Quantitative Methods

March 11, 2024

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Preface

About the notes

- These notes aims to support my lecture at the HS Fresenius but are incomplete and no substitute for taking actively part in class. - A pdf version of these notes is available here
- I appreciate you reading it, and I appreciate any comments.
- This is work in progress so please check for updates regularly.
- Do not distribute without permission.

About the author

Figure 1: Prof. Dr. Stephan Huber[1]

I am a Professor of International Economics and Data Science at HS Fresenius, holding a Diploma in Economics from the University of Regensburg and a Doctoral Degree (summa cum laude) from the University of Trier. I completed postgraduate studies at the Interdisciplinary Graduate Center of Excellence at the Institute for Labor Law and Industrial Relations in the European Union (IAAEU) in Trier. Prior to my current position, I worked as a research assistant to Prof. Dr. Dr. h.c. Joachim Möller at the University of Regensburg, a post-doc at the Leibniz Institute for East and Southeast European Studies (IOS) in Regensburg, and a freelancer at Charles University in Prague.

Throughout my career, I have also worked as a lecturer at various institutions, including the TU Munich, the University of Regensburg, Saarland University, and the Universities of Applied Sciences in Frankfurt and Augsburg. Additionally, I have had the opportunity to teach abroad for the University of Cordoba in Spain, the University of Perugia in Italy, and the Petra Christian University in Surabaya, Indonesia. My published work can be

[1]Source: Picture is taken from https://sites.google.com/view/stephanhuber

found in international journals such as the Canadian Journal of Economics and the Stata Journal. For more information on my work, please visit my private homepage at hubchev.github.io.

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About this course

Workload of M-IBS 8 Quantitative & Qualitative Methods for Business

125 h = 56 h (in-class) + 21 h (guided private study hours) - 48 h (private self-study).

Workload of M-IBS 8.1 Quantitative Methods

62.5 h = 28 h (in-class) + 10.5 h (guided private study hours) - 24 h (private self-study).

Assessment

Students complete this module with a written exam of 120 minutes where 50% of the points stem from *M-IBS 8.1 Quantitative Methods* and 50% from *M-IBS 8.2 Qualitative Methods*. A passing grade in this module is achieved when the overall grade is greater than or equal to 4.0.

Learning outcomes:

After successful completion of the module, students are able to:

- assess and discuss coherent research paradigms, based on quantitative, qualitative, and mixed-methods research approaches,
- explain a broad set of quantitative and qualitative methods to collect, gather, illustrate, analyze, and interpret data,
- distinguish and discuss empirical strategies to identify causal mechanisms, causes, and effects.

How to prepare for the exam:

I am convinced that reading the lecture notes, preparing for class, taking actively part in class, and trying to solve the exercises without going straight to the solutions is the best method for students to

- maximize leisure time and minimize the time needed to prepare for the exam, respectively,
- getting long-term benefits out of the course,
- improve grades, and
- have more fun during lecture hours.

Literature:

Cunningham (2021), Huntington-Klein (2022). Illowsky & Dean (2018). Békés & Kézdi (2021)

Content:

- Research Design
  - How to Measure Socio-Economical Reality
  - How to Identify Causes of Effects
  - How to Identify Effects of Causes
  - The Selection Problem and Ways to Solve It (Matching, Natural Experiments, Laboratory Experiments)
- Statistical Toolbox
  - Types of Data (Cross-section, Panel, Time-series, Georeferenced),
  - Types of Variables (Continuous, Count, Ordinal, Categorial, Qualitative)
  - Data Sampling Methods

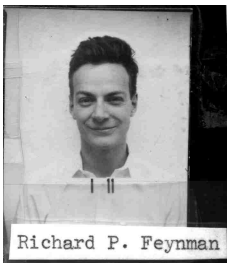
  - Descriptive Methods (Data Visualization, Statistical Moments, Correlation)
  - Methods of Statistical Inference (Distribution, Statistical Tests)
  - Mathematical and Statistical Software Packages (R, SPSS, Excel, WolframAlpha, etc.)

- Methods

  - Data Mining (Graphical Visualizations, Cluster Analysis, Factor Analysis)
  - Regression Analysis (Matching, Instrument Variables, Difference in Difference, Fixed Effects, Regression Discontinuity)
  - Other Methods (Time Series Analysis, Spatial Analysis, Simulations, Qualitative Comparative Analysis, etc.)

About how to learn (and prepare for the exam)

Figure 2: Richard P. Feynman's badge photo from Los Alamos National Laboratory[2]



Richard P. Feynman (see Figure 2):

> "I don't know what's the matter with people: they don't learn by understanding; they learn by some other way by rote, or something. Their knowledge is so fragile!"

Stephan Huber:

> "I agree with Feynman: The key to learning is understanding. However, I believe that there is no understanding without practice, that is, solving problems and exercises by yourself with a pencil and a blank sheet of paper without knowing the solution in advance."

- Study the lecture notes, i.e., try to understand the exercises and solve them yourself.
- Study the exercises, i.e., try to understand the logical rules and solve the problems yourself.

[2]Source: Picture is taken from https://repository.aip.org/islandora/object/nbla%3A299600

- Test yourself with past exams that you will find on ILIAS. The structure of the exam is more or less the same every semester.
- If you have the opportunity to form a group of students to study and prepare for the exam, make use of it. It is great to help each other, and it is very motivating to see that everyone has problems sometimes.
- If you have difficulties with some exercises and the solutions shown do not solve your problem, ask a classmate or contact me. I will do my best to help.

Personal note

Dear students,

If the title of this course "Quantitative & Qualitative Methods for Business" seems uninteresting to you, I assure you that it is actually quite exciting because it focuses on how we can use information to understand how the world and business works and how to interpret facts. The course will enhance your data literacy, help you think critically, and improve your personal decision-making skills.

One way we can do this is by understanding the differences between quantitative and qualitative data and how they can be used to inform our choices.

Quantitative data is information that can be measured, such as numbers and statistics, while qualitative data is information that cannot be measured and is often expressed in words or other non-numerical forms.

Both forms of information are crucial for making good decisions. Without sufficient information, it can be difficult to evaluate the options and potential outcomes of a decision, leading to poor or uninformed choices. In general, the more information a decision-maker has and the faster and better the information can be used, the better they will be to make a sound decision.

The methods we discuss in this course will help you systematically gather information and make sense of it.

Enjoy the course!

1 Doing research

1.1 What is research

Research often involves exploring unknown territory and seeking out new information through methods such as attending conferences, conducting interviews and experiments, and reading related research. This process can lead to the discovery of valuable techniques or insights that address important issues in society or science. Zora Neale Hurston (2010) (see Figure 1.1) paraphrased it beautifully:

> *"Research is formalized curiosity. It is poking and prying with a purpose."* (Hurston, 2010)

Figure 1.1: Zora Neale Hurston, 1891-1960

Source: Photography is taken from Library of Congress: Prints & Photographs Division, Carl van Vechten Collection, Reproduction Number LC-USZ62-54231, see: https://www.loc.gov/pictures/item/2004663047/

Effective research is based on the principles of honesty, transparency and much more. A pithy yet profound quote from Scott Cunningham's book sums up this idea (see Figure 1.2):

> *"True scientists do not collect evidence in order to prove what they want to be true or what others want to believe. That is a form of deception and manipulation called propaganda, and propaganda is not science. Rather, scientific methodologies are devices for forming a particular kind of belief. Scientific methodologies allow us to accept unexpected, and sometimes undesirable, answers."* (Cunningham, 2021, p. 10)

Figure 1.2: Causal Inference: The Mixtape

Source: Cunningham (2021)]

1.2 Everybody can do research

Figure 1.3: Children as little researcher

Source: Image by macrovector on Freepik, see: https://www.freepik.com/free-vector/kindergarten-set-isolated-icons-with-toys-characters-kids-practicing-with-teacher-playing-games-vector-illustration_26760074.htm

Before I go into how empirical research can and should be conducted, I would like to assert that each of us is a researcher in some sense and that you don't need a degree or a higher education to be a (good) researcher. Each of my four children (ages 2, 5, 6, and 8 (at the time of writing this)), for example, explores the world and learns something new every day. Even though none of my children is yet able to verify the novelty of their acquired knowledge and write it down in scientific form, I will claim that mine, like practically all children, are already little scientists. Why? Well, they

explore unknown territory and search for information to discover new techniques that will make their lives pleasant, see Figure 1.3. Of course, they don't attend conferences or read journals to do this. They have never heard terms such as ontology, epistemology, axiology, or quantitative and qualitative methods. They are using methods that they have mastered for their age. They interview me, my wife and all other people around and they conduct experiments. For example, all my children liked to throw plates, cutlery, cups and alike from the table when they were about one year old. At first the throwing was just an accident, but they quickly found out that each throw was followed by a sound when the object touched the stone floor. My first son, in particular, took great delight in making these sounds. He threw everything within reach to the ground and giggled with joy at the clink he made when the object hit the ground. Perhaps he was also enjoying the attention he was getting from us parents through these actions. In any case, the behavior annoyed us. Wiping food scraps off the floor is not a nice thing to do. Unfortunately, at that time my son did not accept any argument to refrain from throwing. Neither a stern look nor a definite "no" helped to stop this behavior. Too great was the joy at the relationship he had figured out, which was, "I throw something off the table and it always clangs beautifully loud." So I started to do some research to figure out what I could do to stop him. The short answer I found can be summed up pretty well as "nothing". There is practically no good method to change the behavior without possibly negatively influencing his early childhood development. The reason is he did some research and we should not suppress that. Besides nature and material research he did social research: He found out that things fall to the ground (gravity), that things break and make different sounds (material research), and that other people notice him when he throws things (social research).

Once, when we were eating at a friend's house, my son (once again) threw everything off the table one after the other in unobserved moments. This time, however, it made no noise. The carpet under the table muffled everything. My son was irritated and at some point became really angry. Why? Well, his surely believed reality and his law "I throw something from the table and then it always clangs beautifully loud." was falsified. Soon he understood that his law only had to be adapted a little. It was then: "I throw something from the table and it clangs then beautifully loudly if a stone floor is under me." He repeated his experiments for a few more weeks, to check its validity. In the meantime he does other experiments trying to contribute to his own knowledge.

In general, the purpose of research is to find new knowledge or discover new ways to use existing knowledge in a creative way so as to generate new concepts, methodologies, inventions and understandings that -now or later- may be of some value for the human mankind. In simple terms, we aim to find something out. We aim to find a new law, a new relationship, a new insight. Or, we aim to challenge and revise existing insights on how the world works. You don't need a degree to do that. All you need is interest, open-mindedness, and a willingness to revise your ideas about how the world works. The latter is perhaps the most important skill you need to be a good researcher. Otherwise, one is a narrow-minded, and bigoted person who is too proud to follow up an insight with a change of mind.

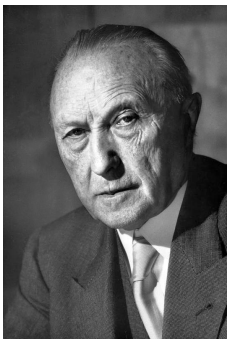
I myself have a quick and happy tendency to change my views because it is a statement of a fresh understanding. Here are two more quotes from Mr. Keynes (see Figure 1.4) and Mr. Adenauer (see Figure 1.5), two historically slightly more significant people than me that are along the same lines and should convince you that changing your mind is not a sign of weakness, but of strength. Especially in science, the willingness to change one's mind is essential.

Figure 1.4: John Maynard Keynes (1883-1946)

Source: Photography is public domain and stems from https://de.wikipedia.org/wiki/John_Maynard_Keynes#/media/Datei:Keynes_1933.jpg

"When the facts change, I change my mind. What do you do, sir?"[1]

Figure 1.5: Konrad Adenauer (1876-1967)



Source: This photography from 1952 is public domain and stems from the Bundesarchiv, B 145 Bild-F078072-0004, Katherine Young, CC BY-SA 3.0 DE.

"What do I care about the rubbish I said yesterday? No one can stop me from getting smarter every day." ("Was interessiert mich mein Geschwätz von gestern? … es kann mich doch niemand daran hindern, jeden Tag klüger zu werden.")[2]

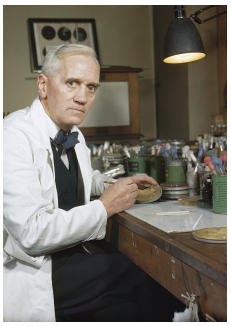
[1] This quote is often attributed to Keynes, but there is no clear evidence for it, see: https://quoteinvestigator.com/2011/07/22/keynes-change-mind/

[2] Freely quoted (and translated) from Weymar (1955, p. 521)

1.3 It's difficult to do good research

Simply trying something and seeing what happens, like my children do, is a research method that relies on luck and chance. Before I go into more grown-up ways of doing research, I want to emphasize that the role of chance and serendipity in research is often downplayed and not acknowledged. The most well-known example of such research is the discovery of penicillin by Alexander Fleming. In 1928, Fleming was studying the properties of staphylococcus bacteria when he noticed that a mold called Penicillium notatum had contaminated one of his bacterial cultures. He noticed that the mold seemed to be inhibiting the growth of the bacteria, and he began to investigate this further. Eventually, he was able to isolate and purify the active ingredient in the mold, which he named penicillin, and he discovered that it had powerful antibiotic properties. This discovery revolutionized the field of medicine and has saved countless lives.

Figure 1.6: (#fig:fleming) Sir Alexander Fleming (1881-1955)[3]



Doing something on purpose and observing how things respond to the action can be considered a research strategy. Acting like a child or just waiting for something to happen by chance can also be considered a research strategy, and of course this can contribute greatly to knowledge. However, it are a naïve and poorly targeted strategies to conduct research. There are more grown-up research methods that are targeting more precisely the gaps in our knowledge and speed up innovation in the field where progress is desperately needed.

What we do and how we observe what is happening should be done in a way to increase the likeliness that we find something new and interesting and in a way that allows us to be rather certain that our results are true and are less likely to be falsified soon later.

For example, assume that there is a disease that can kill people. The childish way to figure out how to cure the disease would be to observe who gets sick and who dies, and finally hope to find a cure for the disease by accidental observation. This is most likely not a very promising and quick method. It would probably be much better to study the matter systematically. For example, a laboratory should first seek to isolate the

[3]Photography is public domain and stems from https://en.wikipedia.org/wiki/File:Synthetic_Production_of_Penicillin_TR1

causative virus or bacterium in order to be able to grow and study it outside the danger to humans. Once this is done, we need a precise plan on how we can use all the available knowledge to cure the disease, protect people from infection, or help them survive the disease. In short, we need a strategic way to conduct research, i.e., a research strategy or design.

A *research strategy* is a general plan for conducting a study and a *research design* is a detailed plan for conducting the study. These words are frequently used interchangeably. A research strategy depends on many things including the question, the resources available, the current state of knowledge, the ambitions, whether quantitative or quantitative data are used, and what is considered to be the criteria of good research.

Before discussing some research strategies that can provide reasonable answers to certain types of questions, we should clarify how to ask a research question and what qualifies a research question.

1.4 Asking questions lika a good researcher

Unfortunately, there is no one research strategy that is appropriate for all questions and, what is worse, there is still controversy about what constitutes good research and how to properly ask a research question. In particular, this controversy takes place between researchers who use quantitative data and statistical methods and researchers who use qualitative data and methods.

Quantitative researchers are interested in both the causes of effects and the effects of causes. Experimental setups can allow to validate causes of effects and to measure the effects of causes. With observational data, however, it is often difficult to investigate the causes of effects. Thus, often quantitative research is more interested to quantify the effects of causes. Qualitative researchers also try to determine the causes of effects . However, their data analysis does rely less on statistical inference. A qualitative data set not necessarily requires (large) random samples or structured data (all the data that you can structure in a spreadsheet) in general, but allows to analyze selective and unstructured data (that is data in form of audio, video, text, images and alike). Qualitative research methods allow to classify these data into patterns or to interpret them in a meaningful way in order to arrive at results. Qualitative researchers are more concerned with the *why and how* of decision making and examine people's behavior, beliefs, perceptions of events, experiences, attitudes, interactions, and more in great depth.

In empirical research, inductive and deductive are two different approaches to reasoning. *Inductive reasoning* is a process of collecting data from various sources, such as interviews, surveys or observations, and then use this data to identify patterns, themes, or relationships that can form the basis of a new hypothesis or theory. The goal of these

exploratory studies, is to generate new ideas or insights about a topic, rather than testing a specific hypothesis. *Deductive reasoning* is a process in which the researcher starts with a general theory or hypothesis with the goal to test a specific hypothesis or theory. In most cases, a combination of both inductive and deductive reasoning may be used to formulate the research question and to design the empirical identification strategy.

In what follows, however, we focus on the criteria for *good research* that are more commonly used in evaluating the quality of quantitative research.

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The Effect ch.1+2

Read chapter 1 and 2 of @Huntington-Klein2022Effect and answer the questions below. The b

![(\#fig:theeffect) The book *The Effect: An Introduction to Research Design and Causalit


1. What is the main focus of the book the author is writing about?
   a) Philosophy of science
   b) Qualitative research methods
   c) Empirical research and quantitative methods to identify and measure causal effects
   d) Statistics

1. What is the main challenge faced by quantitative empirical research, according to the
    a) Difficulty in obtaining accurate measurements
    b) Difficulty in interpreting measurements
    c) Difficulty in obtaining data that allows to answers the research question
    d) Difficulty in designing a research that gets a lot of attention

1. What is the author`s main point about research questions?
    a) They should be well-defined, answerable, and understandable
    b) They should be simple and easy to answer
    c) They should be related to the world of traffic
    d) They should be related to the field of quantum mechanics

  Please find solution to the exercise [in the appendix.](#sol:effect1u2)
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References

Békés, G., & Kézdi, G. (2021). *Data analysis for business, economics, and policy.* Cambridge University Press.

Cunningham, S. (2021). *Causal inference: The mixtape.* Accessed January 30, 2023; Yale University Press. https://mixtape.scunning.com/

Huntington-Klein, N. (2022). *The effect: An introduction to research design and causality.* Accessed January 30, 2023; CRC Press. https://theeffectbook.net

Hurston, Z. N. (2010). *Dust tracks on a road.* HarperCollins.

Illowsky, B., & Dean, S. (2018). *Introductory statistics.* Openstax.

Weymar, P. (1955). *Konrad Adenauer: Die autorisierte Biographie.* Kindler.