Reasoning about (strategic) decisions under uncertainty

Valorization

Knowledge valorization is the process of translating academic knowledge into social benefits. Scientific output and impact are difficult to measure and even harder to predict. This is particularly the case in the short-term. The history of science is full of remarkable ideas, which only gained popularity decades after they were conceived. The problem becomes even worse when we consider fundamental research. Clearly, fundamental insights provide the foundation for many applications but often applications only arise long after a fundamental problem has been solved. So at the time the research was conducted it might have been considered useless, and years later as indispensable. To give the reader an idea of how the insights of this thesis can benefit society, this addendum will outline some conceivable applications.

The research presented in this thesis is concerned with fundamental problems in game and decision theory. No economic or industrial applications are discussed making immediate valorization hard to detect. Therefore, we will discuss the game theoretic findings and the decision-theoretic separately to highlight its respective contributions better.

Classically, game theoretic problems are analyzed using the famous Nash equilibrium. Nash equilibrium aims at finding combinations of choices under which none of the involved persons has an incentive to deviate from her choice. The concept can be very useful when applied in the right context but used in the wrong context it can be of little help. Situations in which a strategic interaction is repeated several times might be described accurately by Nash equilibrium. In this situation, people have several chances to learn how their opponents acted in the past and can adapt their actions accordingly. Thus they might end up choosing such that in the following rounds there is no incentive to choose differently as

the opponent choose a certain action repeatedly. If an analyst is interested in such a setting, Nash equilibrium can be an excellent tool. Many economic decisions, however, do not occur repeatedly with the same set of agents involved. In these cases, Nash equilibrium does usually not perform well in explaining peoples' choices. Nevertheless, Nash equilibrium is often used to analyzed non-repeated settings. The most important large scale applications of Nash equilibrium lie in the field of antitrust cases. Antitrust considerations usually involve billions of dollars and possibly drastic consequences for society in the long-term. Of course, there is more to an antitrust decision than a game theoretic model. However, often game theoretic models are used as an underlying intuition of what might happen, for example, in the case of a merger. This might not affect clear cut cases but possibly border cases.

Experimental evidence in this thesis shows that Nash equilibrium or even its weaker version, quantal response equilibrium, do not perform well in describing and therefore by implication in predicting peoples' choices. Consequently, this research shows the need to adapt the models used in practice. Practitioners should have a close look at the outcome of this experiment and related results in the literature to adapt their models if needed. Fortunately, the models that perform well are also easy to implement.

In antitrust cases, there might be several actors to be considered. First of all, the companies in questions and their respective competitors. Secondly, we have to consider the customers. In a business-to-consumer market, it is possible that companies are more sophisticated in their decision making than consumers. However, the consumers' behavior has a significant impact on the outcome of antitrust decisions. The first project presented in this thesis shows how game theoretic models can be tested more extensively. Therefore, those insights might help to build more realistic game theoretic models allowing more accurate predictions of resulting behavior and by implication better antitrust decisions.

Next to these high impact applications there are also countless applications in everyday life and business. One of the most impactful scenarios for society is so-called public good games. These games are characterized by the fact that the outcome of the group is maximized if everybody participates in producing the public good, e.g., not overfishing a certain species of fish in a given region. The challenge, however, comes from the fact that it is always better for any participant to deviate. In the fishing example, this means that if all participants stuck to their respective contingent, it would be better for the individual fisher to fish

more (given that there is no punishment). These kinds of interactions occur in many fashions, e.g., the emission of CO2, use of grounds for farming, maintenance of public infrastructure, and so on. Hence, it is vital for policy makers to have a clear understanding of the participants' behavior to different incentive structures. Even though, Nash equilibrium might be better suited to describe long-term outcomes, a better understanding of initial reactions is vital. Nash equilibria are often not unique, and the analyst can therefore not predict in which pair of choices will prevail. Experimental evidence shows that initial choices can have an impact on the path towards equilibrium. Therefore, the insights of this thesis can help to understand how people will initially react to a new policy and what equilibrium they are likely to end up in. Consequently, better-informed decisions can have large scale impact on society many important settings.

Game theory is also likely to provide intuition for many small scale business decisions. Almost all business degrees include at least one class dedicated to game theory. These classes will not make the students experts in game theoretic analysis. However, they will certainly shape their approach to strategic interactions. Again, many business decisions are not repeated and can therefore not be accurately described using Nash equilibrium. Taking the insights of this thesis and those of the related literature to implement the more accurate models in the curriculum can also have an indirect effect on society through many small scale decisions.

To sum up, the impact of game theoretic findings on society, recall that situations requiring game theoretic thinking are abundant and appear in large scale applications as well as in small-scale applications. The fundamental research presented in this thesis might not directly contribute to a concrete problem, but it will certainly help future generation to make better strategic decisions in a variety of contexts that have a strong impact on society.

The impact of the decision-theoretic research in this thesis is also not immediately linked to societal problems. Decision-theoretic models build the foundation of almost all economic models. They describe how an economic agent chooses given a set of possible choices. This feature appears in many macroeconomic models was well as in microeconomic models. Central banks use macroeconomic models to predict countries GDP, unemployment rate, and many more variables that are taken into account when considering the supply of money needed to support the economy. There are various macroeconomic models. Some of the more sophisticated ones also take into account the uncertainty economic

agents face. This is where the research in this thesis becomes relevant. The uncertainty economic agents encounter can often not be described with an objective probability. In these cases, the standard subjective expected utility model, which underlies most macroeconomic models, has shown to exclude plausible choices. Thus, macroeconomic models may fail to represent important contingencies and might arrive eventually at incorrect conclusions. Again, it is unlikely that applying an alternative to subjective expected utility will change stable outcomes, but there might be borderline cases where it can have an impact on the predictions. Macroeconomics has yet to fully adopt alternative models of decision making under uncertainty. One of the obstacles is that there is a variety of models and no objective favorite. The research in this thesis shows, however, how most models of decision making under uncertainty are linked—a matter that was previously not well understood. This will help practitioners to make more reliable predictions.

As mentioned earlier, decision theory is the basis for most economic models. Therefore, it also plays a major role in many microeconomic settings with uncertainty. Microeconomics can be used to describe a huge variety of social interactions. For example, it can be used to describe how a person should allocate her time. An example of a high impact decision is the education a person should obtain. Does it pay off in terms of person's utility to get a bachelor degree, or is it better to get a master degree, or maybe a more elementary degree will be beneficiary. This kind of decision depends on the demands of the labor market as well as the person's preferences for money and leisure time. Uncertainty arises in this context through the difficulty of determining objective probabilities for the outcomes of the considered paths induced by the obtained education. Another example is the optimal usage of utilities like water, gas, and electricity. Often the prices increase progressively, which makes choosing optimally more challenging than with linear pricing schemes. Again, a person has to predict its future use of resources to choose optimally, and the prediction is a non-objective probability distribution about future events. Microeconomics covers such a broad range of phenomena that it is impossible to give an exhaustive list of possible implications of the research conducted in this thesis. It should be clear, however, that even though no immediate applications are discussed, the potential impact on society can be significant.

In conclusion, this thesis is concerned with fundamental research in decision and game theory. Basic building blocks of economic models are assessed and

brought closer to peoples' actual behavior. These insights can inform practitioners in policy making and business to make more accurate predictions of peoples' behavior and therefore benefit society. Even though fundamental insights do not translate directly into recommendations, they provide insights which will improve the quality of many large and small scale decisions.