Chapter 2
Uncertainty in the History of Economic Thought

Uncertainty as many faces in contemporary economics. These different faces emerged since the 1950s. They are the consequence of an historical debate in the science of economics, which dates back to the early days of modern economics in the eighteenth century. Since then, economists have an ambivalent relation to the problem of uncertainty, which expresses itself in a Janus-face definition of uncertainty. On the one hand, there is the Fundamental Uncertainty Paradigm, which acknowledges uncertainty as a fundamental source of economic phenomena and which perceives the economy as a not perfectly determined system and economic action as not purely random. Therefore, the knowledge problem is argued to be insurmountable in economics. On the other hand, there is what I call the Neoclassical Uncertainty Paradigm, which assumes that the knowledge problem can be overcome on the basis of rational choice theory combined with subjective probability beliefs. The opponents of this concept are aware that it is unrealistic and hypothetical, yet they argue that it is the only way forward in a modern science of economics. This chapter delineates the emergence of this Janus-face conception of uncertainty. I begin with a critical discussion on the knowledge problem in economics and the early desire for general laws and rational economic action. Then, I discuss the methodological and theoretical advancements of the marginal revolution, which lead to the evolution rational choice theory, which will be discussed in the third section. In the fourth section, I concentrate on the classical distinction between risk and uncertainty in the 1920s. Afterwards I briefly introduce the becoming of the concept of subjective probability theory, which allowed economists to reinterpret uncertainty as a form of quantifiable risk. As a consequence, the Janus-face concept of uncertainty evolved. The last section summarizes my findings.

© Springer International Publishing AG 2017

J. Köhn, *Uncertainty in Economics*, Contributions to Economics,
DOI 10.1007/978-3-319-55351-1_2

2.1 The Uncertain Fundament of Economics

We will start our investigation into the origins of the Neoclassical Uncertainty Paradigms in the eighteenth century. By that time the Scottish enlightenment provided a fruitful breading-ground for a rational analysis of the economy. During this time religion and moral convictions still played an important role in economic thought, yet, critical thought, reason and the observations of reality (evidence) gained importance in the sciences (Backhouse 2002). Scientific objectivity became the ideal of economic reasoning. Inspired by Montesquieu's Spirit of the Laws (1793), economic thinkers like Hume and Smith started to search for "constant and universal principles of human nature" (Wertz 1975: 482). The rise of secularism was the starting point of classical economics and it became the aim of economists to identify the laws that govern human welfare (Backhouse 2002: 111). Most prominently, David Hume argues for the ideal of abstract mathematical reasoning. He writes:

> There remain, therefore, algebra and arithmetic as the only sciences, in which we can carry on a chain of reasoning to any degree of intricacy, and yet preserve a perfect exactness and certainty. We are possessed of a precise standard, by which we can judge of the equality and proportion of numbers; and according as they correspond or not to that standard, we determine their relations, without any possibility of error. When two numbers are so combined, as that the one has always a unite answering to every unite of the other, we pronounce them equal; and it is for want of such a standard of equality in extension, that geometry can scarce be esteemed a perfect and infallible science. Hume (1738: III)

Though, the mathematical and statistical techniques of this time were not satisfactory sophisticated, Hume acknowledged their analytical precision. He furthermore argued that these techniques could be used in order to identify cause and effect of a certain phenomenon. His Treaties on Human Nature, for example can be interpreted as an attempt to identify the causes of human action. Though he used no mathematical techniques, he did a critical analysis of the potential causes of human nature to identify the laws that govern human action.

Beside his theoretical economic achievements, Hume contributed to the philosophy of science and particularly epistemology. He argued that there are three forms of human reason:

> For this reason, it would perhaps be more convenient, in order at once to preserve the common signification of words, and mark the several degrees of evidence, to distinguish human reason into three kinds, viz. THAT FROM KNOWLEDGE, FROM PROOFS, AND FROM PROBABILITIES. By knowledge, I mean the assurance arising from the comparison of ideas. By proofs, those arguments, which are derived from the relation of cause and effect, and which are entirely free from doubt and uncertainty. By probability, that evidence, which is still attended with uncertainty.[1] (Hume 1738: III)

To Hume, reason is generally reached either by argument or by proof (Hepfer 2011). Whereby it is necessary to distinguish between different types of arguments

[1] Bold is in the original.

(varying in the supportive evidence and the way of logical inference), which are associated with different levels of uncertainty. If there is no uncertainty, Hume speaks of knowledge, while he speaks of probabilities (meaning weightings), if there is uncertainty. Consequently, arguments are either based on knowledge or probabilities depending on the level of certainty or uncertainty. Proofs on the other hand, are not dependent on arguments, but on definitions. Reason, which can only be reached by argument, is not opposite to uncertainty.[2] Instead reason is inseparably linked to different levels of uncertainty. Only few arguments are based on knowledge, while in most cases probabilities get used to build arguments.

Particularly, inductive reasoning, which implies a stable causal relation between cause and effect, is inseparably linked to uncertainty. Hume, pointed out, that even though it appears to the observer that some cause brings about some effect, because one could observe this relation several times, it neither needs to be the case that there actually is this relation in reality, nor that it will also hold in the future. For this line of thought Hume became associated with the problem of induction, even though he had never referred to it himself in this way. Instead it was John Maynard Keynes who drew the connection between the problem of induction and Hume's philosophy. In Chap. 18 of his "Treaties on Probability" Keynes draws the reader's attention to the following quote from Hume (1772: Part I):

> Nothing so like as eggs; yet no one, on account of this apparent similarity, expects the same taste and relish in all of them. 'This only after a long course of uniform experiments in any kind, that we attain a firm reliance and security with regard to a particular event. Now there is that process of reasoning, which from one instance draws a conclusion, so different from that which it infers from hundreds of instances that are no way different from that single? This question I propose as much for the sake of information, as that with any intention of raising difficulties. I cannot find, I cannot imagine any such reasoning. But I keep my mind still open to instruction, if any one will vouchsafe to bestow it on me.

Hume points to the problem that conclusions derived from induction cannot be demonstrated with the same certainty as conclusions derived from deductive arguments. No matter how many apparently similar eggs one examines, there is no certainty that any egg, will be like the eggs examined sofar (Hepfer 2011). Put in more general terms, Hume identified that there is no necessity from observation that causal relations in the future will resemble causal relations in the past.[3]

---

[2]Today, uncertainty is often interpreted as a lack of reason. To Hume uncertainty and reason belong inseparable together.

[3]Keynes, therefore, suggests in his discussion of Hume's Problem of Induction pretty much in line with Mill (1848) and Popper (1990, 2002) that one should not discriminate between good and bad or more or less certain conclusions derived from induction on the basis of analogous instances. Instead one should try to analyse the underlying causal structure by conducting crucial experiments or using methods of difference. E.g.: "In an inductive argument, therefore, we start with a number of instances similar in some respect AB, dissimilar in others C. We pick out one or more respects A in which the instances are similar, and argue that some of the other respects B in which they are also similar are likely to be associated with the characteristic A in other unexamined cases: The more comprehensive the essential characteristics A, the greater the variety amongst the non-essential characteristics C, and the less comprehensive the characteristics B which we seek to

This scepticism about the state of human knowledge can also be found in Adam Smith's reasoning about economic choice. Smith recognized that economic decision makers were in most cases confronted with imperfect knowledge. According to him economic knowledge is neither sharp nor clear, instead it is cloudy, amorphous, ambiguous or even not available or existent. Furthermore, he doubts the significance or possibility for probabilistic knowledge. Smith attached much greater value to the use of wise human reasoning and the use of moral rules as a basis for action in situations of uncertainty, than for the application of probability calculus. Whereby, he did not deny that decision makers have some probable knowledge of how the future may turn. Instead of forming calculating chances the form probability beliefs based on trends and argument from analogy (Bardy 2013: 9).[4] Bardy (2013: 1) summarizes Smith's position as follows:

> Instead of sharp, definite, determinate, calculated, and exact probabilistic estimates or distributions, inexact, indefinite, indeterminate, and imprecise estimates of probabilities could be derived and used so that decision makers were able to make choices among different possible options that concerned the future in a rational fashion.

His dislike for the use of probability calculus was rooted in his doubt about the most fundamental assumption underlying conventional theories of probability. He had argued: "The world neither ever saw, nor ever will see, a perfectly fair lottery; or one in which the whole gain compensated the whole loss; because the undertaker could make nothing by it" (Smith 1776: 45).

Smith strengthens his argument against the ergodicity[5] of economic events, by an analysis of the insurance market. He argues, that if, economic reality was purely random, it would be possible to insure (based on probability calculations) against any type of risk and there would be no potential for profits in the insurance market.[6]

---

associate with A, the stronger is the likelihood or probability of the generalisation we seek to establish" (Keynes 1921: 219–220).

[4]Smith (1776: 99) argues, that although "[. . .] the risk [. . .] cannot [. . .] be calculated very exactly [. . .]. [It] admits [. . .] of such a gross estimation, as renders it, in some degree, reducible to strict rule and method".

[5]Ergodicity is used to describe a system or pattern that has the same average behaviour over time. The term is derived from the Greek words ergon and odos and describe a particular work-path. In 1969 Paul A. Samuelson (p. 12) has written that if economists hope to move economics from "the realm of history" into "the realm of science" they must impose the "ergodic hypothesis". A similar argument has been put forward by Lucas (1972) and Lucas and Sargent (1982). See also Samuelson (1947).

[6]E.g.: "The lottery of the law, therefore, is very far from being a perfectly fair lottery; and that as well as many other liberal and honourable professions, is, in point of pecuniary gain, evidently under-recompensed." (Smith 1776: 107). And he (pp. 107–107) continues: "That the chance of loss is frequently undervalued, and scarce ever valued more than it is worth, we may learn from the very moderate profit of insurers. In order to make insurance, either from fire or sea-risk, a trade at all, the common premium must be sufficient to compensate the common losses, to pay the expense of management, and to afford such a profit as might have been drawn from an equal capital employed in any common trade. The person who pays no more than this, evidently pays no more than the real value of the risk, or the lowest price at which he can reasonably expect to insure it. But

Both conditions do not hold in the real economy, and therefore Smith concludes that first of all human knowledge is limited, and secondly, that economic events do not happen randomly. Consequently, probability calculus is of little relevance to economics from Smith's point of view.

Both Hume and Smith, thus were well aware of the limits of human knowledge and rejected probability calculus as a reasonable instrument to handle them. Instead they identified an insurmountable uncertainty accompanying economic problems. This uncertainty has two fundamental sources. First, humans are facing epistemological challenges. One of them is the problem of induction, which states that no matter how much effort one spends, knowledge can never be proofed with certainty based on evidence and human observation. Secondly, economic phenomena such as profit show that economic reality is not characterised by randomness. Consequently, epistemological instruments such as theories of probability, which assume an underlying ergodic ontological structure, are of limited use in economic contexts (they can be used in that part of the economy, which is almost ergodic and therefore insurable). Because of this uncertainty surrounding economic action Hume and Smith both observed that economic actors do not always act rationally (Ashraf et al. 2005). As they only possess limited knowledge, they often behave according to customs and moral rules and show behavioural biases, such as over-enthusiasm (Akerlof and Shiller 2009; Johnson and Fowler 2011: 317). Consequently, classical economics was aware of the problem of uncertainty for both epistemological and ontological reasons and virtue ethics, instead of probability calculus, were used to handle the problem. Furthermore, it becomes obvious that the existence of markets and profits presuppose uncertainty. Without uncertainty, there would be no need for economic reasoning nor action and the science of economics. Adam Smith showed during the eighteenth century, that free trade in a free market is much more efficient in handling the forces of uncertainty for the good of society, than a mercantile or centrally planned economy.

However, only few years later, inspired by Hume's and Smith's plea for more scientific economics, probability calculus gained importance in the economic assessment of uncertainty. In this process, fundamental uncertainty and its necessity for the economic problem became less important. Instead of acknowledging Fundamental Uncertainty and investigating its implications for the science of economics, economists concentrated on the development of probabilistic methods that allowed ignoring the fundamental character of uncertainty in economics. The applied probabilistic methods suggested that the problem of Fundamental Uncertainty, as it had been identified by Hume and Smith can be overcome and that optimal choice was even possible in the face of uncertainty. Benthamite Utilitarianism (1781) provided the intellectual basis for utilitarian calculus of decision-making and which is the methodological point of departure for the calculability and apparent control of uncertainty in economics.

---

though many people have made a little money by insurance, very few have made a great fortune; [. . .]."

2.2 The Marginal Revolution and Probabilistic Utility Maximization

As indicated in the previous part of this chapter, the Smithian interpretation of uncertainty did not become dominant in economic thinking. Instead of virtue ethics, probabilistic reasoning gained importance in the economic discourse on the imperfection of human knowledge. In order to substantiate this point, we have to go deeper into the theoretical developments of that time. Jevons (1863, 1871), Menger (1871), and Walras (1874) brought marginal utility theory to the core of economics independent of each other. Based on Bentham's utilitarian idea of pleasure maximization (1781), according to which political decisions should be taken on the basis of the utility or pleasure the policy could provide for the public, they argued that any economic action should be evaluated based on its utility for the individual. Before we discuss theoretical developments in utility theory during the marginal revolution and its mathematical and probabilistic foundations, let us briefly consider Bentham's idea of pleasure maximization.

In 1781 Jeremy Bentham in his "Introduction to the Principles of Morals and Legislation" brought the idea of utility to the forefront. He suggested the measurement of quantities of pleasure as something positive and pain as something negative. The utility of something is the difference between the positive and the negative effects of it. Consequently, the utility of an action or policy can be positive or negative. Furthermore, the utility of one and the same thing can be different for two persons. While one person may like ice-cream, another person may hate it. For the first person getting a bowl of ice-cream would have a positive utility, while the same event would have a negative utility for the second person. Individual preferences determine how someone evaluates something. Yet, Bentham argued that the utility judgements of one person can be compared to the judgements of the other person. This allows for an overall measurement of utility. Bentham was the first who made an attempt to formalize this idea and use it as a scientific basis for social policy (Stigler 1950: 309). To Bentham, legislations should be judged on the basis of the utility it provides for the members of society. J. B. Say (1880: 138f), then was the first person, who applied utility reasoning to economic problems in the 1820s (Viner 1925). He integrated both the concept of utility as well as the concept of marginal analysis into economic theory and thereby the principle of diminishing marginal utility found its way into economics. Still, marginal utility theory was not applied in economics before the 1870s. By that time the key ideas of the marginal revolution condensed. Jevons unified marginality, utility, maximization and individualism, in a mathematical equilibrium concept. Figure 2.1 shows the formula:

$$\frac{MU_1}{MU_2} = \frac{p_1}{p_2}.$$

Fig. 2.1 Utility function, Jevons (1871)

He (1871: 231) explains his equation as follows:

> Production in a market governed by free competition is an operation by which the (productive) services may be combined in products of appropriate kind and quantity to give the greatest possible satisfaction of needs within the limits of the double condition that each service and each product have only one price in the market, at which supply and demand are equal, and that the prices of the products are equal to their costs of production.

The marginal utility and the marginal costs of a good or service, or taken even more generally, of any action are assumed to be equal to its price. Thereby, utility became measurable in terms of money values. Furthermore, Jevons assumes, following Bentham, that each individual aims to maximize his or her utility. If any market participant is following these principles, equilibrium prices will be reached and overall utility will be maximized. From the level of policy choice this theory was transferred to the individual level. If any individual follows the logic of the theory, overall utility will be maximized. Therefore, it was reasonable to take individual choices on the basis of this originally rather general theory.

Marginal utility theory became a new guide to action in a time in which sensible choice became more and more difficult. Compared to earlier times, a flood of information overwhelmed decision makers in the late nineteenth century. The amount of information available increased significantly, while moral or Christian values crumbled as a basis for reasonable choice (Hacking 1990; Bernstein 1998; Esposito 2007; Ferguson 2009). Quantification became the new guide to action in different areas of life and politics. Jevons was proud of his achievements and introduced a new era for the science of economics and politics. He (1871: Chap. 1) writes:

> Previous to the time of Pascal, who would have thought of measuring doubt and belief? Who would have conceived that the investigation of petty games of chance would have led to the creation of perhaps the most sublime branch of mathematical science-the theory of probability? Now, there can be no doubt that pleasure, pain, labour, utility, value, wealth, money, capital, etc. Are all notions admitting of quantity; nay, the whole of our actions in industry and trade certainly depend upon comparing quantities of advantage and disadvantage.

Jevons's and other economist's enthusiasm for quantitative theories and models reflects the spirit of the time. During the nineteenth century more and more aspects of human life became measured. Statistical data was collected increasingly and statistics got used during the industrial revolution more and more extensively. Bernstein (1998: 191) even writes of an 'explosion' of scientific (meaning statistical) research. These quantitative surveys got used in the growing insurance industry as well as in politics. Fire insurances and trade insurances became used on a larger scale. The insurance companies used statistics as a basis for calculating the insurance rate. In this way, the risk of a house burning down became quantifiable for the first time; it was no longer a matter of bad luck.

At the same time safety and certainty became purchasable. People were bestowed the opportunity to hedge against risks, and thereby escape the wheel of fortune. Purchasing a security did not change the possibility for a house burning down, yet it eliminated the risk of becoming homeless. The price of the insurance therefore was the price for the risk avoidance. Consequently, some uncertainty was

turned into certainty. The possibility of becoming homeless was eliminated and thereby one part of the future predefined and some uncertainty eliminated. Yet, the way in which the future will actually unfold, was still uncertain. Only the potential consequences of potential future developments became certain. One possibility was taken from the future and risk became tangible. However, uncertainty about the development of the future was not turned into certainty about the future. This opened up the possibility for riskier individual behaviour and thereby led to an increase in foreign trade (Willett 1901; Bernstein 1998). The use of statistical methods and probability theory in everyday life strengthened the belief in a free market economy, in which anybody is free to insure against any kind of risk. The introduction of probability theory allowed for the liberation from old social and economic structures and at the same time contributed to a more scientific image of economics, which before had been associated with moral philosophy rather than science. This optimism, brushed away Smith's and Hume's doubts about the uncertainty and incalculability of economic reality.

At that same time, statistics about social measures also got used for policy legitimization. Measures of unemployment, crime rates like income statistics or health measures were collected and policies got evaluated on the basis of the development of these measures. Bentham would have been pleased by these developments. In a way his ideas about the measurement and use of utility were executed in practice. However, also in theory his utility concept gained importance. Both the leading economists and mathematician Francis Edgeworth (1894) and the brilliant young mathematician Frank Ramsey developed concepts of utility measurement machines. Edgeworth's 'hedometer' even found its way into the hard core of economic theory. However, Ramsey's (1926: VII)[7] idea of the creation of a 'psychogalvanometer' remained an ideal. Though these ideas gained no practical relevance in the first place, they can be understood as pre-theories or tools to rational choice theory (Mirowski 1994).

2.3 From Reason to Rational Choice Theory

As already indicated, the ideal of rational choice changed fundamentally at the end of the eighteenth century.[8] Ideas of the free individual replaced clerical and moral ideas about the good life. This increased the experienced uncertainty and ambiguity

[7]For a detailed discussion of Ramsey's concept see Gillies (2012: 53ff).

[8]Yet, in the period between 1870 and 1925 stochastic theory and the development of neoclassical economic theory were not linked. Neither the marginalists, such as Jevons and Edgeworth or pioneers in statistics and economics like Bowley and Allen (1935), Bowley (1939), Keynes (1921, 1936, 1937), Slutsky (1937) and Wald (1939) stressed or emphasised a link between economics and statistics (Mirowski 1989: 222, 1994; Barnett 2011: 190). Though, Jevons used graphical techniques to discuss the price level, whereas Edgeworth worked with index numbers and Bowley (1939) published empirical work on wages and the distribution of income, "none of the first two

of reality significantly. Decisions became more complex and moral evaluation standards vanished. Therefore, the nature of choice changed fundamentally. The new disorientation led to the development of a new actor or decision-making model. Originally, it was the reasonable housefather, who took decisions in advantage of his family (Priddat 2014). Only men had transaction rights during that time, while women were responsible for the internal housekeeping. It was the duty of men to care for their families. Already in the ancient world with its oicos tradition, housekeeping was associated with prudencia, meaning wisdom. The ideal of the rational actor emerged and got revitalised in the nineteenth century. During the dark ages and at the beginning of modern times, moral rules had predetermined choice. However after the dominance of the church crumbled, a new model of choice was needed. The ancient ideal of the oikosdespotes (lat. pater familias) or rational actor, who was making careful decisions based on reason and wisdom with the aim to maximize the wellbeing of his family was rediscovered.[9]

During the marginal revolution, rational action became an individual subjective concept. Instead of acting according to some general rules or morals, action was assumed to be rational, if the actor makes a choice that best satisfies the actors needs or utility. Consequently, selfishness became reinterpreted as behaving reasonably or rationally. While the oikosdespotes was taking care of his family, the new rational actor was satisfying one's own needs. This also implies that anything that goes beyond individual need satisfaction was irrational. The meaning of rationality thus turned from a moral and social connotation to a subjective and individual concept.

Supported by the developments in economic theory rationality became associated with measurability and probability theory was found to be an appropriate tool to create measurability. The general desire for measurability and reason-based choice was also reflected in economics. Economics was aiming to become acknowledged as a science during the late nineteenth century. The marginal revolution had led to an increasing formalism and mathematical orientation in economics (Blaug 1998). Scientificness was then associated with measurability and the economics adopted these mathematical instruments to increase its scientific status (Mirowski 1992, 2002; Schnellenbach 2002). Therefore, the measurable concept of utility got used to operationalize the individual level of need satisfaction. The preferences, needs and desires of one actor determine how much utility a certain action and their consequences cause for that person. Consequently, maximizing the utility of each

---

generations of innovators of neoclassical price theory such as Jevons, Walras, Marshall, Edgeworth, Bowley and so forth felt compelled to link that particular theory to explicit empirical evidence or to pollute their value theory with stochastic concepts" (Mirowski 1989: 224). Darnell (1981) for example had shown that these economists purposefully rejected applying statistics. Edgeworth on the other hand labelled the hope of obtaining demand curves with statistical methods "criminal" (Edgeworth 1894: 473, 1925: 8). E.g.: "There is really only one theorem in the higher part of the calculus (of probabilities), but it is a very difficult one, the theory of errors, or deviation from an average. The direct application of this theory to human affairs are not very considerable" (Edgeworth 1925: 287).

[9]Described more detailed also in Priddat (2014).

action implies that the needs of the actor can be met as best as possible. The concept of utility already integrates balancing costs and benefits. Thus a utility-maximizing actor always acts to its individual benefit given any potential constrains. Therefore, that actor was assumed to act rationally. Finally, Jevons integrated these trends in society and economics and developed a mathematical model of rational choice. This rational actor model integrated the idea of wise decisions by one oicosdespotes and the idea and utility maximization in favour of one individual and thereby reflects the key ideas of the marginal revolution: methodological individualism, maximization and rationality in the form of calculability (Williamson 1993). The new model builds the fundamental unit of choice in economic theory. Furthermore, maximizing the utility of a choice became the new criteria for reasonable choice as it restored decidability. Due to its formal and objective appearance, utility theory provided a scientific criterion for choice. This new scientific concept replaced moral rules of choice.

It was Jevons, who first integrated probability reasoning into economics. Inspired by the use of probability calculus in the insurance industry as well as in politics, Jevons argued that the theory of probability was a sufficient basis for calculations about the future. Based on the idea of normality and average, Jevons assumed that certainty about the future could be reached based on sufficient historical data. Bernstein (1998: 190) even argued that, "He brushed off the problem of uncertainty by announcing that we need simply apply the probabilities learned from past experience and observation". Quotes like the following suggest that Jevons assumed probabilistic knowledge to be a reasonable basis for rational action.[10]

The new quantitative model of choice eliminated some uncertainties and ambiguities, which characterised the problem of choice. The theory of rational choice under conditions of perfect information, which includes statistical knowledge, transformed subjective choice into an objective numerical measure. The development of statistics was essential for the emergence of the statistical concept of knowledge in economics (Schnellenbach 2002; Bilboa 2008).[11]

The concept of imperfect knowledge re-enters into the economic discourse around 1870, during the so-called Marginal Revolution. It was the Austrian Carl Menger, who argued in his "Grundsätze der Volkswirtschaftslehre" (1871) that the imperfection of human knowledge about the quantity and quality of goods as well as about agent's own needs initially requires economic action. Put the other way around, Menger argues that if human knowledge were perfect, there would be no need for economic action. Menger's argument is similar to that of Smith. Consequently, he concludes similarly to the classical economists, that economic relations

[10] The test of correct estimation of probabilities is that the calculations agree with the fact of the average. [. . .] We make calculations of this kind more or less accurately in all ordinary affairs of life (Jevons in Bernstein 1998: 190).

[11] This certainly included the findings of Laplace (1814), Gauss, Bernoulli (1738) and Louis Bachelier (1900). See also Bernstein (1998) and Hacking (1990, 2001, 2006, 2014).

are characterized by the uncertainty of quantities and qualities of production as well as by the unintended consequences of human action (Beckert 1996: 806). This presumption also builds the foundation for the Austrian theory of the entrepreneur, as a risk-taking agent, who is better informed or has more courage than other market participants.[12]

Acknowledging the limits of human knowledge, however, was a serious challenge to contemporary theoretical economics. Léon Walras in his pioneering 1874 work "Elements of Pure Economics" had developed an equilibrium model of a perfect market, which was built on the assumptions of perfect knowledge, no time lag and no monopolistic competition. Walras showed that under these perfect conditions markets always reach Pareto-efficient[13] allocations. Now, the introduction of imperfect information endangered this analytically elegant general equilibrium theory. Menger's emphasis on the imperfection of human knowledge sank into oblivion until Frank Knight (1921) and John Maynard Keynes (1921, 1936, 1937) revitalised the discussion about the problem of uncertainty in economic theory and entrepreneurial practice.

2.4 Separating Uncertainty

Since the beginning of economic reasoning about uncertainty there were two competing schools. One the one side there were the uncertainty purists, who acknowledge uncertainty as an important force in the economy as well as a serious challenge to knowledge about the functioning of the economy and economic theorizing. On the other side, there were those economists, who were well aware of the problem of uncertainty and argued that utility maximizing choice on the basis of probabilistic knowledge is the rational economic way to manage this economy endogenous uncertainty. Between 1920 and 1950 these two schools of thought split up completely. From then on we can distinguish between the Fundamental Uncertainty Paradigm and the Neoclassical Uncertainty Paradigm, which reinterprets uncertainty as risk and thereby neglects its fundamental significance for the economy and economics.

The common starting point of the division was Chicago economist Frank H. Knights dissertation "Risk, Uncertainty and Profit" (1921). He distinguished most prominently between risk and uncertainty. While there was unity about his definition of risk, his conception of uncertainty was interpreted in exclusionary ways. The first interpretation was inspired by Hume, Smith and Menger and defined

[12] As we shall see later, also Friedrich A. von Hayek (2007) bases his fundamental criticism against socialism on this insight. He, similar to other Austrians argued, that central planning is necessarily insufficient, due to the lack of knowledge of the planning agency.

[13] Pareto efficiency is a state of market allocation in which it is impossible to make any one individual better off without making at least one individual worse off (Sen 1970).

uncertainty as a fundamental force underlying all human and economic action. The second, inspired by the probabilistic utility maximizing theories of the Marginalists and particularly Jevons, interpreted uncertainty as a problem of subjective probability theory. The later interpretation became dominant in economics, in the form of the Neoclassical Uncertainty Paradigm, which developed in the 1950s (Lawson 1985a, b; Esposito 2007; Beckert 2011). However, contemporary textbooks, such as Marshall's "Principles of Economics" (1890), already reflect the spirit of the Neoclassical Paradigm in the 1920s.

Underlying Knight's distinction between risk and uncertainty is the assumption that economic choice and entrepreneurial action is only possible if human knowledge is imperfect. In his study on the origin of profit, Knight shows, that profits can only arise in imperfect markets. Beckert (1996: 807) summarises Knight's fundamental rejection of the perfect market model and rational choice theory in this way:

> Under the assumption of perfect markets economic theory cannot explain profits, because the market will attract new suppliers until the price of the good equals the marginal costs of the product. [. . .] Agents are uncertain about the future state of affairs and therefore cannot, in a dynamic economy, make decisions that lead to equilibrium outcomes.

Consequently, Knight rejected a utility maximizing approach to economic choice. In his book, he discussed how entrepreneurs actually make decisions in situations of uncertainty, instead of providing an elegant mathematical theory. *Risk, Uncertainty and Profit* is a scientific study of entrepreneurial practice rather than a book on economic theory (Runde 1998). In analysing entrepreneurial behaviour, Knight found fundamental differences in the stages of knowledge economic decision makers may possess. Thereby he laid the foundation of our modern understanding of the limits of human knowledge in economics. Knight distinguishes three stages of human knowledge; certainty, risk and uncertainty. And according to him economics is particularly concerned with the later two.

Consequently, it was Frank H. Knight (1921), who distinguished risk from uncertainty. In this way uncertainty became defined in contrast to risk and not independently. Based on the assumption that human knowledge, particularly about the future, but also about past and present is imperfect,[14] Knight argues that any economic theory, which assumes full knowledge, is insufficient. In order to understand the workings of the economic system the meaning and significance of the imperfection of human knowledge needs to be examined (Knight 1921: 199). This is his starting point for an inquiry into the nature and function of knowledge and its interrelation with economics. His investigation into the relation between knowledge and economics, leads him to the conclusion that most of the knowledge used in economics is probabilistic knowledge.

He distinguishes between three types of probabilistic knowledge used in economics. First of all, there is a priori probabilistic knowledge, which can be derived

[14]Cf. Knight (1921: 202): "We do not perceive the present as it is and in its totality, nor do we infer the future from the present with any high degree of dependability, nor yet do we accurately know the consequences of our own actions."

from logical principles. A priori probability can be derived from "(a)bsolutely homogenous classification of instances completely identical except for really indeterminate factors." And he (1921: 224) continues that "(t)his judgment of probability is on the same logical plane as the propositions of mathematics." A priori or logical probabilities are therefore applicable to games of chance.

The second type of probabilistic knowledge is based on statistical probabilities, which can be derived from the analysis of empirical data. Naturally, these probabilities are weaker than those derived from a priori principles, as they are based on the conviction that "[. . .] the proportions found in the past will hold in the future." (Knight 1921: 225) Already, Hume (1738, 1772) had argued convincingly, that tough it might be wise for reasonable men to make this assumption, in order to gain insights, there is no certainty that the future will be like the past.

And thirdly, knowledge used in economics is based on estimates. In situations in which estimates are used "there is no valid basis for any kind for classifying instances.[15]" (Knight 1921: 225) In these situations common knowledge or intuitions get used for making economic decisions.

Based on these three types of knowledge in economics, we can now derive the classical dualist conception of risk and uncertainty. To Knight, any situation in which a priori or statistical probabilities are attainable is a situation of risk, whereas situations of uncertainty are those in which only estimates can be used. By the time, Knight was writing his dissertation the third type of knowledge was neglected in economics (Knight 1921: 231). Yet, to him it was the key to understanding the need for economic reasoning as well as for making sense of the origins of profit. Knight, thus, comes to similar conclusions as Menger, even though the two had very different backgrounds.

> It is this true uncertainty which by preventing the theoretically perfect outworking of the tendencies of competition given the characteristic form of "enterprise" to economic organization as a whole and accounts for the peculiar income of the entrepreneur. (Knight 1921: 232)

From this analysis of knowledge in economics Knight (1921: 233) distinguishes between "[. . .] the measurable uncertainty and an immeasurable one [. . .]". The measurable uncertainty, which can be quantified by either a priori or statistical probabilities, he calls "risk". Whereas situations in which no objective probability calculus can be applied and only estimates are available are termed "uncertainty".

Almost as if he had anticipated the upcoming developments in probability theory, he argues that one can also distinguish risk from uncertainty on the basis of objective and subjective probabilities. The difference between the two categories being, that the former are based on objective or interpersonal evidence, whereas the later are based on personal judgement. By the time, Knight was writing there was also a technical difference between the two. While objective probabilities where quantifiable, subjective probabilities were not yet. In the course of time, the details of Knight's theory were neglected, so that his distinction often got restated in an

[15]Italic is in the original.

incomplete way.[16] As a consequence, risk got defined in economics as any kind of measurable imperfection of human knowledge. Risk in economics is thus a case in which agents possess statistical or stochastic knowledge. While uncertainty got defined as a situation, in which agents do not have access to any kind of statistical or stochastic knowledge. Consequently, choice in situations of uncertainty is rather random guess, than rational choice. Yet, Menger (1871) and Knight (1921) had argued that, particularly situations of uncertainty are crucial in economic theory and still they were not compatible to the theory of rational choice and perfect markets, and therefore lay outside of scientific economics.

In the same year (1921) in which Frank Knight's famous book appeared, J. M. Keynes also published his PhD Dissertation "Treaties on Probability". Unlike Knight's book, Keynes' was not a piece of economic research; instead it was a philosophical inquiry into the epistemological foundations of the theory of probability. However, Keynes reached a similar conclusion, namely that there are highly unique situations, about which no numerical probability beliefs can be formed. He (1921: 32) argues, probability "[. . .] is unknown to us through our lack of skill in arguing from given evidence. The evidence justifies a certain degree of knowledge, but the weakness of our reasoning power prevents our knowing what the degree is." Later, in his economic inquiries (1936, 1937), he concludes, like Menger and Knight, that economic situations are in most cases characterised by risk and uncertainty. Therefore, idealistic analyses of market allocations in the tradition of Walras (1874) are according to his view, in most cases, meaningless. Most important economic phenomena, like profit, recession, or investment, can only be explained under the assumption of imperfect knowledge, rather than perfect knowledge (Bateman 1998).

However, by the time Keynes was writing his magnum opus, the neoclassical school of thought dominated economics. There was a joint attempt of economists to become acknowledged as a science similarly precise and mathematically sophisticated as physics. General equilibrium analysis and rational choice theory were particularly suitable for this endeavour. Both theories could be formalised in mathematical terms (Mirowski 1980, 1992, 2002; Weintraub 2002). In the course of time, the two theories, not only became fundamental theories of economics, but also prototypes, of how economic theories have to be in terms of mathematical sophistication and analytical abstraction and elegance. One could even argue, that these theories became constitutive for economics. Any case that could be analysed by these theories was a phenomenon of interest for the science of economics. Any case that could not be approached on the basis of this theory and the applied mathematical methodology, fell outside the interest space of economics.[17] As

[16]Later on, in this dissertation, I will argue that this representation of Knight's classical distinction misrepresents Knight's key ideas. Yet, he is used in the way presented here to legitimize the probabilistic management of uncertainty in economics since the 1950s.

[17]For a more detailed discussion of this thesis, please see Chap. 4. Here, I unfold the argument that shows, that economics became defined on the basis of its methodology and theory, rather than on the basis of real economic problems.

Fundamental Uncertainty did not fit the mathematical economic approach, while being an obvious challenge in economic reality, it became necessary to integrate uncertainty into the rational general equilibrium framework of the newly developing neoclassical scientific economics. New developments in the theory of probability made this integration possible. The newly developed theory of subjective probabilities allowed for the rational calculation of subjective probabilities. This was the starting point of the separation of the uncertainty fundamentalists and the neoclassical subjective probability interpretation of uncertainty.

Opponents of the former interpretation are Chicago Economist Frank H. Knight, Cambridge Economist J. M. Keynes, the Austrian Friedrich A. von Hayek and his student G. L. S. Shackle. They argued that uncertainty is a fundamental characteristic of economic ontology and a serious challenge to economic knowledge. We will discuss their approaches to Fundamental Uncertainty in length in the next part of this book, as their thoughts are diverse and highly relevant for the development of a profound understanding of the problem of uncertainty in economics. Nevertheless, economics was dominated by the neoclassical stochastic Uncertainty Paradigm. The emergence and development of this paradigm is closely linked to the subjective theory of probability and the growing importance of mathematical models and a scientific ethos in economics. One could even argue that the economic mainstream was scared by fundamentalist views on uncertainty. Lucas (1977: 15) for example, noted: "In case of uncertainty, economic reasoning will be of no value." And Arrow's (1951: 417) doubts, when he said that without measurable probabilities "no theory can be formulated" underlines my argument that, Fundamental Uncertainty got neglected due to the fact, that it makes mathematical modelling highly problematic, if not impossible.

2.5 Subjective Probability Theory and Uncertainty

Before the 1920s, the objective view on probability, according to which probabilities can either be calculated based on frequencies from past data or based on logical inference was dominant. Characteristic for both types of objective probabilities is that the state of past or possible events needs to be defined in total. However, Knight had argued that this is impossible in situations of uncertainty. This led him to the conclusion that no probabilities can be calculated in situations of uncertainty. However, only few years after Knights Magnum Opus, Frank P. Ramsey (1926, 1927, 1929, 1931), a British mathematician and philosopher at Cambridge University, who was a close friend to Ludwig Wittgenstein and John M. Keynes, developed the idea of subjective probabilities, which can be defined without a perfectly defined state space. The same idea had also been put forward by the Italian

mathematician Bruno De Finetti (1929). Independently of each other, they argued that degrees of belief can be measured in terms of probability relations. Particularly, Ramsey (1926: 166) admits, that some degrees of belief can be measured more accurately than others, and yet he argues that any kind of subjective degrees of belief about the future can be expressed in terms of numerical probabilities. He reached this conclusion by combining the ideas of utility and probability. To him (1926: 166) the non-objective theory of probability is a branch of formal logic that allows individuals to measure degrees of belief:

> We must therefore try to develop a purely psychological method of measuring belief. It is not enough to measure probability; in order to apportion correctly our belief to the probability we must also be able to measure our belief.

Ramsay's theory of subjective probability is thus a concept that allows for the measurement of rational degrees of belief. And it is based on the assumptions that (1) agents act to their benefit (utility maximising), (2) hold beliefs about everything, (3) beliefs are consistent and therefore rational, (4) an agent's actions reveals their beliefs.[18]

Subjective degrees of beliefs, which can be measured in terms of subjective probabilities, can be derived from hypothetical bets. The concept of betting is key to Ramsey's subjective probability theory. It is based on his view (p. 183), that life "[. . .] is based fundamentally on betting, but this will not seem unreasonable when it is seen that all our lives we are in a sense betting. Whenever we go to the station we are betting that a train will really run, and if we had not a sufficient degree of belief in this we should decline the bet and stay at home. The options God gives us are always conditional on our guessing whether a certain proposition is true."

Ramsey insists that the theory of probability is a part of logic; the logic of partial belief. As a part of formal logic, the theory of probability also underlies the laws of logical reasoning. Consistency of partial belief, is therefore similarly important in the subjective theory of probability as it is in formal logic. If probability beliefs are consistent, they can be classified as rational degrees of belief. This idea of rationality

[18]Consider Ramsey's own words (1926: 176–177): "Let us now discard the assumption that goods are additive and immediately measurable, and try to work out a system with as few assumptions as possible. To begin with we shall suppose, as before, that our subject has certain beliefs about everything; then he will act so that what he believes to be the total consequences of his action will be the best possible. If then we had the power of the Almighty, and could persuade our subject of our power, we could, by offering him options, discover how he placed in order of merit all possible courses of the world. In this way all possible worlds would be put in an order of value, but we should have no definite way of representing them by numbers. There would be no meaning in the assertion that the difference in value between α and β was equal to that between γ and δ. Suppose next that the subject is capable of doubt; then we could test his degree of belief in different propositions by making him offers of the following kind. Would you rather have world α in any event; or world β if p is true, and world γ if p is false? If, then, he was certain that p was true, simply compare α and β and choose between them as if no conditions were attached; but if he were doubtful his choice would not be decided so simply. I propose to lay down axioms and definitions concerning the principles governing choices of this kind. This is, of course, a very schematic version of the situation in real life, but it is, I think, easier to consider it in this form."

interpreted as consistency emerged conjointly with the Neoclassical Uncertainty Paradigm and survived until today. Following Ramsey (1926: 182) rationality in economics of imperfect information, means consistency of beliefs. These beliefs neither need to bet true nor in any way wise, yet they do not contradict the consistency axiom. He writes (1926: 182):

> We find, therefore, that a precise account of the nature of partial belief reveals that the laws of probability are laws of consistency, an extension to partial beliefs of formal logic, the logic of consistency. They do not depend for their meaning on any degree of belief in a proposition being uniquely determined as the rational one; they merely distinguish those sets of beliefs which obey them as consistent ones.

This idea of rationality departs fundamentally from that of classical economics, which interpreted rationality as a way of wise reasoning in the interest of the community. Since the beginning of the twentieth century, however rationality became defined in economics as valid logical reasoning, regardless of its connection to economic reality or truth and independent of its benefits for the economy as a whole. Economic action lost its orientation towards the public welfare.

In 1933 the Russian mathematician Andrey N. Kolmogorov followed this idea in his 'Foundations of the Theory of Probability' and provided a mathematical proof of the subjective theory of probability and thereby described axioms of subjective probability theory still valid today. The theory can be applied to situations, in which objective probability calculus fails. No matter how subjective and weak these numerical measures of subjective belief are, the gap in the measurability of probabilities to which Knight's definition had been pointing was closed.[19]

The flowing quotes from Marshall's The Principles of Economics (1890) already indicate this development. Marshall describes the intersubjective calculability of probabilities in situations of uncertainty (p. 100): "The different uses between which a commodity is distributed need not all be present uses; some may be present and some future. A prudent person will endeavour to distribute his means between all their several uses, present and future, in such a way that they will have in each the same marginal utility. But in estimating the present marginal utility of a distant source of pleasure a twofold allowance must be made; firstly, for its uncertainty (this is an objective property which all well-informed persons would estimate in the same way); and secondly, for the difference in the value to them of a distant as compared with a present pleasure (this is a subjective property which different people would estimate in different ways according to their individual characters, and their circumstances at the time)."

[19]The developments in the theory of probability will be discussed in more detail later in this dissertation. For the historical overview of this chapter it is sufficient to note that probabilities became measurable in situations of uncertainty in the basis of the newly developed subjective theory of probability.

To Marshall a probability measure is an objective property in situations of uncertainty, which can be calculated by well-informed and rational men. Marshall continues in the footnotes (p. 102):

> We may however consider here how to measure numerically the present value of a future pleasure, on the supposition that we know, (i) its amount, (ii) the date at which it will come, if it comes at all, (iii) the chance that it will come, and (iv) the rate at which the person in question discounts future pleasures. If the probability that a pleasure will be enjoyed is three to one, so that three chances out of four are in its favour, the value of its expectation is three-fourths of what it would be if it were certain: if the probability that it will be enjoyed were only seven to five, so that only seven chances out of twelve are in its favour, the value of its expectation is only seven twelfths of what it would be if the event were certain, and so on. [This is its actuarial value: but further allowance may have to be made for the fact that the true value to anyone of an uncertain gain is generally less than its actuarial value (see the note on p. 135).] If the anticipated pleasure is both uncertain and distant, we have a twofold deduction to make from its full value. We will suppose, for instance, that a person would give 10 s. for a gratification if it were present and certain, but that it is due a year hence, and the probability of its happening then is three to one. Suppose also that he discounts the future at the rate of twenty per cent per annum. Then the value to him of the anticipation of it is $3/4 \times 80/100 \times 10$ s. i.e. 6 s.

In this way, Marshall, had adopted Jevon's idea of rational choice based on probabilistic knowledge. Even before the subjective theory of probability had been developed, Marshall introduced the ideas of intersubjective probabilities in the face of uncertainty as a basis for rational choice.

2.6 The Janus-Face of Uncertainty in Economics

From this point on, we have to distinguish two types of uncertainty in economics. Firstly, there is the Fundamental Uncertainty proposed by Knight (1921) and Keynes (1921, 1936, 1937), in line with Hume (1738), Smith (1776), and Menger (1871). This Paradigm turns against the idea of complete determinism and randomness in economics. Instead Knight and Keynes suggest, that uncertainty is an unquantifiable fundamental in economics that brings about surprise and the need for reasonable economic decisions. We will discuss this type of uncertainty more deeply in the second part of this essay.

Secondly, there is the Neoclassical Uncertainty Paradigm, which assumes that any economic situation can be treated "*as if*" it was a situation of risk, even though, there is no option to assign objective numerical probabilities to possible future events. This concept ignores the possibility, that there might be future events, which are unknown to the individual. The original conception of risk merged in the Neoclassical Uncertainty Paradigm. Underlying this concept are the assumptions of complete determinism and randomness of economic events (Beckert 2011).

References

Akerlof GA, Shiller RJ (2009) Animal spirits: how human psychology drives the economy, and why it matters for global capitalism. Princeton University Press, Princeton
Arrow KJ (1951) Mathematical models in the social sciences. In: Lerner D, Lasswell H (eds) Policy Sciences in the United States. Stanford University Press, Stanford, pp 129–154
Ashraf N, Camerer C, Lowenstein F (2005) Adam smith, behavioral economis. J Econ Perspect 19 (3):131–145
Bachelier L (1900) Théorie de la spéculation. Ann Sci École Norm S 3(17):21–86
Backhouse RE (2002) The Penguin history of economics. Penguin, London
Bardy ME (2013) Adam Smith's theory of probability and the roles of risk and uncertainty in economic decision making. Working Papers California State University—Department of Operations Management
Barnett V (2011) E.E. Slutsky as economist and mathematician: crossing the limits of knowledge. Routledge, London
Bateman BW (1998) Keynes' uncertain revolution. University of Michigan Press, Ann Arbor
Beckert J (1996) What is sociological about economic sociology? Uncertainty and the embeddedness of economic action. Theory Soc 25(6):803–840
Beckert J (2011) Imagined futures fictionality in economic action. Max-Planck-Institut für Gesellschaftsforschung Discussion Paper 8, pp 1–30
Bentham J (1781) Introduction to the principles of morals and legislation. Batoche Books, Kitchener
Bernoulli D (1738) Expositions on the new theory on the measurement of risk
Bernstein PL (1998) Against the gods: the remarkable story of risk. Wiley, New York
Bilboa I (2008) Rational choice. MIT Press, Cambridge, MA
Blaug M (1998) The problems with formalism: interview with Mark Blaug. Challenge 41(3):35–45
Bowley AL, Allen RDG (1935) Family expenditure. A study of its variation. Staples
Bowley AL (1939) Three studies in national income. Cambridge University Press, Cambridge
Darnell A (1981) A. L. Bowley, 1869–1957. In: O'Brien DP, Presley JR (eds) Pioneers of modern economics in Britain. MacMillan, London
de Finetti B (1929) L'invenzione della verità. R. Cortina
Edgeworth F (1894) The measurement of utility by money. Econ J
Edgeworth F (1925) Papers relating to political economy
Esposito E (2007) Die Fiktion der wahrscheinlichen Realität. Suhrkamp, Berlin
Ferguson N (2009) The ascent of money: a financial history of the world. Penguin Books, London
Gillies D (2012) An objective theory of probaility. Routledge, London
Hacking I (1990) The taming of chance. Cambridge University Press, Cambridge
Hacking I (2001) An introduction to probability and inductive logic. Cambridge University Press, Cambridge
Hacking I (2006) The emergence of probability: a philosophical study of early ideas about probability, induction and statistical inference. Cambridge University Press, Cambridge
Hacking I (2014) Why is there philosophy of mathematics at all? Cambridge University Press, Cambridge
Hayek FA (2007) The road to serfdom: text and documents. University of Chicago Press, Chicago
Hepfer K (2011) Die Konstruktion der Erkenntnis: 'Imagination' im Treatise on Human Nature. Archiv für Geschichte der Philosophie 9:349–365
Hume D (1738) A treatise of human nature. Biblio Bazaar, Charleston
Hume D (1772) An enquiry concerning human understanding. Hackett, Indianapolis
Jevons WS (1863) A general mathematical theory of political economy.
Jevons WS (1871) The theory of political economy. Palgrave Macmillan, London
Johnson DPD, Fowler JH (2011) The evolution of overconfidence. Nature 477(11):327–320
Keynes JM (1921) A treatise on probability. Rough Draft Printers, New York
Keynes JM (1936) The general theory of employment, interest and money. Palgrave Macmillan, London
Keynes JM (1937) The general theory of employment. Quart J Econ 52(3):209–223

Knight FH (1921) Risk, uncertainty and profit. Nabu Press, Charleston
Kolmogorov A (1933) Foundations of the theory of probability. Chelsea Publishing Company, New York
Laplace PS (1814) Philosophical essay on probabilities. Wiley
Lawson T (1985a) Uncertainty and economic analysis. Econ J 95(380):909–927
Lawson T (1985b) Keynes' economics: methodological issues. Croom Helm, London
Lucas RE (1972) Expectations and the neutrality of money. J Econ Theor 4:103–124
Lucas RE (1977) Understanding business cycles. University of Chicago, Chicago
Lucas RE, Sargent TJ (1982) Rational expectations and econometric practice. University of Minnesota Press
Marshall A (1890) Principles of economics. Prometheus Books
Menger C (1871) Grundsätze der Volkswirtschaftslehre. Mohr Siebeck, Tübingen
Mill JS (1848) Principles of political economy with some of their applications to social philosophy. Hackett, Indianapolis
Mirowski P (1980) The birth of the business cycle. J Econ Hist 40(1):171–174
Mirowski P (1989) The probabilistic counter-revolution, or how stochastic concepts came to neoclassical economic theory. Oxf Econ Pap 41:217–235
Mirowski P (1992) More heat than light: economics as social physics, physics as nature's economics. Cambridge University Press, Cambridge
Mirowski P (1994) Edgeworth's writings on chance, economic hazard, and statistics. Rowman & Littefield, Lanham
Mirowski P (2002) Machine dreams: economics becomes a cyborg science. Cambridge University Press, Cambridge
Montesquieu C, Baron de. (1793) De L'esprit Des Loix (The spirit of laws). Cambridge University Press, Cambridge
Popper KR (1990) World of propensities. Thoemmes Continuum
Popper KR (2002) The logic of scientific discovery. Psychology Press
Priddat BP (2014) Economics of persuasion. In: Ökonomie zwischen Markt, Kommunikation und Überredung. Metropolis, Marburg
Ramsey FP (1926) Truth and probability. Ramsey (1931) The foundations of mathematics and other logical essays. Harcourt, Brace, New York, pp 156–198
Ramsey FP (1927) Facts and propositions. Harcourt, Brace, New York
Ramsey FP (1929) On a problem in formal logic. Harcourt, Brace, New York
Ramsey FP (1931) In: Braithwaite RB (ed) Mathematics and other logical essays. Harcourt, Brace, New York
Runde J (1998) Clarifying Frank Knight's discussion of the meaning of risk and uncertainty, (1921). Camb J Econ 22:539–546
Samuelson PA (1947) Economics. McGraw-Hill Irwin, New York
Samuelson PA (1969) Classical and neoclassical theory. Penguin Books, London
Say JB (1880) A treatise on political economy or the production, distribution, and consumption of wealth. Batoche Books, Kitchener (This is an English translation of Say's Traité d'economie politique, first published in 1803)
Schnellenbach J (2002) New political economy, scientism and knowledge: a critique from a Hayekian perspective, and a proposal for an extension of the research agenda. Am J Econ Soc 61(1):193–214
Sen AK (1970) Collective choice and social welfare. Holden-Day, San Francisco
Slutsky E (1937) The summation of random causes as the source of cyclic processes. Econometrica 5(2):105–146
Smith A (1776) Wealth of nations: an inquiary into the nature and causes of the wealth of nations. Prometheus Books, New York
Stigler GJ (1950) The development of utility theory I. J Polit Econ 58(4):307–327
Viner J (1925) The utility theory and its critics. J Polit Econ XXXIII: 369–387

Wald A (1939) Contributions to the theory of statistical estimation and testing hypotheses. Ann Math Stat 10(4):299–326
Walras L (1874) Éléments d'économie pure ou théorie de la richesse sociale
Weintraub ER (2002) How economics became a mathematical science. Duke University Press, Durham
Wertz SK (1975) Hume, history, and human nature. J Hist Ideas 36(3):481–496
Willett AH (1901) The economic theory of risk and insurance. Columbia University Press, New York
Williamson O (1993) Calculativeness, trust, and economic organization. J Law Econ 36:543–486



http://www.springer.com/978-3-319-55350-4

Uncertainty in Economics
A New Approach
Köhn, J.
2017, IX, 199 p. 9 illus., Hardcover
ISBN: 978-3-319-55350-4