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Late Nineteenth Century Britain: A Social, Political, and Methodological Context for the Rise of Multivariate Statistics

DANIEL J. DENIS & KARA R. DOCHERTY¹

Abstract

George Udny Yule, student of Karl Pearson, is usually credited with the first complete multiple regression (Yule, 1899). And although this monumental work has been well documented by historians of statistics (e.g., see Desrosières, 1998; Stigler, 1986), the social, political, and methodological ambitions that gave rise to this project have been less recognized. In the present piece, we trace the earliest post-Galton seeds of multivariate innovation. In late nineteenth century, we get a first glimpse of how social and political influences merged with methodological and statistical concerns to inspire a new multivariate technique and extend on Galton's bivariate correlation. Charles Stewart Loch, then secretary for the Charity Organization Society (C.O.S), responded to Charles Booth's extensive and ground-breaking study *The Aged Poor in England and Wales*, and vehemently rejected conclusions surmised by Booth. In critically evaluating Booth's methodology, we find that Loch played an instrumental role in bringing awareness of the need for a new statistical methodology.

Résumé

On attribue d'habitude à George Udny Yule, étudiant de Karl Pearson, la première rétrogradation multiple (Yule, 1899). Et, bien que ce travail monumental ait été bien documenté par les historiens de la statistique (par exemple, voir Desrosières, 1998; Stigler, 1986), les ambitions sociales, politiques et méthodologiques qui ont motivé le projet sont moins connues. Dans ce papier, nous localisons les premières tentatives d'innovation multivariée après Galton. Charles Stewart Loch, alors secrétaire pour la Société d'Organisation de Charité (C.O.S), a réagi à l'étude extensive de Charles Booth *The Aged Poor in England and Wales* et en a rejeté avec véhémence les conclusions. Nous montrons que Loch a contribué à la prise de conscience de la nécessité d'une nouvelle méthodologie statistique.

¹ Correspondence concerning this article should be addressed to Daniel J. Denis (daniel.denis@umontana.edu), Department of Psychology, University of Montana, 32 Campus Drive, Missoula, Montana, , 59812, U.S.A.

Statistical methodologies usually arise in conjunction with social and political drives (e.g., see Mackenzie, 1981). Applied statistical tools, coupled with a fertile *Zeitgeist*, often serve as replies to questions of great social and political interest. Just as Francis Galton's invention of correlation and regression is a special case, the rise of multivariate statistical methods in late nineteenth century Britain is also testimony to this claim. In 1892, Francis Ysidro Edgeworth (1845 - 1926), a distant cousin of Galton, would publish "Correlated Averages" in which, using some of Galton's original data, would show how bivariate correlations could be calculated in a simpler way than in Galton's original computations. More important, he would also demonstrate how the theory of bivariate correlation could be extended to the multivariate case.¹ Unfortunately, his treatment was relatively technical and did not facilitate the use of real data. The true "growth spurt" in applied multivariate analysis would occur shortly after Edgeworth's paper in the context of a social problem that was of chief social interest in late nineteenth century Britain, that of policy governing the administration of poor relief.

The goal of this article is to provide an account of the social, political and methodological context in which early multivariate methodologies were first conceptualized and applied. Although the first applied multivariate analysis is generally credited with George Udny Yule (1871-1951) (Desrosières, 1998),² student of Karl Pearson, the context in which Yule's pioneering work came about is less well documented. As will be seen, Yule's work arose primarily out of an intense social and methodological debate over a claim made by Charles Booth in *The Aged Poor in England and Wales* published in 1894. A key, but as yet unrecognized figure in this debate was Sir

Charles Stewart Loch, then secretary of the Charitable Organization Society.³ Loch's criticism of Booth's methodology in the mid-1890s would soon be followed by Yule, and by 1899, Yule's multivariate analysis would be complete.

The article begins with an overview of Charles Booth's work and his claim that there was no relationship between pauperism and type of relief (in-door vs. out-door). As will be seen, the implications of Booth's conclusions were in direct opposition to opinions held by Loch and the C.O.S. Next, Loch's critique of Booth's work is reviewed. The debate between Booth and Loch helped to spark the development of a multivariate statistical method and to provide an ideal social and methodological context for its inception. Yule's critique of Booth then follows and a methodological link between Yule's work and that of Loch's is suggested.

Charles Booth and The Aged Poor

The Poor Law Amendment Act of 1834 sought to create in Britain a unified system that would govern and control the distribution of relief (i.e., welfare) in such a manner that able-bodied paupers would have to earn their relief by working in "poor houses." Presumably, the Poor Law was designed to help discourage the population at large from "wanting to be poor" since relief would only be given to those who were willing to tolerate the rather harsh, and sometimes humbling and humiliating conditions of working in London's poor houses (Davis, 1999). Essentially, the law was passed to "deal rigorously with voluntary pauperism" (Fawcett, 1975, p. 14). Only those paupers unable to work in poor houses, and this included the elderly, would be given out-door relief⁴ and would be excused from earning their monetary assistance.⁵

In the late 1880s, Charles Booth, a business man with a keen interest in the social conditions of the poor, set out to conduct one of the first complete surveys of poverty in England.⁶ This work, *Life and Labour of the People in London* spanned the years 1889 to 1903 and consisted of seventeen volumes. In a related work, *The Aged Poor in England and Wales*, published in 1894, Booth addressed a problem that he considered to be of prime importance, that of a lack of rules or policy governing the distribution of relief to the poor. Booth was concerned that apart from able-bodied persons, there generally did not appear to be any rules or guidelines with regard to the distribution of relief. In the preface to *The Aged Poor*, Booth explained why knowing the conditions of the poor was important:

The great importance of these comparisons arises from the fact that, as regards the treatment of the old, the Poor Law and regulations of the Local Government Board leave the most complete liberty of administration As regards the able-bodied there are, indeed, regulations which have the force of law, prescribing the terms of which relief may be given; but for those who are not able-bodied, and these include almost all the old, each Board of Guardians is at liberty to adopt its own rules and to change them at will, or to act without any rules at all. Each Board is free to give any sum it may think fit as out relief The result of so much freedom of action is an extraordinary diversity of administration, only affected by the personal influence of the Government Inspectors To make more possible and more profitable a study of the six hundred and forty-eight separate lessons in administration which the conduct of the Poor Law Unions of England and Wales afford, is the object of this book. (Booth, 1894a, pp. v-vi)

Booth's book is filled with many numerical tables purporting to show various relationships that characterize conditions of the poor. The method adopted by Booth was to group unions⁷ "similar in most respects but differing much in administrative policy, to show the result of different systems of administration with considerable effect" (Booth, 1894a, p. 56). A total of twenty groups of unions were produced, using a year count of paupers, presumably with similar characteristics in each group. For each group, Booth compared the unions at the top and at the bottom (i.e., those groups showing the most and the least pauperism) with the average of the "union group" under consideration. One of the general conclusions that arose from Charles Booth's work, one that was at great odds with Charles Stewart Loch, was that there was no relation between out-door relief and pauperism. According to Booth, whether or not you received out-relief or in-door relief, this did not influence your chance of being a pauper. He concluded: "The proportion of relief given out of doors bears no general relation to the total percentage of pauperism" (Booth, 1894a, p. 423). Essentially, Booth claimed that even if out-door relief was given, it did not in itself increase the percentage of pauperism. Such a claim and conclusion would, consequently, allow certain people (e.g., the elderly) to obtain out-relief more easily and not be subjected to working in poor houses. His claim, if indeed correct, would have far reaching consequences on the political interpretation of the Poor Law of 1834. If there was indeed no relationship between type of relief (i.e., in-door versus out-door) and rate of pauperism, then could there be any justification for *not* administering out-relief more freely and liberally, especially to the elderly? One of Booth's political goals then, was to demonstrate, through a *quantitative analysis*, that the elderly require a pension (Booth, 1899; Brooks, 1892; Rae, 1892; Spicker, 1990).

The implications of Booth's claim were at odds with many who held that the only way to reduce the amount of paupers, and hence limit the rate of poverty, was to make poverty a grossly "unpleasant condition" with aversive consequences. Radical advocates of this view were staunch upholders of the Poor Law of 1834. The Charitable Organization Society was one such organization that was largely opposed to any policy that awarded relief on an out-of-door basis.

Charles Stewart Loch and the Charity Organization Society

The Charitable Organization Society, or C.O.S, was founded in 1869. One of its goals was to promote an efficient distribution of charitable resources, and minimize waste (Englander, 1998; Mackay, 1896). Its members included such personel as Octavia Hill, Charles Bosanquet, Edward Denison, and their "indefatigable" secretary (Englander, 1998), Charles Stewart Loch. Loch was born on September 4, 1849, and died on January 23, 1923. He attended Trinity, Glenalmond, and Balliol Colleges at Oxford before being appointed as Secretary to the C.O.S in 1876. Although he was Professor of Economic Science and Statistics at King's College, London from 1904 to 1908, Loch's major contributions occurred with the C.O.S. As remarked in his obituary, "Sir Charles became recognized as an expert authority on questions affecting the condition of the poor and the administration of public and voluntary assistance" (E.C.P., 1923).

Loch's involvement in the poverty debate began in earnest in 1893, when he was appointed to the Royal Commission on the Aged Poor. The Commission was set up to investigate the problems of long-term care for an ageing population. The workhouses of the poor were crowded with ill elderly folk (Murphy, 1999), and essentially, the role of the Commission was to report on ways of resolving this problem. The Commission would

issue its report and findings in 1895. For those who wanted new reform on the Poor Law, and favored pensions for the elderly, the 1895 Commission “was a disaster from start to finish” (Murphy, 1999, p. 681). The Commission, instead of recommending to jettison the Poor Law tradition, would recommend the essential upholding of it (Abbott, 1911). As noted by Green (1895), “The government expected to receive from the Commission some valuable suggestions on the best mode of providing for the aged poor . . . to find the bulk of the report devoted to suggestions for improving rather than superseding the present Poor Law machinery” (p. 294).

It is in this context that the debate between Booth and Loch arose, and where Yule would enter the act with a novel statistical solution.

Booth vs. Loch

In a review of Booth’s book published in 1894 in *The Economic Journal*, Loch argued tenaciously for why he believed Charles Booth’s conclusion to be grossly misleading. Loch wrote: “Mr. Booth’s general conclusion (p. 29) is that it is proven that ‘the numbers in receipt of indoor relief are very much increased when outdoor relief is not given,’ and that ‘a decrease in out relief is almost balanced by an actual increase in indoor relief’” (Loch, 1894, p. 472). Booth’s claim generally implied that if you do not give the poor out-door relief, they will seek it through in-door relief means. In essence, this meant that people would in fact subject themselves to the poor houses in order to earn relief if it was not given to them out-of-doors. Hence, Booth held that *poverty did not necessarily increase with a liberal policy of out-door relief*. If one was poor, there was a more or less legitimate reason for it, and it was not just to escape the duties of working in London’s poor houses. The Charity Organization Society opposed Booth’s finding. As noted by

Bales, “Of the philanthropists interested in Booth’s work the Charity Organization Society might have been expected to show the greatest interest, but for the C.O.S., Booth’s proposals for ‘limited socialism’ were totally objectionable. His plans they damned . . . with the faintest of praise” (Bales, 1999, p. 158).

Why would the C.O.S., a group of philanthropists, reject Booth’s claim? His finding of no relation between pauperism and out-door relief was in direct contrast to what was held by Charles Loch and the C.O.S. The C.O.S. essentially believed that if you increase the amount of out-relief, people would essentially take advantage of “easy money” and the rate of pauperism would also increase. Furthermore, the C.O.S saw it’s duty to help empower the poor, through teaching them how to manage their resources, rather than providing them with unearned resources. As noted by MacKinnon, for the C.O.S, “almost all who could not be assisted privately should enter the workhouse . . . some members of the C.O.S wanted to abolish outdoor relief altogether” (1987, p. 606). Indeed, Loch held that “all pauperism, all habitual dependence on the State for maintenance, is grievous” (Loch, 1895a). The opinion was not an arbitrary one at the time (Farnam, 1888) but, as noted by Englander (1998), was based on a foundational philosophy regarding the moral development of the masses. As remarked by Owen, “his [Loch’s] whole career and that of the agency [C.O.S.] which he dominated rested on the thesis that pauperism (and to a considerable extent, poverty) was the result of moral weakness on the part of the individual” (Owen, 1964, p. 228). The C.O.S. promoted a self-reliant individualism (Lynd, 1968; Rose, 1972) and according to Himmelfarb (1991), one of the missions of the C.O.S. could be seen as upholding the strict, somewhat extreme (Roberts, 1963) out-relief policy of the Poor Law of 1834. For the C.O.S., living conditions associated with

poverty had to be made extremely undesirable if poverty was ever to be reduced. Working in the poor houses of London would provide, at minimum, plenty of incentive for one to not “want” to be poor. For Loch and the C.O.S. then, the role of a charitable organization was, in part, to limit governmental support to individuals (Loch, 1893a; 1893b; 1895b; 1899), and to instill a sense of responsibility in its recipients:

[...] a statutory and rate-supported allowance system reduces all remedies [i.e., solutions to poverty] to one – to the granting of money: it thus deprives the people of one most useful means of *social education*⁸ [emphasis added], the personal responsibility of charity, and it prevents any large growth of that responsibility. (Loch, 1904, p. 5)⁹

Prior to Booth’s surveys, the debate over the issue of in-door versus out-door relief resolved itself largely out of preference, not based on any substantial information and certainly not based on any statistical information. By the late 1880s however, Booth’s claim that there was no relationship between out-door relief and pauperism was not so bold a conjecture, and was based on something more than political opinion about welfare policy. Indeed, as remarked by Bales, “what is undeniable is that Booth’s research findings altered the nature of political argument, and more than prompting specific actions contributed to a trend of basing new social policy on scientific study” (Bales, 1999, p. 164). Booth’s general survey-approach into the conditions of the poor were novel, and he is regarded as a true pioneer in social survey methods (Bales, 1996; Bulmer, Bales and Sklar, 1991). It is Booth’s analysis, on which he based his controversial conclusion of no relation between pauperism and out-door relief, that would come under fire by Charles Stewart Loch and the C.O.S. The remainder of this article is

the story of how Loch's objections to Booth's work, using a methodological argument, helped to create and contextualize a statistical sub-plot to the social-political debate of how to administer and allocate welfare in late nineteenth century Britain. As will be seen, the methodological and philosophical problems emphasized by Loch (and later Yule), helped to provide a context for one of the first complete applied uses of a newly developed multivariate statistical method.¹⁰

Loch's Critique of Booth's Analysis

At the outset of his review of Booth's *The Aged Poor*, Loch left little doubt about his opinion concerning Booth's methodology:

It is hardly possible for any reader to judge of the correctness or sufficiency of the large mass of statistical statements which Mr. C. Booth's book contains, unless he has himself traveled over the ground that it covers, or reanalyzed to some extent the data upon which its propositions are founded. (Loch, 1894, p. 468)

According to Loch, there were many problems with Booth's work. First, Loch disagreed with Booth's having used a year count in computing his tables of individual comparisons of unions, arguing that people might transfer from one union to another over a course of a year. This would result in a double or even triple count of certain individuals. Loch cited this problem alone as sufficient reason to discredit the findings: "We have said enough, we think, to show that all his comparative statements of year pauperism as to London and London unions must be considered untrustworthy" (Loch, 1894, p. 471). In place of the year count, Loch recommended that the "day count" of

paupers be used, arguing that “the day count is a more precise index of pauperism than the year count. And it is also a fairer test” (Loch, 1894, p. 471).

A second critique of Loch, more relevant to the germ of multiple regression, concerned the ahistorical nature of the individual comparisons. He argued that since Booth’s tables were not historical, but were based only on a single year, they did not yield what Loch called “conclusive data” (Loch, 1894, p. 473). The problem Loch had with the comparisons was that they were based on a single year only, and did not consider change in population as a potentially influential “covariate.” Loch argued: “As the tables are not historical, they do not allow of any comparison of past and present -- a condition essential to the formation of a correct conclusion” (Loch, 1894, p. 473). With this argument, Loch inched closer to specifying what is needed for a more accurate analysis of Booth’s data -- a multivariate technique: “. . . for instance, the effect of increasing population in reducing the percentages of pauperism is entirely overlooked, and unions are credited with a low pauperism to which on administrative grounds they are in no way entitled” (Loch, 1894, p. 473).

Loch’s argument was, methodologically speaking, that since the change in population from 1871 to 1891 was not controlled for when comparing rates of pauperism, Booth’s substantive conclusions were misleading.¹¹ He then argued that if one were to take the percentage of indoor paupers and outdoor paupers relative to the population, this would improve matters a great deal. By doing so, he said, one could then make comparisons of a union with itself, and hence produce “historical” (Loch, 1894, p. 473) tables of comparison. What Loch really wanted, more generally, was to have some way of *controlling for extraneous variables* (i.e., in this case, population) that might otherwise

influence the relationship (or comparison) between the variables under consideration. If one were to have “historical” tables, one could account for a change in pauperism *over time*. This would presumably control for the unwanted influence of population size.¹² Loch envisioned another way of solving the problem however, and it is in the following passage where he spelled out the conceptual basis for a method of multiple regression, a statistical method later to be taken up by statistician George Udny Yule:

Failing this plan there is another – to group the Unions and compare them in groups – but for that too the tables are wanting. Unions cannot be compared with one another unless *some system* [emphasis added] be adopted by which differences in the number, sex, or age of the population be ‘standardised’ for purposes of comparison. This is neither done nor attempted. This, the real difficulty of the problem, is ignored. Yet, if our objection on this score be well grounded, the inutility of almost all the tables of comparison in the book must be admitted. (Loch, 1894, pp. 473-474)

Loch could not have described the need for a multivariate technique any better than he did in the above passage. In arguing for some system by which number (i.e., population), sex, or age be “standardised,” Loch made a direct conceptual link to partialling out extraneous variation. That is, since population, sex and age *may*¹³ have unduly influenced Booth’s individual comparisons, Loch wanted them standardised (i.e., partialled out, or controlled for), so that an accurate comparison of unions could be achieved. Loch then went on to critically evaluate the way in which Booth arbitrarily¹⁴ grouped his unions when making comparisons. In representing different groups or classifications of unions, Booth gave Table 1, with a description of how the unions were grouped.

Table 1

Booth's Grouping of Unions and Pauperism Statistics (reprinted from Loch, 1894)

Union.	From Mr. Pell's return, 1891.			Out relief to total (Mr. Booth).
	Indoor on Population.	Outdoor on Population.	Total pauperism on Population.	
A.—				
Freebridge Lynn, Norfolk ...	0·4	4·1	4·5	85·0
Flegg, Norfolk	0·7	3·3	4·0	68·0
Hambledon, Surrey	0·9	2·6	3·5	57·0
A B.—				
Dunmow, Essex... ..	1·1	3·7	4·8	60·0
Warminster, Wilts	0·5	4·6	5·1	84·0
Wincanton, Somerset	0·8	4·9	5·7	74·0
North Witchford, Cambridge ...	0·8	2·6	3·4	64·0
Cranbrook, Kent	0·8	2·7	3·5	57·0
Sturminster, Dorset	0·6	4·3	4·9	74·0
B.—				
Lutterworth, Leicester	0·3	2·7	3·0	82·0
Settle, W. Riding	0·3	1·0	1·3	61·0
Leyburn, N. Riding	0·4	1·8	2·2	70·0
Bootle, Cumberland	0·5	1·4	1·9	56·0
Linton, Cambridge	0·9	6·2	7·1	84·0
Cosford, Suffolk	1·0	4·4	5·4	68·0
B C.—				
Stockbridge, Hants	1·1	4·1	5·2	46·0
Tisbury, Wilts	1·0	4·2	5·2	63·0
Tenbury, Worcester	0·8	2·0	2·8	52·0
C.—				
Ongar, Essex	1·2	3·4	4·6	44·
Cricklade, Wilts	0·7	3·2	3·9	71·
D.—				
Brixworth, Northampton ...	0·8	0·5	1·3	26·0
Bradfield, Berks	0·7	0·4	1·1	18·0

All unions receiving a grouping of "A" were thought by Booth to be of a similar kind, and so on for each grouping. The criteria for each group follow:

A. Out relief given, subject to good behavior, not only in cases of actual destitution, but with a view of assisting the old who are in a state of poverty.

B. Out relief given, subject (1) to good character, (2) actual destitution, and (3) contributions from relatives legally liable; but without pressure on other relatives and without entering into the question of adequate maintenance being assured.

C. Out relief given subject to: --

(1) Good character.

- (2) Actual destitution.
 - (3) Full contribution from relatives legally liable.
 - (4) Full contribution from relatives not legally liable.
 - (5) Proof that maintenance is secured.
- D. Practical refusal of outdoor relief. (Loch, 1894, p. 479)

Although it is clear from the above that Booth did make some attempt to classify unions into groups, Loch disagreed with Booth's method of "clumping" unions together, and argued that there was hardly any justification, or any *standard* for the way in which they were grouped:

Tested by such a table, the classification by administration seems hardly serious. In fact, the unions, without regard to any common standard, or to any economic or historical considerations, have arbitrarily grouped themselves as A's or B's, &c. The result is mere confusion. Every form of administration produces every kind of result – with the exception of D, where there has been, as every one knows, a declared policy It is easy from such a chaos to argue that administration has but little effect on pauperism. The classification means nothing, and nothing but inconclusiveness can be drawn from it Those who wish to justify a happy-go-lucky administration can find no better friend than Mr. Booth. (Loch, 1894, pp. 480-481)

The happy-go-lucky administration Loch referred to was, of course, precisely his concern of the consequences of having a misleading analysis of poverty statistics. If Booth's conclusion of no relation between out-door relief and degree of pauperism was correct, then surely, there would be no incentive for an administration to "tighten its belt"

in terms of the amount of out-relief given, and as a consequence, the Poor Law of 1834 would need amending, or be dropped altogether. Loch's primary criticism was that Booth had not properly controlled for influential "third variables," variables that would have unduly influenced the comparisons of interest. To show that the number of paupers *relative to population size* actually decreased over time, Loch gave Table 2.

Table 2 Paupers Relative to Population (reprinted from Loch, 1894)

Unions.	Year.	Popula- tion.	Paupers. ¹		Total.	Percentage of 'out' to total paupers.	Percentage of total paupers to total population.
			In.	Out.			
1. Fylde.	1861	25,682	86	634	720	88·0	2·8
	1871	30,626	130	670	800	83·7	2·6
	1881	40,910	155	363	518	70·0	1·2
	1891	56,317	128	408	536	76·1	·9
2. Richmond (Surrey).	1861	18,802	163	509	672	75·7	3·5
	1871	26,145	249	562	811	69·2	3·1
	1881	33,633	247	274	521	52·5	1·5
	1891	41,548	324	221	545	40·5	1·3

¹ Less lunatics and vagrants.

Table 2 Con't

Unions.	Year.	Popula- tion.	Paupers ¹		Total.	Percentage of 'out' to total paupers.	Percentage of total paupers to total population.
			In.	Out.			
3. Wharfedale.	1861	—	—	—	—	—	—
	1871	39,142	43	646	689	93.7	1.7
	1881	46,705	78	681	759	89.7	1.6
	1891	51,256	63	515	578	89.1	1.1
4. Haslingden.	1861	69,781	86	711	797	89.2	1.1
	1871	79,956	143	516	659	78.3	.8
	1881	95,293	206	983	1,189	82.6	1.2
	1891	103,408	172	635	807	78.6	.7
5. Preston.	1861	110,523	589	2,752	3,341	82.3	3.0
	1871	115,846	730	1,348	2,078	64.8	1.7
	1881	129,160	779	620	1,399	44.3	1.0
	1891	143,541	610	546	1,156	47.2	.8
6. Wirrall.	1861	18,420	160	3,369	3,529	95.4	19.1
	1871	23,419	97	538	635	84.7	2.7
	1881	27,928	93	421	514	81.9	1.8
	1891	39,623	109	346	455	76.0	1.1
7. Reigate.	1861	20,109	172	735	907	81.0	4.5
	1871	27,303	198	711	909	78.2	3.3
	1881	30,359	186	307	493	62.2	1.6
	1891	36,580	158	331	489	67.6	1.3
8. Atcham, ² Shrewsbury.	1861	—	—	—	—	—	—
	1871	45,565	138	129	267	48.3	.5
	1881	48,633	373	88	461	19.0	.9
	1891	48,346	359	70	429	16.3	.8
9. Penzance.	1861	54,554	129	704	833	84.5	1.5
	1871	54,160	193	1,441	1,634	88.1	3.0
	1881	50,311	122	1,122	1,244	90.1	2.4
	1891	48,276	81	861	942	91.4	1.9
10. Lancaster.	1861	35,297	68	907	975	93.0	2.7
	1871	32,661	110	786	896	87.7	2.7
	1881	40,838	87	315	402	78.3	.9
	1891	52,024	151	296	447	66.2	.8
11. West Ward.	1861	8,072	37	248	285	87.0	3.5
	1871	8,248	28	213	241	88.3	2.9
	1881	8,225	22	133	155	85.8	1.8
	1891	7,709	20	125	145	86.2	1.8
12. Church Stretton.	1861	6,289	40	335	375	89.3	5.9
	1871	6,343	61	170	231	73.5	3.6
	1881	5,672	68	106	174	60.9	3.0
	1891	5,401	66	96	162	59.2	2.9
13. Tregaron.	1861	10,737	No Workhouse	561	561	—	5.2
	1871	10,677	„	670	670	—	6.2
	1881	10,272	10	309	319	96.8	3.1
	1891	8,613	23	180	203	88.6	2.3
14. Cleobury Mortimer.	1861	8,304	56	407	463	87.9	5.5
	1871	8,317	86	326	412	79.1	4.9
	1881	8,138	43	85	128	66.4	1.5
	1891	8,163	47	60	107	56.0	1.3

¹ Less lunatics and vagrants.² Atcham Union now includes Shrewsbury.

Note that in Loch's table, as the number of out-relief paupers decreased (i.e., col. 5), so did the percentage of total paupers to total population (i.e., col. 8) also decrease. Indeed, as the number of out-paupers was reduced, so too was the percentage of pauperism. These statistics were opposite to those found by Booth, and if correct, would support Loch's view that a reduction in poverty was associated with a reduction in out-door relief.

The Relevance of Loch's Critique

Loch's critique of Booth was important for it helped demonstrate the need for a multivariate procedure. Further, as will be discussed, his objection to Booth may have influenced later work,¹⁵ or at minimum, foreshadowed the first famed applied multiple regression. As will be seen, there is evidence that Yule was very familiar with Loch's concerns, and this may have prompted Yule to apply a novel but sophisticated multivariate solution to the problem of poverty statistics. In Loch's critique, he realized a *major* problem with Booth's statistical tables. The problem, in modern terms, is that unless the *correct*¹⁶ correlated "third variables" (i.e., confounding variables) were controlled for, any conclusions made based on comparing or correlating unions would be potentially misleading. As mentioned by Loch, population change might be a major influence in comparing the unions, such that if population was not accounted for or held constant, it would greatly influence the relationship between the variables of interest (i.e., out-door relief and pauperism). Essentially, Loch wanted to remove the influence of correlated variables, not in an arbitrary fashion, but rather in order to get a more precise

and accurate estimate of the bivariate correlation of interest, that between pauperism and out-door relief.

What makes Loch an even more significant figure in the conceptual and to some degree, statistical development of multivariate methods is that although his criticisms of Booth were well founded and clear in terms of the problem and the solution, it would not be the first time that he would tackle the issue of “nuisance variables.” In 1895, in an article titled “Returns as an Instrument in Social Science,” Loch, again referring to Booth’s classification of unions, questioned the use of statistics in analyzing returns, *lest there be a method for controlling extraneous variables*. Loch wrote:

If then, our difficulties are so great, and our skill, impartiality, and patience so much less than in other branches of science, are we not inclined to push the statistical method in social science too far? Should we not substitute for statistics description similar to that which a naturalist might use, content to describe case after case, so that the type may show itself? *We would thus avoid the arbitrary distinction of classes, and perhaps find a more natural division in types – types to be found (to use Mr. C. Booth’s terminology), say, in classes A, B, and C, types with similar characteristics in whatever class they may be temporarily located. . . .* My purpose will be served if I can promote what is, in my opinion, a more sober and scientific use of statistical data, and, especially in some of our parliamentary returns, a more precise, instructive, and scientific collection of them. We want finer instruments and a finer use of instruments. (Loch, 1895a, pp. 287-288)

Hence, Loch criticized both the arbitrary allocation of classes, and suggested, albeit somewhat indirectly, that a method was needed to produce classes with *similar*

characteristics. In this, Loch was not explicitly suggesting something that resembled multiple correlation or regression, but what was key in Loch's writing was the idea of "controlling" for variables that were influencing the relationship of interest. Loch wanted to compare classes that were similar in characteristics, and hence provided a more accurate and precise correlation without the confounding influence of extraneous variables. Although he did not say so in these terms, nor was he quite sure on how to do this statistically, he wanted to partial out variables that were both correlated to pauperism *and* to out-relief. He even shied away from using statistics if a solution to the problem, either in statistical method (i.e., a finer instrument) or in using these instruments, was not found. The suggestion was that without controlling for correlated variables, we may be better off examining "case by case" in order to learn from the data. If we did not "sharpen" either how we perceived the data, or how we analyzed it, statistical analysis could indeed be a dangerous venture: "In social science, studied without the naturalist's spirit, our statistics may become not error merely, but irremediable error – a maze of figures, which no reader has the clue to unravel" (Loch, 1895a, p. 287). What was key then in the above quote, and indeed much of Loch's writings on methodology, was that he consistently emphasized the need to control for extraneous variation, and had a keen sense that without correcting for correlated variables, the ensuing correlations could not be considered accurate. The "finer instrument" foreshadowed by Loch was a multivariate method. Yule, much more mathematically talented than Loch, would follow through on Loch's objections of Booth's analysis, and would give a statistical rationale for including a third variable in the regression equation. Yule's initial reaction to Loch's criticisms, and to Booth's work more generally, now follow.

Yule's Follow Up

In 1895, one year after Loch's review of Booth, George Udny Yule¹⁷ published a note telling that he had read Loch's critique. Yule began where Loch left off: "Mr. Loch argues, if I understand him rightly, that an anti-out-relief policy brings about a decrease of total pauperism *in time*, that this is the important point, and that Mr. Booth's statement is of less consequence" (Yule, 1895, p. 603). What Yule wrote next left little doubt that for him, the solution was to apply an extension of bivariate correlation: "But if one variable be correlated with the rate of change of another the two variables themselves will, in general, also be correlated" (Yule, 1895, p. 603). He then suggested a method by which a solution to the problem could be found: "Let us then examine the subject from the point of view of correlation: in all former papers, so far as I am aware, it has been treated very inadequately by the comparison of small groups or even of isolated unions"¹⁸ (Yule, 1895, p. 603). In this, Yule immediately rejected the idea of forming smaller groups as a control for extraneous variation. In this sense, the use of multiple regression can be said to have been sparked partially out of a methodological desire to avoid classifying observations into smaller groups. In Yule's writing, we also get a sense of just why multiple correlation was essential in addressing problems in poverty statistics. If the issue was to partial out, or control extraneous "noisy" variation, one could presumably do this easily enough by selecting groups that were homogeneous with regard to the third variables. That is, if the goal was to partial out age, then why not just select subsets of age groups, and perform the correlations on these subsets? This would entail taking cross-

sections of age groups, and performing bivariate correlations for each subset. Essentially, this would be the method used by Loch, largely as a last resort. However, as Yule recognized, this was not an efficient way of proceeding. He gave the reason that to do so would, in many circumstances, make samples extremely small, small enough to not allow for an accurate analysis. In his 1896 analysis of the Booth data using partial correlation (Yule, 1896a), Yule addressed the problem of sample size, and suggested the method of multiple correlation as a solution:

In the attempt, too often unsuccessful, to get a group of individuals similar in all respects save one, we may merely make the group dangerously small. *If there is any good reason to fear disturbances of results by other variables than the one with which we are immediately concerned, the proper method to be employed is, it seems to me, that of 'multiple correlation.'* [emphasis added] This method enables us to deal with facility with three variables, and if need be with more, and to form coefficients of correlation between any two of the variables while eliminating the effects of variations in the third (or others). Such 'net coefficients' [i.e., partial coefficients] will probably play an important part in future statistical researches. (Yule, 1896a, p. 615)

Hence, Yule advocated a method of multiple correlation to settle the debate over poverty statistics. Such a method would allow one to control for extraneous influential variables without having to create artificially small groups. Booth however, claimed to have made an attempt to control for influential variation. This was evident in Booth's reply to Loch and Yule later in 1896, in which he wrote:¹⁹

... the idea of this method of grouping being that wherever the population is on the whole similarly employed, and similarly conditioned as to sparseness or density, the

unions might be compared in order to show what was the effect of varying systems of administration on pauperism. In laying these comparisons before my readers I admitted the necessity of more local knowledge ‘to tread safely,’ and that the ‘results attained were chiefly negative.’ (Booth, 1896, pp. 70-71)

It would appear then that Booth made an attempt to partial out “noise” variables (e.g., employment), but not to the satisfaction of Loch, who argued that additional variables needed to be taken into consideration (e.g., sex, population size) in order to ensure an accurate analysis. Booth’s analysis did not side well with Yule either, who held that the grouping of the third variable was an inefficient way of proceeding.

Hence, two questions seem to arise in the conceptualization and application of a multivariate solution: 1) how to successfully partial out extraneous variation, and 2) which variables to partial out. One might say that Yule’s analysis of 1897 “On the Theory of Correlation,” (1897a) was successful in that it would give a method for partialling. However, the more pressing issue seemed to be *which* variables to include in the regression equation. Although beyond the scope of this article, Yule, in his masterpiece of 1897, did offer a suggestion for determining influential third variables and hence provided a loose rationale for *which* variables to include in the regression equation.

There was a third problem that also arose in considering a multivariate solution, that of substantiating a “causal relation” between the response variable and the predictor(s). This problem would be brought to bear only two years after Yule’s 1897 “tour de force” (Stigler, 1986) publication on multiple regression. In a talk read before the Royal Statistical Society in 1899, Yule, after conducting a full analysis of Booth’s poverty data, presented additional statistical evidence in the form of regression equations showing a

correlation between changes in pauperism and changes in out-relief. Indeed, using his newly developed powerful statistical tool, this would, at first glance, appear to be the “dagger in the heart” of Booth’s claim that no relation existed between rate of pauperism and out-relief:

It seems impossible to attribute the greater part, at all events, of the observed correlation between changes in pauperism and changes in out-relief ratio to anything but a direct influence of change of policy on change of pauperism, the change in policy not being due to any external causes such as growth of population or economic changes. (Yule, 1899, p. 277)

Yule’s conclusion was that since extraneous factors considered did *not* appear to influence the change in pauperism, administration policy seemed to be a likely “cause.” Indeed, Yule, a page earlier, argued that “therefore this greatest change must have been effected by some factors other than the economic; administration seems the only alternative” (Yule, 1899, p. 266). Although it was true that Yule had successfully solved the question of how to partial extraneous variation without arbitrarily grouping the third variable, the question of *isolating* influential variables still proved somewhat elusive. It would be quite easy for a modern methodologist to criticize Yule’s conclusion by arguing that although external “causes” such as population and economic change may not have been directly responsible for a change in pauperism, this did not in itself, in any way, isolate administration as the “causal agent.” A. W. Flux, in an appended discussion that followed Yule’s paper, pointed this out precisely as a major problem with Yule’s work, and Yule’s substantive claim about the so-called “causes” of changes in pauperism. Flux wrote:

It is with the penultimate word of the last phrase [i.e., the phrase on p. 266 of Yule, cited above] that I find it difficult to agree, and the diagram is precisely what suggests that it *may* not be a result of administrative change. May it not be suggested that a growing degree of prudence or foresight might both reduce pauperism and the marriage-rate? (Flux, p. 287, in Yule, 1899)

Flux's criticism of Yule's substantive conclusion was accurate, and the issue he raised can still today be considered an example of a most troubling aspect of multiple regression, or of the problem of scientific inference in general. Yule's analysis successfully partialled out extraneous variation, but this did not give him methodological "authority" to link pauperism with administration, not in a causal fashion. Yule mentioned Loch in his 1899 paper, and it was in relation to the potentially influential variable of population that Loch considered vital to partial out of the relationship between out-door relief and pauperism. What is more, Yule appeared to have considered Loch's warning of population being an extraneous variable to be controlled for: "Mr. Loch has several times put forward the view of changes in population affecting rates of pauperism" (Yule, 1899, p. 253). To this, Yule referenced Loch's 1894 article in a footnote (see footnote 8, page 253).

Hence, although Yule would be the true innovator in terms of applying early multivariate methodology to the statistics of poverty, Charles Stewart Loch can be said to have been a "conceptual contributor" to the methodological debate, and helped nurture the context in which a multivariate solution arose. What is even more significant about Loch's influence, is that his method of 1894 appears to have approximated very closely, at least conceptually, the solution eventually obtained by Yule in 1897.

The Man Behind the Scenes: Karl Pearson

The genius of Yule was no doubt in recognizing that the novel technique of multiple regression could help solve the poverty debate. However, much of Yule's work was a product of what he had learned in Karl Pearson's lab and through courses Pearson was teaching at University College (Yule, 1897b). Yule's contribution was to show how multiple regression could be *applied* to a pressing social-political problem. Karl Pearson however was the true innovator of the mathematics and derivations behind Yule's contributions.

Work by Karl Pearson, published only one year before Yule's, produced similar results as Yule's. Indeed, it is highly likely that Yule, being Pearson's student, relied extensively on Pearson's work for his 1897 analysis. The difference between Pearson's work and that of Yule's, as will be discussed further, lay more in the *application* of the method along with its clarity of presentation rather than in any inherent technical discrepancies. As well, by the mid-1890s, Yule had developed interests in fields other than eugenics and biometry (Hepple, 2001), and hence while the biometric school was busying itself with problems of heredity and the like, Yule was becoming increasingly interested in applying newly developed statistical technology outside of eugenics. As Desrosières noted, by 1895, Yule was slowly but surely beginning to distance himself from the intellectual passions of Pearson:

While initially proving to be his master's faithful disciple in regard to techniques of regression and correlation, he [Yule] applied them to entirely different fields and thus

entered into contact with other circles. Theories of evolution and eugenics did not interest him, but in 1895 he became a member of the Royal Statistical Society, to which neither Galton nor Pearson belonged. . . . Concerned with solving social and economic problems involving poverty and public health, these “statisticians” sought to treat these problems as distinct from passionate and polemical arguments, objectifying them by means of statistics generated by administrative or private sources. (Desrosières, 1998, p. 133)

Given there is little question that Yule was heavily influenced by Pearson’s work on correlation and regression, it is appropriate to briefly review some of the technical precursors to Yule’s 1897 analysis. In 1896, Pearson’s “Mathematical Contributions to the Theory of Evolution. III. Regression, Heredity, and Panmixia” appeared in *Philosophical Transactions of the Royal Society of London* and gave regression formulae for the case of three variables. Pearson’s analysis was restricted to jointly normal variables and was largely technical, many times referring to the mathematical treatment given by Auguste Bravais in 1846.²⁰ Yule’s work (1897a) was in part to extend correlation and regression to skewed distributions, and hence helped prepare the path for his 1899 piece on the applied multiple regression analysis of the poverty data. Although their respective purposes were different, it is still possible nevertheless to tease out the more obvious and more easily understood elements from Pearson’s work, and observe how they relate to the work of Yule. For instance, for variables h_i , Pearson gave the following formula for predicting h_1 from a combined knowledge of h_2 and h_3 :

$$h_1 = \frac{r_3 - r_1 r_2}{1 - r_1^2} \frac{\sigma_1}{\sigma_2} h_2 + \frac{r_2 - r_1 r_3}{1 - r_1^2} \frac{\sigma_1}{\sigma_3} h_3 \quad (1.1)$$

From the above expression, Pearson named the ratio

$$\frac{r_3 - r_1 r_2}{1 - r_1^2} \quad (1.2)$$

the “coefficient of double correlation” (Pearson, 1896, p. 287) for what in n

terminology is multiple R . By multiplying the coefficient of double correlation by the

$$\frac{r_3 - r_1 r_2}{1 - r_1^2} \frac{\sigma_1}{\sigma_2} \quad (1.3)$$

ratio of standard deviations, Pearson obtained:

for which he coined “coefficients of double regression” (Pearson, 1896, p. 287).

Pearson went on to demonstrate the use of these formulae in an example titled “Double Regression and Biparental Inheritance” in which he used some of Francis Galton’s data on families. In the example, Pearson attempted to show how Galton’s so-called “mid-parent theory” (i.e., theory of regression) “must be looked upon as only an approximation of a rough kind” (Pearson, 1896, p. 288).

That Karl Pearson gave formulae for calculating multiple correlation and multiple regression is significant. That he demonstrated how these formulae could be *applied* is even more so. At first glance, it would appear that while applying their work to different areas of investigation, both Pearson and Yule accomplished a similar feat. Both gave theoretical justification for their work, and both offered examples of how their work could be applied to problems of great interest in nineteenth century Britain. However, innovative as Pearson’s work may have been, it has not historically received praise comparable to that of Yule’s work on the same subject. According to Stigler, Yule’s work of 1897, not Pearson’s of 1896, put the theory of correlation forever on a new footing:

. . . the paper had a new and broader outlook that at once put the developing theory of correlation in a perspective from which it could deal with the problems of the social sciences and reconciled it formally with the traditional method of least squares from the theory of errors. As such Yule's work marked the completion of a final stage in the development of what could be called Galton's program and formed a cap on nineteenth-century work on statistics for the social sciences. . . . a nearly complete tutorial on correlational analysis as well as a striking reformulation of existing work. (Stigler, 1986, pp. 354-355)

Resolving issues of priority usually proves to be elusive, and shall not be the goal in the present case. However, in the reading of such historians as Stigler, one cannot help but get the sense that Yule's paper on multiple regression is given primary credit while in the shadows lay Pearson's contributions. Although there can be little question that both Pearson and Yule were instrumental men in contributing to the theory of correlation and multiple regression, it would be negligent at this point not to show, at least in part, how Yule's work in a strong sense "flowed" from that of Pearson's. For instance, in "On the Theory of Correlation," Yule discussed regression for the case of three variables and gave a formula that was all but identical to Pearson's "coefficient of double regression":

$$x_1 = \frac{r_{12} - r_{13}r_{23}}{1 - r_{23}^2} \frac{\sigma_1}{\sigma_2} x_2 + \frac{r_{13} - r_{12}r_{23}}{1 - r_{23}^2} \frac{\sigma_1}{\sigma_2} x_3 \quad (1.4)$$

Essentially, the only difference between Yule's formula for double regression and that of Pearson's was that Yule used different subscripts for r to denote the various correlation coefficients, and used x instead of h to denote the regression coefficients. What is more,

(1.5)

both Pearson and Yule gave values of the standard error of regression. For the case of three variables, Yule gave the standard error as:

$$\sigma_1 \sqrt{1 - R_1^2}$$

while Pearson, specifying it only for the case of two variables, gave it as:

$$\sigma_1 \sqrt{1 - r^2} \tag{1.6}$$

There are, of course, many other common technical features binding the work of Pearson and Yule. The above details are not meant as an exhaustive comparison by any means, but are given simply to suggest that although Yule's work of 1897 was indeed foundational, it can be said to have arisen largely from the pioneering work of Karl Pearson. Pearson's work of 1896 was thorough, complete, and could, as Yule's, serve as an instructive tutorial on correlation and regression for even the modern student of statistics. The difference between the work of Pearson and Yule was perhaps in its *appeal*. The clarity of Yule's presentation was nothing short of exquisite, and his teaching style was equally so. Through reading his works on statistics, one feels as though they are being instructed by a great teacher in the field, and it is perhaps this feature, along with its applied appeal, that made Yule's work indeed a true "tour de force" (Stigler, 1986, p. 355).

Loch's 1906 Review of Poverty Statistics: A Link to Yule

In 1906, well after Yule published his analysis of poverty statistics in 1897, Loch wrote a paper titled "Statistics of Population and Pauperism in England and Wales, 1861-

1901” in which he gave an alternate analysis of poverty statistics. On page 290 of the paper, he referred to a method, used by him in 1894, to be the method used in the present analysis:

In accordance with a method I adopted in 1894, we may try to deal with the composition of the pauperism in a series of years more closely by population groups. We have no continuous age count returns of pauperism. We can, however, I think, divide the part of the population returned as paupers approximately into age groups. (Loch, 1906, p. 290)

We again see Loch’s general method, and that was to control for variables (in this case, age) by grouping individuals into different age groups. What was most noteworthy about Loch’s paper however was the discussion appended to it. There was a commentary by Sir J. Athelstane Baines who said:

. . . in a letter just received by Mr. Yule . . . the question was asked whether the age-periods adopted in the Burt returns commended themselves to Dr. Loch, or whether he considered that more suitable ones might not be selected? Mr. Yule also pointed out that in a paper on statistics of pauperism read by him before the Society in 1899, he had reached, by mathematical analysis, much the same general conclusions as to the course of the pauperism-rate as Dr. Loch had reached from a very different method of approach. It was satisfactory, he (the speaker) thought, from the statistical point of view, that two experts, handling the data on different lines, should so nearly agree in their results. (Baines, cited in Loch, 1906)

The above reading is very telling. It is supportive of a link between Loch and Yule and the innovation of applied multivariate methods of late nineteenth century. What was

significant about Bain's words was that Loch and Yule, at least in regard to the question of his 1906 paper, appeared to have arrived at similar conclusions, but based on different statistical methodologies. What was perhaps most interesting, was that like his paper of 1894, Loch's 1906 paper contained *no* advanced computations of any kind. There were no correlation coefficients, there were no intricate calculations of regression coefficients and elaborate linear equations as found in Yule's 1899 analysis. Yule's method was to partial out extraneous variation using the newly developed method of multiple regression. Loch's method was also to partial out, but instead of regarding extraneous variables as continuous, and including them in the final solution (e.g., in a multiple regression equation), which he did not know how to do, he produced representative groups and in this way, attempted to control for the influence of extraneous factors. Recall however that Yule noted this not to be a good way of proceeding, since sample sizes in each group would become dangerously small should one partial this way.

Conclusion: Charles Stewart Loch - A Contributor to Multivariate Methods

The present article sought to uncover the earliest seeds of multivariate thinking post-Galton's innovative contribution of the bivariate correlation. And although most historians of statistics correctly credit Yule²¹ as a true pioneer in this regard, our goal was to highlight the contributions of an as yet, unknown figure in the history of statistics – Charles Stewart Loch, as well as to detail the social and political context in which Yule's multiple regression arose. And although history cannot consider Loch of nearly the same prominence as Yule,²² we hope to have shown that Loch is nonetheless deserving of a place in the history of statistics, one whose recognition of a methodological problem,

coupled with social-political motivation, helped to lay a foundation for multivariate analysis.

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Footnotes

1. Although Edgeworth's work is highly noteworthy, it fails to be regarded as a significant piece in the history of statistics. Reasons for this might be that Edgeworth's treatment of multivariate statistics proceeded primarily from the calculus of probabilities, and according to Walker (1975) led to a very difficult method of computation. Indeed, Edgeworth's contributions to statistics are probably underrated (Johnson & Kotz, 1997). He may not have attained as much "fame" for his contributions because he was not driven by a political agenda, as were Galton, Pearson and Yule, and did not have a "passion" for eugenics (Desrosières, 1998). The influence of Edgeworth however should not be overlooked. It is clear that Yule, who is usually credited with the first multivariate analysis, read Edgeworth's 1892 paper. For details, see Yule (1897a).

2. It should be noted that Desrosières does not call Yule's first analysis by the name of "multiple regression." Rather, he calls it "the first 'econometric' study ever carried out" (Desrosières, 1998, p. 140). For the purposes of this article however, no distinction between these two terms is made. Also, some "purists" may prefer to identify multiple regression as a "multivariable" technique rather than a multivariate one. In the present piece, no distinction between these two terms is made. Multiple regression is usually seen

by historians of statistics (e.g., Stigler, 1986) as the “breeding ground” for multivariate methodology.

3. For a history of the C.O.S., see Mowat, C. L. (1961). *The charity organization society, 1869-1913: Its ideas and work*. Methuen & Co. Ltd.

4. “Out-door relief” refers to monies allocated to the recipient without him/her having to earn it in the poor houses of London (i.e., outside of the poor house). “In-door relief” refers to monies *earned* by the recipient through his/her work in the poor houses.

5. For a history of poverty and poor laws in Britain, see Englander (1998) and Davis (1999).

6. See Fried and Elman (1968) for a brief overview of how Booth’s interests in the conditions of the poor came about in the early 1880s.

7. A “union” in late nineteenth century Britain was defined as a unit consisting of usually thousands of parishes. These “units” (i.e., unions) were the basic “blocks” of governmental poor relief. That is, the government essentially distributed poor relief to unions and not to individual parishes.

8. The idea that Loch believed poverty, and the philanthropy to deal with it, could provide a “social education” is supported further by Laybourn who notes that Loch saw philanthropy as an “educational tool” (Laybourn, 1995, p. 139).

9. The importance Loch placed on upholding the Poor Law of 1834 is perhaps best understood by his counter opinion to those who found the Poor Law to be “socially repugnant”: “We may realize that the hard exterior of this social repugnance preserves within itself some of the finest and strongest elements of our noble national character, the decay of which would be our greatest grief.” (Loch, 1904, p. 331)

10. It is interesting to note that nowhere in Bales (1996, 1999) is there mention of Charles Stewart Loch. He draws our attention to the objections raised by the C.O.S., but gives Loch no special mention. This is odd given that Loch, as will be discussed later, was perhaps the most vehement opponent to Booth's claims.

11. Loch's objections to Booth's analysis are also found in a paper by Booth published in 1894 titled "Statistics of pauperism in old age."

12. As will be seen later, the important aspect of Loch's concern lay more with *which* variables to control, rather than simply controlling for arbitrary variables.

13. The word "may" is emphasized simply because it seems that even by Loch's analysis, he could not be certain which variables to control for. A solution to this problem would be suggested by Yule (1897a).

14. Although Booth did group the unions, Loch's criticism was that they were grouped rather loosely, and by no common standard.

15. As will be discussed later, Loch may have influenced Yule's subsequent analysis of the poverty data.

16. As mentioned, Booth apparently did attempt to control for variation, but according to Loch, he did not control for the *correct* variables.

17. See Kendall (1952) for an obituary of Yule and a brief summary of his contributions. Yule's original contributions to correlation and regression have, for the most part, endured to the present, so much so that according to Johnson and Kotz, "his work on correlation and regression is now so standard that only history buffs would consult the original sources" (Johnson & Kotz, 1997, p. 169).

18. The idea of including a third variable without artificially classifying observations into groups served as one of the motives for Yule's innovative analysis of the poverty data. The method of making groups of the third variable was used previously by both Booth and Loch.

19. There is evidence that Booth read Yule's analysis of 1897, but found Yule's method dauntingly difficult, or at least, arcane to him. Booth wrote: "I am constrained to try to construct on the same lines a more correct table . . . with the fear of Mr. Yule and his mysterious methods constantly before my mind" (Booth, 1899, p. 216). Moreover, Loch was not hesitant to admit that although he appreciated Yule's work, he did not fully understand it (see Yule, 1896b, p. 352).

20. It should also be noted that although Yule's arithmetic for correlation and regression were relatively novel, in addition to Bravais (1846), for whom Walker (1975) claims to have fallen just short of discovering correlation, work on the formal development of correlation dates back to at least Gauss (1809) and Legendre (1805). According to Pearson (1920), Bravais' work, although mathematically enlightening, lacked the "organical association" concept contained in Galton's later work on correlation.

21. It is clearly the case that throughout the poverty debate, Loch and Yule wanted the same thing – to control for extraneous variation. It is also just as clear that Loch did not know how to do this using an elegant statistical procedure (i.e., multiple regression), while Yule did. In a discussion of a paper by Loch in 1898 titled "Poor Relief in Scotland: Its Statistics and Development, 1791 to 1891," in which Loch presented an enormous amount of numerical tables in an effort to support his thesis of minimizing out-

relief, Yule, again, hinted that proper control of extraneous variation was key: “The causes which affected pauperism might be taken in three groups: first, the actual economic conditions; secondly, the character of the people and the age distribution; and thirdly, the character of the administration. If the crude rate of pauperism was adjusted for two of these the effect of the remaining one might be shown” (Loch, 1898). Why Yule did not remind Loch that multiple regression was the correct statistical solution to his “numerical comparison” problem, is not at all clear.

22. That Yule is a prominent statistician in the history of science is clear. It is also clear that Yule’s methods were innovative and advanced. However, it is curious to note that over a decade after Yule’s work, then president of the Royal Statistical Society, George Hamilton, made no mention of Yule in his presidential address on the statistics of pauperism (Hamilton, 1910).