

# The Graphs of the CDF, Power and Its Interpretation on Several Types of Binomial Probability Distribution

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## ABSTRACT

The research discussed the graphically analyzed of the cumulative distribution function (cdf), and the power function of hypothesis testing on the binomial distribution. In this research, we also showed (derived) the formula of the power function on special case of binomial such us Negative Binomial and the Geometric distribution. The result showed that the degree of freedom, bound of the rejection area, and parameter shape significantly affect to the curves of the power function. The curves of the power are sigmoid and they increase quickly to be one on the small parameter shape and large degree of freedom.

**Keywords:** Binomial distribution, the power function of hypothesis testing, R-code

## 1. INTRODUCTION

Here, we interested to study the use of the power and size in testing the hypothesis parameter and their graphically analyse for improving the inference population (Pratikno, [2]). Following, Wackerly, et. al. [5], we note that there are three definitions related to the hypothesis testing, namely a probability error type I ( $\alpha$ ), a probability error type II ( $\beta$ ) and a **power function**. In addition, the power is defined as a probability to reject  $H_0$  under  $H_1$  in testing hypothesis,  $H_0: \theta = \theta_0$  versus  $H_1: \theta \neq \theta_0$ , for parameter  $\theta$ , as a statistical technique to investigate the population inference. Moreover, the size is then defined as the probability to reject  $H_0$  under  $H_0$ . We then choose the maximum power and minimum sizes as the theoretical concept to compare the testing.

Many authors such as, Pratikno [2], Khan [12-14], Khan and Saleh [15,16,17, 20, 21], Khan and Hoque [19], Saleh [1], Yunus [6], and Yunus and Khan [7-10], already studied the power and size of the tests on the hypothesis testing. Furthermore, we noted from the previous research some authors studied the power in testing intercept with non-sample prior information (NSPI), such as Pratikno [2], Khan and Pratikno [20] and Khan [12]. They used the probability integral of the cumulative distribution function (cdf) to compute the power and size. Moreover, Pratikno [2] and Khan et al. [9] used the formula of the power to compute the cdf of the bivariate noncentral  $F$  (BNCF) distribution in

regression models. Others authors have also contributed to the research of the power in the context of the hypothesis testing, such as Khan [12-14], Khan and Saleh [15,16,17, 20, 21], Khan and Hoque [17], Saleh [1], Yunus [6], and Yunus and Khan [7-10]. Due to the complicated and hard computational, Pratikno [2] and Khan et al. [9] used the BNCF distribution to compute the power using *R-code* (see Pratikno [2] and Khan et.al. [18]).

The research methodology for investigating the power and size as follows: (1) we have to determine the sufficiently statistics, (2) we then create the rejection area using uniformly most powerful test (UMPT) to derive the formula of the power of the geometric distribution, and (3) we finally compute and figure the graphs using *R-code*.

In this paper, Section 1 presented the introduction. The graphically analyzed of the cdf of the Binomial, Negative Binomial and Geometric distributions, and the power function are given in Section 2. The conclusion is given in Section 3.

## 2. THE GRAPHICALLY ANALYZED OF THE PDF, CDF, AND THE POWER-SIZE OF THE BINOMIAL AND GEOMETRIC DISTRIBUTION

### 2.1. The cdf Graphs of the Binomial, Negative Binomial and Geometric Distributions

Following Pratikno et al. [4], the general probability mass function (pmf) of the **Binomial** distribution with  $X_i$  Bernoulli trials with parameter  $p$ , and number of trial  $n$ , is given as

$$p(x) = P(X = x) = \binom{n}{x} p^x (1-p)^{n-x}; \tag{1}$$

with  $\binom{n}{x} = \frac{n!}{n!(n-x)!}$

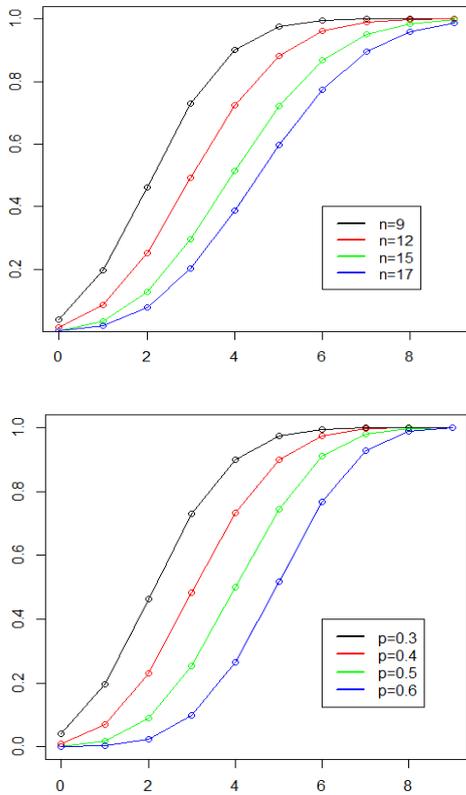
Similarly, the probability mass function of  $X$  as random variable of the **Negative Binomial** distribution of success on  $n$  Bernoulli trials, with  $r$  success on  $x$ ,  $X \sim BN(r, p)$ , is then presented as

$$p(x) = P(X = x) = \binom{x-1}{r-1} p^r (1-p)^{x-r}, \quad x = r, r+1, \tag{2}$$

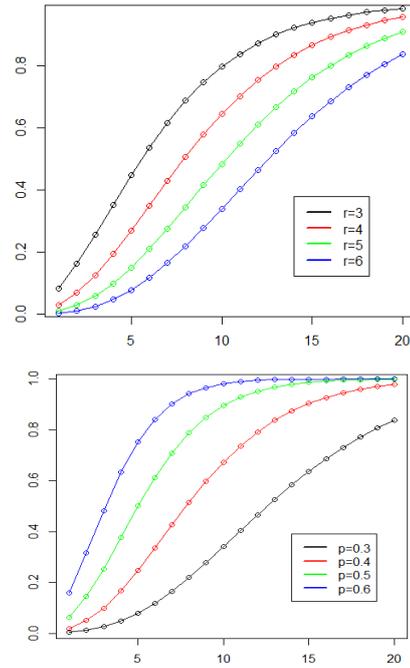
For  $r=1$ , the distribution of the random variable  $X$  will be Geometric distribution,  $X \sim BN(1, p) = \text{Geo}(r=1, p)$ , with pmf is given as

$$p(x) = P(X = x) = p(1-p)^{x-1}, \quad x = 1, 2, 3, \tag{3}$$

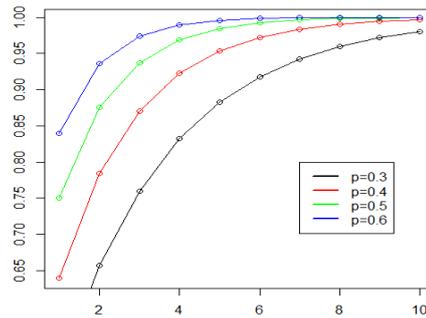
Using the equation (1), (2) and (3), we presented the graphs (curves) of the cdf of the three distributions,  $P(X \leq x)$  at Figures 1, 2, and 3, respectively.



**Figure 1.** The graphs of the cdf of the binomial distribution on several  $n$  and  $p$ .



**Figure 2.** The graphs of the cdf of the Negative binomial distribution on several  $n$  and  $p$ .



**Figure 3.** The graphs of the cdf of the Geometric distribution on several  $p$ .

From Figure 1, 2, and 3, we see that the all the curves are nonlinear (sigmoid). They increase as for small  $n$  and they increase as the  $p$  increase. They are going to be one (quickly) for large  $p$  ( $p$  increases). It means that both  $n$  and  $p$  really significant affect to the skew-ness of their curves.

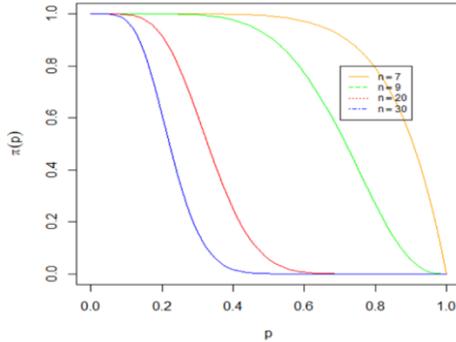
### 2.2. The Graphs of the Power Functions

To derive the formula of the power function, we set the joint distribution of the random variable,  $X_1, \dots, X_n$ . Furthermore, we find sufficiency statistics and rejection area to define the power and size. Here, we then got the sufficiency statistics  $S = \sum_i^m x_i$  that follows to specified distribution. In this case, we then find the rejection area using *most powerful (MP) test*. Due to the similarity of the distribution among Binomial, Negative Binomial and Geometric distribution, we then obtained the general

power function of the Binomial distribution to testing  $H_0 : p = p_0$  versus  $H_1 : p > p_0$  as

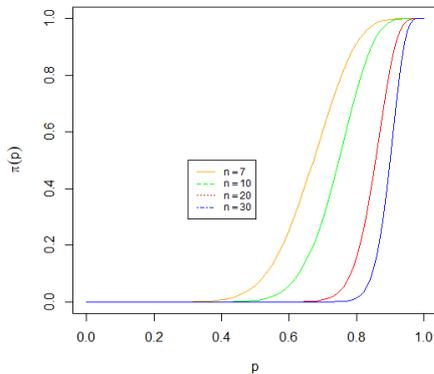
$$\begin{aligned} \pi(p) &= P(\text{reject } H_0 | \text{under } H_1 : p) \\ &= P\left(\sum_{i=1}^m X_i \geq k | p\right) = 1 - P(S \leq k-1 | p) \end{aligned} \quad (4)$$

Using the equation (4), we then produce the graphs of the power and size function on Binomial, Negative Binomial and Geometric distribution at the Picture of the bottom.



**Figure 4.** The power of the Binomial distribution with the rejection area 4 on several  $n$

We see from Figure 4., the curves are sigmoid and tend to be quickly to be one for large  $n$  and small  $p$ .



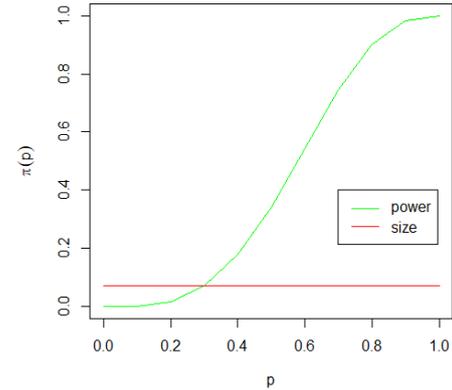
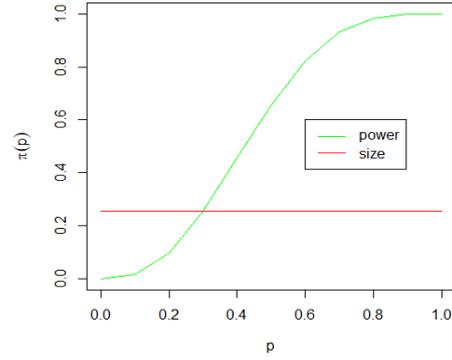
**Figure 5.** The power of the Negative Binomial distribution with the rejection area 6 on several  $n$

From Figure 5., we see that the curves of the power are also sigmoid, and they are quickly to be zero for small  $n$  and  $p$ .

Furthermore, we noted that the graphs on Figure 6 are produced using the formula of the power

$$\pi(p) = \sum_{s=3}^6 \binom{s-1}{3-1} p^3 (1-p)^{s-3}$$

in testing  $H_0 : p = 0.3$  versus  $H_1 : p > 0.3$  with the  $m$  values are 3 and 4.



**Figure 6.** The power and size of the Geometric distribution with  $RR = \{(x_1, x_2, \dots, x_m) | s \geq 6\}$

We see from Figure 6., it is clear that the power and size increase for small (lower)  $m$  and they decrease as the  $m$  increase. Note that the curve of the power function is sigmoid, but the size is constant. To evaluate the values of the size, we presented the manually computation form the power function

$$\pi(p) = 1 - \left[ \sum_{s=0}^5 \binom{9}{s} p^s (1-p)^{9-s} \right]$$

under  $H_0$  when  $p_0=0.3$  and  $m=3$ ,

$$\alpha = \pi(0.3) = 1 - \left[ (0.7)^9 + \dots + 126(0.3)^5 (0.7)^4 \right] = 0.026$$

$p_0 = 0.3$  and  $m = 4$ ,  $\alpha = \pi(0.3) = 0.07$ , respectively.

### 3. CONCLUSION

There several steps to derive the power function on distributions. The important step is finding the rejection area using UMPT test. The result showed that the power function is depended  $n$  and  $p$ , and they tend to be sigmoid and quickly to be one for large  $p$  (except on Binomial distribution)

### AUTHORS' CONTRIBUTIONS

All authors, BP, ELW, JSS, JJ, and MM, have contributions about CONCEPT, METHOD, EDITING, and ANALYSIS. The first author BP provided feedback, discussed result and contributed to the final manuscript.

## ACKNOWLEDGMENTS

We thankfully to the LPPM UNSOED for providing us granting of research of the BLU UNSOED, 2021.

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