The Early Career Section offers information and suggestions for graduate students, job seekers, early career academics of all types, and those who mentor them. Angela Gibney serves as the editor of this section. Next month's theme will be research.

Careers in Business, Industry, and Government

A Mathematician's Field Guide to Jobs in the Finance Industry: Practical Advice for Those Far from Home

Thomas Fleming

1. Terra Incognita

To outsiders, the finance industry can appear as an amorphous mass of companies whose business is somehow related to "the market." In fact, there are a variety of firms, engaged in a variety of types of activity, offering a variety of jobs to the mathematically inclined. The companies are often broken into broad categories. The *sell side* or *broker/dealers* refers to investment banks who execute financial transactions mainly at the request of their clients. Sell-side firms tend to be large companies, such as the big-name banks you may have heard of, and their clients tend to be large industrial corporations, as well as the investment managers and hedge funds mentioned below. *Investment managers* are companies that collect money from individuals, university endowments, pension funds, or other institutional investors, and then make investments in stocks, bonds, or other assets on behalf of their clients, for example by managing a mutual fund. These include large well-known mutual fund and insurance companies, as well as smaller boutique managers. *Alternative investment managers* or *hedge funds* work similarly to investment managers, but typically pursue more complex investment strategies and are subject to fewer regulations. Some hedge funds are quite large, others have only a handful of employees, but few of them are household names. Hedge funds and investment managers are often collectively referred to as the *buy side*. *Proprietary trading companies* work similarly to hedge funds, but typically only manage the capital of their employees or private owners. They tend to be small companies that are not well known outside of the finance industry, but include many of the companies engaged in high-frequency trading.

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Fintechs are companies that are attempting to use new software or business approaches to replace or improve aspects of the traditional financial system. These are typically more similar to a technology start-up than a traditional finance company. This taxonomy is not complete; there are numerous other types of businesses that operate in or adjacent to the finance industry.

Firms in the financial industry are often informally divided into areas known as the *front office*, which refers to the groups engaged in the primary revenue generating business of the firm, such as trading, portfolio management, or interacting with customers; the *back office,* which refers to support functions such as accounting, human resources, or technology groups; and the *middle office,* which, while more vaguely defined, generally encompasses support functions that interact closely with the front office, such as risk, treasury, or certain operational functions.

Within a single firm, mathematicians can be found throughout all three areas, doing many different jobs. Here are a few of the most common. *Desk quants* are often found at sell-side firms, and they provide data analysis, pricing models, and other technical support to a group of traders. Desk quants have a mix of mathematical backgrounds, but need strong communication skills. *Researchers* at quantitative investment managers often develop *signals*, which are predictions of future asset price movements based on data. Thus, researchers generally have strong statistics and machine learning backgrounds. Other researchers with deep knowledge of optimization techniques might work on *portfolio construction*, combining signals into investment holdings, or on determining the optimal method of executing trades. *Risk managers* model the movement of asset prices and attempt to quantify the potential losses the company may face. They often use linear algebra in their work. *Quant developers* build software tools, and as such typically have expertise in programming languages and working with large data sets.

2. Culture Shock

Much like spending a sabbatical in a foreign country, there will be some differences between your life in finance and your life before. Every firm in finance is different, and some will be exceptions to the generalities below; however, here are a few of the changes to expect.

Academic work has a great degree of flexibility in both time and space; work in the finance industry generally has little of either. That is, while grading homework at a coffee shop or proving theorems after midnight may be normal habits for an academic, those working in finance often have an inflexible schedule driven by market hours. There is preparation before the start of trading, activity while the market is open, and then work to respond to the day's events after the market closes. This typically means spending 10+ hours per day in the office, during standard working hours.

The word "office" may conjure images of a room with a door that closes, but this is not the typical working environment in finance. The general rule is a large, open-plan space, with seating in cubicles or at *bench desks*, which are essentially long tables with a computer and chair every few feet. The sound level can vary from busy coffee shop to major sporting event, depending on the firm and the day. While COVID-19 has led to increases in remote work, how much the work environment will change remains to be seen.

Another important difference is the time scale of the work. It may take months or even years of grappling with a mathematical research problem to yield publishable results. In finance, projects typically need to show results in weeks to a few months at most. Even projects with longer durations need to show incremental progress. Further, in mathematics, the work dictates the time frame. That is, you spend however much time is needed to prove the result you are after. In finance, the time frame often dictates the work. When an answer is needed quickly, you need to find an approximation or make assumptions to get an answer, rather than spending the longer time needed to find the fully correct result.

Also, as a mathematician, you probably have a great deal of freedom to choose the problems you think about. When working at a financial firm, as in any industrial job, the topics you work on will likely be dictated by your manager, especially during your first few years.

Math departments are populated by math professors and math students. Financial firms require a much broader mix of skills and expertise from their employees. As a result, many of your colleagues may not have analytical backgrounds and may approach the world in a very different way than you do.

Finally, it is important to remember that while interrupting a mathematician's talk by saying "That can't be right!" is generally viewed as an invitation to a friendly discussion of the idea at hand, for nonmathematicians such direct disagreement, particularly from someone junior in the hierarchy, can be offensive.

3. Getting the First Job

Mathematics is in the realm of ideas, and many theorems can be proven using nothing more than a pencil, some paper, and a great deal of cleverness. Problems in finance are generally attacked by analyzing data, and that data lives in computers. Thus, fluency in programming and data manipulation is crucial. While there are many languages in use, some of the most common tools are the scripting languages Python and R, the query language SQL, and C++.

Financial firms hire mathematicians as much for what they are able to learn as for what they already know. However, some of the material covered in a graduate mathematics education is directly applicable to the world of finance. Here is an incomplete list of some of the most useful topics.

Much of the work in finance is computational, so facility with the practical application of both calculus and linear algebra is important, and experience with computational simulations is helpful. Probability and statistics often appear in interviews, and regression and point estimation are widely used on the job. Nonparametric statistics and machine learning are used in roles where forecasting is important, as is econometrics, including factor models, filtering, and time-series techniques. Stochastic calculus is used in some pricing models. Knowledge of optimization algorithms and how to apply them in practice is valuable, as the goal of nearly every finance business is to make as much revenue as possible, subject to some constraints.

The best, if most labor intensive, way to find jobs is to network. This means searching through your friends, acquaintances, alumni of any institution you've been affiliated with, or anyone else who might plausibly talk to you, to find someone who works in finance, or who can introduce you to someone who does.

When you find someone in the industry to talk to, tell them a little bit about yourself, but mostly ask the person about their career, the kinds of things their firm does, and what mathematicians do at their firm. Don't explicitly ask for a job—that will be clear from your interest. Do ask if they can recommend anyone else for you to talk to.

Most companies in the finance industry work with *recruiters*, also known as *head hunters*, which are independent companies whose sole business is finding job candidates for specialized roles, including most quantitative jobs. There are a large number of recruiting firms, some better than others. Ask the people you network with, or your university career center, to recommend a good recruiter.

If you are in a university setting, attending career fairs or information sessions is a good chance to get face-to-face interaction with a firm that is hiring. These may be campus-wide affairs, or they may be organized by a single program or department. Finding them may take some detective work.

Applying for jobs directly through a company's website, or through a job listing site, is a relatively quick process, but most listings attract many applicants, and the chance of standing out from the field is low. Low, but not zero.

Cast a wide net. Your first job may not be your ideal job, but moving within the industry is often easier than transitioning into it.

The jobs for which mathematicians are hired usually require technical knowledge, so the interviews will usually contain at least some technical questions. That is, you will often be asked to think through a problem or write some code. Sitting silently and staring at a blank sheet of paper may be a good way to prove theorems, but it is not a good interview strategy. In an interview, it is much better to think out loud and communicate your thought process, even when you are uncertain or take a wrong turn. Also, as a highly trained mathematician, you are likely to "know what you don't know" and may answer less confidently than someone with less expertise. When asked a question, avoid phrases like "I'm not an expert" or "That isn't really my area." Simply begin discussing what you do know about the topic, and you may surprise the interviewer (and yourself) with how much you know about it.

Interviewers usually leave some time for the candidate to ask questions at the end of the interview. This is your chance to get some sense of what the job really is and what doing it every day will actually be like. Since you are changing careers, moving from an academic environment to a corporate one, it is important to make good use of this opportunity. Questions like "What is a typical day like?", "What are some examples of projects that the person you hire will work on?", "How does this group contribute to the overall business?" and "What do you like best about this firm, and what could be better?" will at least give you some hints as to what you are getting yourself into.

4. Keys to Success

In mathematics, following your interests is often the key to victory—it's much easier to prove theorems on topics you enjoy. In finance, getting distracted by intriguing problems of limited use for the business is considered to be the classic personality flaw of a quant. It certainly can be career limiting.

A quant who understands how the business works, and how their work can contribute to the business being better, is a valuable part of the team. Choosing the right problems—the ones you can solve and that will have an impact—is often called *being commercial*, a phrase that is deployed as a high complement.

These skills are particularly important as there are generally more problems to be addressed than you will have time to solve. It is critical to be able to prioritize between competing demands, both from managers and your own sense of importance. Similarly, the problems will almost always be time-sensitive, so effective time management is necessary to squeeze the most productivity possible out of a day.

Any large organization develops politics, and financial firms are larger than any mathematics department. Gaining the confidence of senior people is important to a successful career. Double checking to avoid errors in work that will be presented to senior managers and preparing answers for potential follow-up questions are early steps to becoming a trusted advisor. Working in an area where technical expertise is valued will help you stand out as well. Finally, you may have skills or expertise that your boss does not. It is important that they see you as a partner in their success, and not as a threat to their career.

In the end, businesses in the finance industry are focused on making money, and the surest route to success is to help the business make more money, more effectively. This is why people often prefer to work in a front office

function—the more clearly and directly your work impacts the bottom line, the better.

5. Getting the Second Job

There are a lot of different types of jobs within the finance industry, and your first job is unlikely to be your dream job. However, once in the finance industry, you will quickly meet a lot of other people within the industry. Talk to them and to people in other areas at your firm. Ask them about what they do and what their job is like.

If you discover an area that seems more appealing than the track you are on, moving into it takes some preparation. Figure out what skills are needed for that job and learn them. Even better, find a project in your current role that uses those skills so that you have experience applying them. The timing of the job change is important, too. Moving out of a job too quickly after starting will raise eyebrows, but taking a new job after 2–3 years in your first one is generally seen as acceptable.

Finally, there is no tenure in finance. Turnover is high, and layoffs are common. Every year is a new test, a new chance to prove you can contribute, innovate, and succeed. Good luck!

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Credits

Author photo is courtesy of Thomas Fleming.

A Mathematical Experience in a BIG Career

Kelly B. Yancey

"Intellectual growth should commence at birth and cease only at death."

—Albert Einstein

Research staff members at the Institute for Defense Analyses–Center for Computing Sciences (CCS) are life-long learners. We continue to become proficient in new areas of mathematics and computer science and apply that knowledge to the National Security Agency's mission-research endeavors. It is an exciting and highly collaborative place to work. In addition to high-performance computing for cryptography, CCS's work includes cryptography itself, extensive projects in network security and related cyber issues, signal processing, and emerging algorithmic and mathematical techniques for analyzing extremely complex data sets.

In a 2019 article in the Early Career section of the *Notices* [Yan19] I discussed some of the benefits of working as a research staff member at CCS, a career that I began in August 2016 after I finished a research postdoc at the University of Maryland, College Park (UMD). As I shared in that article, having an open mind about what it means to be a research mathematician has been crucial to my success in finding a satisfying career that works for me and my family.

In 2015, after the second year of my postdoc at UMD, I participated in SCAMP at CCS to learn about a research environment outside of academia. SCAMP is a 10-week summer workshop, hosted every summer by CCS, where researchers tackle difficult problems in support of the National Security Agency's mission. I loved several things about this opportunity: the research environment, my collaborators, and the hard problems that needed to be solved. SCAMP, which brings together mathematicians from a variety of backgrounds and careers, is the subject of a different article in this issue by David Saltman [Sal21].

In my earlier piece and in David Saltman's article, there is advice on how to decide if a career in support of the NSA's mission is right for you. In my 2019 article I also discussed how the chances of being hired by government and industry greatly increase if you prepare ahead of time by participating in summer internships in graduate school or during a postdoc, by taking a few courses in data science or machine learning or statistics, and by learning to program. In this article I highlight the kind of mathematics

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