

Proposal for a Joint
Master of Science Program in Economics and Computation (MSEC)
conducted by the
Departments of Computer Science and Economics

November 2, 2013

1. Rationale for the program

The Departments of Economics and Computer Science propose a joint Master of Science program. This proposal is being submitted to the Graduate School for consideration in spring 2013 for implementation in AY 2014-15, with the first entering class arriving in August 2014.

The Economics Department has an interest in a joint program because of its potential (a) to successfully recruit for its graduate program from undergraduate majors in Engineering, Applied Mathematics, and the quantitative physical sciences (loosely, STEM majors), especially from top programs; (b) to enhance the role of the Master program in serving as a conduit through which STEM majors can be prepared for the Economics doctoral program; and (c) as a further step in product differentiation from other Economics MA programs. Duke's Economics MA program is already positioned as the most quantitative in the United States; the joint Master program with Computer Science would further strengthen this reputation, making the Economics Department attractive to a broader group of students—especially those preparing for PhDs—even if they do not pursue this joint program. The Economics Department does *not* view this joint Master as a means to expand its overall (already large) MA program.

The Department of Computer Science has an interest in a joint program because of (a) the evident interest in Master degrees in computer science linked to economics, finance, and related areas; (b) the potential to broaden the flow of students to PhD programs in computer science at Duke and elsewhere; and (c) the opportunity that this joint program provides to further strengthen the connections between Computer Science and Economics.

The MSEC program is the natural culmination of an already extremely close relationship between the two departments. There is a thriving joint CS-Economics seminar series run by Vince Conitzer. For many years, Don Rose has taught a master's level numerical methods course that is both cross-listed and aimed at economists; Economics provides the course TAs. There is interest in both departments in future hiring in computational economics and in having further joint appointments. Many Economics graduate students have undergraduate degrees in Computer Science, and are interested in building cross-disciplinary strengths.

The proposed program is truly interdisciplinary, and as such cannot be realized as a track within the existing Master programs in either department. The proposal is not to add a few computer science courses to a curriculum in economics, or vice versa. The field of economics and computation has recently emerged from two converging intellectual needs. On one hand, as data turns into big data, it becomes increasingly important for at least a subset of economists to understand concepts and methods in computer science as they address increasingly complex questions on larger repositories of data that reside in the cloud and require sophisticated computational methods. On the other hand, the explosion of online activities has made it necessary for computer scientists to understand the economics of the internet, internet-based communication and broadcast networks and systems, electronic commerce, and online auction systems. In addition, it is useful for computer and communication system designers to understand how economic incentives can help utilize resources optimally and for the common good. All these issues are at the core of an exciting new area of research that now has its own

journal, the *ACM Transactions on Economics and Computation*, with Duke's Vince Conitzer and Google's R. Preston McAfee as joint editors-in-chief.

The program that is most similar to the one we propose is arguably the MS in Management Science and Engineering at Stanford (see <http://www.stanford.edu/dept/MSandE/about/history.html>). This department is the outcome of a merger between Operations Research and Engineering - Economic Systems (EES). The Stanford program emphasizes the confluence of management and engineering, and is thereby somewhat similar to Duke's Master of Engineering Management Program. However, the Stanford program includes more courses on information science, optimization, and other computational aspects, making it germane to our proposal.

Another program with significant resonances with the proposed MSEC is the undergraduate program in *Networked and Social Systems Engineering* at the University of Pennsylvania. While the header of the program emphasizes social networks, two of its four concentration areas are at the nexus of economics and computation. These areas are *Networked and Cloud Services*, on both the technological and economic aspects of social networks, and *Economics and Networked Markets*, on the role of computation and communication technology on financial and other markets. It is not a coincidence that machine learning and computational economics expert Michael Kearns directs this program. Despite the similarities, the UPenn program is a bachelor program, not a Master's. The fact that the most closely related programs in the US and the world are different in significant ways from our proposal signals that Duke has an opportunity to lead in an emerging area.

There is ample evidence of interest in the confluence of economics and computation, both at other institutions and at Duke. There are computational economics *courses* at schools like Stanford University (see a description at <http://economics.stanford.edu/courses/computational-economics>) and the University of Chicago, which hosts the *Initiative for Computational Economics*, sponsored by an exceptionally distinguished group of faculty (see <http://ice.uchicago.edu/personnel.htm>) that include Nobel Laureates James Heckman (Nobel 2000) and Lars Peter Hansen (Nobel 2013). Other schools with courses or in computational economics include MIT, Carnegie Mellon, and Northwestern (Kellogg). Schools that have activities in computational economics tend to be among the most elite. That said, none of them have a master's program exactly like the one we propose, and it seems likely that this void will be filled sooner rather than later.

Anecdotal evidence from courses at Duke indicates potentially high demand for a program in the proposed area. Last spring, Ed Tower's Econ 567 computer modeling course had 34 students enrolled; Don Rose had 18 in Econ 690/CompSci 590 numerical methods; Juan Rubio-Ramirez had 9 in his Econ 883/04-04 computational economics PhD seminar. Vincent Conitzer's CompSci 296.1 course in computational microeconomics had an enrollment of 21 students, above nominal capacity. These numbers reflect spontaneous demand, without any effort to promote a graduate program.

One might ask why the substantial and growing demand for economics and computation cannot be satisfied by an existing master's program at Duke. In response, we note that the Computer Science master's program is structured so that a student really cannot take sufficient courses in Economics to gain an advanced mastery of the field. While Economics' master's program appears to be more flexible, in practice it, too, does not enable its students to gain deep knowledge in computer science, since its students also are expected to take advanced Statistics and Mathematics courses. Thus, while the current Economics MA does have a computational track, it would be regarded as superficial by Computer Science standards. Of course, a student could take two separate master's programs, and thereby gain even deeper knowledge than from

the MSEC curriculum. However, there are large time and financial costs to doing so. Of equal importance, we envision that a large portion of MSEC students will proceed to doctoral study, and accumulating too many prior degrees sends a negative (“eternal student”) signal to admissions committees.

2. Relationship to existing programs at Duke

Computer Science offers a Master of Science in Computer Science (MSCS) that currently admits up to about ten students per year. This program is on computer science only, with no connection with economics. Courses, projects, and graduation criteria for the MSCS are entirely supervised by CS faculty. The proposed MSEC focuses specifically on both the computation for economics and the economics of computation.

The Computer Science policies for MSCS and MSEC will be the same in terms of general requirements, with the only difference being the specific courses required for graduation in the two programs, and the topics of the projects students work on.

The Computer Science department recently revised its MS in Computer Science to reflect compatibility with the proposed MSEC program. In particular Computer Science now allows a “course only” option, as well as a project or thesis options.

Because of the small size of both programs, the CS faculty and staff can devote personal attention to all students equally, and we do not see particular problems concerning the identity of MSEC students within the Computer Science department.

As long as the sizes of the two programs remain small, the DGS in CS will handle all master students as part of the normal administrative load. If either program were to grow significantly beyond the numbers envisioned initially, revenue from the programs will be used to hire additional support staff as needed.

3. Statement of resources needed for the program:

a. business plan indicating the program expenses and how they will be covered

Please refer to budget under section e.

There will be administrative costs, consisting primarily of additional workload for the MS program directors in each department and the DGSA’s, to administer the program and handle applications and admissions. The program will require faculty to assume advisory roles on Master’s committees. We propose a revenue sharing plan of 1/2 Graduate School, 1/4 Economics, and 1/4 Computer Science after accounting for financial aid. In order to attract top students – especially given the anticipated minority student target group – a minimum average support level of 33% of tuition and fees is anticipated to be necessary. The infrastructure of the MSEC program will be based mostly in Economics, but courses and projects will be in both departments.

Periodic Re-evaluation:

Every three years after the completion of the first year of study by the first class admitted, each department will conduct a review of the program to establish whether it shall be continued for an additional three-year period.

b. review of resources available (personnel, finances, space, library, etc.).

Primary administrative support to MSEC will be provided by the Economics Department, which has substantial capacity in the area. 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. EcoTeach plays an integral role in actualizing the Economics Department's vision of a vibrant research community at the student level and is constantly creating key field courses at both the undergraduate and graduate level to deepen students' understanding of specialized topics beyond what is covered in economics core courses.

Economics MA Program key administrative faculty and staff:

- Dr. Kent Kimbrough, Program Director
- Dr. Charles Becker, Program Development Coordinator
- Dr. Thomas Nechyba, EcoTeach Director
- Ms. Jennifer Becker, Graduate Studies Program Coordinator
- Ms. Megh Freeland, EcoTeach Senior Program Coordinator

Master's 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
- Career services
- Administrative issues such as: orientation, admissions, financial aid, course registration, graduation completion exercises and payroll.

A primary goal of the Economics MA Program is to secure favorable placement for its students. As a result the program focuses directly on rigorous training for PhD placement and administrative assistance for career placement. These characteristics also will hold for the MSEC program.

DGSs or their designates will handle the modest numbers of additional MSEC students as part of their current administrative load for the MS programs in the two departments. The Economics Department's PhD and job placement services also will be used for MSEC students. If the MSEC program grows significantly beyond the initially proposed numbers, revenue will be used to hire support staff as needed.

c. statement of additional resources needed. None

d. potential or actual outside funding. None

e. five-year student, faculty and resources projections

See attached spreadsheet

No new courses are envisioned. However, both Computer Science and Economics face capacity constraints in some existing courses, and therefore anticipate the possibility of having to open additional sections at some point in the face of general increases in enrollment. Therefore, we budget a student instructional burden, assuming one additional section offering per term for every six FTE students enrolled based on an average enrollment of about 20 students/course.

4. Students (sources, characteristics, opportunities available to graduates):

Entering class of 3 to 5 students/year.

Both departments regard this initiative as being targeted largely to students intending or likely to continue to PhD studies, while recognizing that the professional market for terminal degree students is excellent as well. The two departments will run recruitment jointly and with this consideration in mind. In order to attract top students—especially given the anticipated minority student target group—a minimum *average* support level of 33% of tuition and fees is anticipated.

The Economics and Computer Science Departments have longstanding commitments to recruitment of underrepresented minority students and see the MSEC program as strengthening that effort. Over the past eight years, the Economics masters' programs have been successful in recruiting nearly 30 underrepresented minority students. A major source of students have been MSI technical universities such as North Carolina A&T and Florida A&M. We anticipate that the MSEC program, especially in concert with the Economics-Statistical Science MSEM program, will further raise Duke's visibility and competitiveness at these institutions.

At present, MSEC does require an internship (which could be taken by international students on a CPT work authorization that does not cut into OPT time). However, MSEC will apply for recognition as a STEM program, which will allow international students to extend the 12-month OPT work authorization for an additional 17 months. As noted below, if demand warrants, an applied track with CPT authorization will be developed in the future.

5. Degree requirements for the program (credits, courses, prerequisites, RCR training, examinations, papers, internships, experience):

Students will receive a degree of Master of Science in Economics and Computation.

Each student will have a Master committee of three faculty members drawn from the Economics and Computer Science departments, with both departments having faculty representation on each committee. One committee member can be from a third department if approved by the Directors of Graduate Studies of all three departments. Committee members from each department are chosen among the faculty according to that department's policies. The student will take a course of study that is subject to the approval of both program directors. Graduation requirements are as follows:

Upon satisfactory completion of their studies in the program:

- (1) Each student will take the Graduate School required minimum of 30 graduate course credits, not including remedial courses (defined below). As an exception, 6 of the 30 credits can be substituted with undergraduate course credits upon approval of both program directors. This is a standard option for students in masters programs at Duke. Students in MSEC coming from an Economics background may need upper level

undergraduate Computer Science courses; those coming from a CS background may benefit from the intuition gained in upper level undergraduate Economics seminars.

(2) At least 12 credits must be graded graduate Computer Science (COMPSCI) courses numbered 500 or higher, and at least 12 credits must be in core Economics (ECON) courses, as detailed below.

(3) 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 Masters studies. The portfolio must include *one* of the following two items:

- A **capstone course** in either Computer Science or Economics, as defined below, in addition to a description of the outcome of each of the projects the student has completed in both the capstone course and any other project-based courses taken in the program. Existing courses will receive capstone designation for the MSEC program by mutual agreement of the departments.
- A written Master thesis or project report on an approved topic developed via independent study with one or more Computer Science and/or Economics faculty advisors if available. This document is expected to describe a mature project with research content.

Courses

• Computer Science:

- If some of the 12 required graduate COMPSCI course credits are substituted with undergraduate COMPSCI courses as per the exception mentioned at point (1) above, then the undergraduate COMPSCI course(s) must be among the following (or approved substitute): COMPSCI 210, 220, 230, 270, 316, 330. A graduate COMPSCI course on the same topic as an undergraduate COMPSCI course taken as a substitute does not count towards the 12 required credits in Computer Science.
- Any graded graduate COMPSCI course (including independent study) with a significant project component may serve as a capstone course.

• Economics: 12+ credits with no more than 6 from any one of the three sub-fields:

- Microeconomics (ECON 601, 605, 701, 705)
- Macroeconomics (ECON 552, 602, 606, 702, 706)
- Econometrics (ECON 608, 612, 613, 703, 707)
- or approved substitutes. Capstone courses for Economics include 590+ numbered courses taught in computational economics, seminars in macroeconomics, seminars in structural microeconomics modeling, or other seminars or courses approved by the Economics MSEC director.

• A student can earn the remaining credits needed to reach the required minimum of 30 through additional courses in COMPSCI and/or ECON, as well as through guided independent study in COMPSCI and/or ECON if available. Courses and independent studies in other departments may be counted as well if approved by both program directors.

• Remedial/preparatory courses from the following may be required, but are not counted towards the 30 credits required above.

- ESL courses as mandated
- Linear algebra and multivariable calculus at the level of Math 202 or higher
- Knowledge of probability at the undergraduate level
- COMPSCI 230 (Discrete Math)

RCR training

All Duke masters' students are required to complete a 4-hour RCR training program at the beginning of their study, and this also would apply to MSEC students.

Tracks

Initially, MSEC will consist of a single program. However, we envision the eventual creation of an Applied Economics and Computation track if demand warrants. Such an applied track would require the participants to have an internship experience in industry.

6. Descriptions of new courses to be offered in connection with the program and identification of teaching faculty:

The dual Master's program will not require the creation of new courses, or additional sections. However, as noted above, additional enrollments from MSEC and other students may necessitate the offering of additional sections.

7. Curriculum vitae of faculty who will participate in the program:

See Addendum I for full CVs

Charles Becker, Director of MA Program Development, and Research Professor

Peter Arcidiacono, Professor of Economics

Thomas Nechyba, Professor of Economics and Public Policy

Juan Rubio Ramirez, Professor of Economics

Ed Tower, Professor of Economics

Vincent Conitzer, Professor of Computer Science and Economics

Donald Rose, Professor of Computer Science and Mathematics

Prof Rose will work with the chair of Computer Science and will play a major role as a Computer Science advisor to students in the program. MSEC program co-directors initially will be Becker and Rose.

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

See addendum II

9. A student learning outcomes assessment process indicating how data on student learning outcomes is to be gathered and how it will be used to improve the program.

Our student learning outcomes assessment includes an evaluation of a student portfolio of work and PhD program placements. The Portfolio should contain:

- All student (final) papers and slides from oral or written presentations, both from capstone and other courses, as well as relevant computer programs. Material created by the student as a research or teaching assistant also may be included.
- Updated resume
- 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 plans, and a discussion of the effectiveness and limitations of the MS program in helping meet these goals. If the student undertook an internship as part of his or her academic program, a written description of the project, including a discussion of how the experience relates to the student's field and a summary of what was learned, must be included in the portfolio,

along with copies of any non-proprietary documents or presentations created by the student during that period.

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 an electronic copy of the portfolio to the Committee two weeks prior to the final examination date.

- The Examining Committee will review the material submitted and hear a 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 the Computer Science and Economics departments in evaluating the effectiveness of the MSEC program.

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 MSEC website jointly maintained by the Computer Science and Economics departments.