ms. Linsey Hughes, MBA, non-Academic Career Services Director within the Duke Financial Economics Center (DFE) ***NEW***

Mr. John Caccavale, MBA, Executive Director of the Duke Financial Economics Center (DFE)

Ms. Jennifer Valentyn, MS Finance Program Coordinator

Ms. Amy Clayton, EcoTeach Senior Program Coordinator

Masters students, including prospective, current, and alumni, visit EcoTeach for answers to all administrative and academic matters in support of successful completion of their degree requirements.

EcoTeach staff helps with:

- Academic advising
- Degree progression tracking
- Research and academic assignments
- Administrative issues such as: orientation, admissions, financial aid, course registration,
- graduation completion exercises and payroll.

**2(c) Placement**

A primary goal of the Finance MS Program is to secure favorable placement for all of our students. As a result the program focuses directly on rigorous training for both PhD placement and career opportunities.

From the perspective of students seeking careers in the financial markets, the depth and breadth of financial market connections provided by the Duke Financial Economics Center personnel (see Section 2(b)) will distinguish this program from its peers. The quantitative finance job market is quite fragmented, with many money management firms, hedge funds, trading firms, and quantitative research groups, each looking for a very small number of candidates at any one time. The DFE is uniquely placed to carve out a new recruiting niche with these firms, given the extent of its large and growing network in the financial markets. These opportunities are distinct from the large recruiting programs run by the big Wall Street investment banks, for whom undergraduates (and to some extent MBAs) are the primary targets. The MSQF graduates will not be competing for these undergraduate opportunities; by the same token, it would be a rare undergraduate (or MBA) who would qualify for the type of highly quantitative finance role applicable to the MSQF students.

From the perspective of students seeking placement in top PhD programs, the Economics department's outstanding and growing faculty in the field of financial economics (see Section 2(d)) are ideally positioned to guide and mentor these students in their application process. The existing Economics MA program already has a strong record of placing its graduates into PhD programs, both at business schools such as Stanford, Columbia, Rochester, Fuqua, and LBS, and into economics departments at Maryland, University of Virginia, and Duke.

**2(d) Statement of additional resources needed and available outside funding.**

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All of the *essential* courses needed for the proposed MS in Quantitative Finance are already taught at Duke, in both the Economics department and in related departments (Mathematics, Statistics, Fuqua School of Business and Computer Science, see Section 3(b) below).

We have identified some new courses that we believe would be valuable *additions* to the Program; see Section 3(b). We anticipate that these and other new courses will be introduced by three new Chaired Professors arising from recent endowments to the Duke Financial Economics Center (DFE):

- Chaired Full Professor (expected fall 2015)
- Chaired Visiting Professor (ongoing)
- Chaired Associate Professor of the Practice (expected fall 2015 or 2016).

### **2(e) Five-year student, faculty and resources projections**

- Initial entering class of 10 to 15 students/year in total, with potential to grow to 25 or more over 5 years.
- As noted above, we anticipate that some of these students will be those who would previously have chosen the Financial Economics track in the existing Economics MA program, and whose primary interest is a career in the financial markets.
- Additional students with career interests in this area will find both the quantitative rigor and advising resources (for both academia and the markets) compelling.
- 5 year student, faculty and resource projections [*spreadsheet*]

### **3. Degree requirements for the program (credits, courses, prerequisites, RCR training, examinations, papers, internships, experience).**

Students will receive a degree of Master of Science in Quantitative Finance upon satisfactory completion of their studies in the Program.

Each student will have a Master committee of three faculty members, with up to one committee member from outside the Economics department if approved by the Director of Graduate Studies in the Economics department.

#### **3(a) Graduation requirements are as follows:**

(1) Each student will take the Graduate School required minimum of 30 graduate course credits (ten courses), not including remedial courses (defined below).

(2) As an exception, up to *two* elective courses may be taken at the undergraduate level (3XX and 4XX)

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(3) At least 18 course credits (6 courses) must be graded ECON courses, as detailed below (in some cases, students may count Fuqua FIN courses in place of ECON electives, with advance approval from the MS Program Director).

(4) To receive the degree, a student must pass a final exam administered by the student's committee. The exam is based on a portfolio of learning and research activities carried out during their Master studies. The portfolio must include *one* of the following two items:

- For the “Professional” track (students interested in a career in finance): a written description of a project carried out as part of an approved internship with a financial firm, or the finance department of a non-finance corporation, that includes significant quantitative financial analysis.
  - The Duke Financial Economics Center (DFE) works closely with a number of hedge funds and fund-of-funds to obtain summer internships for both undergraduate and Master's students. (For example, a fund-of-funds in Charlotte, NC, started by former DUMAC executives, has employed Economics MA students as summer interns in four out of the last six years.)
  - The Economics department recently hired Linsey Hughes (see Section 2(b)) who has 10 years of hedge fund advisory experience in New York, and is already generating additional relationships and internship opportunities for Master's students.
  - Further assistance with internship opportunities is anticipated from some of the 24 DFE Steering Committee members, two of whom have previously provided summer internship opportunities for Duke students and have indicated commitment for future years.
  - We anticipate being able to place 5-7 Master's students with summer internships in the first year of the MSQF, with this number increasing in subsequent years to a maximum of 10-12.
- For the “Academic” track (students wishing to apply to PhD programs); *either*:
  - A Capstone course in financial economics, as described below, *or*
  - a written Master thesis or project report on an approved topic developed via independent study with one or more Economics faculty advisors. This document is expected to describe a mature project with research content.
- Evaluation of MSQF Internships / Capstones / Theses: All MSQF students' internship reports (for the “Professional” track) and Capstone Research Reports or Theses (for the “Academic” track) will be evaluated by two Economics department faculty members, at least one of whom will be an MSQF Program Director. Both internship and theses writeups are expected to demonstrate the following:
  - Compelling evidence of relevance of the research/report in the context of either the current literature (for theses) or the firm's business needs (for internships).
  - Thorough interpretation and implications of the report's findings.
  - Discussion of ethical issues or concerns relating to business practices (within an internship) and/or broader economic implications of research output (with a thesis).
  - Clear and professionally reported citations (where applicable)
  - Applicable methodology and data analysis

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- Writing appropriate for the target audience (either academic or business-oriented)

### 3(b) Courses

- *Pre-requisite* undergraduate level courses (students must have completed these to a satisfactory level prior to participating in the MSQF Program):
  - Probability & Statistics at an advanced undergraduate level
  - Linear Algebra and Multivariate Calculus at an advanced undergraduate level
- *Core* (students must take *all* of these):
  - Time Series Econometrics (Econ 612)
  - Intermediate Finance (Econ 573 – for “professional” track) *or* Financial Markets & Investment (Econ 571 – for “academic” track)
  - Mathematical Finance (Econ 673 / Math 581)
  - Volatility Modeling and High-Frequency Finance (Econ 6XX)
  - Continuous Time Finance (Econ 6XX)
  - **Mandatory seminar series on Ethical Considerations in Finance (zero credits): potentially in collaboration with other departments such as Fuqua, Pratt’s MEM Finance track, etc.**
- *Electives in the Economics department* (at least 3 of students’ 5 electives must be chosen from this group)
  - Corporate Finance (Econ 373)
  - Forecasting (Econ 413)
  - International Finance (Econ 570)
  - Hedge Funds (Econ 5XX)
  - Selected Topics / Research Seminar in Economics (Econ 690)
  - Real Analysis for Economists (PhD Econ 711)
  - Time Series Econometrics (PhD Econ 883.XX)
  - Beyond Money & Markets (PhD Econ 885.XX)
  - International Finance (PhD Econ 882.XX)
  - Finance in Macroeconomics (PhD Econ 882.XX)
- *Electives from other Departments* (up to 2 of students’ 5 electives may be chosen from this group)
  - CPS 590: Advanced Topics in Computer Science
  - Stats 611: Intro to Statistical Methods
  - ECON 684/MATH 582: Derivatives
  - ACCT 596: Accounting for Mergers & Acquisitions (Fuqua MBA Finance)
  - BA 951: Empirical Asset Pricing (Fuqua PhD)
  - BA 910: Bayesian Inference and Decision (Fuqua Decision Science PhD)
- *Additional electives, not currently offered, that would be valuable additions to those currently offered*
  - Financial Risk Management (**to include a significant component on the history of financial speculation; and how complex financial products have increasingly magnified the scope of financial “bubbles” and severity of subsequent crashes**).
  - Fixed Income Securities
  - Dynamic Asset Management

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- Venture Capital & Private Equity
- Equity Valuation and Fundamental Analysis
- *Capstone courses*
  - Capstone courses include 590+ numbered courses with significant project component, or other seminars or courses approved by the program director.
- A student can earn any remaining credits needed to reach the required minimum of 30 through additional courses in ECON, as well as through guided independent study in ECON if available. Courses and independent studies in other departments may also be counted if approved by the program director.
- Remedial/preparatory course in ESL as mandated

#### **4. Descriptions of new courses to be offered in connection with the program and identification of teaching faculty.**

##### ECON 6XX: Volatility Modeling and High-Frequency Finance

A revolution in modeling and forecasting financial market volatility and correlations has swept academic research and the financial services industry over the past two decades, with the new methods finding wide-ranging applications in asset pricing, investments, risk measurement and management, and economic forecasting. This course surveys some of the most popular modeling procedures currently in use, with an emphasis on practical empirical applications. **The course will also include explicit evaluation of extreme loss scenarios where such econometric forecasting tools fail to incorporate “tail risk” driven by unexpectedly large market moves and/or “irrational” human behavior.** Topics covered include: ARCH and GARCH models; multivariate volatility models and correlations; stochastic volatility models; high-frequency data and realized volatilities, market microstructure effects; jumps and price discovery; options implied volatilities and volatility trading.

##### ECON 6XX: Continuous Time Finance

The object of this course is to provide an introduction to continuous time finance, including arbitrage theory, stochastic optimal control theory, and dynamic equilibrium theory. The course also contains an introduction to stochastic differential equations and Itô calculus, the main mathematical tools employed in this area. Topics covered include: elements of stochastic calculus; the Black-Scholes model and the Black-Scholes equation; no arbitrage and equivalent martingale measures; derivative pricing with stochastic volatility and jumps; portfolio choice in continuous time; empirical methods for option pricing.

##### ***Potential teaching faculty for these courses include:***

Tim Bollerslev

Jia Li



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Andrew Patton  
George Tauchen  
Chaired Full Professor (expected Fall 2015)  
Chaired Visiting Professor (ongoing)  
Chaired Associate Professor of the Practice (expected Fall 2015 or 2016)

### **5. Curriculum vitae of faculty who will participate in the program.**

See Addendum 2 for full CVs

Charles Becker  
Tim Bollerslev  
Connel Fullenkamp  
Jia Li  
Andrew Patton  
Emma Rasiel  
George Tauchen

### **6. A statement of support from the dean of the sponsoring school and any additional clearances obtained or required**

*See Addendum*

### **7. A student learning outcomes assessment process indicating how data on student learning outcomes is to be gathered into a portfolio and utilized to improve the program.**

Our student learning outcomes assessment includes an evaluation of a student portfolio of work and PhD Program Placements, as well as professional career placements:

#### **7(a) The Portfolio should contain:**

- All student (final) papers and slides from oral or written presentations as applicable. Material created by the student as a research or teaching assistant also may be included.
- Updated resume / curriculum vitae
- A document (expected 2-5 pages) that examines the student's objectives upon arrival into the MS program and at the conclusion. This self-assessment statement also should include a discussion of the student's long-run goals, and a discussion of the effectiveness and limitations of the MS program in helping meet these goals. **A component of this discussion should include lessons learned about the extent to which complex financial tools can increasingly be contributors to systemic economic instability on a global scale. Students will be expected to reflect on the responsibility required of those who create, utilize and disseminate those tools. Equally important, students will have to reflect on the potential for being a minority voice of caution where short term gain from such tools may have negative systemic impact in the long run. Determining under what circumstances this cautionary role is appropriate should also be considered.**
- *Professional Track*: a written description of the student's internship, including a discussion of how the experience relates to the student's field and a summary of what was learned, along with copies of any non-proprietary documents or presentations created by the student during that period.

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- *Academic Track*: a written thesis or project report on an approved topic developed via independent study with one or more Economics faculty advisors; or final paper(s) and slides (if applicable) from oral or written presentations from capstone course.

### **7(b) Evaluation of Portfolio**

Determination that the content of the portfolio is sufficient to merit recommendation for graduation is made by the student's committee.

Each student will be expected to submit a hard copy of the portfolio to the Committee two weeks prior to the final examination date.

- The Examining Committee (comprised of 3 Graduate Faculty members, in accordance with the Graduate School requirements) will review the material submitted and will hear an obligatory brief (expected duration: 15 minutes) presentation of the content from the student in an oral defense. If the content is satisfactory, the Examining Committee will approve the student for graduation.
- Each student is required to submit a portfolio update at the end of each term except for at the end of the first semester. This may be submitted electronically, and should be sent to the MS program staff administrator and the student's academic advisor. The timeliness of these submissions will be a factor considered by the Examining Committee.

The purpose of the Portfolio requirement is to ensure that all MS students engage in creative learning and the production of knowledge, rather than simply absorbing material. These also encourage students to reflect during their period of study on the appropriateness of their chosen courses, internships, and other activities. The material gathered will be of value as well in applying for jobs or doctoral programs; it also will assist Duke Economics in evaluating the effectiveness of its program.

### **7(c) PhD Program and Career Placements**

We will collect data through surveys of graduating students. This information will assist us in determining our student's success in securing admission to top PhD program in related disciplines. For those students not pursuing PhD Programs, we will collect data that will assist us in assessing the student's ability to secure employment that is challenging and respected within the profession. Results will be posted on the Economics department website.

Specifically, we will collect and evaluate the following data for the PhD track:

- (1) Portfolio evaluation: we will use a rubric to assess the quality of the PhD track students' theses. The following criteria will be graded on a 3-point scale:
  - a. Clear statement of research goal and its relevance / value within the context of the existing literature.
  - b. Sound research methods and analysis.
  - c. Clear presentation of results (both written and oral) and their importance.
- (2) Academics: Performance of MSQF students in PhD-level courses, both in terms of quantity and course grade (contemporary PhD students' performance in these same courses may be used as a benchmark).
- (3) Surveys of MSQF program graduates:

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- a. Immediately post-graduation: admission to top PhD programs in Economics and related fields.
- b. 2 years post-graduation: assessment of their progress through PhD coursework.
- c. 6 years post-graduation: assessment of their PhD completion and subsequent placement, whether academic or otherwise.

We will collect and evaluate the following data for the Career track:

- (1) Portfolio evaluation: the students' internship reports will be evaluated in terms of how they connect their role as an intern to their academic studies. They should also identify skills or areas of knowledge that they were lacking during their internship, and how they sought to rectify these gaps in their subsequent study.
- (2) Academics: Performance in PhD courses as well as advanced quantitative courses in mathematics, computer science, and statistics (with a scale of "unsatisfactory" to "highly satisfactory").
- (3) Surveys of MSQF program graduates:
  - a. Immediately post-graduation: job placement by company, field, job title, and geographic location.
  - b. 2 years post-graduation: update on ongoing career path, including promotions if applicable.
  - c. 6 years post-graduation: update on ongoing career, as well as potential employment opportunities for then-current MSQF candidates within their corporation.

We will collect and evaluate the following for both tracks:

1. Review ethical discussion components of students' theses / internship documents, to determine whether the program goal of students' explicit reflections of ethical considerations (as discussed above in Section 1) has been sufficiently addressed within their written reports.
2. Ongoing assessment by program directors of changes in ethical considerations in the face of dynamic market conditions, new technologies, and evolving regulatory environment.

### **ADDENDA**

Addendum 1: Budget

Addendum 2: Faculty CVs

Addendum 3: Letters of Support