Statistical Thinking between Natural and Social Sciences and the Issue of the Unity of Science: from Quetelet to the Vienna Circle

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Introduction

The application of statistical methods and models both in the natural and social sciences is nowadays a trivial fact nobody would deny. Bold analogies even suggest the application of the same statistical models to fields as different as statistical mechanics and economics, among them the case of the young and controversial discipline of Econophysics[i]. Less trivial, however, is the answer to the philosophical question, which has been raised ever since the possibility of "commuting" statistical thinking and models between natural and social sciences has emerged: whether such a methodological kinship would imply some kind of more profound unity of the natural and the social domain.

Starting with Adolphe Quetelet (1796-1874) and ending with the Vienna Circle (from the late 1920s until the 1940s), this paper offers a brief historical and philosophical reconstruction of some important stages in the development of statistics as "commuting" between the natural and the social sciences. This reconstruction is meant to highlight (with respect to the authors under consideration):

(1) the existence of a significant correlation between the readiness to "transfer" statistical thinking from natural to social sciences and vice versa, on the one hand, and the standpoints on the issue of the unity/disunity of science, on the other;

(2) the historical roots and the fortunes of the analogy between statistical models of society and statistical models of gases.

1. Adolphe Quetelet: Statistics and the Unity of Sciences

The Belgian astronomer and social statistician Adolphe Quetelet is a figure who has awaked especially in the 1980s the interest of many historians of probability and statistics[ii].

One of Quetelet's most significant features is certainly his interdisciplinary outlook. Being the founder and director of the Royal Astronomical Observatory in Brussels and pursuing at the

same time a brilliant career as a social statistician, he found himself at the intersection of different research areas which were developing at the same time and to whose convergence Quetelet himself very much contributed: the classical probability calculus, and especially the newly developed "law of large numbers", the theory of observational errors in astronomy and social statistics.

A unitary conception of natural and social phenomena characterizes Quetelet's perspective and his "transversal" application of statistics. Significantly enough, his most famous work was entitled *Essai de physique sociale*[iii]. In the "Preface" to the first English edition Quetelet explains: "In giving to my work the title of Social Physics, I have had no other aim than to collect, in a uniform order, the phenomena affecting man, nearly as physical science brings together the phenomena appertaining to the material world."[iv]

Each of the following constitutive elements of Quetelet's *physique sociale* fills the gap between social and natural sciences and is, at the same time, intrinsically related to the application of probability and statistics.

(i) Observation and quantification of facts

Quetelet's Social Physics starts with the observation of facts, the facts – Quetelet writes – that "society presents to our view"[v]. This is the first, essential step towards talking about human beings scientifically, avoiding any speculative "Theory of Man"[vi]. Not only "physical qualities" (births, deaths, stature, weight, strength etc.), but also "moral" (dispositions to behave good or evil) and "intellectual" (intellectual power) qualities are conceived of as facts to be observed – if not "directly", then through their effects:

"The analysis of the moral man through his actions and of the intellectual man through his production […] form[s] one of the most interesting parts of the sciences of observation, applied to anthropology. *It may be seen, in my work, that the course which I have adopted is that followed by the natural philosopher.*"[vii]

The "qualities of man" are expressed by facts, and these facts are illustrated by statistics: births, deaths, diseases, suicides, crimes, prostitution, production of works of literature, philosophy, science, etc. Statistics allows us to *measure, to quantify* the qualities of men and society exactly as we would measure the properties of a physical object.

(ii) The law of large numbers and other "laws"

Once we have collected enough data, "a miracle occurs": out of the large numbers regularities emerge. According to Quetelet, for example, the number of murders committed in France

every year - but also the percentage of these murders committed, say, by strangulation - converges toward a mean; furthermore, this mean remains stable in the course of the years, providing that the "organization of the social state"[viii] remains the same. Also the physical traits of man, if they are measured sufficiently many times for a particular population, would converge toward a mean (so that we can speak, for example, of a French *homme moyen*): "It would appear, then, that moral phenomena, when observed on a great scale, are found to resemble physical phenomena"[ix].

Relying on the stabilities emerging out of the large numbers Quetelet can further look for statistical *correlations*, for example, between the "residence in town or country" and the "ratio of births of the two sexes", or between "the period of the maximum of conceptions" and "that of the greatest numbers of rapes"[x]. Quetelet's aim is the same as the natural scientist's, to wit, "to discover the laws forming the connecting links of phenomena"[xi]:

> "Having…observed the progress made by astronomical science in regards to worlds, why should not we endeavour to follow the same course in respect to man? Would it not be an absurdity to suppose, that, whilst all is regulated by such admirable laws, man's existence alone should be capricious […]?"[xii]

(iii) Causes

Quetelet also infers from statistical regularities to the existence of causes. The model of causation found in Quetelet's work follows exactly what Lorenz Krüger – referring in general to classical probability in the age of determinism – has called "the deterministic account of statistical regularities". This account "was built on two complementary ideas: (i) the causal efficacy of structural conditions […] and (ii) the mutual compensation of accidental causes"[xiii]. Correspondingly, we find in Quetelet on the one hand the idea of a constant causal influence, for example by "a given state of society"[xiv] or by a Nature's tendency to realize the "typical (e.g. French) man". On the other hand, Quetelet talks of "accidental causes" – for example, the free decisions or the accidental properties of single individuals – that compensate each other and happen to be normally distributed exactly like errors in a repeated measurement. This mutual compensation is the effect of what Quetelet calls the "law of accidental causes": "Variations, which arise from accidental causes, are regulated with such harmony and precision that we can classify them *in advance* numerically and by order of magnitude, within their limits"[xv].

(iv) Predicting

Social Physics is not only a description of facts. It can tell us "in advance" something about future facts: like natural sciences, it allows prediction; like probability calculus, it suggests a rational degree of expectation. According to Quetelet, "we might even predict annually how many individuals will stain their hands with the blood of their fellow-men, how many will be forgers, how many will deal in poison, pretty nearly in the same way as we may foretell the annual births and deaths"[xvi].

It should be clear by now that in Quetelet's thought the application of statistical models within his social physics and a unitary conception of science were strongly interwoven: in particular, the application of statistics to the social domain let its kinship with the natural one emerge. But what kind of unity of science was advocated by Quetelet? Quetelet refused Comte's idea of a hierarchy of sciences and of course did not share Comte's dislike for the use of mathematics in social sciences. In fact, Quetelet was committed to a *methodological* unity of science[xvii]. Furthermore, his talking of a *physique sociale* and even of a *mecanique sociale*, as well as his insistence on the lawful character of social phenomena (which thus resemble natural ones), both suggest that Quetelet also tended to support a *nomological* and an *ontological* unity of science[xviii]. Such a unitary conception of science and Quetelet's "transversal" use of statistics went hand in hand and supported each other.

2. Reactions to Quetelet's work in the 19th Century

The philosophical issue about the unity/disunity of science played a big role also in the context of the reception of Quetelet's work.

Notwithstanding Quetelet's international reputation, his ideas about statistical laws and the unity of the sciences were not welcomed with enthusiasm in the German-speaking world. There the will to divorce *Naturwissenschaften* from *Sozial-* and *Geisteswissenschaften* went hand in hand with a different conception of statistics, one that rejected the notion of statistical law and any causal talk about society[xix]. In the first place, German academic statisticians and social scientists resisted the identification of statistics with numbers until the 1860s. Later, after the 1860s, statistics was conceived of by most Germans as a method for mass observation and for description, but most German statisticians, like Engel, Fallati, Casper and Rümelin, questioned Quetelet's idea of statistical regularities being laws or symptoms of true causal relations. The German tendency to emphasize the role of history and culture in defining

the identity of peoples and nations collided with any attempt to apply to a society fixed and unhistorical laws; furthermore, the will to promote state-directed reforms collided with the idea of a society intrinsically ruled by "spontaneous" laws.

Most importantly, a statistical approach to society would neglect – according to the Germans – the single individual and his or her (free) will and motives. The German economist and statistician Georg Friedrich Knapp, for example, criticized in 1871-72 any approach which, like Quetelet's one, "explains from the outside to the inside; […] sees the constancy of the whole and limits therefore the individual. The German school […] explains from the inside to the outside; it takes the individual as he is and looks for reasons of the constancy of the whole."[xx]

Diametrically opposite ideas *both* about statistics and about the relationship between natural and social sciences are at the bottom of the enthusiastic reaction to Quetelet's work by Thomas Buckle, the author of the gigantic, unfinished work *History of Civilization in England*[xxi]. Buckle appeals to statistics and to Quetelet's work in order to argue for the scientific nature of history. According to him, statisticians have been the first to deliver the "proofs of the regularity of human actions"[xxii]. Consequently he feels legitimated in pursuing his "study of the movements of Man" just like natural scientists study the "movements of nature"[xxiii]: seeking laws[xxiv] and causes and trying to predict. In fact Buckle makes an explicit plea for the unity of science: referring to the moral and to the natural domain, he expresses the hope that his work "will at least have the merit of contributing something towards filling up that wide and dreary chasm, which, to the hindrance of our knowledge, separates subjects that are intimately related, and should never be disunited"[xxv].

For what concerns natural scientists, the British mathematician and astronomer John Herschel wrote a long, favorable comment on the statistical work of his colleague Quetelet in 1850[xxvi]. Herschel strongly supports the application of statistics and probability calculus to the inquiries in the social and in the political domain, and expresses this position together with his unitary conception of science:

> [Statistics] is the basis of social and political dynamics, and affords the only secure ground on which the truth or falsehood of the theories and hypotheses of this complicated science can be brought to the test. It is not unadvisedly that we use the term Dynamics as applied to the mechanism and movements of the social body; *nor it is by any loose metaphor or strained analogy* that much of the language of mechanical philosophy finds a parallel meaning in the discussion of such subjects.[xxvii]

Herschel takes here the applicability of statistics within social and political inquiries as indicating a kind of homogeneity between social and natural "Dynamics" which is more than a mere analogy.

On the contrary, according to Glenn Shafer[xxviii], Maxwell and Boltzmann were only using "analogies" or "didactic devices" as they – in turn – referred to social statistics in their foundational writings on statistical mechanics, like in the following passages:

"The modern atomists have […] adopted a method which is, I believe, new in the department of mathematical physics, though it has long been in use in the section of Statistics. When the working members of Section F get hold of a report of the Census, or any other document containing the numerical data of Economic and Social Science, they begin by distributing the whole population into groups, according to age, income-tax, education, religious belief, or criminal convictions. The number of individuals is far too great to allow of their tracing the history of each separately, so that, in order to reduce their labour within human limits, they concentrate their attention on a small number of artificial groups. The varying number of individuals in each group, and not the varying state of each individual, is the primary datum from which they work. […] The smallest portion of matter which we can subject to experiment consists of millions of molecules, no one of which ever becomes individually sensible to us. We cannot, therefore, ascertain the actual motion of any one of these molecules; so that we are obliged […] to adopt the statistical method of dealing with large groups of molecules."[xxix]

"As is well known, Buckle has shown by statistics that if only we take a large enough number of people, then so long as external circumstances do not change significantly, there is complete constancy not only in the processes determined by nature, such as number of deaths, diseases and so on, but also of the relative number of so-called voluntary actions, such as marriage at a certain age, crime, suicide and the like. Likewise with molecules […]"[xxx]

Shafer's idea of such references being only "analogies" and "didactic devices" is meant to undermine Porter's thesis according to which Quetelet's social statistics had inspired the probabilistic thinking and models of natural scientists like Maxwell and Boltzmann, thus playing a significant role in the origins of statistical mechanics. Again, a certain wish to emphasize the gap between social and natural sciences seems to be responsible for Shafer's aversion even to the purely historical arguments supporting the idea of a transfer of statistical methods from the social to the natural sciences[xxxi]. Still, his suggestion should be taken seriously. An inquiry into Maxwell's and Boltzmann's respective conceptions of the relationship between social and natural sciences would be necessary before one could take a stand on this issue, though. If Shafer were right, one could furthermore ask why, while importing statistical models from the natural into the social sciences had implied (at least in the cases I have mentioned above) a unitary conception of the sciences, importing statistical models from social statistics to statistical mechanics would have amounted only to an analogy with didactical purposes. These issues cannot be solved within the limits of this paper. What I

would like to suggest in the next section is rather that Maxwell's and Boltzmann's "analogies" have had a greater impact and importance than Shafer is disposed to recognize.

3. Statistics and the unity of science in the Vienna Circle

The analogy between social statistics and statistical mechanics has had a significant resonance within the Vienna Circle, and in particular in some writings by Neurath, Frank and Zilsel. Considering the significance of Boltzmann for the Vienna Circle, it is possible that its members became acquainted with this analogy through him.

Philipp Frank, in his book on *The Law of Causality and its Limits*[xxxii], goes as far as to refer to a gas model in order to explain the "materialist conception of history" and to argue for its scientific nature. Single individuals – writes Frank – are like gas molecules, and in principle we could even assume that they behave according to deterministic, psychophysical micro laws. But, explains Frank,

> "Historical and sociological sciences […] do not deal with the psychological states of individuals; they speak of social conditions like density of population, diseases, political parties, constitutions of states, etc. We then often ask whether we can predict the state variables of the future if the present are known. […] In principle we can always assume in the sense of classical physics that there are laws if we enter into ever finer structures. We have however to assume that all observable state variables define only a macrostate for which there can be no strict laws at all, but […] only predictions about average conduct."[xxxiii]

Frank appeals here – like Quetelet had done in his *Physique Sociale* – to the applicability of statistical models to society as to something that would testify the possibility of pursuing social sciences "scientifically", and thus speaks in favor of the continuity of these latter with the natural sciences. Indeed, the outright rejection of any in-principle distinction between social and natural sciences was a most important matter especially within the so-called "left-wing" of the Vienna Circle, which pursued the project of *Einheitswissenschaft*, or "Unity of Science". This commitment supports Neurath's contention that the Viennese Logical Empiricism was more kindred in spirit to the British and to the French philosophical traditions than to the German one[xxxiv]. The Vienna Circle's "left-wing" was closer to Quetelet and Buckle than to the 19th century German statisticians.

Still, from the last quotation from Frank a much more "modest" attitude than Quetelet's becomes apparent: Frank places a new emphasis on the *limits* of predictions. By the time

when Frank wrote his book, the development of statistical mechanics and quantum mechanics had yielded a most interesting and significant consequence for the Vienna Circle's unitary conception of science. While Quetelet and his followers pointed to statistics to argue that the social sciences resemble the natural sciences with respect to causality, lawfulness, prediction and – in sum – *determinacy*, the Vienna Circle members pointed to statistics to show that the natural sciences are not essentially different from the social sciences, since both are characterized by a certain degree of *in*determinacy, which however does not prevent the formulation of laws and predictions.

This new perspective repeatedly comes to the fore in Zilsel's writings, from the very beginning to the end of his life[xxxv]. Zilsel appeals to the degree of indeterminacy in physics in order to contest the presumptive non-causal character of life sciences[xxxvi], sociology and history[xxxvii]. If physics – he argues – delivers causal laws and nonetheless admits indeterminacy, a degree of indeterminacy in sociology and history cannot be taken as proof of their non-causal or their non-explicative character.

Along the same lines, Neurath writes:

"When [sociologists] plead their case for the inclusion of sociological predictions, like those of all the other sciences, into the unified science of Physicalism, they will be less inclined to claim that sociology achieves as much as the most successful sciences. Rather, they will point out that certain limitations, to which sociology most obviously is subject, also hold for all the other sciences to some degree and that sociological predictions are scientific predictions like all the others."[xxxviii]

Neurath's idea of a "Sociology in the Framework of Physicalism"[xxxix] shows a significant resemblance with Quetelet's program. Neurath himself recognized it:

"All empirical sciences are, in the end, physics in the widest sense. Quetelet speaks of 'social physics', when he derives his average man and then tries to ascertain how certain changes of social quantities are linked, for instance changes of criminality with changes in food prices. One might speak of the physics of society in the same way as of the physics of a machine."[xl]

Still, a brief comparison between the already mentioned keystones of Quetelet's social physics and Neurath's meta-reflection on sociology brings to light Neurath's new awareness about the limitations to which *both* natural and social sciences appear to be subjected.

(i) Observation and quantification of facts

To Quetelet's reliance on "social facts" corresponds Neurath's wish to trace back the statements of social science to observable "states of affairs"[xli] or to spatio-temporal descriptions[xlii]. Neurath's "social behaviourism", and his dislike of any reference to "intentions", "introspection", "empathy", "comprehension" or other mental states in social science[xliii], shows an interesting resemblance to Quetelet's idea of inquiring moral and intellectual properties "through their products".

However, Neurath does not share Quetelet's blind faith in "facts". With respect to statistics in particular – Neurath warns us – the precision and clarity of the mathematical form in which statistical "facts" are expressed should not distract from the *conventional* nature of the numerical indexes and of the reference classes we choose[xliv].

(ii) The "law" of large numbers

The belief in the emergence of stability out of the large numbers is still present in Neurath, and it is acknowledged as a heritage from Quetelet (note how Neurath formulates here exactly Porter's above mentioned thesis!):

"The scientific approach is most difficult to introduce wherever there is interest in the future fate of single individuals […] Where the subject is masses and groupings of men, stability is larger, and the instability of the individual is less conspicuous. Therefore such questions are more amenable to scientific treatment, and the interest in such questions furthers the scientific attitude. The modern statistical approach, which has become so significant in physics, has its origins in sociological methods that were advocated about the middle of the nineteenth century and even earlier by Quetelet and others."[xlv]

(iii) Correlations instead of Laws and Causes

Still, Neurath does not share Quetelet's belief in "statistical laws" and he does not like "the cause-effect phraseology"[xlvi]. All sciences – Neurath argues – just seek for *correlations*[xlvii]. The elimination of the reference to laws and causes and the reliance on the "weaker" concept of "correlation" put Neurath in a better position than Quetelet's to argue in favor of the unity of science, since Neurath does not have to provide any deterministic account of statistical regularities in order to point out what sociology and physics have in common.

(iv) Prediction

In fact Neurath shifts the main focus of attention from the concepts of laws and causes to the concept of prediction[xlviii]. He warns against the many limits of sociological predictions[xlix], but

– as already mentioned – he also argues that these limits hold for every science: it is just a matter of degree.

To sum up, a significant echo of Quetelet's unitary conception of the sciences and of his "transversal" use of statistical models can be found in Neurath, Frank and Zilsel's writings. Still, the important developments undergone in the meantime by science (e.g. the indeterministic turn in Physics) and by its philosophy (e.g. the impact of conventionalism and pragmatism) are reflected in a new awareness of the limitations to which any science is subjected and in a new deflationist attitude with respect to facts, laws and causes: These latter appear to have been de-ontologized and to some extent relativized[l], so that any further account about their "mirroring" a deterministic world becomes meaningless and pointless.

Conclusion

Let me conclude by highlighting the main findings of my selective historical *tour de force* from Quetelet to Neurath with respect to the two main issues mentioned in the Introduction.

(1) My reconstruction has shown how in many cases the readiness to "transfer" statistical thinking from natural to social sciences and vice versa has been (and still is[li]) related to the standpoint on the issue of the unity or disunity of science.

In the 19th century Adolphe Quetelet, perhaps the most important pioneer of the quantitative methods in social science, applied to society the same statistical methods he used to apply as astronomer and expressed his unitary conception of the sciences by giving to his inquiries into society the name of "social physics". While authors like Thomas Buckle and John Herschel appreciated Quetelet's statistical work and explicitly shared his unitary conception of the natural and the social sciences, in Germany a conception of statistics different than Quetelet's and the conviction of an in-principle gap between the natural and the social sciences went mostly hand in hand.

Interestingly enough, from the late 1920s until the 1940s some Vienna Circle members still referred to statistics in order to argue in favor of the unity of the social and the natural sciences – like Quetelet and his followers had done. Nevertheless, one can identify an interesting twist in Frank, Zisel and Neurath's arguments. While Quetelet and his followers pointed to statistics to argue that the social sciences resemble the natural sciences with respect to causality, lawfulness, prediction and – in sum – *determinacy*, the Vienna Circle members pointed to statistics to show that the natural sciences are not essentially different from the

social sciences, since both are characterized by a certain degree of *in*determinacy, which however does not prevent the identification of significant correlations and the formulation predictions.

(2) The literature by Frank, Zilsel and Neurath which I have considered also provides new evidence for Theodore Porter's thesis according to which "a close and significant relationship between social statistics and the origins of probabilism in physics is apparent"[lii]. The analogy between statistical models of society and statistical models of gases – whose historical impact has been minimized by Shafer in the context of his criticism to Porter – seems in fact to have been well-known in the Vienna Circle. Furthermore, Neurath formulated already in 1930 exactly Porter's thesis.

[i] Cf. Bikas K. Chakrabarti/Anirban Chakraborti/Arnab Chatterjee, *Econophysics and Sociophysics. Trends and Perspectives*, Weinham: Wiley-VCH 2006; *Science and Culture. Special issue on: Fifteen Years of Econophysics Research*, 76, 9-10, 2010.

[ii] For instance, Quetelet's work is a major issue in many contributions to the volume: Lorenz Krüger/Lorraine J. Daston/Michael Heidelberger (Ed.), *The Probabilistic Revolution, Vol. I: Ideas in History.* Cambridge, Mass.: MIT Press 1987. Cf. also Theodore M. Porter, *The Rise of Statistical Thinking 1820-1900*, Princeton: Princeton University Press 1986 (Part II); Stephen M. Stigler, *The History of Statistics*, Cambridge, Mass. / London: Belknap Press of Harvard University Press 1986 (Part II, Ch. 5); Gerd Gigerenzer *et al.* (Ed.), *The Empire of Chance*, Cambridge: Cambridge University Press 1989 (Ch. 2); Ian Hacking, *The Taming of Chance*, Cambridge: Cambridge University Press 1990 (Ch. 13-15 and 20-21).

[iii] The first version of Quetelet's Social Physics was published in 1835 with the title *Sur l'homme et le développement de ses facultés ou Essai de physique sociale*. In this paper I refer to the first English translation of this edition: Adolphe Quetelet, *A Treatise on Man and the Development of his Faculties*, Edinburgh: William and Robert Chambers 1842. In 1869, Quetelet would publish a revised and enlarged edition of this work under the title *Physique sociale, ou Essai sur le développement des facultés de l'homme*.

[iv] Quetelet, *A Treatise on Man and the Development of his Faculties*, *op. cit.,* p. vii.

[v] *Ibid.*, p. vii.

[vi] *Ibid.*, p. 8.

[vii] *Ibid.*, p. viii; my emphasis.

[viii] *Ibid.*, p. 6.

[ix] *Ibid.*, p. 6.

[x] Cf. *Ibid.*, p. 12 and p. 22 respectively. The revised and enlarged edition of Quetelet's social physics (see above, n. 3.) entails a much greater variety of such correlations.

[xi] *Ibid.*, p. 8.

[xii] *Ibid.*, p. 9. Quetelet's "normal" distributions and "stable" means, as well as Quetelet's "laws", appear quite problematic to a modern eye: with respect to the former, cf. for instance Ian Hacking, *The Taming of Chance*, *op. cit.*, S. 113; with respect to the latter, cf. Bernard-Pierre Lécuyer, "Probability in Vital and Social Statistics: Quetelet, Farr, and the Bertillons", in: Krüger/Daston/Heidelberger (Ed.), *The Probabilistic Revolution, Vol. I: Ideas in History, op. cit.*, pp. 317-335 (see p. 321).

[xiii] Lorenz Krüger, "The Slow Rise of Probablism: Philosophical Arguments in the Nineteenth Century", in: Krüger/Daston/Heidelberger (Ed.), *The Probabilistic Revolution, Vol. I: Ideas in History*, *op. cit.*, pp. 59-85 (see p. 71).

[xiv] Quetelet, *A Treatise on Man and the Development of his Faculties*, *op. cit.,* p. vii.

[xv] Quetelet, cit. in Lécuyer, "Probability in Vital and Social Statistics: Quetelet, Farr, and the Bertillons", *op. cit.*, p. 320; my emphasis.

[xvi] Quetelet, *A Treatise on Man and the Development of his Faculties*, *op. cit.*, p. 6.

[xvii] Cf. Porter, *The Rise of Statistical Thinking* 1820-1900, op. *cit.*, p. 41-42: "Quetelet maintained that a single method was appropriate for every science". Porter deals here also with the relationship between Quetelet and Comte.

[xviii] Quetelet always defended himself from the charge of denying human free will by underlying that the statistical laws of his Social Physics do not apply to single individuals (cf. for instance Quetelet, *A Treatise on Man and the Development of his Faculties*, *op. cit.,* p. 7). Nevertheless, he does not seem to have considered the hypothesis that this limitation on the validity of statistical laws could imply an in-principle difference between his Social Physics and, say, Newtonian physics.

[xix] The first German translation of Quetelet's *Physique Sociale* appeared already in 1838. On the reception of Quetelet's work in the German speaking world, cf. Wilhelm Winkler, "Das Problem der Willensfreiheit in der Statistik", in: *Revue de l'Institut International de Statistique / Review of the International Statistical Institute*, Vol. 5, No. 2, 1937, p. 115-131 (see esp. p. 128-130); Paul F. Lazarsfeld, "Notes on the History of Quantification in Sociology – Trends, Sources and Problems", *Isis*, Vol. 52, No. 2, 1961, p. 277-333 (see p. 283-294 and p. 309-310); Theodore M. Porter, "Lawless Society: Social Science and the Reinterpretation of Statistics in Germany, 1850-1880", in Krüger/Daston/Heidelberger (Ed.), *op. cit.*, pp. 351-375, and Hacking, *The Taming of Chance*, *op. cit.*, Ch. 5 and 15.

[xx] Cit. in Michael Heidelberger, "From Mill via von Kries to Max Weber: Causality, Explanation, and Understanding", in: Ulijana Fest (Ed), *Historical Perspectives on Erklären and Verstehen*, Dordrecht/ Heidelberg/London/New York: Springer 2010, pp. 241-265.

[xxi] Thomas Buckle, *History of Civilization in England*, vols. I-V, Leipzig: Brockhaus 1865.

[xxii] *Ibid.,* vol. I, p. 19-20.

[xxiii] *Ibid.*, vol. I, p. 7.

[xxiv] Cf. *Ibid.*, vol. I, p. 26.

[xxv] *Ibid.*, vol. I, p. 33.
[xxvi] John Herschel, "Quetelet on Probabilities", in: *The Edinburgh Review*, July 1850. Quetelet would later use this comment as Introduction to his enlarged version of the *Physique Sociale*.
[xxvii] *Ibid.*, p. 434-35; my emphasis. See also p. 373 and 437.
[xxviii] Glenn R. Shafer, "Review of: T.M. Porter, *The Rise of Statistical Thinking 1820-1900*". In: *Annals of Science* 47, March 1990, pp. 207-209.
[xxix] James Clerk Maxwell, "Molecules. A Lecture" [1873], in: W. D. Niven (Ed.), *The Scientific Papers of James Clerk Maxwell*, Vol. II, Cambridge: Cambridge University Press 1890, pp. 361-377 (see pp. 373-74).
[xxx] Ludwig Boltzmann, "The Second Law of Thermodynamics" (Engl. transl. of: "Der zweite Hauptsatz der mechanischen Wärmetheorie", 1886), in: Boltzmann, *Theoretical Physics and Philosophical Problems: Selected Writings*, Dordrecht: Reidel 1974, pp. 13-32 (see p. 20).
[xxxi] Cf. Shafer's very polemical arguments at p. 208 of his "Review of: T.M. Porter, *The Rise of Statistical Thinking 1820-1900*", *op. cit.*
[xxxii] Philipp Frank, *The Law of Causality and Its Limits* (Engl. transl. of: *Das Kausalgesetz und seine Grenzen*, 1932), Robert S. Cohen (Ed.), Dordrecht: Reidel 1998 (see in particular Ch. 8).
[xxxiii] *Ibid.*, p. 198.
[xxxiv] Cf. Otto Neurath, „Die Entwicklung des Wiener Kreises und die Zukunft des Logischen Empirismus", in: Neurath, *Gesammelte philosophische und methodologischen Schriften*, Rudolf Haller and Heiner Rutte (Ed.), Vienna: Hölder-Pichler-Tempsky, Vol. 2, pp. 673-702 (see p. 676).
[xxxv] In his first book, *Das Anwendungsproblem*, Zilsel gave an indeterministic foundation to *all* scientific laws, which are conceived of as mere statistical regularities emerging from indeterminacy (Edgar Zilsel, *Das Anwendungsproblem*, Leipzig: Barth 1916). Towards the end of his life, in 1941, Zilsel would write: "historical phenomena are scarcely more difficult to predict than the weather and certainly not more difficult than volcanic eruptions and earthquakes. What would scientists think of a geophysicist who gives up the search for geophysical laws because of their inexactness?" (Edgar Zilsel, "Physics and the Problem of Historico-Sociological Laws", in *Philospohy of Science*, Vol. 8, No. 4, 1941, pp. 567-579; see p. 570).
[xxxvi] Cf. Edgar Zilsel, "Naturphilosophie" in: Franz Schnaß (Ed.), *Einführung in die Philosophie*, Osterwieck-Harz: Zickfeldt 1928, pp. 107-143 (see p. 138).
[xxxvii] Cf. e.g. Zilsel, "Physics and the Problem of Historico-Sociological Laws", *op. cit.*
[xxxviii] Otto Neurath, "Sociological Predictions" (Engl. transl. of "Soziologische Prognosen", 1936), in: Neurath, *Economic Writings. Selections 1904-1945*, Dordrecht/Boston/London: Dordrecht 2004, pp. 506-512 (see pp. 511-512).
[xxxix] Otto Neurath, "Sociology in the Framework of Physicalism", (Engl. transl. of "Soziologie im Physikalismus", 1931), in: Neurath, *Philosophical Papers 1913-1946*, Dordrecht/Boston/Lancaster: D. Reidel 1983, pp. 58-90.
[xl] Otto Neurath, "Empirical Sociology" (Engl. transl. of *Empirische Soziologie*, 1931), in: Neurath, *Empiricism and Sociology*, Dordrecht/Boston: D. Reidel 1973, pp. 319-421 (see p. 390).
[xli] This expression recurs in Neurath, *Empiricism and Sociology*, *op. cit.*
[xlii] Neurath "Sociology in the Framework of Physicalism", *op. cit.*, p. 61.
[xliii] Cf. e.g. Neurath, "Empirical Sociology", *op. cit.*, p. 325 and "Sociology in the Framework of Physicalism", *op. cit.*, pp. 68ff .
[xliv] Cf. Otto Neurath, *Foundations of the Social Sciences*, Chicago: University of Chicago Press 1944, pp. 24-25 and 33.
[xlv] Otto Neurath, "Ways of the Scientific World-Conception" (Engl. transl. of: "Wege der wissenschaftlichen Weltauffassung", 1930), in: Neurath, *Philosophical Papers*, *op. cit.*, pp. 32-47 (see pp. 44-45).
[xlvi] Cf. Neurath, *Foundations of the Social Sciences*, *op. cit.*, pp. 20-21.
[xlvii] Cf. Neurath, "Sociology in the Framework of Physicalism", *op. cit.*, p. 68.
[xlviii] Cf. *Ibid.*., p. 61 and Neurath, "Sociological Predictions", *op. cit.*
[xlix] Cf. Neurath, "Empirical Sociology", *op. cit.,* § 10; "Sociological Predictions", *op. cit.*; *Foundations of the Social Sciences*, *op. cit.*, §12.
[l] Concerning Neurath, cf. the incisive résumé of his epistemology in: Nancy Cartwright / Jordi Cat / Lola Fleck / Thomas Uebel, *Otto Neurath: Philosophy between Science and Politics*, Cambridge: Cambridge University Press 1996, p. 3: "Knowledge has no foundations. The things we believe can only be checked against other beliefs; nothing is certain; and all is historically conditioned".
[li] Cf. the case of Shafer, *supra*, p. 8. Another, more recent example is Donald Gillies, who has argued for the opportunity of interpreting statistics and probability in the natural sciences differently than in the social sciences as natural and social sciences would be different in principle (cf. Donald Gillies, *Philosophical Theories of Probabilities*, New York: Routledge 2000, p. 187-200).
[lii] Porter, *The Rise of Statistical Thinking, op. cit.*, p. 192.