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COMPARISON OF THE EEOCC FOUR-FIFTHS RULE AND
A ONE, TWO OR THREE σ BINOMIAL CRITERION

Working Paper 80-801*

by

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I. INTRODUCTION

Enforcement of anti-discrimination legislation requires that there be a criterion for establishing that there has been discrimination. Four types of criteria have been validated in the courts. They are (1) disparate treatment, (2) present effects of past discrimination, (3) reasonable accommodation, and (4) adverse impact.

Disparate treatment means that equals are treated unequally or unequals are treated equally.² This argument, used in McDonnell Douglas Corp. v. Green (Supreme Court), generally has involved a single plaintiff.

In the second category of discrimination there is a challenge to policies or practices which perpetuate in the present the effects of past discrimination. This form of discrimination and the two which follow were developed in the courts in the 16 years since the passage of the Civil Rights Act of 1964. An example of present effects of past discrimination would be a case where blatant discrimination had existed before the passage of the Act and upon passage company policies are "Gerry" built to give the appearance of compliance, while the effect is to perpetuate historic discrimination. A landmark case of present effects was Quarles v. Philip Morris, Inc. This case involved departmental seniority structure in a company that had departments of varying

¹Barbara Lindemann and Paul Grossman. Employment Discrimination Law. Bureau of National Affairs, Inc., Washington, D. C., 1976, p. 1.

²Richard H. Leftwich and Ansel M. Sharp. Economics of Social Issues, 3rd edition, Business Publications, Inc., Dallas, Texas, 1978, p. 234.

desirability. Prior to the effective date of the Civil Rights Act of 1964, the employer hired blacks only into the least desirable department. Upon passage the company ceased this practice, but subsequently flatly barred transfers between departments or required that blacks forfeit their seniority if they wished to transfer to a different and higher paying department. This practice tended to lock blacks into the department in which they had been originally placed. In 1968, the Virginia Court ruled against Philip Morris, deciding that they had engaged in unlawful employment practices against Quarles.

Reasonable accommodation involves instances where employers fail to make reasonable accommodations to an employee's handicap or religious observance. An obvious example would be the discharge of an employee for refusing to work on the sabbath where an accommodation to the employee's religious practices would not work an undue hardship on the conduct of the employer's business. Cummins v. Parker Seal Co. is a typical case involving work schedule accommodations in which the worker claimed discriminatory discharge and the employer was unable to show that the worker's schedule could not be reconciled with his religious practices.

The final category, adverse impact, addresses discrimination in which employment policies or practices have a disparate impact on affected groups which are not justified by business necessity. Examples include the use of a general intelligence test as a prerequisite to be hired, which disqualifies substantially more blacks than whites and which cannot be shown to be job related. Another example is a policy of discharging employees whose wages were garnished a certain number of times where such a rule impacts minority employees more so than white employees and where such a rule cannot be shown to be necessary for the safe and efficient operation of the business. The classic case of adverse impact was Griggs v. Duke Power Company. This case involved the practices of

the company in 1965, of requiring job applicants to take a general intelligence test and the hiring requirement that the applicant be a high school graduate. These requirements were applied to new hires and transfers in labor and coal handling positions, including jobs which the court ruled were not such as to warrant such requirements, and thus decided in favor of Griggs. In this landmark case the Supreme Court ruled that Title VII prohibits "not only overt discrimination but also practices that are fair in form, but discriminatory in operation."³ The fact that Duke Power received the judgment of discrimination in spite of the defense of "good intent or absence of discriminatory intent" meant that adverse impact cases rely more heavily on statistics for the proof in establishing a prima facie case of discrimination than do the other categories, since the court must look at effects rather than motivation.⁴

The use of statistics in establishing the prima facie case of discrimination is particularly crucial in court cases because it often determines whether the court will hear the case or not; and even more important to the plaintiff, if acceptable, the statistics can establish the prima facie case of discrimination and place the burden of proof on the defendant.

The standard rule used in adverse impact cases has been the four-fifths rule which states that if the selection rate for promotion and hiring for any group is less than four-fifths that for the group with the highest rate, then adverse impact may be concluded. Recent publications by Greenberg⁵ and

³Sar A. Levitan, Garth L. Mangum and Ray Marshall. Human Resources And Labor Markets, 2nd edition, Harper and Row, Publishers, New York, 1976, p. 454

⁴Schlei and Grossman. Employment Discrimination Law, p. 10.

⁵Irwin Greenberg. "An Analysis of the EEOCC 'Four-Fifths' Rule." Management Science, Vol. 25, No. 8, August 1979, pp. 762-69.

Boardman⁶ (who assume a predetermined number of people are hired and selected) have pointed out that there are very high chances of Type I error (concluding that there is discrimination when discrimination actually does not exist) and Type II error (concluding that there is no discrimination when discrimination actually exists) when the four-fifths rule is used. While discrimination cases often argue over the question of whether or not "substantial disparity" has been shown, there is no record of the use of statistical inference criteria in employment discrimination cases.⁷

The Supreme Court, however, has held on several occasions that "where gross statistical disparities can be shown, these alone may in a proper case constitute prima facie proof of a pattern or practice of discrimination."⁸ In this context, it seems clear that to accurately define non-compliance, one must also clearly stipulate what constitutes "gross statistical disparity." The court addressed this issue in two recent cases: Castaneda v. Partida and Hazelwood School District v. United States. In both cases, the Court pointed toward the use of a precise statistical measure, the standard deviation, as the method to appropriately gauge the significance of observed disparities.

"(as) a general rule for large samples, if the difference between the expected value and the observed number is greater than two or three standard deviations, then the hypothesis that (the disparity) was random would be suspect."⁹

⁶Anthony Boardman, "Another Analysis of the EEOC 'Fourth Fifths' Rule." Management Science, Vo. 25, No. 8, August 1979, pp. 770-776.

⁷Although in EEOCs Guidelines on employee selection procedures, statistical significance of a disparity "ordinarily means that the relationship should be sufficiently high so as to have a probability of no more than 1 to 20 to have occurred by chance."

⁸Hazelwood School District, et al. v. United States, U.S.L.W. 4883, 6-28-77.

⁹Claudio Castaneda v. Rodrigo Partida, 45 U.S.L.W. 4306, 3-22-77.

It is important to note that Castaneda v. Partida involved the ethnic composition of the jury and is not directly related to employment discrimination. However, the precedents used in one type of case are often adopted in other types of litigation; thus, this measure might easily be applied to employment discrimination.

Although the four-fifths rule provides a criterion which is easier for a jury to understand, a statistical criterion like 3σ (or 2σ) may prove a sounder method of establishing whether or not there is discrimination. The three standard deviation rule sets up a zone within which no discrimination is concluded; the four-fifths rule is a line below which discrimination may be concluded. Generally the four-fifths cutoff line (see charts) will fall within the acceptable standard deviation zone. The purpose of this paper is to derive a mathematical expression to compute the crossover point where the four-fifths rule and the 3σ rule (and 2σ) no longer coincide and thereby to study the circumstances under which the application of the two rules will give divergent results. Previous papers have shown how the application of two different statistical techniques in legal cases can provide different results.¹⁰ However, this has been free choice of techniques where criteria were not specified by legal precedent. Since the four-fifths rule has been universally employed and the three standard deviation rule has gained acceptance in other types of discrimination cases, the comparison of these two types of rules is especially important.

¹⁰Drane and Spradlin. "Additional comments on the application of Statistical Analysis to Differential Pass-Fail Rates in Employment Testing." Duquesne Law Review, Vol. 17, #3&4, 1978-79. pp. 777-783.

II. COMPARISON OF FOUR-FIFTHS RULE AND 3 STANDARD DEVIATION CRITERION

Assume two populations, 1 and 2, and define:

N_1 = applicants from population 1 (white),

n_1 = selections from population 1,

N_2 = applicants from population 2 (black),

n_2 = selections from population 2.

The two discrimination criteria will be applied to determine if there has been discrimination against group N_2 .

a) By the four-fifths rule, there is no discrimination if:

$$\frac{n_2/N_2}{n_1/N_1} \geq 0.8 \quad (1)$$

b) By the 3σ rule based on the binomial distribution there is no discrimination if n_2 is within $\pm 3\sigma$ from the expected value, based on applicant populations. Mathematically the case of no discrimination occurs when

$$\frac{n_2 - \mu}{\sigma} < 3 \quad (2)$$

$$\mu = np_2 \text{ and } \sigma = \sqrt{np_1(1-p_1)}$$

p_1 = probability of a 1 from total $N_1 + N_2$

p_2 = probability of a 2 from total $N_1 + N_2$

$$n = n_1 + n_2$$

$$\text{therefore } \mu = \frac{N_2}{N_1 + N_2} (n_1 + n_2), \quad (3)$$

$$\sigma = \sqrt{(n_1+n_2)p_2(1-p_2)}, \quad (4)$$

$$\text{and, } p_2 = \frac{N_2}{N_1 + N_2} \quad (5)$$

Equation (2) addresses discrimination for the 3σ case. A more general case to consider is an arbitrary number of standard deviations, z ; thus for any number of σ 's, discrimination occurs if

$$\frac{n_2 - \mu}{\sigma} < z \quad (6)$$

is satisfied.

Substitution of Equations (3)-(5) in Equation (6) results in the following expression.

$$\frac{n_2 N_1 - n_1 N_2}{\sqrt{(n_1 + n_2) N_1 N_2}} < z \quad (7)$$

Consider the full distribution around the mean as $\mu \pm z\sigma$. Define n_{2-} as the minimum number of selections from population 2 to satisfy the $z\sigma$ rule. Selection less than n_{2-} is defined as discrimination against population 2. Define n_{2+} as the maximum number of selection from population 2 that satisfies the $z\sigma$ rule. Selection greater than n_{2+} is defined as discrimination against population 1. The extreme values for nondiscrimination, n_{2-} and n_{2+} can be found by replacing the inequality in Equation (7) with an equality and solving the quadratic equation obtained from Equation (7),

$$z^2 = \frac{(n_2 N_1 - n_1 N_2)^2}{N_1 N_2 (n_1 + n_2)} = \frac{(N_1 n_2)^2 - 2n_1 n_2 N_1 N_2 + (N_2 n_1)^2}{N_1 N_2 (n_1 + n_2)}$$

Solve for n_2 (percentage of blacks) in terms of (n_1, N_1, N_2, z)

$$z^2 N_1 N_2 n_1 + z^2 N_1 N_2 n_2 = N_1^2 n_2^2 - 2n_1 n_2 N_1 N_2 + N_2^2 n_1^2$$

Divide by N_1^2

$$\frac{z^2 N_2 n_1}{N_1} + \frac{z^2 N_2 n_2}{N_1} = n_2^2 - \frac{2n_1 n_2 N_2}{N_1} + \frac{N_2^2}{N_1^2} n_1^2$$

Rearrange in quadratic form:

$$n_2^2 - n_2 \frac{N_2}{N_1} (2n_1 + z^2) + n_1 \frac{N_2}{N_1} \frac{N_2 n_1 - z^2}{N_1} = 0 \quad (8)$$

Solving for the roots yields equations 9 and 10.

$$n_{2-} = 1/2 \frac{N_2}{N_1} (2n_1 + z^2) - z \sqrt{z^2 + 4n_1 \left(1 + \frac{N_1}{N_2}\right)} \quad (9)$$

$$n_{2+} = \frac{1}{2} \frac{N_2}{N_1} \left[2n_1 + z^2 + z \sqrt{z^2 + 4n_1 \left(\frac{1+N_1}{N_2} \right)} \right] \quad (10)$$

As the size of n_1 increases, n_{2-} and n_{2+} are asymptotic to the line

$$n_2 = n_1 \frac{N_2}{N_1} \quad (11)$$

thus for large values of n_1 , n_{2-} derived from the 3σ law is greater than the n_2 required by the 4/5 law (see Charts 1, 2, 3 and Tables 1, 2, 3). It can also be seen that for more moderate levels of n_1 , the opposite is true. Thus there is a point where the line for the 4/5 rule and n_{2-} will cross.

III. CRITERIA FOR DIFFERENT POPULATION RATIOS

In Tables 1, 2, 3 and Figures 1, 2, 3 we compute values for and plot several limiting cases:

Case A: $N_2 = N_1$ - population of applicants equally divided

Case B: $N_2 = 0.5N_1$ - population of minority applicants are 1/2 of majority

Case C: $N_2 = 0.1N_1$ - population of minority applicants is 1/10 of majority (similar to actual population ratios)

Using Equation (9) and computing values for n_2 for these different population ratios we have:

Case A: $N_2 = N_1$: (3 σ criterion)

$$n_2 = \left(\frac{9}{2} + n_1 \pm 3 \sqrt{9 + 8n_1} \right) \quad (12)$$

Case B: $N_2 = .5N_1$: (3 σ criterion)

$$n_2 = (1/4) (9 + 2n_1 \pm 3 \sqrt{9 + 12n_1}) \quad (13)$$

Case C: $N_2 = .1N_1$: (3 σ criterion)

$$n_2 = .05 (9 + 2n_1 \pm 3 \sqrt{9 + 44n_1}) \quad (14)$$

Table 1

Case A: $N_1 = N_2$

n_1	$n_2 (+)$	$n_2 (-)$	4/5 Rule $n_2 = 0.8n_1$
0	9.0	0	0
10	28.6	.4	8
20	44.0	5.0	16
50	84.8	24.2	40
100	147.1	61.9	80
200	264.6	144.4	160
500	599.4	409.6	400
600	708.4	500.6	480
700	816.8	592.2	560
750	870.8	638.2	600
1000	1,138.6	870.4	800

Table 2

Case B: $N_2 = .5N_1$

n_1	$n_2 (+)$	$n_2 (-)$	4/5 Rule $n_2 = \frac{.8n_1}{N_2}$ N_1
0	4.5	0	0
10	15.8	-	4
20	24.1	0.4	8
50	45.8	8.7	20
100	78.4	26.2	40
200	139.1	65.4	80
900	530.2	374.2	360
1000	584.4	420.0	400

Table 3

Case C: $N_2 = .1N_1$

n_1	$n_2 (+)$	$n_2 (-)$	4/5 Rule $n_2 = \frac{.8n_1}{N_2}$ N_1
0	0.9	0	0
10	4.6	-	.8
20	6.9	-	1.6
50	12.5	-	4
100	20.4	0.5	8
200	34.5	6.4	16
1000	131.9	69.0	80
2000	244.8	155.95	160
3000	355.0	245.95	240

IV. CONDITIONS UNDER WHICH FOUR-FIFTHS RULE AND 3σ CRITERION
GIVE DIFFERENT RESULTS - CROSSOVER POINT

The results of the preceding section clearly indicate that there is significant divergence between the 3σ and the 4/5 criteria. As n_1 becomes large enough the minimal number of n_2 hires suggested by the four-fifths rule is less than that advocated by the 3σ zone whereas the opposite is true at lower values of n_1 . Tables 1, 2, and 3 indicate that as the ratio of the minority population of applicants to the majority population of applicants becomes smaller this crossover point occurs at a higher value of n_1 . Thus where $N_1 = N_2$ the crossover is between 300 and 400, where $N_1 = 2N_2$ the crossover is near 900, where $N_1 = 10N_2$ the crossover is between 2,000 and 3,000. We will now derive a formula for this crossover point, where the number of selections of population 2 is the same for the 4/5 rule and the 3σ criterion.

Using our smaller root, since the four-fifths line crosses the lower limit of the 3σ zone, we will derive an equation to determine the crossover value n_1^* .

$$n_2 = 1/2 \frac{N_2}{N_1} \left[(2n_1 + z^2) - z \sqrt{z^2 + 4n_1 \left(\frac{1+N_1}{N_2} \right)} \right] \quad \text{using equation (9)}$$

$$n_2 = 0.8 n_1 \frac{N_2}{N_1} \quad (\text{four-fifths rule) and equation (1)}$$

$$0.8 n_1^* \frac{N_2}{N_1} = 1/2 \frac{N_2}{N_1} \left[(2n_1^* + z^2) - z \sqrt{z^2 + 4n_1^* \left(\frac{1+N_1}{N_2} \right)} \right] \quad (15)$$

set equation (9) equal to the 4/5 rule.

$$n_1^* = 25z^2 \left(0.8 + \frac{N_1}{N_2} \right) \quad (16)$$

Now solving for the crossover value for n_2 (called n_2^*) when $n_1 = n_1^*$ we get

$$n_2^* = 20z^2 \frac{N_2}{N_1} \left(0.8 + \frac{N_1}{N_2} \right) \quad (17)$$

Substituting in this equation for the three cases in Tables 1, 2, 3:

$(N_2 = N_1)$, $(N_2 = .5N_1)$ and $(N_2 = .1N_1)$ we derive our crossover values.

Table 4

Crossover points - 4/5 rule and 3σ criteria

z	N_2/N_1	Total Selections		
		n_1^*	n_2^*	$n_1^* + n_2^*$
3	1	405	324	729
3	0.5	630	252	882
3	0.1	2430	194.4	2624

Note that crossover values based on the 3σ criteria yield large number of hires and promotions. At values of n_1 less than n_1^* the four-fifths rule requires a higher number of selections from population 2 than required by the 3σ criteria. Use of narrower confidence bands, 2σ or σ may lead to more usable results. Tables 5 and 6 show the crossover points for the three cases of Table 4 for the 2σ and 1σ calculations based on Equations (16) and (17). Note that the total selections column $n_1 + n_2$ can be used when a fixed number of selections is needed.

V. COMPARING THE FOUR-FIFTHS RULE AND THE 2σ AND 1σ CRITERIA

Since we are using a large sample size the binomial distribution closely approximates the normal and $\mu \pm 2\sigma$ will include approximately 95.5% of the area under the curve. The crossover points are n_1^* and n_2^* . Using a 1σ criterion the confidence interval $\mu \pm 1\sigma$ will include 68.3% of the area under the curve, we calculate values for Table 6.

Table 5

Crossover points, 4/5 rule and 2σ criteria

z	N_2/N_1	Total Selections		
		n_1^*	n_2^*	$n_1^* + n_2^*$
2	1	180	144	324
2	0.5	280	112	392
2	0.1	1080	86.4	1166

Table 6

Crossover points 4/5 rule and σ criteria

z	N_2/N_1	Total Selections		
		n_1^*	n_2^*	$n_1^* + n_2^*$
1	1	45	36	81
1	0.5	70	28	98
1	0.1	270	21.6	292

Tables 4, 5, and 6 have shown the number of hires in each group at the crossover point of the 1, 2, and 3σ rules and the 4/5 rule. Table 7 shows the minimal number of minority hires (or promotions) for a given number of hires or promotions in the majority groups as well as the total number of hires for different population ratios and the four different criteria (1σ , 2σ , 3σ , and the 4/5 rule).

VI. CONCLUSIONS

The use of a 1σ , 2σ , or 3σ criterion based on the binomial distribution will provide a criterion which does not always overlap with the currently used 4/5 rule. Particularly where there are a large number of selections, the 4/5 rule will be more lenient about the definition of discrimination than the

Table 7

Comparison of Number of Minority, Majority, and Total
Persons Hired for 1σ , 2σ , and 3σ , and Four-Fifths Rule,
For Different Population Characteristics

		3 σ Rule		2 σ Rule		1 σ Rule		4/5 Rule		
		n ₁	n ₂ -	n ₁ +n ₂ -	n ₂ -	n ₁ +n ₂ -	n ₂ -	n ₁ +n ₂ -	n ₂	n ₁ +n ₂
N ₁ =N ₂	10	.4	10.4	3	13	6	16	8.0	18	
	20	5.0	25.0	9.2	29.2	14.2	34.2	16.0	36	
	50	24.2	74.2	32.0	82.0	40.5	90.5	40.0	90	
	100	61.9	161.9	73.6	173.6	86.4	186.4	80.0	180	
	200	144.4	344.4	162.0	362.0	180.5	380.5	160.0	360	
	500	409.6	909.6	438.7	938.7	468.9	968.9	400.0	900	
	1000	870.4	1870.4	912.6	1912.6	955.8	1955.8	800.0	1800	
3000	2772.2	5772.2	2847.0	5847.0	2923.0	5923.0	2400.0	5400		
N ₂ = .5N ₁	10	-	-	.5	10.5	2.5	12.5	4.0	14.0	
	20	.5	20.5	3.2	23.2	6.4	26.4	8.0	28.0	
	50	8.8	58.8	13.8	63.8	19.1	69.1	20.0	70.0	
	100	26.0	126.0	33.7	133.7	41.6	141.6	40.0	140.0	
	200	65.5	265.5	76.5	276.5	88.0	288.0	80.0	280.0	
	500	194.1	694.1	212.3	712.3	230.9	730.9	200.0	700.0	
	1000	420.0	1420.0	446.2	1446.2	472.8	1472.8	400.0	1400.0	
3000	1359.9	4359.9	1406.2	4406.2	1343.0	4452.8	1200.0	4200.0		
N ₂ = .1N ₁	10	-	-	-	-	0	10	0.8	10.8	
	20	-	-	-	-	0.6	20.6	1.6	21.6	
	50	-	-	-	-	2.7	52.7	4.0	54.0	
	100	.6	100.6	3.6	103.6	6.8	106.8	8.0	108.0	
	200	6.3	206.3	10.8	210.8	15.4	215.4	16.0	216.0	
	500	28.2	528.2	35.4	535.4	42.6	542.6	40.0	540.0	
	1000	68.9	1068.9	79.2	1079.2	89.5	1089.5	80.0	1080.0	
3000	245.9	3245.9	263.8	3263.8	281.8	3281.8	240.0	3240.0		

statistical inference criteria, since the binomial criteria takes sample size into account. The opposite is true below the crossover point. The crossover point shows where the two rules agree depending on the relative proportions of each of the groups in the applicant population.

The possibilities of more than one criterion for discrimination create a gaming situation. For sample sizes below the various crossover points the 3σ , 2σ , or 1σ rule is optimal for the company and above the crossover point the $4/5$ rule is optimal for the company. Moreover, the minimum number of "hires" or promotions specified by these rules may be used as a maximum by those desiring to discriminate and yet not be penalized. However all legislation or judicial precedent which sets concrete bounds can be used in this way. On the other hand, legislation or judicial precedent which allows for use of any of a wide variety of types of statistical techniques allows for more gaming as it is usually possible to find one technique to substantiate any case. Thus it becomes important for the law to specify a unique criterion. Statistical inference which accounts for sample size should be used for the establishment of such a criterion. The 1σ or 2σ rule which provides a 68% or 95.5% confidence level, and has a crossover point earlier than the 3σ rule might be most suitable. Initially, a one or two σ rule would allow for more type I error than a 3σ rule, however it would allow for less type II error, particularly where the number of choices are small. The 1, 2, or 3σ rules specify a constant type I error, however as sample size is increased the type II error will decrease. Thus the institution of a 1, 2, or 3σ criteria will as opposed to the $4/5$ rule give more protection to the small business and subject the larger business to more scrutiny.

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FIGURE 1

SELECTIONS FROM POPULATION 2, n_2 AS FUNCTION OF SELECTIONS FROM POPULATION 1, n_1 , FOR FOUR-FIFTHS RULE AND 3 σ CRITERIA. $N_2/N_1 = 1$

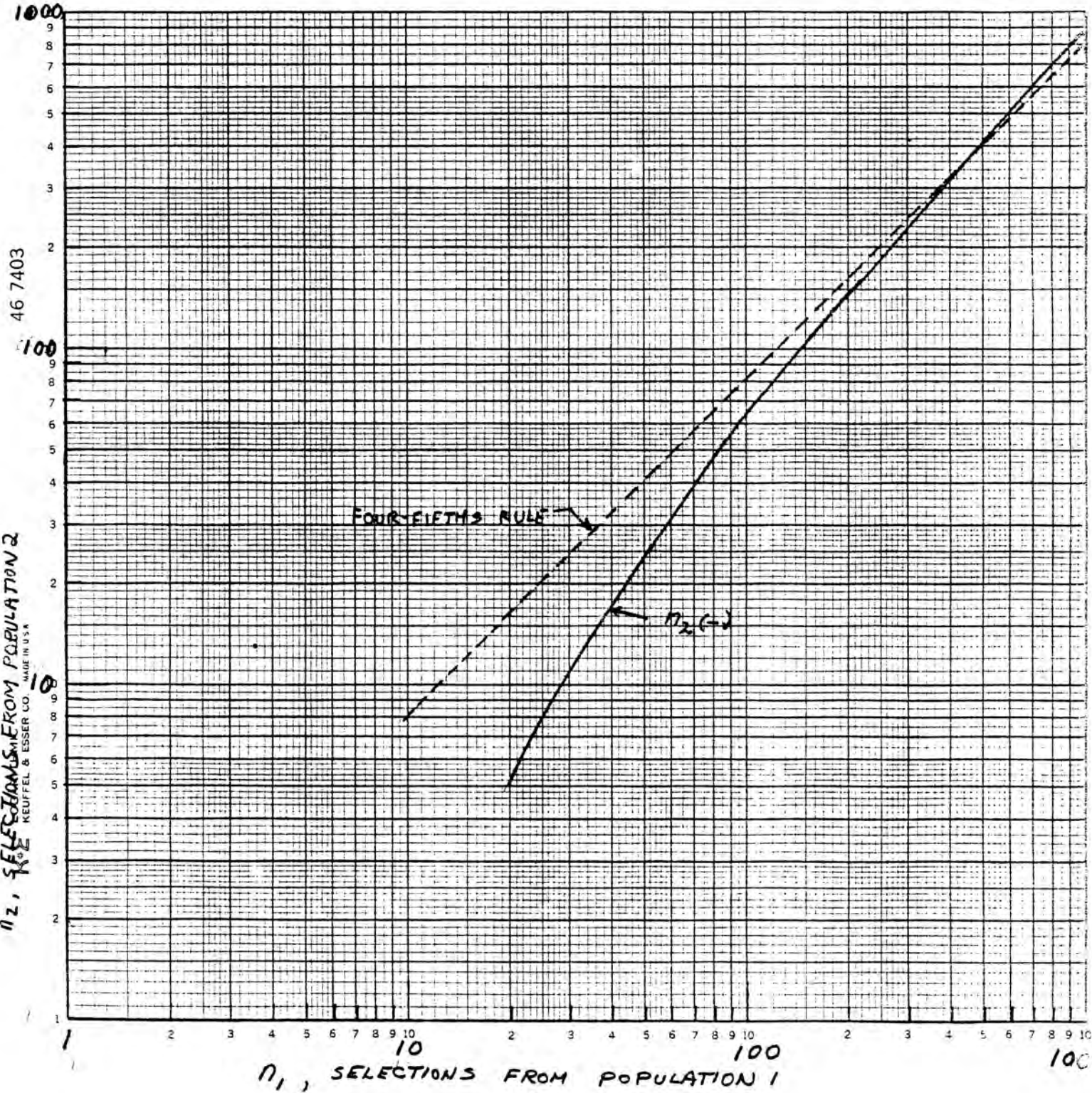


FIGURE 2
 SELECTIONS FROM POPULATION 2, n_2 AS A FUNCTION
 OF SELECTIONS FROM POPULATION 1, n_1 FOR FOUR-FIFTHS
 RULE AND 36 CRITERIA. $N_2/N_1 = 0.5$

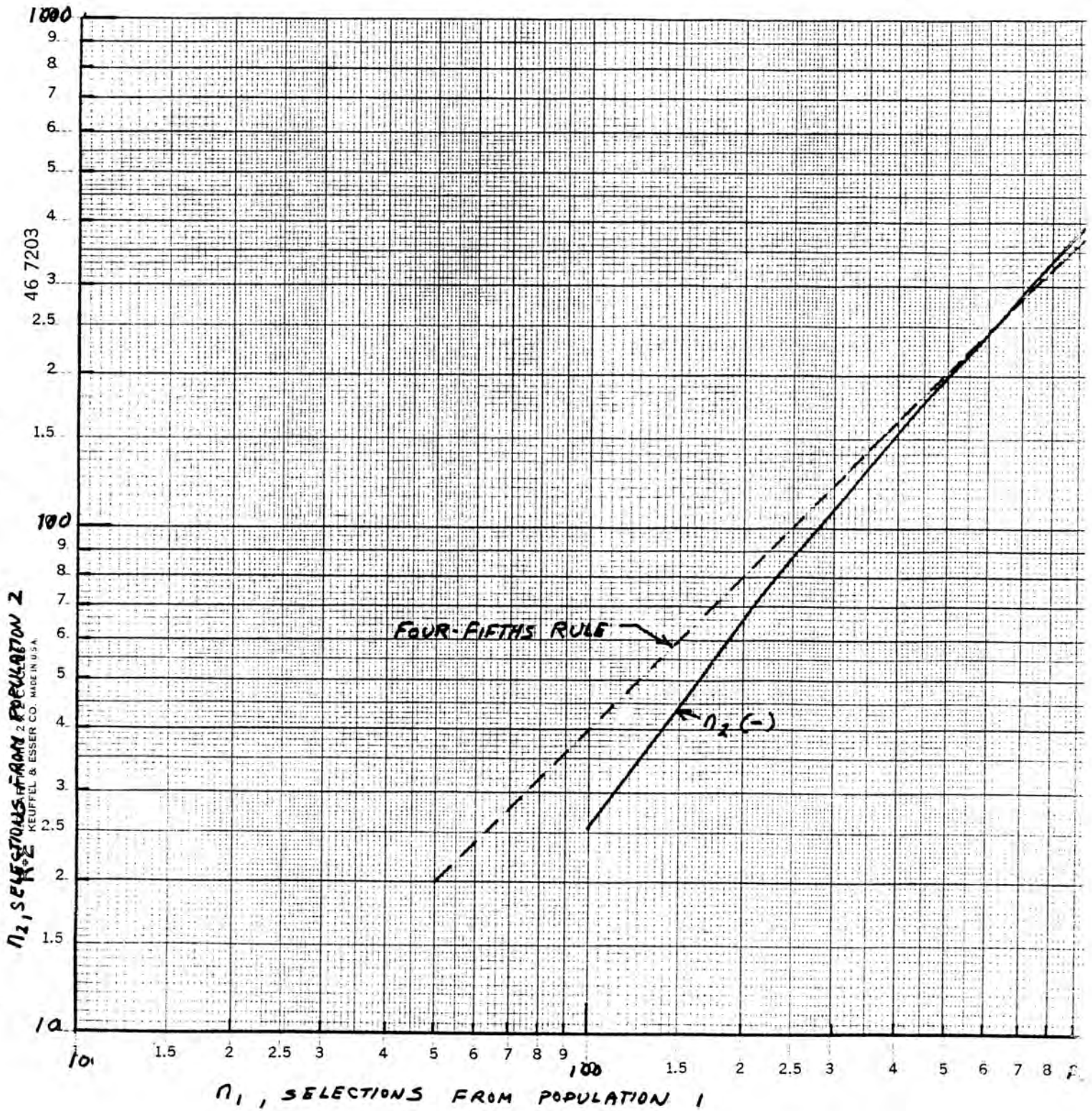
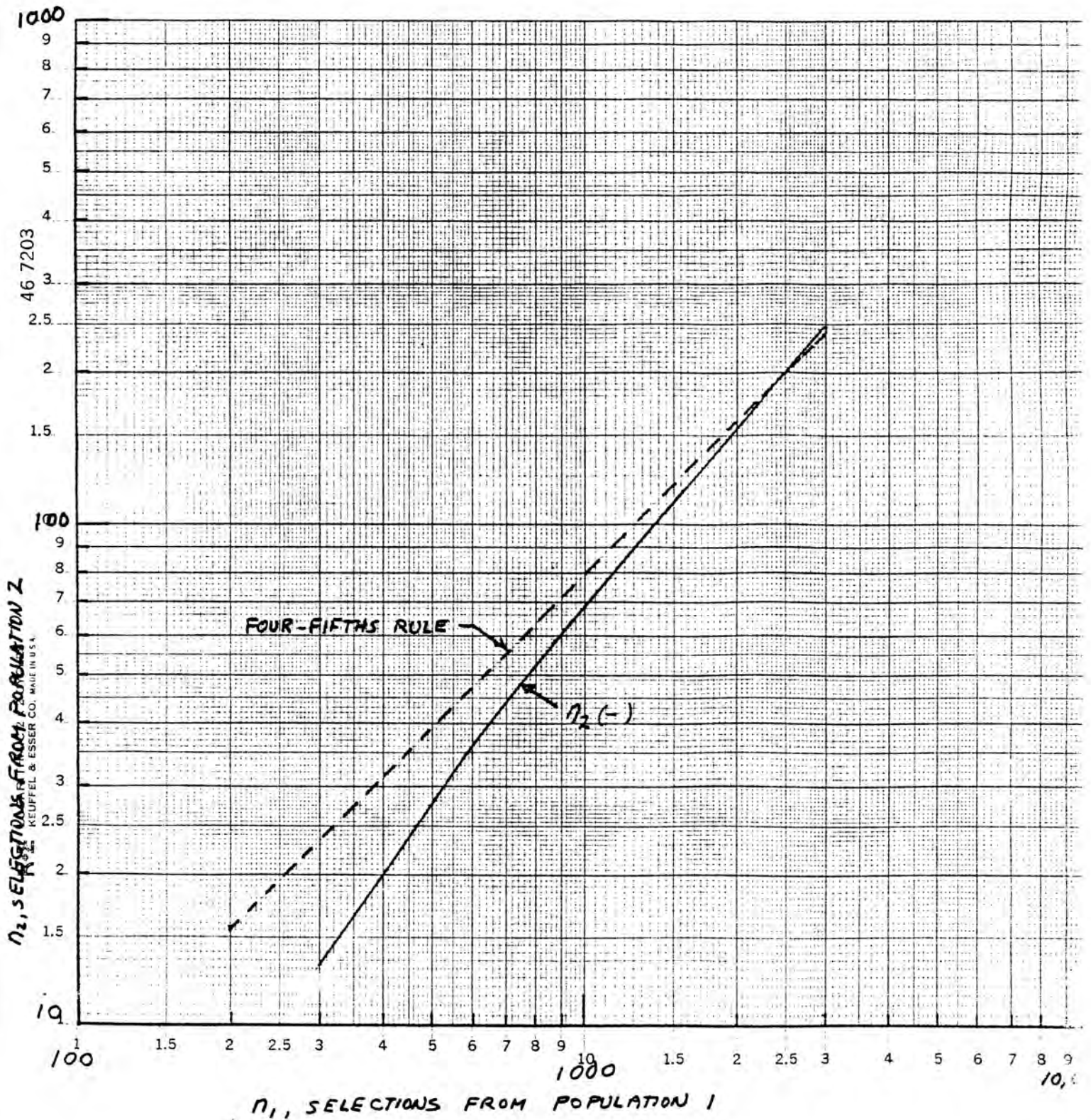


FIGURE 3
 SELECTIONS FROM POPULATION 2, n_2 AS FUNCTION
 OF SELECTIONS FROM POPULATION 1, n_1 , FOR FOUR-FIFTHS
 RULE AND 3 σ CRITERIA. $N_2/N_1 = 0.1$

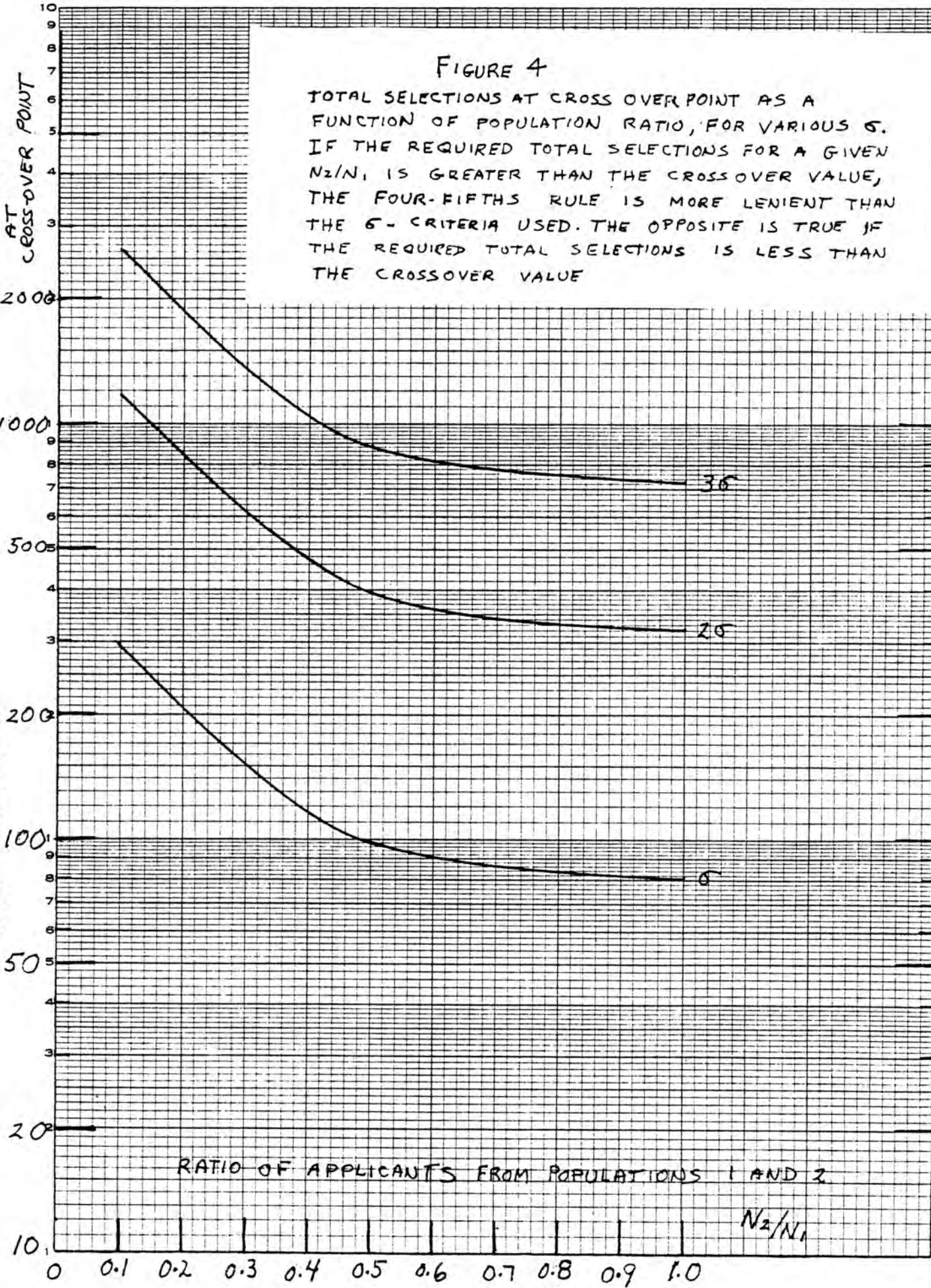


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TOTAL SELECTIONS AT CROSS-OVER POINT

FIGURE 4
TOTAL SELECTIONS AT CROSS OVER POINT AS A FUNCTION OF POPULATION RATIO, FOR VARIOUS σ . IF THE REQUIRED TOTAL SELECTIONS FOR A GIVEN N_2/N_1 IS GREATER THAN THE CROSS OVER VALUE, THE FOUR-FIFTHS RULE IS MORE LENIENT THAN THE σ - CRITERIA USED. THE OPPOSITE IS TRUE IF THE REQUIRED TOTAL SELECTIONS IS LESS THAN THE CROSSOVER VALUE



RATIO OF APPLICANTS FROM POPULATIONS 1 AND 2

N_2/N_1

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