REVERSIBLE STATISTICS: THE MAKING OF STATISTICAL FACTS AND ARTIFACTS IN ECONOMICS

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Abstract — The study aims is to describe how the inclusion and exclusion of materials and calculative devices construct the boundaries and distinctions between statistical facts and artifacts in economics. My methodological approach is inspired by John Graunt’s (1667) Political arithmetic and more recent work within constructivism and the field of Science and Technology Studies (STS). The result of this approach is here termed reversible statistics, reconstructing the findings of a statistical study within economics in three different ways. It is argued that all three accounts are quite normal, albeit in different ways. The presence and absence of diverse materials, both natural and political, is what distinguishes them from each other. Arguments are presented for a more symmetric relation between the scientific statistical text and the reader. I will argue that a more symmetric relation can be achieved by accounting for the significance of the materials and the equipment that enters into the production of statistics.

Key words: Reversible statistics, diverse materials, constructivism, economics, science, and technology.

THE MAKING OF STATISTICS AND THE NOTION OF REVERSIBILITY

Statistics as an institutionalized scientific practice is closely related to the rise of the modern state. After having been established, the state ceased to be the subject matter of statistics, and it became a sub-discipline of mathematics and many other disciplines (Österberg, 1988). However, prior to becoming an institutionalized scientific domain of knowledge production, statistics were known under different names, such as ‘political arithmetic’ (Johannisson, 1988). The history of statistics is closely linked with political arithmetic and the significant contributions of John Graunt. He was a man of trade and the author of '*Natural and Political Observations Made upon the Bills of Mortality*' published in 1662. The book was instrumental in that it exposed the Royal Society to political arithmetic, perhaps for the first time. Graunt was not confined to the calculation of numbers, but paid close attention to how numbers became produced and what they came to represent. Graunt was also a man of the world. While investigating the public accounts of people dying from syphilis, he became aware of the significant role of taboos and emotions in society. According to Graunt, public accounts of deaths caused by syphilis were distributed as written texts and were read as daily news by members of the community. Being listed as having died from syphilis was taboo in the community and thus something that relatives and friends of the dead wanted to prevent. By offering due quantities of money and gin to the public accountants of dead people, primarily “only *hated* persons, and such, whose very *Noses* were eaten off, were reported” (Graunt, 1676: 356) as having died from syphilis and counted a such. Graunt's observations and insights into the production of death statistics in 17th century deserves a few comments:

Distinguishing between natural and political in the number of deaths appears to have been an immensely complex task: Those counted and listed as having died of syphilis seems to be the result of a closely intertwined process of negotiation consisting of heterogeneous entities - a fascinating mix of taboos, hatred, and diverse material things such as dead bodies, rotten noses, money, gin and written texts. The process of making public the numbers of people dying from syphilis included all these material things. So, bringing facts into existence seems to presuppose the presence of diverse materials. The list could be presented as facts that speak for themselves, as if de-coupled from the process and the materials it entails. Moreover, publishing texts listing numbers and names also requires someone to compose the list in the first place - the statistician - and that the public reads and acts upon the list.

Sometimes, the public tried to avoid taboos by shortening the list, mobilizing gin and money in the process or, alternatively, the list was expanded in acts of hate or scorn. In both cases, taboos and emotions were reproduced in interaction with the statistics in the making. The production of statistics thus becomes a collective achievement, consisting of both humans and non-human materials like a list, a bottle of gin and hybrid entities such as rotten noses. With due help of such materials, the production of death statistics - the listing of figures and names - creates and modifies the object described. Facts become public facts ingrained with taboos and emotions and representing the officially sanctioned story - in this case the statistics on the deaths from syphilis.

The reader may argue that Graunt's account of the arithmetic complexities of syphilis is an extreme case and not representative of contemporary science and statistics. Representative or not, the comments on Graunt's case are in line with contemporary studies of scientific knowledge production, notably constructivism and STS-studies (e.g. Latour and Woolgar 1979/1986; Knorr-Cetina 1981, Callon 1986, 1991, 1998, Latour, 1987; Aikrich, 1992, Law, 1994; Knorr-Cetina, 1994, MacKenzie, 1999). In one of the first major studies of this sort, Latour and Woolgar (1979/1986) provided an account of ordinary life in a laboratory of normal science (a laboratory that had won the Nobel Prize by the time the study was completed). The site was facing the same problems as anyone authoring an account, i.e., to produce order out of chaos by literary inscriptions. The authors describe the construction of a fact - how a statement becomes ”transformed into a fact and hence freed from the circumstances of its production” (Latour and Woolgar, 1986: 105). Literary inscription devices - hard material things - are used to ”harden” facts. The process reveals war-like events in which things become allies with scientists, enrolled and mobilized by the latter to convince others of the importance of the activities taking place in the laboratory. ”They [the scientists] are so persuasive, in fact, that within the confines of their laboratory it is possible to forget the material dimensions of the laboratory, the bench work, and the influence of the past, and to focus only on the ”facts” that are being pointed out.” (ibid.: 70). A ”fact” then has gone through a process of stabilization so as to become an almost irreversible (Callon, 1991) entity. It is an effect and outcome of a process of negotiation by which heterogeneity (chaos) is transformed into homogeneity (order). The difference taken for granted between “facts” of nature (or things in themselves - independent of humans) and “artifacts” (phenomena produced by humans) becomes blurred, in that laboratory scientists strive to make the difference between facts and artifacts given. MacKenzie (1978, 1999) provides detailed accounts of the negotiated history of statistics. It is a history of controversies regarding how to best measure a statistical coefficient. Yule disputed Pearson's proposal once he introduced it a hundred years ago. In the hands of the most eminent of statisticians, coefficients of statistical associations do not remain entirely unaltered - as if they were made by nature or the laws of pure mathematics. They also become political entities, or hybrids. For Yule an entity to be topicalized, questioned and bypassed through the articulation of alternatives. For Pearson an intellectual resource to facilitate the program of Eugenics (MacKenzie, 1999). With the work of Callon (1998), STS claims regarding the significance of materials and equipment has been extended to the science of economics as well as to the economy it self. In this work, the market is no longer assumed to exist in a natural state but becomes a negotiated entity –performed with due help of economics and associated calculative devices.

In a similar vein, the aim of this article is to describe how the boundaries and distinctions between facts and artifacts in economics use of statistics are constructed, and made (ir)reversible by the inclusion and exclusion of diverse materials, both natural and political things. Or in the words of Czarniawska (1997: 26) 'The boundary has been drawn, but it is always in a danger of being erased, which means that the researcher's task is to describe how boundaries are constructed and maintained, rather than taking them for granted.'

Setting the Agenda for Reversible statistics

Graunt seemed to recognize the capacity of the observed field to construct the official reality desired (and to avoid what was taboo). He also seemed to recognize the fascinating interaction between the statisticians of his time, the public accountants of death, and the rest of the likewise creative field he wrote about. Graunt was thus able to read the death statistics of his time as a skilled anthropologist and constructivist - recontextualizing the official statistics in the light of how they were actually co-produced and stabilized in a network of people and things. But what would contemporary statistics inspired by Graunt look like? To begin with, there is what I will name 'Reversible statistics'. This serves to underscore two points: (1) that the normal contemporary practice of ‘Statistics’ is constituting the primary field of interest. (2) Reversed statistics does not involve the invention of something new, but rather the ‘reversal’ of the history of statistics by recreating Graunt's observations and insights regarding the significance of diverse materials. Following McCloskey (1992), it should be emphasized that in the present context, the term “significance” is not used to mean “statistically significant” but is used to convey the meaning of what is suggested here to be of substantive importance in the making of statistical facts and artifacts. Reversible Statistics thus seeks to create observations and insights in keeping with Graunt’s approach, albeit within the field of contemporary statistics. Drawing upon constructivism and work associated with Science and Technology Studies (STS) make this move easier.

Hence, case studies describing statistics as a continuous process of ongoing events constructed and reconstructed by people and diverse things is in line with such an approach. To practice reversible statistics, however, urges me to call upon Graunt once more in order to recognize the presence of a creative and reflexive field, and by adopting his symmetrical understanding of those who describe the field, the public accountants of today - statisticians. The relevant strategy of inquiry here will be akin to the one suggested by Latour (1987) and Akrich (1992). It involves the 're-enacting' and ‘de-scription’ of things (also in a material sense), which the authors of statistical texts have gone through, the rhetoric involved, the presence of allies, and the enrollment and mobilization of the numbers, geometrical figures, equations, and mathematics in the text. Stated as a methodological approach, this will allow the author to enter into the process while statistical facts are in the making.

The Organization of the Remaining Arguments

In order to produce a case of reversible statistics, I will draw on a publication in which statistics represents a significant part of the text (Carlsson, Taymaz, Tryggestad, 1995[1]). The publication can be seen as belonging to a particular branch of economic sciences - the economics of science, technology and innovation. I have selected this work, and not works of others, merely because it is the one that I am most familiar with. The work – it will be argued – is also quite normal in its use of statistics. In addition, one could perhaps also argue that there seems already to be several examples of authors that have made detailed analyses of and interesting comments upon the statistical works of others. (See e.g. McCloskey and Ziliaks’ (1996) detailed review of the use of statistical significance during the history of economics.)

The statistical work underlying the publication was conducted as a part of a larger research project initiated and funded in 1987 by the governmental policy making body, the Swedish National Board for Technical Development and the Swedish

[1] A previous version of this publication was published in O. Granstrand (ed.), Economics of Technology (Amsterdam: Elsevier, 1994).

Council for Planning and Coordination of Research (FRN). The work in progress was reported at international conferences organized by academic institutions as well as governmental bodies. The case will be organized as a move 'along the spectrum from habit to inquiry' (Rorty 1994: 94). Along that move, the case will operate with a distinction between contextualization and recontextualization (ibid.) while adding new entities and events. The publication in question forms the first part of the case and is presented in the next section under the subheading 'The stage story: a contextualization'. The notion of 'stage' is based upon the theatre metaphor (Czarniawska-Joerges, 1992). The metaphor draws attention to those at the center of the stage while reminding us that there can be a back stage where the creative art of stage-managing takes place. The second part of the case is labeled 'The stage story extended by a print out: a first recontextualization'. Here the initial part of the case is recontextualized by the inclusion of a sheet of paper - a printout suggesting there to be other variables and a time dimension. This material entity was left on the cutting floor when the work underlying the stage story was published. Thus, by adding materiality - the excluded printout - to the events at hand, the case itself can be recontextualized. The first recontextualization will highlight certain of the statistical consequences of various statistical practices, thereby moving from a story involving a rather homogeneous statistical account to a case of less stable, more heterogeneous results, including other variables, a time dimension and additional computing resources.

In the second recontextualization, 'The reversible story', I use the theatre metaphor to draw attention to the (re)distribution of roles, i.e., who is acting and who is authoring the script. In the making of scientific facts, Latour (1999) argues that the roles can be reversed. 'We cannot even claim that…it is only the author, the human author, who is doing the work in the writing of the paper, since what is at stake in the text is precisely the *reversal* of authorship and authority" (ibid.: 132, emphasis added). Hence the second recontextualization will inquire into the question of possible reversed roles between humans and non-humans in the authoring of statistical accounts.

To summarize, the claim made for a reversible statistics is that in order to describe how the boundaries and distinctions between statistical facts and artifacts are constructed, we must pay close attention to the significance of diverse materials and calculative devices – including the possibility of reversed roles among the humans and non-humans involved. Conversely, the point is not to present a confession of how statistics can be consciously manipulated by humans. The art of stage management can be far more complex than that, as suggested by the notion of ‘reversal of roles’. Nor is the point to debunk statistics or economics, be it generally or more specifically, but to explain what is going on in the production of facts and artifacts of statistics. To conclude, in a case of reversible statistics, the resources of contemporary statistics should be used to substantiate the claims made. Statistics is thus both a resource and something to topicalize for further inquiry, given the agenda for reversible statistics.

The Case of Reversible Statistics

The stage story: a contextualization

In order to allow the reader to get close to the original text, from which the ‘stage story’ is crafted, I have chosen a supporting rhetoric style. The style will be that of a 'zero' interpretation in which I attempt to reproduce the 'native language' of the original publication.

The story goes like this:

The research problem was defined in light of the inconclusive evidence in economics of the causal relationship between automation technology and economic performance. '…while it is often assumed that there is a strongly positive impact of automation on economic performance, there is little conclusive empirical evidence…This state of affairs suggests that there is no easy or general answer to the question, ”What is the relationship between automation and economic performance?”…[Yet]…the fact of the matter is that investments in automation technology are being made every day, in increasing magnitude. How can this be explained?' (Carlsson, Taymaz, Tryggestad, 1995: 391, 392). Field interviews and a questionnaire survey formed the two main empirical sources for answering the research question. The questionnaire survey was conducted annually by an industry-funded institute for economic and social research. The questionnaire was justified as a way to 'broaden the systematic collection of data to a larger set of situations than could be handled in the form of interviews… we appended a set of questions about the degree of factory automation in each of the 347 responding units. About 150 of these units answered at least some of the questions on automation' (ibid.: 398). Hence, by using a survey, we would be in a better position empirically to generate results that were generalizable across a larger set of firms and situations. The questions in the questionnaire were operationalized into variables. Data from the questionnaires were assigned to these variables making them operational for statistical analysis. Some of the results were reported in the form of a correlation matrix[*]:

[*] See Appendix; Table 1, for the correlation matrix published.

'An examination of the correlation matrix yields some interesting results. For the manufacturing industry as a whole, the level of automation is highly (and positively) correlated with the level of productivity and somewhat less strongly with profitability; it is not at all correlated with sales growth and is somewhat negatively correlated with the R&D/sales ratio' (ibid.: 402). The authors pointed out that quite a different 'picture' emerged for engineering firms 'These results confirm the interview finding that there is not a simple relationship between automation and other variables but rather a more complex one…' (ibid.: 402).

On the pages that followed, the authors also introduced a factor analysis and accounted for the methodological problems: 'In order to sort out the relationship between the degree of automation and other variables and thus gain further insight we applied factor analysis to the survey data… For this analysis we made use of a subset of the variables…primarily "hard" (objective) data (such as the 5-year growth rate of sales, employment level etc.)…Because of the difficulties generated by missing data in this type of analysis, we are forced to restrict the investigation to 36 units for which data are sufficiently complete…'(ibid.: 403). Above all, it was the variable AUTOLEV (defined as 'degree of automation, %') that suffered from the difficulties of missing data. That was not the best of circumstances, given the research question and the aim to provide insights into the relationship between automation and economic performance.

The final approach towards the aim was a micro-to-macro simulation of the national economy. The computer-based simulation model 'MOSES…[the Model Of the Swedish Economic System was used to]…model automation decisions and to get an idea of the nature and order of magnitude of the economic impact of automation both at the micro and macro levels…' (ibid.: 392). In the MOSES simulation the data from many years of annual surveys entered into the analysis. Dynamic changes between the years 1983-1988 were simulated for the manufacturing sector as well as for the nation[2]. Since the question 'degree of automation' only was part of the survey from 1988, the data set obtained from this survey was not entirely compatible with those from previous years. The authors solved the issue by doing several operationalizations, e.g., '.improved technology…was operationalized via improved labor productivity associated with investment in new capital…' (ibid.: 412).

[2] It should perhaps be explicated that MOSES includes 'a number of firms, some of which are real (with data supplied mainly through an annual survey) and some of which are synthetic…' (Carlsson & Taymaz, 1995: 379). The authors give credit to the model development done by Eliasson (1989) and Albrecht and Lindberg (1989) in Albrecht et al. (1989). An earlier version of MOSES was in use when the Swedish government formulated the technology policy for automation in the 1980s.

In the concluding remarks it was pointed out that 'the results in the interviews as well as in the survey and in the simulations confirm the findings in previous studies that the impact of automation is highly conditional upon the particular setting in which the automation takes place and upon the ways in which it is implemented' (ibid.: 413-4). End of story.

Nothing special is going on in the ‘stage story’. The remaining part of this case is to a certain extent an account of how normal the ‘stage story’ is. To begin with, it is an account of how the statistical results were made and pointed out. The authors describe carefully how the study was built upon various methodologies and considerable amounts of data from several years of questionnaire surveys. They began with the interviews, felt an urge then for a broader questionnaire survey, accounted for problems of missing data, listing both 'hard objective' and 'subjective' data and variables. Finally, the researchers carried out a simulation with a time dimension, using computer based MOSES, aggregating from micro (individual firms) to macro (the national economy). Yet again the publication is the story of a normal statistical analysis of relationships between variables, use being made of a standard statistical program for computerized statistical calculation, SPSS (Statistical Package for Social Sciences). So what can be added to the story? How can it be re-staged, or recontextualized?

The stage story extended by a print-out: the first recontextualization

The stage story can be continued by adding an event including diverse materials, such as a text on a piece of paper with numeric inscriptions. In this case the significant event is not as dramatic as in the Graunt case. Dead bodies are replaced with a text listing a set of variables that once were part of a different correlation matrix than the one published. The variables PROF83 (profit margin 1983) and PROD83 (labor productivity 1983) are the newcomers, suggesting a time dimension for the years 1983-1988. As we have already learned, this is the same time dimension that was used in the MOSES simulations. The no longer missing correlation matrix is shown in the Appendix, Table 2. The table portrays a slightly edited copy of the original as it came out of the printer at that time. Only the headings and subheadings of the original have been edited. (Pencil marks added to the original version years later).

From industrial visits the authors (Carlsson, Taymaz, Tryggestad, 1995) were aware of the implementation problems surrounding automation technology. Our hosts in the field regarded the introduction of automation technology as an event over time - something, which did not immediately yield any positive economic returns simply by being physically present on the factory floor. This explains the relevance of a time dimension in the published study. The authors had explored a time dimension in the simulation model, to be sure, yet did not introduce and explore a time dimension neither in the published correlation matrix, nor in the factor analysis. In the depths of the laboratory of economics, however, prior to the publications of the results - they did take the first steps down that road, as one can see from the correlation matrix that was excluded. From the no longer missing correlation matrix one can see that the researchers correlated the two missing variables, PROD83 and PROF83 with a subset of the variables appearing in the published correlation matrix (see also Appendix, tables 1 and 2).

What will happen if we grant the missing variables the right to show what they can? Can PROD83 and PROF83 in any way add to the statistical results and the conclusions already at hand? Can they be used to say something else about the relevance of time in the context of automation and economics? Those questions were never answered in the first publication, but in a case of reversible statistics, the author can at least make a try.

One can imagine that the variable AUTOLEV (the degree of automation) for a particular year would show a non-significant or even a negative correlation with productivity (PROD88) and with profitability (PROF88) for that year, due to implementation problems. This was also in line with the lessons learned during our visits to companies. Positive economic effects may well appear years later if at all. One can also imagine that the variable AUTOLEV for that same year was determined by the productivity and profitability found in previous years. After all, automation technology is not obtained for free. The money invested is one aspect of the matter (read: profitability) and the investment in relation to a not so distant history in the course of production, including the costs of labor (read: labor productivity) is another aspect. This makes the time dimension relevant. How should one reconstruct a study then seeking to incorporate the two expelled variables in a way complying with our interest in the time dimension and the insights regarding its relevance for automation technology and economic performance?

In the 1995 publication, the focus of interest was explicitly on the *impact* of automation technology on economic performance. This research question will remain the same. The examined population will remain the same. The data from the questionnaire survey will remain the same. So the methodological question is not whether the reported strong correlation between AUTOLEV and PROD88 is more or less statistical significant in another, randomly selected population. Hence, the sampling problem does not exist in this recontextualization, since this is not what is at stake. What is at stake, is this: Given the same research question and sample, can other results and conclusions be made if the no longer missing correlation matrix is allowed materialize? Can the no longer missing correlation matrix be used to examine the role and impact of automation technology in a way that is not already done?

Given a research question with an explicit focus on the impact of technology (independent variable) on economic performance (dependent variable) Structural Equation Modeling (SEM) can be a good candidate in furthering the investigation. 'SEM can estimate many equations at once, and they can be interrelated, meaning that the dependent variable in one equation can be independent variable in other equation(s).' Hair et. al. (1998: 586).

Lisrel, Jöreskog and Sörbom (1993) simplify the life of those interested in Structural Equation Modeling, a computer-based statistical program allowing the user to specify and analyze a vast number of relations between independent and dependent variables in a rapid and flexible way. In addition, the program is designed to generate automatically graphical representations of the statistical relationships analyzed. However, Structural Equation Modeling presupposes a set of hypotheses to guide the work: 'The fundamental assumption in structural equation models is that the error term in each relation is uncorrelated with all the independent constructs. Studies should be planned and designed, and variables should be chosen so that this is the case.' (Jöreskog and Sörbom, 1993: 112-3). It is somewhat doubtful whether the published study adheres to such a design by intent. At that time the authors (Carlsson, Taymaz, Tryggestad, 1995) did not know about Lisrel, and Structural Equation Modeling was at least not part of what the present author was contemplating. On the other hand, if PROD83 and PROF83 were included as independent variables, they could fulfill the specified design requirements by 'accident'. Hence, given a time dimension, it was difficult to imagine that productivity and profitability in the 1983 annual survey were dependent on, say, automation level, productivity and profitability in the 1988 annual survey. I decided to work from the hypothesis that the reverse relation would hold, i.e., that PROD83 and PROF83 were independent (cause) variables in relation to the dependent (effect) variables PROD88 and PROF88. Given this causal working hypothesis, a time dimension going from 1983 to 1988 was incorporated into the model specification. But still the important questions underlying the first publication remained outside the model specification: what is the relationship between automation technology and economic performance? Does automation technology have any impact on economic performance? The adopted strategy of inquiry can be labeled ‘Model Generating’ (MG) in which, 'the researcher has specified a tentative initial model. If the initial model does not fit the given data, the model should be modified and tested again using the same data. Several models may be tested in this process. The goal may be to find a model which not only fits the data well from a statistical point of view, but also has the property that every parameter of the model can be given a substantively meaningful interpretation' (Jöreskog and Sörbom, 1992: 115).

It should be noted that the authors (ibid.) emphasize the difference between statistical and substantive criteria for assessing the relevance of a given model, much in the same way as McClosky (1992) does. Hence, it does not suffice that the model fits data well from a statistical point of view, as can be judged by a goodness-of-fit measure, but the model must also be given substantively meaningful interpretation.

In the initial model, the time dimension was included, with PROD83 and PROF83 serving as independent (causal) variables together with AUTOLEV, GROW (Growth rate of sales, 1983-88) and RDTOTAL (R&D intensity, R&D cost/sales). The dependent variables associated with economic performance were PROD88 and PROF88. Before running the model in the computer, the sample size was set to 56. The sample size was thus defined in a conservative way, being based on the correlation coefficient estimated with the smallest number of observations in the no longer missing correlation matrix (see Appendix, Table 2). It should be emphasized along with McCloskey and Ziliak (1996) and others that a less conservative sample size, ceteris paribus, tends to produce more statistical significant correlations among a given set of variables due to the increased statistical power from the sample size. So in order to comply with these concerns and the critique of the misuse of statistical significance (McCloskey 1992; Jöreskog and Sörbom, 1993; McCloskey and Ziliak, 1996), it was decided to specify the sample size in a conservative way. The t-values reaching statistical significance were set to 1.96 (at the 5% level. See also Jöreskog and Sörbom, 1993). When the model was run, it turned out that RDTOTAL was to be eliminated from further analysis due to a lack of statistical significance: no t-value was equal to or larger than 1.96 for this variable. Now, the time had come to use the remaining variables in order to build a more complex causal model. The present author assumed that there was a causal relation between PROD88 and PROF88 such that high labor productivity was regarded - in accordance to most elementary textbooks in economics - as being a factor contributing to profitability. Hence, the direction of the causal relation was assumed to be from PROD88 (independent variable) to PROF88 (dependent variable). It was further assumed that GROW could be regarded as an independent variable in relation to productivity and profitability in the year of 1988. In order to maintain the logical consistency of the model, the same assumption regarding the direction of the relation between productivity and profitability in 1988 was taken to hold for 1983. Finally, the degree of automation in the 1988 survey (AUTOLEV) was treated as a dependent variable in relation to productivity and profitability in 1983, but as an independent variable in relation to PROD88 and PROF88. This model specification is shown in Figure 1 below:

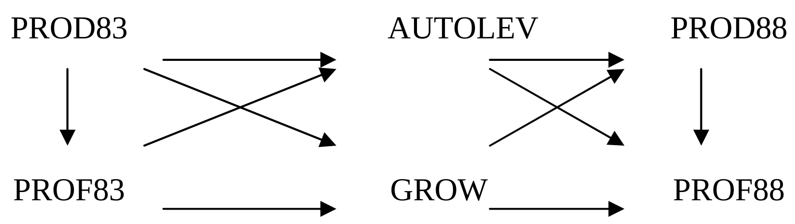

Figure 1. The complex model.

The goodness-of-fit statistics were not satisfying. CHI-SQUARE was 76.235, with 5 degrees of freedom and a P-value of 0.00. This result suggested a poor fit between the model and the data. A closer inspection of Lisrel's modification indices revealed that the model could be re-estimated in a way that would reduce the error terms (CHI-SQUARE) substantially. I decided to simplify the model by only including relationships that were statistically significant. Accordingly, only t-values equal to or larger than 1.96 were attended to - with one exception, the relation between PROD88 and PROF88. This exception was allowed in order to simplify the comparison with the first study, which focused specifically on the relation between degree of automation (AUTOLEV), on the one hand, and the economic performance variables PROD88 and PROF88, on the other. Hence the re-estimated model should not only comply with statistical criterion such as goodness-of-fit measures, but more important, it should also comply with the requirements of a substantive interpretation given the working hypothesis and the purpose at hand. The re-estimated model gave the following results:

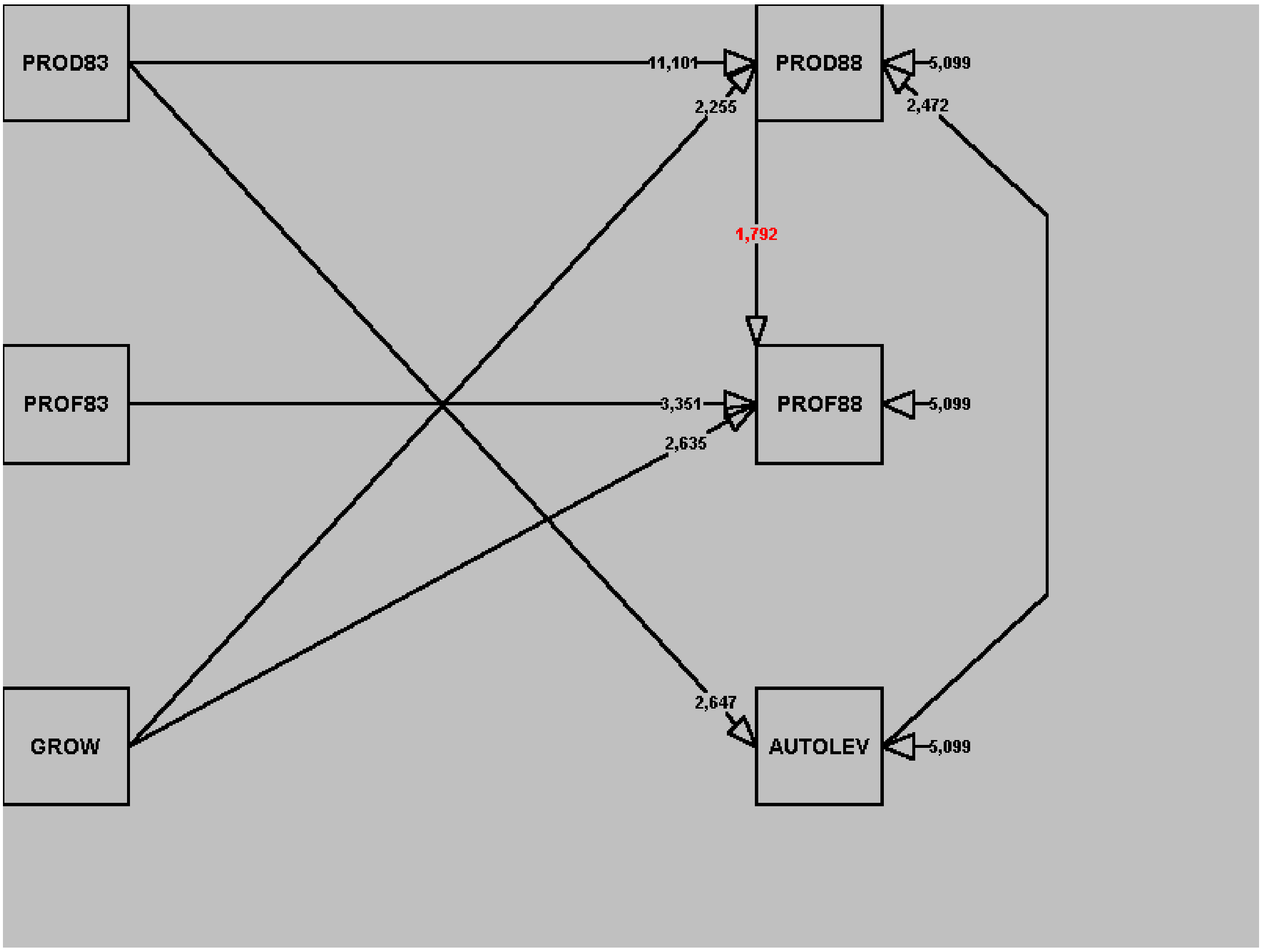

Figure 2. The re-estimated model

CHI-SQUARE was 3.701 with 5 degrees of freedom and a P-value of 0.593. The goodness-of-fit indices AGFI and GFI were positive and below 1.0 as they should be (Jöreskog and Sörbom, 1993). The statistics for 'Fitted residuals' was around 0.000, with some small positive values and one small negative value. This suggested that the model was neither overestimated nor underestimated with respect to the correlation matrix analyzed. All relations — with one explicit exception — were statistically significant. Hence, it is concluded that the model fits the data reasonably well. But then again, can the model be interpreted in a substantive and meaningful way, given the research question, the working hypothesis and the purpose at hand? Before answering that question, it can be useful to recall some of the results from the 1995 publication while comparing them with those from the Lisrel analysis. The authors (Carlsson, Taymaz, Tryggestad, 1995) emphasized the correlation between the degree of automation (AUTOLEV) and other variables, viz. the strong correlation with productivity (PROD88), the less strong correlation with profitability (PROF88), the somewhat negative correlation with the R&D/sales ratio (RDTOTAL), and the lack of correlation with sales growth (GROW). The similarity between the correlation matrixes (see also appendix, table 1 and 2) with respect to AUTOLEV and the other variables can be summarized in the following way (the ** sign indicates strong correlation, statistically significant at the 5 % level):

Table 3. The correlation between AUTOLEV and other variables in the two stories.

The stage story:		The stage story - recontextualized:	
PROD88	**(.4766)	PROD88	**(.4478)
PROF88	(.1679)	PROF88	(.1674)
RDTOTAL	(-.2316)	RDTOTAL	(-.1488)
GROW	(-.0997)	GROW	(-.0192)

Thus far, the two correlation matrixes tell almost the same story, there being only marginal differences (except RDTOTAL), which reflect differences in the number of observations and the associated problem of missing values. If the 1995 publication had used the no longer missing correlation matrix (Appendix, Table 2) the same results would probably have been reported for the variables summarized above. What can a LISREL analysis using the excluded variables and the time dimension add to these results? When PROD83 and PROF83 are allowed to enter into such an analysis, the results become more heterogeneous. Based on the last model specification in Figure 2, the relation between AUTOLEV and PROD88 is no longer the strongest one. On the contrary, that relation can now be ranked as number five from the top or as number three from the bottom with respect to the t-values obtained:

Table 4. Ranked t-values for model 2 (figure 2)

1. PROD83-PROD88 (11.101)	5. AUTOLEV-PROD88 (2.472)
2. PROF83-PROF88 (3.351)	6. GROW-PROD88 (2.255)
3. PROD83-AUTOLEV (2.647)	7. PROD88-PROF88 (1.792)
4. GROW-PROF88 (2.635)	

The relation between AUTOLEV and PROD88 is now the second weakest of the statistically significant relations. For GROW and PROF88, the relation is akin to what can be read off in the correlation matrix that was published - a positive and statistically significant relation. Yet for the same variable GROW there is also a new positive and statistically significant relation that pops up, that between GROW and PROD88. This is a relation that does not lend itself easily to being read off from any of the two correlation matrixes presented in the appendix.

Hence, a *substantive interpretation* would suggest that for the population examined:

1. The degree of automation at a given time is only marginally influenced by sales growth and by former profitability, and is more influenced by labor productivity in earlier years, that is, by PROD83.
2. a) At a given time the degree of automation has a smaller direct impact on profitability than on productivity. b) To the extent automation has an impact on profitability, the impact is mediated in a largely indirect way through present productivity.

This last result is basically in line with what was pointed out in the 1995 publication, only certain nuances have been added regarding the mediating role of present productivity. The first part is not at all in line with the results from 1995, since PROD83 and PROF83 were excluded from further analysis. Also worth noting are the statistically significant causal relations going from PROD83 to AUTOLEV, and from AUTOLEV to PROD88. The Lisrel analysis is thus capable of demonstrating the particular influence that certain of the relations between variables exert on other variables throughout the model, e.g. the path of statistically significant relations going from PROD83, passing through AUTOLEV to PROD88. Here, the significance of time is revealed most clearly, linking present productivity (PROD 88) to past productivity (PROD83), while demonstrating the mediating role of present level of automation (AUTOLEV).

Yet this is not the end of the significance of time. The significance of time can also be statistically confirmed and substantively interpreted with the help of an experiment. The statistically significant relations between AUTOLEV and PROD88, GROW and PROD88, as well as the somewhat weaker relation between PROD88 and PROF88, are influenced by PROD83 and by the strong relation between that variable and PROD88. If this relation is eliminated from the model, the model becomes a strong candidate for rejection. Such an experiment will also suggest that the correlations pointed out at the time of publication as being interesting are rather unstable. This case can be illustrated statistically by introducing a simulation experiment in which the relation between PROD83 and PROD88 is eliminated from the model shown in Figure 2 – much in the same way as PROD83 was eliminated from the published correlation matrix. The relation identified as being of special interest, i.e., the strong correlation between AUTOLEV and

PROD88, is altered. That relation has now become the strongest of all – much in the same way as was pointed out in the 1995 publication. The difference between the re-estimated model (figure 2) and the simulation model are summarized as ranked t-values below (Table 5):

Table 5. Ranked t-values for model 2 and 3

The re-estimated model (figure 2):	The simulation model:
1. PROD83-PROD88 (11.101)	1. AUTOLEV-PROD88 (3.651)
2. PROF83-PROF88 (3.351)	2. PROF83-PROF88 (3.359)
3. PROD83-AUTOLEV (2.647)	3. PROD83-AUTOLEV (2.647)
4. GROW-PROF88 (2.635)	4. GROW-PROF88 (2.635)
5. AUTOLEV-PROD88 (2.472)	5. PROD88-PROF88 (1.796)
6. GROW-PROD88 (2.255)	6. GROW-PROD88 (.834)
7. PROD88-PROF88 (1.792)	

Hence, all t-values have changed except for the statistically significant relations going from PROD83 to AUTOLEV, and from GROW to PROF88. The relation between GROW and PROD88 is changed from a statistically significant relation to the weak relation that can be read off from the published correlation matrix. Perhaps more interesting yet is to compare the goodness-of-fit statistics. With a CHI-SQUARE of 70.509 at 6 degrees of freedom and a P-value of 0.00, the fit between data and the simulation model is poor[3]. It is concluded that the simulation Model should be rejected in a direct comparison with the re-estimated model (figure 2) - if the statistical criterion of goodness-of-fit measurement is allowed to decide. But then again, there may be substantive reasons for a reversal of that conclusion. Does it make more sense to exclude than to include the path from PROD83 to PROD88? In the 1995 publication, this question was never addressed. In the present recontextualization, the question should be articulated for further discussion. During a Lisrel lecture at the Deparment of Business Administration, Lund University, a similar simulation was carried out in the presence of several economic researchers. The path from PROD83 to PROD88 was added and excluded. None of the researchers rejected the idea that it made sense to include that path as it suggested the

[3] Following the recommendation of Hair *et al* (1998) an extended simulation was conducted by setting the sample size to 200. As should be expected, the t-values increased quite substantially in the simulation model. The path between PROD88 and PROF88 became statistically significant. On average, a 90-100% increase in the t-values was recorded. With a chi-square of 255.113 at 6 degrees of freedom and a P-value =0.0, the fit between model and data is still poor.

significance of time in explaining improved productivity. The phenomenon of improved productivity over time is also well recognized within the field reflected in established notions, such as the '*experience curve*' and '*learning-by-doing*'. Such learning can take place – as the model in Figure 2 suggests, directly – not only by passing through the mediating role of present automation technology, as is suggested in the simulation model. Hence, the conclusion is that the path from PROD83 to PROD88 should be maintained as it makes sense in terms of direct learning effects. But it should be emphasized that this interpretation is difficult to make – if not impossible - by simply looking at this path in isolation. The interpretation makes sense in the context of the whole model of Figure 2. And perhaps the interpretation makes even more sense if we add the context of the simulation experiment. Hence, it is concluded that the simulation model can be rejected on both statistical and substantive grounds in favor of model 2.

To summarize: it has been argued that within the framework of the research questions and the data available, the 1995 publication could have reached different results and conclusions regarding the role and impact of automation technology on economic performance.

The reversible story: a second recontextualization

This final section of the case is devoted to an analysis of the distribution of roles among the humans and non-humans involved in the making of statistical accounts. The question of who is the author and thus to claim authorship, will be addressed. The claim made here is that humans are not the only ones that can claim the subjectivity associated with an actor, such as being an author. Humans may act, but somebody or something else may be involved in keeping the act going on. So "What´s going on?" McCloskey (1992: 361) asks while looking back on a systematic misuse of statistical significance within the economics profession. "I dunno. You go figure. But when figuring don`t use statistical significance". Following McCloskey's advice, the present recontextualization will draw upon the intellectual resources associated with constructivism and STS in order to seek some answers to the interesting question of what is going on.

A "significant" coefficient…means that the sampling problem has been solved… That is all it means, and all its mathematics justifies"(McCloskey 1992: 360). In the economists' practice, the distinction between "statistical significance" and "substantive significance" is all too often conflated, McCloskey and Ziliak (1996) argue. The former comes to represent the latter, albeit the two meanings of significance should be distinguished. Hence, in the hands of economists, "statistical significance" translates into multiple meanings of some "substantive" sort. When the distinction is betrayed in the economists' practice, a hybrid entity emerges. It is no longer pure statistics, only limited to the mathematical laws and the accepted statistical standards and principles. Nor is it simply an entity referring to the empirical word, being of practical and political relevance only. As a hybrid entity, it has acquired both the almost natural law-like qualities from the exact mathematical sciences as well as the practical relevance associated with the political. Hence, the entity has turned into a hybrid, of being both natural and political at the same time. The production of such hybrid entities, both natural and political, makes economists quite normal members of the research community, as several STS studies of 'Science in the making' have already shown (see also references above).

However, is it normal statistical practice to exclude variables, statistically significant correlation coefficients and correlation matrixes? To begin with, this is the case (compare the two first sections of the case) - although it is seldom accounted for in the published text. The lack of such accounts seems to be rather normal practice. Instead of incorporating a time dimension into the published correlation matrix, and thus following that path of investigation, the investigation went in the other direction through introducing factor analysis in which no time dimension was present. In this way, the factor analysis came to be based on a correlation matrix involving the problem of missing data reported. In the correlation matrix, which no longer is missing, the problem of missing data is less pronounced. The correlation coefficients are estimated here on the basis of 56 observations or more, which can be compared with the 36 units of observation in the published correlation matrix. Hence, the difference as compared with the data that was missing had less to do with the field that answered the questionnaire and more to do with the selection of a set of correlation matrixes to be used in the further analysis.

Thus, selectivity in the enrollment of different correlation matrixes seems to be an important aspect of the process of stabilization that turns figures into irreversible facts. The published correlation matrix (appendix table 1) became a stabilized object - no longer an entity worth commenting on.

Reversible statistics endeavor to account for the things that are missing or barely are granted any existence and significance in the laboratory of statistics - in this case the variables and correlation matrixes left on the cutting floor. In the 1995 publication no account was given of that event, but then again, this seems to be quite normal. Reversible statistics seek to provide an account of what could have been different, to reverse the case at hand. A first step in that direction has been accomplished in the last section by recontextualizing the case with a missing correlation matrix. That event suggests the significance of materials in the making of statistical facts. By adding diverse materials and calculative devices such as computer based SPSS, Lisrel and a printer, events such as a missing piece of paper can be multiplied in great magnitude. The computer based analysis allows for so many alternative model specifications, so many different population sizes, so many different significance levels, so many print outs – to be fast and flexible executed by a PC and a printer. The pile on the cutting floor will grow with a rate following the increased computing power of statistics. There will always be another story to tell – and this state of affairs is becoming more prominent with the presence of computer based calculative devices. Hence, the multiplication of possible stories is normal and to be expected, once the significance of diverse material things such as computers, printers and print outs are acknowledged in the analysis of what is going on.

In a recent investigation of computer based integrated circuit design (Kreiner and Tryggestad, 2002), reflective designers recognized that there were cases when the distribution of roles among the humans and non-humans involved shifted. The so-called design tool was no longer simply a tool in the hands of the designer, but delivered also the instructions and the premises for the design work. Who was the master and who was the servant (or tool) during the design process was not always easy to sort out, due to the seductive computer based artifacts.

An early version of computer based MOSES was instrumental in providing the calculations that showed the positive impact of automation on productivity. That result was used as a convincing argument for introducing computer based automation in the engineering industry in the 1980s. MOSES was thus capable of hardening facts and figures so as to make them political relevant. In the publication from 1995, the refined MOSES was in place. MOSES was adding weight to the results through a multitude of algorithms, years of annually surveys - aggregating all the way up so as to become relevant to national policy makers. MOSES plays the role of hard science of computer based mathematics and economics, containing “real” firms. MOSES carries also an association to the political, with a history of national technology policy making. The very name MOSES carries a few associations to mythological and moral qualities*. MOSES is yet another hybrid that threatens to erase the distinction between what is natural and what is political in economics. There are few good reasons to assume that economists are so much different from designers of integrated circuits. Both can very well be persuaded by computer based artifacts. Sometimes the artifact, or the model, seems to be in charge. McCloskey (1990/92: 4) is commenting upon a the same issue. “Economic metaphors if pushed too far, as a 500-equation model of the American economy can be, produce storytelling nonsense.” Somebody has to perform the 500-equation model. Humans among themselves are not so good at it. For better or worse few 500-equation stories would exist if computers did not produce them. So the question is, who is the author of the economists' stories? Who produced the story and can claim authorship? This question is not so straightforward as it may seem.

The case of reversible statistics suggests that roles of authorship can be reversed during the course of events. The case also suggests that the presence of computer based models such as MOSES can be instrumental in authorizing the results from calculations, so as to make them harder, more of an indisputable fact, and hence more of potential “substantive” relevance for policy-making. “Statistical significance”, is only one of many possible entities that can be instrumental in hardening facts.

To take another example of the significance of diverse materials – the questionnaire: The use of surveys is normal procedure in statistics. But what is actually going on each time statistics is being made through a questionnaire? A process of translation (Callon 1986, Latour, 1987) takes place. This process involves humans on both sides of the questionnaire, “respondents” as well as statisticians. In the 1995 publication, humans on both sides of the questionnaire are implicitly portrayed as being passive mediators or mere *intermediaries* (Latour, 1999). The act of answering the questionnaire is being portrayed as a sort of reflex - as the ”respondents” delivering answers upon request. This is a quite normal way of accounting for the act of answering a questionnaire. The act is accounted for by a rhetoric excluding any second thoughts, the pain and troubles that went into answering the question ”State the degree (in percentage) of automation in the production process for the different products” (AUTOLEV). At the same time, the questionnaire survey translates a thousand silent voices – the other members of the ”respondent organization” – to one homogeneous voice speaking on behalf of them all: ”In factory X of company Y, for product Z, the automation level is between 25-50%”. The answer from one questionnaire then acts as a stand-in representing many humans. But not only that, the one answer

* A not so distant relative to MOSES is baptized ADAM (Annual Danish Aggregate Model).

acts perhaps first and foremost as a stand-in representing another non-human – the particular collective known as the “firm”.

Of the 347 potential ”respondents”, 94 were later to be entered into the computer as ”cases” associated with the variable AUTOLEV. The authors did their work in the normal way when confronted with the ”missing observations”. A number of ”missing observations” was contacted by phone in order to reduce their magnitude in the final report. In several cases the statisticians succeeded quite well in convincing them of the importance of delivering a statement regarding the ”degree of automation”. Hence, by negotiating with the ”missing observations”, they were translated into ”cases” to be entered into the computer. These additional cases were in turn instrumental in order to approach the norm among statisticians for what is an acceptable number of observations to be used when correlation coefficients are to be estimated. Those who simply refused to answer the question, some of them highly familiar with the complexities involved in the notion of automation, were translated into the black box of ”missing observations” finally reported in the 1995 publication. This seems to be quite normal practice in statistics. (It is not equally normal to open the black box reported as ”missing observations” by giving an account of the heterogeneity inside it). The remaining part of the procedure is then portrayed as a simple one-to-one translation between the answers obtained in the questionnaire and the data which is entered into the computer: ” CASE 1: ENTER AUTOLEV=0.25”. The statisticians are thus translated into being carriers of pure data - no second thoughts, no tinkering and no trembling hands - their intervening between the answers in the questionnaire and the data entered into the computer. No account of trembling hands was given. Even this seems to be quite normal. Statisticians and the voices from the field go along with the *script* (Akrich 1992) of “rigorous statistics”, and enact the roles as “respondents” and “one-to-one translators”. Both roles are enacted in the interaction with the questionnaire. It is the questionnaire that acts as a stand-in representing “rigorous science and statistics ” in relation to those humans answering it. In relation to those humans receiving the answers, the questionnaire is seen as a carrier of pure data – of what is “real”. Those who re-enact (Latour 1987) and de-scribe (Akrich 1992) the script, who questions the questionnaire as a stand-in for “rigorous science and statistics”, are translated into “missing observations”, the negation of data – that of which is less real. When statisticians and those answering the questionnaire go along with the script, diverse materials in the network of which they form a part circumscribe them. The questionnaire and the computer become the active mediators between passive human intermediaries. In the laboratory, the circumscribed statisticians say ”This is the best we can do, and at any rate it is no different from what others are doing”. The translation between questionnaires and computers works in this way, reducing heterogeneity to homogeneity among the humans involved.

To take a third example – the significance of diverse materials in the making of data. What is data? To perform statistical calculations, data is required. To perform the calculations and conduct the statistical investigation, data must be made into being. When data are made into “real” entities, they have gone through the process of translation just described, involving diverse materials such as a questionnaire survey and a computer. But data can also be made into “synthetic” entities. The computer is now delegated the role as *data generator*. Hence, the difference between “real”- and “synthetic” data is constructed from the (re)distribution of roles among the diverse material entities involved: When both the questionnaire and the computer is present in the making of data, they become “real”. When all the work of making data is delegated to the computer, it becomes “synthetic”. This is also the moment when the not so co-operative “missing observations” are translated and made into “synthetic” entities. Hence, the negotiated character of “missing observation” takes one more turn in the laboratory of statistics. Through delegation, the computer is completing the work where the statistician and the potential “respondent” stopped short. When the humans involved failed to negotiate a statement producing “real” data, the computer was able to complete the task by translating “missed observations” into “synthetic” data. “Data” seems to be both natural and political entities. They are made from diverse materials; they are negotiated in a process of translation to become “real” and “synthetic”. Both “real” and “synthetic” data are the twin outcomes of the same process of translation. These outcomes are then converted into an “input file” or “data base” for further calculation. In the laboratory of statistics, the humans wonder whether “ data is co-operative today”. This is the moment of truth when “input” is converted into “output” by pressing the “run” button on the computer. The statistical analysis is run. As free and independent actors, data can be more or less co-operative. Humans have been delegated the role as their servants, to carry them over to be published, and to make them public. Data have become facts that speak for themselves - as can be seen in Appendix, Table 1.

To conclude and summarize the case of reversible statistics: The 1995 publication (the stage story) has been recontextualized. In the first recontextualization, the significance of diverse materials such as a print-out of a missing correlation matrix has been investigated. From this investigation it is concluded that the results from the 1995 publication could have been different given the conditions and the particular setting in which the study was conducted. In the second recontextualization, the significance of diverse materials such as computer based automation of statistics; questionnaire surveys and "real" and "synthetic" data are investigated. It is argued that the diverse materials may reverse the roles among the humans and non-humans involved in the production of statistics. Thus, it is not self-evident who can claim authority and authorship in the making of statistical facts and artifacts. For example, the very distinction between facts and artifacts of statistics, e.g., between what data is "real" and what is "synthetic", is an outcome of a process of translation and negotiations among the humans and non-humans involved. Such outcomes are highly circumscribed by the presence and absence of diverse materials from which the statistical facts and artifacts are made.

A simple test for reversible statistics is to ask whether the stage story remains unaltered in the hands and eyes of the reader. If the stage story remains unaltered after reading the whole case, the case of reversible statistics has probably failed. If something has been added, there can still be room for a case on reversible statistics. The reader has now participated in re-enacting the stage story, making it less irreversible. At the same time, the reader participates in translating and extending the notion of what normal statistics is: From its being a stage story, to its being an extended story, to its being the reversible story, all these normal scientific accounts. A closer attention to the significance of the diverse materials of statistics can thus pave the way for a more symmetric relation between the statistical text and the reader.

On the whole, the case of reversible statistics is a rather normal one: no gin, dead bodies, rotten noses, hate, and syphilis, at best a few small taboos revealed in the process. Things were slightly different in the heydays of political arithmetic - or perhaps the difference is not that great after all. What is natural and what is political, what are facts and what are artifacts in the case of reversible statistics seems to be a rather complex task to sort out. Indeed, the very distinctions and boundaries between facts and artifacts seem to be in flux in the laboratory of statistics – as elsewhere.

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APPENDIX

Table 1. The published correlation matrix (source: Carlsson, Taymaz, Tryggestad, 1995, pp. 415-6)

Correlation Matrix for Variables in the Factor Analysis

VARIABLES	F1	F2	F3	CODE	KONK-PK	KONK-PROC	KONK-KOMM	KONK-ORG	KONK-ARB	KONK-FOU	KONK-KVAL
F1	1.0000										
F2	.0137	1.0000									
F3	-.0830	.0042	1.0000								
CODE	.2713	-.1134	.3111	1.0000							
KONKPK	.5697**	-.4498*	-.1888	.2041	1.0000						
KONKPROC	.4920*	-.0178	-.6670**	-.0607	.4992**	1.0000					
KONKKOMM	.5153**	.2376	.0041	.1723	.2657	.2926	1.0000				
KONKORG	.3008	-.1219	-.2259	.0284	.5203**	.4144*	.2106	1.0000			
KONKARB	.1858	-.1641	-.3221	.1004	.5837**	.3646	.0757	.7568**	1.0000		
KONKFOU	.5565**	-.0014	-.2432	.0861	.5013**	.3279	.3891*	.6078**	.5031**	1.0000	
KONKKVAL	.0580	-.1323	-.0740	-.0942	.4642*	.2878	.1145	.4173*	.4985**	.2699	1.0000
KONKFLEX	.5106*	-.1893	-.1033	.0567	.5092**	.3025	.5574**	.4723**	.1422	.5398**	.2795
KONKRAAV	-.0043	.4028*	-.1338	-.4306*	-.1256	.0557	.0015	-.0477	.0024	.0000	.0468
PROD88	.0374	.8459**	-.1235	-.2035	-.3598	.0109	.2448	-.1308	-.1234	-.0692	-.1913
PROF88	.7053**	.2460	.1466	.2192	.1638	.0909	.2986	.1334	.0247	.2837	-.1509
GROW	.7804**	-.1973	-.0626	.1763	.4515*	.1688	.3665	.1395	.0168	.3622	-.0571
EMPLOY	-.0089	.0768	.7802**	.2333	-.0221	-.2195	.0639	-.0778	-.2809	-.2375	.1798
AUTLEVEL	.0495	.7862**	.0898	-.1729	-.1023	.0772	.2406	.0186	.0285	.1225	-.0152
RDTOTAL	.5265**	-.1593	.6163**	.4533*	.1876	-.1166	.2837	.0784	-.0609	.2186	.0246
SKILL	.6700**	.3166	.0913	.2166	.2485	.1281	.4367*	.1211	.2033	.2533	.0926
PROD	.0323	-.4357*	.5471**	.2387	.3922*	-.6013**	-.0811	.0358	.1482	.1031	.1300
BOTH	.5994**	-.2539	.4968*	.0638	.8448**	.8854**	.3137	.5327**	.5365**	.4650*	.4311*
TRAINL	.0174	.3979*	-.0203	.0393	-.2825	-.1607	.1800	-.0098	-.0253	.1553	-.1460
TRAINS	-.0686	-.2913	-.0466	.1264	.0035	-.0338	.1894	.0061	.0768	.1139	.1587

APPENDIX (Continued)

VARIABLES	KONK-FLEX	KONK-RAAV	PROD88	PROF88	GROW	EMPLOY	AUT-LEVEL	RD-TOTAL	SKILL	PROD	BOTH
KONKFLEX	1.0000										
KONKRAAV	-.0167	1.0000									
PROD88	-.1685	.3225	1.0000								
PROF88	.1443	-.0026	.1915	1.0000							
GROW	.4988**	-.0449	-.0271	.4383*	1.0000						
EMPLOY	.0444	-.0590	-.0470	.1260	.0921	1.0000					
AUTLEVEL	-.0899	.3951*	.4766**	.1679	-.0997	.1581	1.0000				
RDTOTAL	.3113	-.3043	-.2188	.4000*	.3985*	.3251	-.2316	1.0000			
SKILL	.2444	.1075	.1902	.4301*	.2906	-.0690	.2103	.3858*	1.0000		
PROD	.1378	-.1749	-.3353	.0633	.2379	.2130	-.1689	.2942	.0946	1.0000	
BOTH	.4538*	-.0330	-.1843	.1497	.3484	-.1456	.0025	.0301	.2127	-.1609	1.0000
TRAINL	.0851	-.0866	.3687	.1026	.0260	-.0801	.2175	.0621	.2508	-.0907	-.2481
TRAINS	.1952	-.2383	-.2867	-.2565	.0275	-.1109	-.2322	.0870	.0812	.0397	-.0188

Table 2. The no longer missing correlation matrix

SPSS/PC+

```
CORRELATIONS /VARIABLES PROD83 PROD88 PROF83 PROF88 GROW AUTLEVEL RDTOTAL
RDSWEDEN /OPTIONS 2 5 /STATISTICS 1.
```

Variable	Cases	Mean	Std Dev
PROD83	246	674.6347	550.5459
PROD88	249	1023.7427	626.4116
PROF83	245	30.5474	14.6949
PROF88	230	30.4888	15.4328
GROW	178	150.2384	61.9140
AUTLEVEL	94	45.5040	29.3867
RDTOTAL	78	.0426	.0578
RDSWEDEN	76	.0386	.0489

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Correlations:	PROD83	PROD88	PROF83	PROF88	GROW	AUTLEVE
PROD83	1.0000 (246) P= .	.8457 (184) P= .000	-.0790 (245) P= .109	.1205 (172) P= .058	-.0681 (178) P= .183	.3446 (62) P= .003
PROD88	.8457 (184) P= .000	1.0000 (249) P= .	-.0611 (183) P= .206	.2151 (230) P= .001	.0941 (178) P= .106	.4478 (75) P= .000
PROF83	-.0790 (245) P= .109	-.0611 (183) P= .206	1.0000 (245) P= .	.3799 (171) P= .000	.0056 (177) P= .471	.1674 (62) P= .097
PROF88	.1205 (172) P= .058	.2151 (230) P= .001	.3799 (171) P= .000	1.0000 (230) P= .	.3300 (168) P= .000	.2547 (70) P= .017

(Coefficient / (Cases) / 1-tailed Significance)

' " is printed if a coefficient cannot be computed

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Correlations:	PROD83	PROD88	PROF83	PROF88	GROW	AUTLEVE
GROW	-.0681 (178) P= .183	.0941 (178) P= .106	.0056 (177) P= .471	.3300 (168) P= .000	1.0000 (178) P= .	-.0192 (56) P= .444
AUTLEVEL	.3446 (62) P= .003	.4478 (75) P= .000	.1674 (62) P= .097	.2547 (70) P= .017	-.0192 (56) P= .444	1.0000 (94) P= .
RDTOTAL	-.1811 (57) P= .089	-.2055 (77) P= .036	.2999 (57) P= .012	.3379 (71) P= .002	.2971 (57) P= .012	-.1488 (60) P= .128
RDSWEDEN	-.1817 (57) P= .088	-.2086 (75) P= .036	.2892 (57) P= .015	.3644 (70) P= .001	.2920 (57) P= .014	-.0801 (58) P= .275