THE GROWING USE OF STATISTICAL ANALYSIS IN JUDICIAL DECISION–MAKING : AN OVERVIEW

One of the most interesting features of judicial work in recent years has been the reliance on formal statistical methods in adjusticative processes. The courts in a number of jurisdictions, but particularly the United States, have often resorted to statistical techniques while grappling with specific problems. The extent to which this has been the case is not *well*-known amongst students of the administration of justice in Asia. Nor are scholars in the region *fully* aware of the potential usefulness of statistics in judicial proceedings. Our aim is *to partly rectify this situation by providing a survey of relevant developments.*

Now the recourse to statistical analysis in judicial decision-making is by no means novel. Applications of both descriptive and inferential statistics in court work can be traced at least as far back as the nineteenth century. In the infamous trial of Alfred C. Dreyfus in 1899, for instance, statistical concepts were employed rather extensively.[1] It is nonetheless true that the courts have started resorting to statistics on a scale not known before in the second part of the twentieth century. This upswing has been well documented[2] and duly acknowledged by various judges. Thus, in *Alabama v. United States*[3] the court stated that "statistics often tell much, and the courts listen".[4] And in *Jones v. Lee Way Motor Freight, Inc.*,[5] the court similarly observed that "statistics often demonstrate more than the testimony of many witnesses."[6]

[1] See, in this connection, L.H. Tribe, "Trial by Mathematics", *Harvard Law Review*, 84 (1971), 1329.

[2] In particular, see: J. Dawson, "Scientific Investigation of Fact – The Role of the Statistician", *Forum*, 11 (1976), 897; W.C. Curtis and L.E. Wilson, "The Use of Statistics and Statisticians in the Litigation Process", *Jurimetrics Journal*, 20 (1979), 109.

[3] 304 F.2d 583 (5th Cir.) *aff'd per curiam*, 371 U.S. 37 (1962).

[4] *Ibid.*, 583.

[5] 431 F.2d 245 (10th Cir. 1970).

[6] *Ibid.*, 247.

Perhaps the best well-known example of statistical analysis in judicial decision-making is that of personal injury and wrongful death cases, particularly those involving the use of life table analysis to estimate the expected years of life remaining but for the injury.[7] In certain instances, of course, Workmen's Compensation establishes schedules of payment due to the injured person. In other cases, however, there are no readily available guidelines to the decision-makers to employ in calculating the extent of impairment in earnings capacity. Under such circumstances, life table analysis may be relied upon in conjunction with appropriate economic procedures[8] to provide the necessary answer.

A typical example here would be that of "John Doe", a long-haul Alabama truck driver who was injured in an automobile-motorcycle accident on July 1, 1974.[9] Doe was disabled as a result of these injuries, which required amputation of one leg. It was medically established that the impairment will definitely prevent him from pursuing his previous occupation in the future. Based on available medical records, there was every reason to believe that, prior to the accident, Doe would have experienced a normal life expectancy. At the time of the injuries, he was 45 years old. He was born on January 15, 1929. Thus, his life expectancy was 27 years at the time of the accident for a total life expectancy of 72 years which will be reached in 2001.

Prior to sustaining his injuries, Doe's annual income as a long-haul truck driver was US$15,000. During the ten-year period ending December 31, 1973, he received total income as an employee of the trucking industry in the amount of US$110,000. As a result of the accident, Doe has been rendered incapable of performing certain types of jobs, as well as precluded from many occupational fields. With his impairment, it was established that the highest annual income he could now

[7]For example, see: *O'Connor v. U.S.*, 269 F.2d 578 (2d Cir. 159); W.C. Curtis and L.E. Wilson, "Determining Loss of Earnings Resulting from Impairment or Death, *Alabama Lawyer*, 37 (1976), 221; R.D. Greenberg, "Quantitative Aspects of Legal Analysis", *Insurance Law Journal*, (1976), 589.

[8]Which are also largely statistical in nature.

[9]The example is from: W.C. Curtis and L.E. Wilson, "Determining Loss of Earnings Resulting from Impairment or Death", *op. cit.*

expect to receive would be US$5,000 per year in jobs requiring limited mobility, probably of a sedentary nature, such as a warehouse clerk. Employment of this type might be associated with the trucking industry which would take advantage of his previous experience.

In making the estimate of lost earnings from the accident, it was assumed that Doe would have been employed as a long-haul driver until the normal retirement age of 65 for his occupation (other ages can be used depending upon the nature of the individual's profession or occupation). Assuming a retirement age of 65, Doe would have a remaining working life expectancy of 20 years. The difference between his expected earnings to age 65 prior to the accident and expected earnings after the accident was deemed to constitute his lost earnings.

The initial step in preparing the estimate thus was to calculate the amount Doe might have earned prior to his injury between ages 45 and 65. From this was subtracted the amount he would be able to earn during the same period after his disability. That was accomplished without making any allowances for growth in his income or discounting his income to present value. The second step required the assumption of growth rate in Doe's earnings. Adjustments for productivity were made to allow for improvements in technology and in the quality and skills of the labour force.[10] Further adjustments were made to allow for increases in earnings due to inflationary pressures.[11] Lastly, Doe's expected loss of income was discounted to present value (this adjustment is required to allow for the fact that a dollar received 20 years from now is not worth a dollar received today).[12]

As indicated, tort law is a domain of judicial decision-making in which applications of statistical analysis have probably been the most common. Even in Asia the courts have made an extensive use of the procedures described above, although with-

[10]The long–term annual rate of change in output per man-hour was used as the adjustment factor.

[11]The average increase in the consumer price index during the 25 years prior to the accident was used as the adjustment factor.

[12]Interest rates on long-term government securities were used to derive the discount rate.

out really turning them to *full* account. Another well-known example of statistical reasoning in judicial proceedings is that of anti-trust cases. Most Asian countries, of course, do not have an anti-trust policy, but a good many industrialised states have opted for such a policy and have pursued it with considerable vigour. The goals and instruments of anti-trust are complex and, their prevalence notwithstanding, very much in dispute. This is not the place to dissect the policy and the means employed in its implementation[13] – rather to demonstrate how the courts have availed themselves of the tools of statistics in the relevant adjudicative processes.

Statistical analysis has been applied in judicial decision-making involving anti-trust mainly in anti-merger cases.[14] In such cases the courts (as well as the regulatory bodies concerned) have come to rely increasingly on numerical measures of concentration developed by economic statisticians in appraising the competitive character of an industry and the effects thereon of mergers. A distinction has to be drawn here between *horizontal* and *vertical* mergers. The measure of economic concentration most frequently used by participants in judicial proceedings in the horizontal merger cases is the concentration ratio. This is a percentage figure representing the aggregate market share of a given number of leading firms in an industry. Thus, if the first two firms in an industry control, respectively, 30 and 10 per cent of the market, the two-firm concentration ratio for that market is 40 per cent. Economic trends and individual mergers have been assessed in terms of these ratios and by considering changes in the number of firms in the relevant lines of commerce. The concentration ratio most commonly employed by economists is the aggregate market per-

[13] For an in-depth discussion of the pros and cons of anti-trust, see: M. Sharp, *The State, the Enterprise and the Individual* (London: Weidenfeld and Nicolson, 1973); R.A. Posner, *Antitrust Law* (Chicago: University of Chicago Press, 1976); F.M. Scherer, "The Posnerian Harvest", *Yale Law Journal*, 86 (1977), 974; R.H. Bork, *The Antitrust Paradox* (New York: Basic Books, 1978); D. Dewey, "Antitrust and Economic Theory", *Yale Law Journal*, 87 (1978), 1516.

[14] The most important of these cases have been reviewed in: W.C. Curtis and L.E. Wilson, "The Use of Statistics and Statisticians in the Litigation Process", *op. cit.*; M.O. Finkelstein and R.M. Friedberg, "The Application of an Entropy Theory of Concentration to the Clayton Act", *Yale Law Journal*, 76 (1967), 677; M.O. Finkelstein, *Quantitative Methods in Law* (New York: Free Press, 1978).

centage of the top four firms, although concentration ratios based on different numbers of firms are not uncommon. In the vertical merger cases a somewhat different measure has been used. The yardstick in question is the percentage foreclosure test which measures the degree to which the market has shrunk for the remaining competitive firms.

Neither measure is fully satisfactory. Indeed, recently Finkelestein[15] has developed an "entropy measure of concentration"[16] which is derived from theoretical considerations relating the number and sizes of firms in a market to the degree of competition anticipated for that market. The derivation requires a more sophisticated mathematical argument than is common in the law or is necessary to grapple with methods of measurement which lack theoretical underpinning. The mathematical techniques by which the argument is expressed may, in fact, be regarded by many legal practitioners with such trepidation (as an appeal to some *ultima thule* of the mind!) that it will probably take a major educational effort to have the new (or any similar) measure widely adopted. It is nonetheless arguable that time has come to venture beyond elementary measures because developments in merger law have simply outrun them.[17]

In an article published in 1980 Fisher[18] has identified yet another area of anti-trust law which may lend itself to statistical analysis, viz. that concerning price-fixing.[19] He suggests that

[15] M.O. Finkelstein and R.M. Friedberg, *op.cit.*; M.O. Finkelstein, *op.cit.*

[16] The key term here is "entropy" because it formally resembles a measure of entropy – the degree of molecular disorder in a gas – which is used in a branch of physics known as the kinetic theory of gases.

[17] It is also arguable that even though their symbolism may be more baffling and the chains of reasoning more involved, complex statistical measures are not essentially different from their simpler counterparts – such as percentages – which have enjoyed an extensive use in the law. A measure which may be somewhat easier to apply in the judicial context than Finkelstein's is the Herfindahl index. See, in this connection, R.A. Posner, "Oligopoly and the Antitrust Laws", *Stanford Law Review*, 21 (1969), 1562.

[18] F.M. Fisher, "Multiple Regression in Legal Proceedings", *Columbia Law Review*, 80 (1980), 702.

[19] For an evaluation of legal provisions related to price-fixing, see: W.H. Page, "Antitrust Damages and Economic Efficiency", *University of Chicago Law Review*, 47 (1980), 467.

regression models,[20] both of the single equation and simultaneous equation variety, be constructed with a view to determining what the price would be had the market been competitive. The argumentation is very subtle but somewhat inconclusive. Given the difficulties inherent in estimating the necessary equations, it would not be unfair to conclude that the methods outlined are promising but not immediately applicable. As matters stand now, there seems to be no easy way of putting into practice the theoretical possibilities that Fisher has so cogently explored.

The third example of statistical analysis in judicial decision-making is that of deceptive advertising and trademark infringement cases.[21] The approach adopted here has been to employ an array of survey research methodologies in order to obtain consumer feedback which is instrumental in establishing deception and infringement. The courts have not only accepted the results of sample surveys as viable evidence, but have also been actively engaged (with the assistance of statistical consultants) in their interpretation. For instance, in one such well-known case, *Bristol-Myers Co. vs. FTC*[22], the judicial ruling was:

> "Based on the results of the survey, the corporation published advertisements from which the casual reader would reasonably infer that careful inquiry among the members of the dentist profession had disclosed that a large majority of the dentists in this country not only used Ipana but recommended it to their patients . . . We are of the opinion that these sweeping statements were not justified by the answers to the questionnaire and that in consequence, as the Board found, the advertisements were misleading and likely to deceive the public . . . This is not to express the opinion that all advertisements based upon surveys must be barred, but merely that the information in the possession of the

[20] The suggestion is preceded by a lucid discussion of the role of regression analysis in judicial decision-making. This subject is also dealt with in: M.O. Finkelstein, "Regression Models in Administrative Proceedings", *Harvard Law Review*, 86 (1973), 1442; M.O. Finkelstein, "The Judicial Reception of Multiple Regression Studies in Race and Sex Discrimination Cases", *Columbia Law Review*, 80 (1980), 737.

[21] See, in this connection, W.C. Curtis and L.E. Wilson, "The Use of Statistics and Statisticians in the Litigation Process", *op. cit.*

[22] 185 F.2d 58 (4th Cir. 1950).

manufacturers in this case was insufficient to support its advertisements . . ."[23]

All the above illustrations belong to domains of the law which closely interface with society's productive sub-system. Perhaps the most interesting example, however, of statistical analysis in judicial decision-making is that of civil liberties cases involving social discrimination. For obvious reasons civil liberties have not loomed large on the Asian legislative agenda, but most industrialised countries have enacted laws to safeguard at least the most fundamental of these liberties (in some of the countries concerned civil liberties are further entrenched in a constitution). In the United States, for instance. social discrimination in its manifold forms is legally prohibited and its victims may seek redress through the courts. Social discrimination suits there have long relied upon statistics as a means of proof and statistical reasoning has featured prominently in age[24], housing[25], jury[26], school[27] and voting[28] discrimination actions. For illustration purposes we focus on employment discrimination cases[29] because of their sheer volume, strategic importance and relative complexity.

The legislation serving as a benchmark in cases of alleged labour discrimination in the United States has consisted of the Civil Rights Act of 1866 and Title VII of the Civil Rights Act of

[23] *Ibid.*, 60–61.

[24] Foe example, see: *Hodgson v. First Fed. Sav. and Loan Ass'n.*, 455 F.2d 828, 823 (5th Cir. 1972).

[25] For example, see: *Kennedy Park Homes Ass'n. v. Lackawanna*, 436 F.2d 108, 113 (2th Cir, 1969), *cert. denied*, 401 U.S. 1010 (1971).

[26] For example, see: *Turner v. Fouche*, 396 U.S. 346, 360 (1970).

[27] For example, see: *United States v. Hinds County Bd. of Educ.* 417 F.2d 852, 858 (5th Cir. 1969), *cert. denied*, 396 U.S. 1032 (1970).

[28] For example, see: *Alabama v. United States*, 304 F.2d 583, 586 (5th Cir.), *aff'd per curiam*, 371 U.S. 37 (1962).

[29] For a discussion of these, see: W.C. Curtis and L.E. Wilson, "The Use of Statistics and Statisticians in the Litigation Process", *op. cit.*; W.V. Dorsaneo III, "Statistical Evidence in Employment Discrimination Litigation", *Southwestern Law Journal*, 29 (1975), 859; B. Schlei and P. Grossman, *Employment Discrimination Law* (Washington: Bureau of National Affairs, 1976); D. Whitten, "Statistics and Title VII Proof", *Houston Law Review*, 15 (1978), 1031; E.W. Shoben, "Compound Discrimination", *New York University Law Review*, 55 (1978), 793.

1964, as amended.[30] Initially, the enforcement of this legislation was largely confined to individual, intentional acts of discrimination. Limitations that may have restricted the courts in its enforcement were, however, eliminated by the Supreme Court in the landmark decision *Griggs v. Duke Power Co.*[31] The Court held that "Congress directed the thrust of the (Title VII) Act to the *consequences* of employment practices not simply motivation". With emphasis on consequences rather than intent, broader techniques of analysis and proof became necessary to establish discrimination. An increasing recourse to statistical reasoning was the logical outcome of this new focus.

The use of statistics in Title VII cases generally hinges on the assumption that legally significant inferences can be obtained by comparing the composition of an employer's work force with that of the population from which the employees are drawn. The "prima facie rule" or "rule of exclusion", first set out in 1881 by Justice Harlan in *Neal v. Delaware*,[32] is followed in these cases. The prima facie rule requires that the plaintiff bears the burden of introducing evidence demonstrating a substantial statistical underrepresentation, or a harmful effect on the class he represents.[33] If the disparity is large enough, it creates a prima facie case of Title VII violation. This shifts the burden of proof to the defendant to introduce evidence which will rebut the prima facie case; if he fails to rebut, a verdict may be directed against him. If the defendant does present a reasonable, nondiscriminatory explanation for the

[30] For a discussion, see: W.V. Dorsaneo III, *op. cit.*, B. Schlei and P. Grossman, *op.cit.*

[31] 401 U.S. 424 (1971).

[32] 103 U.S. 370 (1881). Observing that no Negro had ever served as a juror in Delaware, even though Negroes constituted one six of the population, Justice Harlan stated: "The showing . . . presented a *prima facie* case of denial, by the officers charged with the selection of grand and petit jurors, of that equality of protection which has been secured by the Constitution and laws of the United States. It was, we think, under all the circumstances, a violent presumption which the state court indulged, that such uniform exclusion of that race from juries, during a period of many years, was solely because, in the judgment of those officers, fairly exercised, the black race in Delaware were utterly disqualified, by want of intelligence, experience, or moral integrity, to sit on juries."

[33] For examples of ways to calculate such ratios, see: B. Schlei and P. Grossman, *op. cit.*

statistical disparity, the burden of proof shifts back to the plaintiff.[34]

One of the most frequent uses of such a procedure is in circumstances wherein a test (or, for that matter, any requirement) is relied upon for employment selection.[35] The plaintiff introduces statistical evidence to demonstrate that a significantly larger percentage of his class, usually referred to as the affected class, fails the test as compared with members of the other class. This showing creates a prima facie case of discrimination in violation of Title VII. The burden of proof is then shifted to the defendant to prove that the test is "job related", that is, one designed to measure the ability to learn to perform a particular job or category of jobs.[36] The employer can meet this burden by showing that the test has been validated under appropriate and accepted validating procedures, which accurately predict both success and failure on the job. The test will be acknowledged as a "business necessity" to the defendant when validation is coupled with evidence that there are no acceptable alternatives that would also serve the employer's legitimate interest in "efficient and trustworthy workmanship" with less negative impact on the protected class.[37]

[34] If the defendant presents a reasonable rebuttal, the plaintiff does not necessarily lose. Determination of the outcome of the issues rests with the judge. See: *Sime v. Trustees of Cal. State Univ.*, 526 F. 2d 1112, 1114 (9th Cir. 1975); *Peters v. Jefferson Chem. Co.*, 516 F. 2d 447, 450 (5th Cir. 1975).

[35] See, in this connection, W.V. Dorsaneo III, *op. cit.*; B. Schlei and P. Grossman, *op. cit.*; D. Whitten, *op. cit.*; W.C. Curtis and L.E. Wilson, "The Use of Statistics and Statisticians in the Litigation Process", *op. cit.*

[36] *Griggs v. Duke Power Co.* illustrates the method of showing the discriminatory effect of a particular employment requirement. The employer required a high school diploma and a satisfactory intelligence test score for certain jobs previously limited to white employees. The 1960 census for North Carolina reflected that 34 per cent of the white male population completed high school, as compared to only 12 per cent of the black male population. The high school diploma requirement, therefore, altered the racial pattern of available population in a manner which artificially reduced the percentage of black males. The employer failed to justify the requirement of a high school diploma as necessary.

[37] One district court has described the importance of statistics in this process as follows: "The demonstration of gross statistical disparity amounts to a prima facie showing of discrimination, thus shifting to the opposite party the burden of going forward with exculpatory evidence . . . This is taken to mean that the plaintiff, although still bearing the risk of non-persuasion, can by the use of persuasive statistics cast upon the defendant the duty of producing at least equally persuasive

The use of statistical analysis in cases concerning the alleged discriminatory effect of employment requirements has assumed an increasingly sophisticated form in recent years. The courts have shown willingness to venture outside the realm of descriptive statistics – or the mere juxtaposition of percentages[38] – and engage in some inferential work.[39] By far the most important development in this respect has been the endorsement by the Supreme Court of a statistical method which may bring more precision into Title VII cases that rely upon statistics for evidence. The method was originally introduced in *Castaneda v. Partida*[40] a landmark jury discrimination case. Three months after *Castaneda* the Supreme Court extended its use to Title VII cases in *Hazelwood School District* v. *United States.*[41]

The Court in *Castaneda* resorted to a binomial distribution model.[42] Pursuant to this method, the first number employed

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controverting evidence if he can." See: *Ochoa* v. *Monsanto Co.*, 335 F. Supp. 53, 58 (S.D. Tex. 1971).

[38] It should to noted, in this connection, that statistical analysis employed in Title VII cases can be characterised as *demographic* as well as *comparative*. The differences between the two approaches are elaborated in appendix I.

[39] In the first historical phase of statistical evaluation the disparities were so great (employers had thousands of employees and little or even no minority representation) that no question arose about the conclusions to be drawn from the statistics, and no choice existed for the courts except to find discrimination. A defendant had difficulty convincingly countering the conclusion that the absence of minority groups or women from his work-force was due to anything but willfull exclusion. As the court stated in *United States v. Hinds County Board of Education* (417 F.2d 852, 5th Cir. 1969), *cert. denied*, 396 U.S. 1032 (1970): "nothing is as emphatic as zero". However, as landmark court decisions have been handed down, and as defendants have become more proficient in Title VII proof, such massive statistical disparities, especially in connection with race or national origin claims, have become rare. Courts have found it necessary to analyse smaller statistical disparities to establish whether they support a prima facie inference of Title VII violation. The decisions these courts have made based upon statistical disparities which are less than overwhelming in size have been inconsistent. The differences amongst the courts emphasise the need to formulate a consistent standard for the purpose of determining when statistical evidence will create a prima facie case. See, in this connection, D. Whitten, *op. cit.*

[40] 430 U.S. 482 (1977).

[41] 433 U.S. 299, 308–09 n. 14 (1977).

[42] For a detailed discussion, see: M.O. Finkelstein, "The Application of Statistical Decision Theory to the Jury Discrimination Cases", *Harvard Law Review*, 80 (1966), 338. See also: W.G. Prahl, "The Civil Petitioner's Right to Representative Grand Juries and a Statistical Method of Showing Discrimination in Jury Selection Cases

is the number of people in the work force. The percentage representation of the affected class (Class *A*) in the qualified general population is multiplied by the number of people in the work force, generating a number which reflects the *expected representation* of Class *A* in the defendant's work force. The *expected representation* of Class *A* is compared to the *actual representation* of Class *A* in the defendant's work force. If the expected representation is greater than the actual representation, the next issue is one of statistical significance: When does the difference between the two numbers become large enough to create a prima facie case of Title VII violation?

In *Castaneda* the Supreme Court opted for a statistical solution to the problem. The solution consists of multiplying the number that is the total work force by the percentage representation of Class *A* and then by the percentage representation of Class *B*. The *standard deviation* is produced by finding the square root of the product of the three numbers (written as an equation, with *WF* meaning work force, *A* signifying the affected class's percentage representation, *B* meaning the percentage representation of the majority class, and *Sd* being the standard deviation, then *Sd = the square root of WFxAxB).* If the actual representation is two or three standard deviations less than the expected representation, the difference is considered statistically suspect, and establishes a prima facie case of Title VII violation.

The facts in *Castaneda* demonstrated that 870 people were summoned as grand jurors over a period of eleven years. Mexican-Americans comprised 79.1 per cent of the group from which potential grand jurors were selected, and Anglo/Caucasians 20.9 per cent. Of all grand jurors selected during the eleven years, 339 were Mexican-American. The expected representation would have been 688. In order to determine whether the difference between the expected representation of Mexican-American grand jurors (688) and the actual representation (339) was statistically significant, the Court multiplied 870 by 9.791 and 0.209, generating 143.82753. The square root of that

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Generally", *UCLA Law Review*, 20 (1973), 581; P.W. Sperlich and M.L. Jaspovice, "Statistical Decision Theory and the Selection of Grand Jurors", *Hastings Constitutional Law Quarterly*, 2 (1975), 75.

number is approximately twelve; by definition, the standard deviation is twelve. The Court concluded that the expected representation was twenty nine standard deviations more than the actual representation. Expert testimony revealed that such a variance between expected respresentation and actual representation would occur by chance only one time in ten to the 140th power, therefore the disparity was statistically significant.

In *Hazelwood* the Supreme Court examined the hiring of 405 teachers over a period of two years. With a representation of 15.4 per cent blacks amongst all teachers within the area of recruitment, the expected number of blacks hired would have been sixty-two. Only fifteen were actually hired. This was a difference of six standard deviations which, again, was statistically adequate to establish a prima facie case of Title VII violation.

The binomial model resorted to in *Castaneda* and *Hazelwood* represents an intriguing fusion of judicial proceedings and statistical principles. The method, however, cannot be readily applied to cases which depend on comparative (as distinct from demographic) statistics.[43] For this reason, Shoben has advocated[44] that in such instances a statistical test for differences between independent proportions be adopted.[45] The binomial model and the test proposed by Shoben afford the courts with powerful tools for decision-making in cases of alleged discrimination in employee promotion as well as selection. Discriminatory practices of employers (including wage discrimination) can also be tackled in the judicial context by means of the twin

[43] The difference between comparative and demographic statistics is elaborated in appendix I. Another limitation of the binomial model stems from the fact that it requires a large sample (as a result, it is useful only insofar as the evaluation of the hiring practices of employers with a substantial work force is concerned). See, in this connection. D. Whitten, op. cit., *E.W. Shoben, "Differential Pass-Fail Rates in Employment Testing"*, Harvard Law Review, 91 (1978), 793; B.C. Spradlin and J.W. Drane, "Additional Comments on the Application of Statistical Analysis of Differential Pass-Fail Rates in Employment Testing", *Duquense Law Review*, 17 (1978–79), 777.

[44] E.W. Shoben, "Differential Pass-Fail Rates in Employment Testing", *op.cit.*

[45] A percentage allowance test and the four-fifths tests have also been recomended. See, in this connection, D. Whitten, *op. cit.*

techniques of regression analysis and analysis of variance.[46] The courts have not yet availed themselves of the latter[47] on a large scale, but their potential is very considerable. In fact, it is arguable that social discrimination is fast emerging as the domain of the law in which judicial and statistical reasoning display the most symbiotic relationship.[48]

Our final example of statistical analysis in judicial decision-making concerns evidence rather than substantive law (to the extent that this distinction is valid). Specifically, we wish to draw the readers' attention to the growing reliance by the courts on probability theory in the fact-finding process. This, of course, is a relatively recent development. Heretofore the formal style of judicial inference has been, almost exclusively, that of *two-valued deductive logic* (mitigated only by the legal profession's rough-cut and undisciplined common sense).[49]

[46] See, in this connection, F.M. Fisher, *op. cit.*, Note, "Beyond the Prime Facie Case in Employment Discrimination", *Harvard Law Review*, 89 (1975), 387.

[47] The same is true of the descriptive methods developed by political scientists and sociologists to study bureaucratic representation. These methods are highlighted in: V. Subramaniam, "Representative Bureaucracy", *American Political Science Review*, 61 (1967), 1010; D. Hellreigel and L. Short, "Equal Employment Opportunity in the Federal Government", *Public Administration Review*, 32 (1972), 851; D. Nachmias and D.H. Rosenbloom, "Measuring Bureaucratic Representation and Integration", *Public Administration Review*, 33 (1973), 590; P.N. Grabosky and D.H. Rosenbloom, "Racial and Ethnic Integration in the Federal Service", *Social Science Quarterly*, 56 (1975), 71; K.J. Meier, "Representative Bureaucracy", American *Political Science Review*, 69 (1975), 526; R.L. Rittenoure, *Black Employment in the South* (Austin: University of Texas Bureau of Business Research, 1976); R.L. Rittenoure, "Measuring Fair Employment Practices", *American Journal of Economics and Sociology*, 37 (1978), 113; R. Alvarez *et al.*, eds., *Discrimination in Organizations* (San Francisco : Yossey–Bass, 1979).

[48] We have not touched upon the uses of statistics in cases of constitutional interpretation because they are only remotely relevant to the Asian context. The subject has been dealt with at some length in: M.O. Finkelstein, *op. cit.*; J.F. Banzhaf III, "Weighted Voting Doesn't Work", *Rutgers Law Review*, 19 (1965), 317; J.F. Banzhaf III, "Multimember Electoral Districts – Do They Violate the 'One Man, One Vote' Principle", *Yale Law Journal*, 75 (1966), 1309; L. Brilmayer and L. Kornhauser, "Review", *University of Chicago Law Review*, 45 (1978), 116. We should also emphasise that statistical analysis in any of the areas surveyed above is fraught with certain problems. These problems are confronted in: L.H. Tribe, *op.cit.*; W.C. Curtis and L.E. Wilson, "The Use of Statistics and Statisticians in the Litigation Process", *op.cit.*; L. Brilmayer and L. Kornhauser, *op.cit.*

[49] See, in this connection, reference 14 in appendix II.

Perhaps the most obvious manifestation of this questionable style is in the application of legal rules to specific cases.

Thus, as matters still largely stand, a legal rule might provide that some legal consequence C obtains whenever facts f_1, f_2 and f_3 occur. When such a rule is applied to a specific case, a fact-finder is supposed to determine whether or not the critical facts are present in order to establish whether the consequence C will follow. So a jury, if it is the fact-finder, would be instructed to decide whether or not each of the facts f_1, f_2 and f_3, has ocurred, and it would further be instructed to conclude C if it finds all of them to be present.

The difficulty is that the fact-finder would inevitably[50] have some doubts about whether each fact is present in its case. Even if it determines all three facts to have occurred, the uncertainty[51] that qualifies those findings should *rationally* be carried over to qualify the conclusion C. Indeed, whatever uncertainties there are about f_1, f_2 *and* f_3 in this example should have an accumulative effect. Thus, it might well be that the fact-finder would rationally find all three facts to have occurred and then proceed to conclude C as the rule directs, *even though the accumulation of uncertainties makes the conclusion rationally unsound.* Put another way, *legal rules do not take uncertainty into account.* As stated, the logic they employ is a two-valued logic – two-valued in the sense that it deals only

[50] It is very seldom that judicial decision-making takes the form of decision-making under conditions of certainty.

[51] Generally speaking, uncertainty is said to exist if a process can lead to *several* (as distinct from *one*) possible outcomes. The concept of uncertainty is closely linked to that of probability. For it is roughly true to say that, once the probability of occurrence of some event of interest is assessed, the magnitude of uncertainty is defined. To illustrate this consider three different assessments for the probability of rain tomorrow. Mr. *A* assigns a probability of 0.05, Mr. *B* assigns a probability of 0.5 and Mr. *C.* assigns a probability of 0.95. Mr. *A* and Mr.*C* judge that rain is very unlikely and very likely to occur respectively. In their minds the degree of uncertainty attached to the event "rain tomorrow" is very small. Mr. *B* on the other hand assesses a 50/50 chance to rain and this assessment indicates that this degree of uncertainty is at its maximum value, because rain and fine weather are equally likely events. It follows from this intuitive discussion that when the probability of any event (it does not have to be rain) is approximately 0.5, uncertainty about that event is greatest. This uncertainty decreases as the probability either falls below or increases above the value 0.5. By extension, the probability concept gives us an indication of the quantitative magnitude of uncertainty about some event once a probability assessment for the occurrence of the event has been made.

with propositions that are either true of false (one or the other, never both).[52] Either f_1 has occurred or else it has not; there is no middle ground — and so with f_2 *and* f_3. By the same token, consequence C either obtains or else it does not, and according to the rule the C-bell should ring whenever all three f-buttons are pushed.[53]

Systematic criticism of the two-valued deductive logic as a basis for judicial inference started surfacing in the legal literature already in the 1940s.[54] This criticism has become more pronounced in the following decades.[55] In fact, it is fair to say the legal writers have been arguing with considerable force as of the 1960s that judicial fact-finding should be aligned more closely with probability theory, or that uncertainties concerning

[52] Two-valued logics are characterised by Aristotle's law of the excluded middle. Any proposition, under the law, is either true or false; it must be one or the other, but cannot be both. Under these conditions, the *reducio ad absurdum* form of argument is valid: if a proposition leads to a contradiction (the absurdity), then the proposition must not be true; and if it is not true, it therefore must (since there is no "middle" between true and false) be false. Similarly, a proposition can be proved true by showing that its denial, or negation, leads to a contradiction.

[53] See, in this connection, reference 3 in appendix II. As indicated, the shortcomings of two-valued deductive inference are mitigated to some extent by common sense. If a decision-maker felt doubtful about a fact, his common sense would tell him to have similar doubts about any conclusions that depend on it. On the other hand, the mind's longing for certitude and repose very often short-circuits its common sense. Thus it is that a decision-maker who has made up his mind about some fact would be inclined to forget the tremendous uncertainty he had faced before coming to the determination. According to the psychological theory of cognitive dissonance reduction, when a difficult choice is made, the knowledge of being committed to the choice is "dissonant" with the knowledge of factors that had militated against the choice, and the mind seeks to restore peace by reducing the dissonance: "There are two major ways in which the individual can reduce dissonance in this situation. He can persuade himself that the attractive features of the rejected alternative are not really so attractive as he had originally thought, and that the unattractive features of the chosen alternative are not really unattractive. He can also provide additional justification for his choice by exaggerating the attractive features of the chosen alternative and the unattractive features of the rejected alternative. In other words, according to the theory the process of dissonance reduction should lead, after the decision, to an increase in the desirability of the chosen alternative and a decrease in the desirability of the rejected alternative. This phenomenon has been demonstrated in a variety of experiments." See: L. Festinger, "Cognitive Dissonance", *Scientific American*, 207 (October, 1962), 93, 95.

[54] In particular, see: References 33 and 47 in appendix II. For an earlier attempt, see Reference 48 in appendix II.

[55] In particular, see: References 2, 14, 29 and 63 in appendix II.

individual facts in specific cases ought to be[56] expressed in probailistic terms and combined together[57] in accordance with the rules of probability.

The upsurge in scholarly criticism has been accompanied by a corresponding reorientation in judicial practice. The courts, too, have begun showing greater willingness to accept probabilistic estimates of fact, particularly if these happened to be in the form of objective probabilities.[58] The number of cases with at least part of the evidence presented supported by probabilistic arguments has proliferated[59] and landmark decisions have been subjected to careful scrutiny by leading experts.[60] In the process, the courts have generally become more adept at handling both the concept and rules of probability.

Perhaps the most interesting development in this respect has been the suggestion[61] that Bayesian procedures be employed to evaluate evidence in the course of judicial proceedings. These procedures can facilitate fact-finding by the courts in a number of areas.[62] They are also of considerable heuristic value[63] since the formula which underpins them provides a conceptual apparatus for systematically evaluating information generated during a trial. That formula reads as follows:

[56] Insofar as possible.

[57] If necessary.

[58] Objective probability has to be distinguished from its subjective (or personalistic) counterpart. The latter can be defined as the *degree of belief or degree of confidence placed in the occurrence of an event by a particular individual based on the evidence* available to him. The courts have also proved willing to rely occasionally on subjective estimates of fact but their record in this respect is not particularly good. For example, see: Reference 26 in appendix II. On the other hand, the courts have gained considerable experience in handling objective probabilities (which are based on either mathematical derivations or relative frequencies) in a number of areas. For example, see: References 13, 38, 39, 40, 49, 55, 60, 61 and 68 in appendix II.

[59] For a discussion of several of these cases, see: Reference 45 in appendix II.

[60] In particular, see: References 23, 26, 56 and 62 in appendix II.

[61] See, in this connection, references 5, 8, 15, 16, 18, 22, 24, 27, 28, 32, 34, 35, 36, 41, 42, 43, 44, 46, 54, 66 and 69 in appendix II. It is desirable to read the above articles, book chapter and book in conjunction with: References 31, 52, 58, 59 and 70 in that appendix.

[62] For example, see: References 4, 9, 21, 22 and 24 in appendix II.

[63] This is implicitly acknowledged even by a critic. See: L.H. Tribe, "An Ounce of Detention", *Virginia Law Review*, 56 (1979), 371.

$$P(G/E) = \frac{P(G) \quad P(E/G)}{P(E)}$$

Or: The probability a person is guilty *(G)*, given evidence *E* is the prior probability[64] he is guilty *(P(G))*, multiplied by the probability of *E* given he is guilty *(P(E/G))*, divided by the prior probability of *E(P(E))*. The idea is that the court starts with a probility of guilt *(P(G))*, *which is revised as it is presented with* relevant facts.[65]

The probabilistic approach to evidence in general, and Bayesian procedures in particular, have had their fair share of detractors.[66] Most of the criticisms, however, levelled at the approach in its various forms have been largely answered by its exponents.[67] Probability theory is certainly not likely to revolutionise judicial fact-finding to the extent once expected, and the notion of a computerised trial has simply disappeared from the literature; yet, on balance, it seems fair to conclude

[64]Prior probability is unconditional probability, or probability not conditional on the occurrence of another event. Whenever we speak of conditional probability we use the term *given* (for example, the probability of a positive test outcome given a certain disease).

[65]For example: "Suppose a person accused of being a witch has a 'frightened look'. If the prior probability of being a witch is *p*, but everybody accused of this has, not unreasonably, a frightened look, the probability of her being a witch is still *p*,

$$P(G/E) = \frac{1}{1} p = p,$$

and one hasn't found anything . . . Again suppose a prosecutor produces two qualified witnesses to testify that they heard the sounds of a violent struggle in a house, that they saw the accused emerge from the house with a bloodstained knife in his hand, and that the house was empty save for the body of the victim. If the prior probability the accused did it is *p*, and the probability of the evidence given he did it is 1, but the evidence is otherwise not probable, perhaps 0.01, then the probability he did it goes up a hundredfold:

$$P(G/E) = p \frac{1}{.01} = 100\, p."$$

See: Reference 5 in appendix II.

[66]In particular, see: References 7, 10, 53 and 64 in appendix II. See also: References 11, 12 and 65 in that appendix.

[67]In particular, see: References 4, 6, 20, 25, 28, 35, 37, 57, 67 and 71 in appendix II. See also: References 19, 30 and 72 in that appendix.

that probabilistic estimates and probability rules can be of some operational value in the context of problem-solving by the courts and that Bayes' formula is a heuristic device of considerable importance[68] in the management of evidence.

Our survey comes now to an end. We have identified the main application areas of statistical analysis in judicial decision-making. The actual and potential uses of statistics in the law, of course, go far beyond the work of the courts. Our concern with the latter stems from the fact that their overall performance leaves something to be desired and that they have been much slower in availing themselves of the fruits of modern science than the executive and legislative branches of government. Writing two decades ago, Cowan[69] sought to impress on American students of the administration of justice the idea that the legal and scientific modes of enquiry are not incompatible. We hope that this article will serve a similar purpose by sensitising their Asian counterparts to the possibility of employing a variety of statistical techniques to improve judicial decision-making in the region.

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[68] This presumably applies to the concept of probability in general and all its rules.

[69] T.A. Cowan, "Decision Theory in Law, Science and Technology" *Rutgers Law Review*, 17 (1963), 499.

APPENDIX I

Demographic and Comparative Statistics in Title VII Cases

As noted in the text, statistical analyses employed in Title VII cases can be characterised as demographic as well as comparative. Comparative statistics are used to challenge *directly* employment tests and other criteria for employment. The plaintiff presents the success rate of each class in an attempt to prove that the affected class is unfairly disadvantaged by the challenged criterion. An example of this approach is seen in *Grigg v. Duke Power Co.* referred to earlier. (Another well-known case in point is *Western Addition Community Organization v. Alioto,* 340 F. Supp. 1351 (n'd. Cal. 1972). In this case, the plaintiff challenged the continued use of a hiring test by the San Francisco Fire Department. In 1968, 37 per cent of the white and 35 per cent of the Mexican-American applicants passed the test while only 12 per cent of the black applicants were successful. The Department subsequently endeavoured to eliminate the discriminatory elements in the test, but the court nonetheless found for the plaintiff because under the new test 57 per cent of the whites and only 20 per cent of the blacks achieved passing scores.) Under the demographic method, on the other hand, the exact composition of an employer's work force is compared with that of the general population in the geographical area. An example of this approach is seen in *Penn v. Stumpf,* 308 F. Supp. 1238 (N.D. Cal. 1970). In this case the plaintiffs challenged the employment testing of the Oakland Police Department by alleging a "striking" statistical disparity between the percentages of non-Caucasion policemen and the city's non-Caucasion population, only 3-4 per cent of the members of the police force were black. Furthermore, there were only eight more blacks on the force than in 1940, when blacks comprised 3 per cent of the city's total population. The court observed that: "while such a showing of a significant statistical discrepancy is not in itself dispositive, it is at least some indication that discriminatory forces, albeit subtle ones,

may be afoot." There is one fundamental distinction between the two statistical methods and their relative value in demonstrating discrimination. Comparative statistics may *directly* establish that a specific employment requirement has a different impact on one class than another. If the demographic approach is relied upon, however, a discriminatory pattern in the defendant's employment practices must be *inferred from the statistical disparity between the work force and the general population.* The difficulty with the demographic method is that the inference may be false if, for example, the measured geographical area does not coincide with the relevant labour market. Demographic statistics, at the same time, are of considerable importance in situations in which the employer or union have failed to maintain records from which a comparative analysis could be undertaken. Demographic statistics may also argue for judicial relief in some cases where comparative statistics alone do not. (For example, if an organization employs only five blacks out of ten thousand employees in a labour market which is 50 per cent black, something is obviously amiss even if the success rates of blacks and whites on an employment test are equal. Possible explanations for the statistics may be the exceptional qualifications of the five blacks who actually secured jobs and the defendant's bad reputation in the black community. In this situation the apparent equality revealed by comparative statistics should not prevent the court from demanding a more complete explanation from the employers). Thus, although the comparative approach is generally more reliable than the demographic one and should be a prerequisite of the prima facie case when possible, it does not completely obviate the need for demographic comparisons. The sufficiency of the evidence to establish the prima facie case should depend on the type of statistics introduced by the plaintiff. If differential impact is shown by comparative evidence, the case should be established. If for some reason the comparative evidence is unavailable, unreliable, or inconclusive, the plaintiff may buttress his claim with demographic statistics; In such a case, however, the plaintiff should be prepared to introduce evidence of surrounding circumstance to support his reliance on demographic evidence. For a detailed discussion of this point, see: Note, "Employment Discrimination", *Virginia Law Review,* 59 (1973), 463.

APPENDIX II

Bibliography on Actual and Potential Uses of Probability Theory in the Fact-Finding Process

Of the application areas surveyed in the text, the one which we believe should be of the most immediate interest to students of the administration of justice in Asia concerns the use, whether actual or potential, of probability theory in evidence (in effect, the original impetus for writing this article came as a result of our frustration in the face of the tendency of participants in Hong Kong's longest ever judicial inquiry to express themselves in unqualifed rather than probabilistic terms, thus completely ignoring the fact that they provided an input to what could be described as decision-making under conditions of uncertainty). We have prepared, therefore, a comprehensive bibliography on the subject which should enable the reader to explore it further. The bibliography consists of:

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