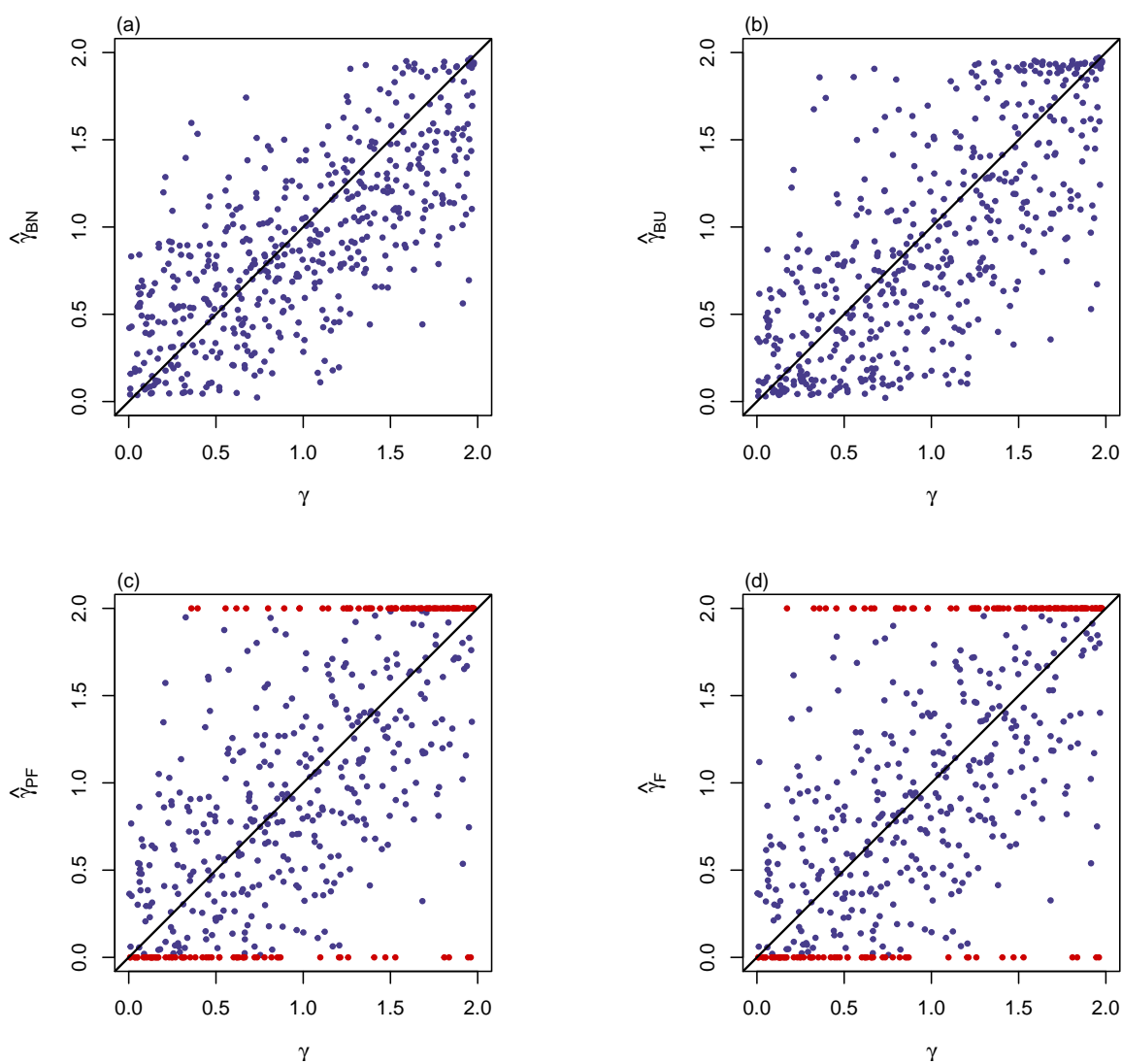
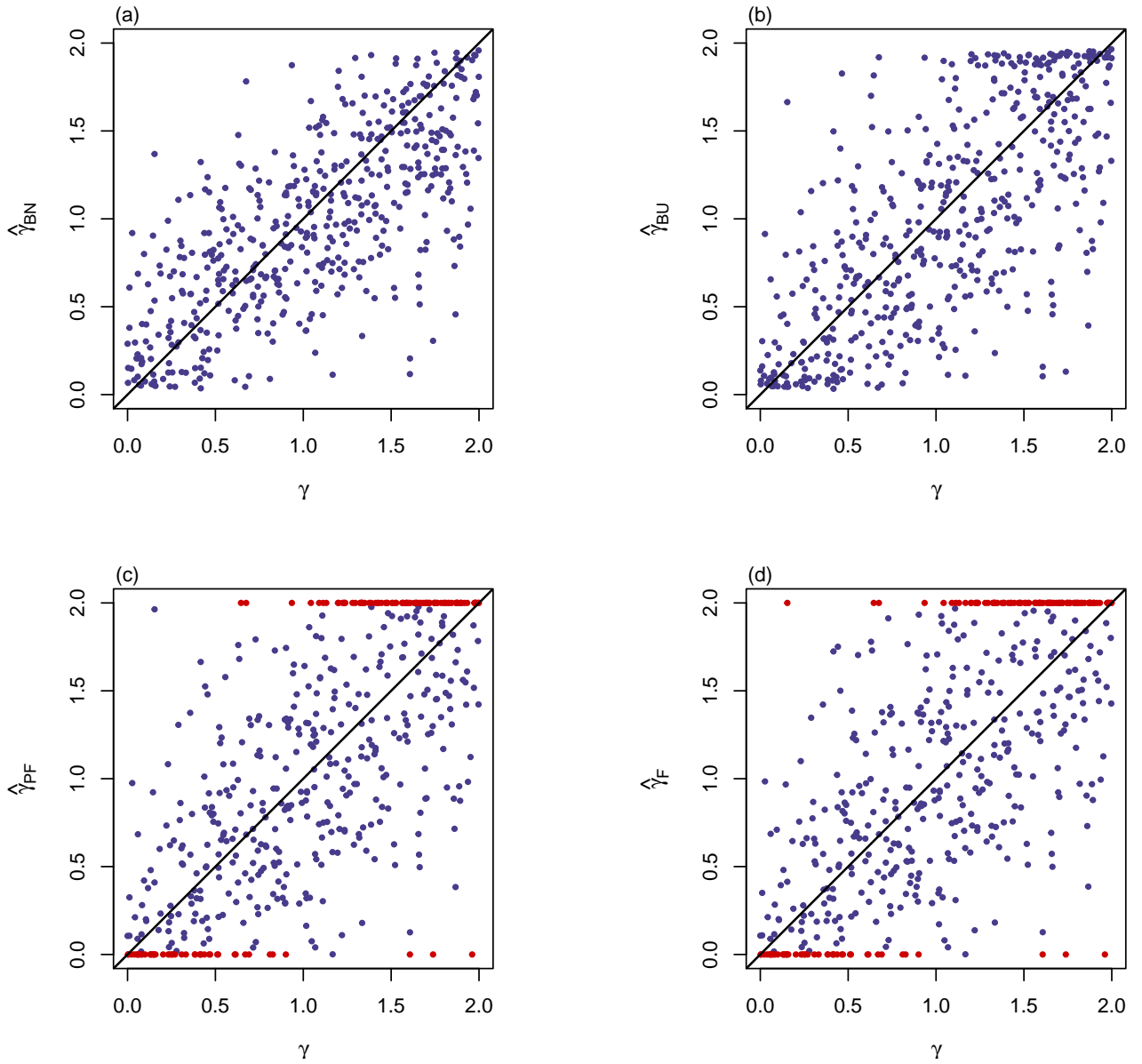


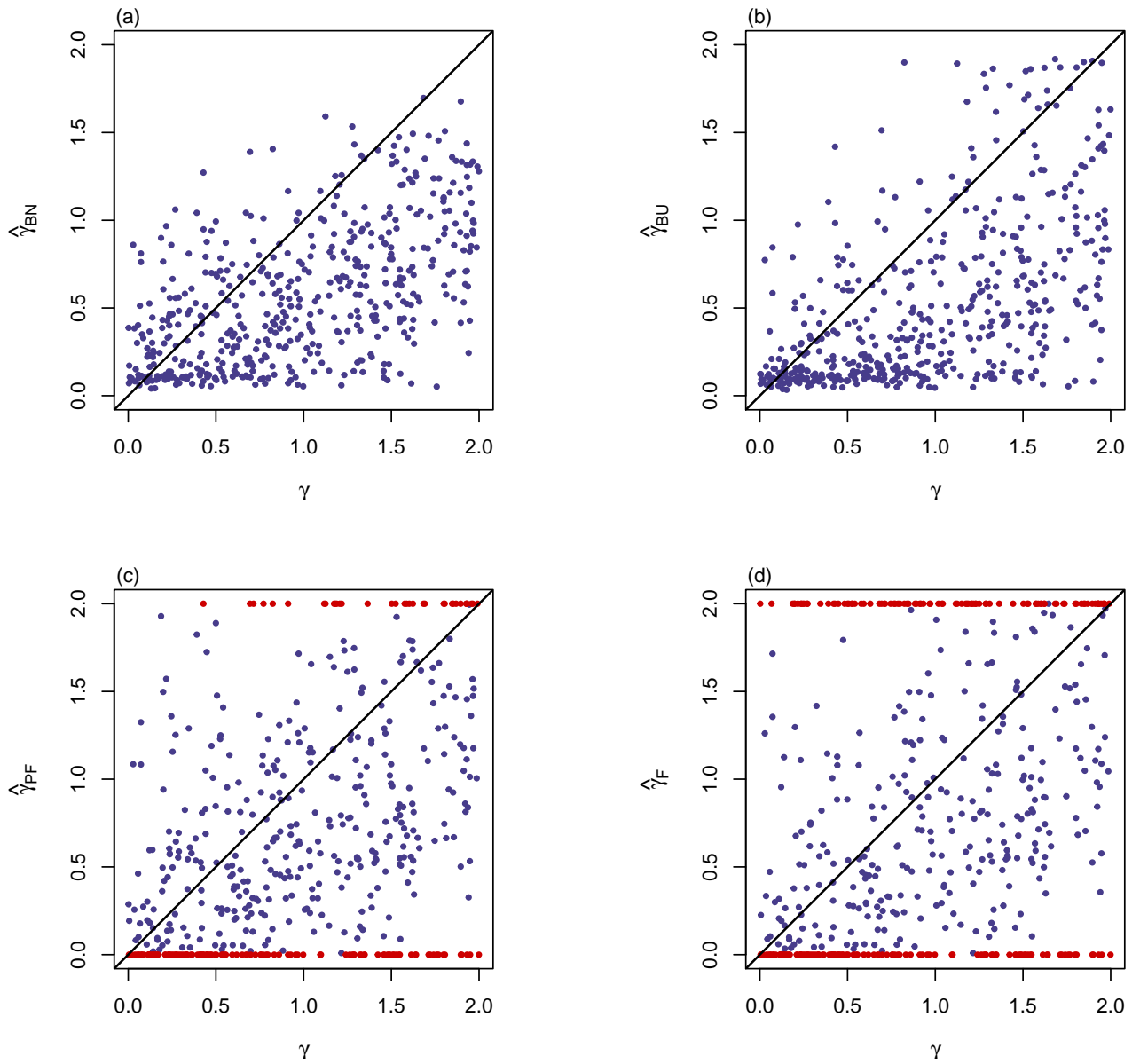
Additional file 1: Supplementary Figures S1–S22



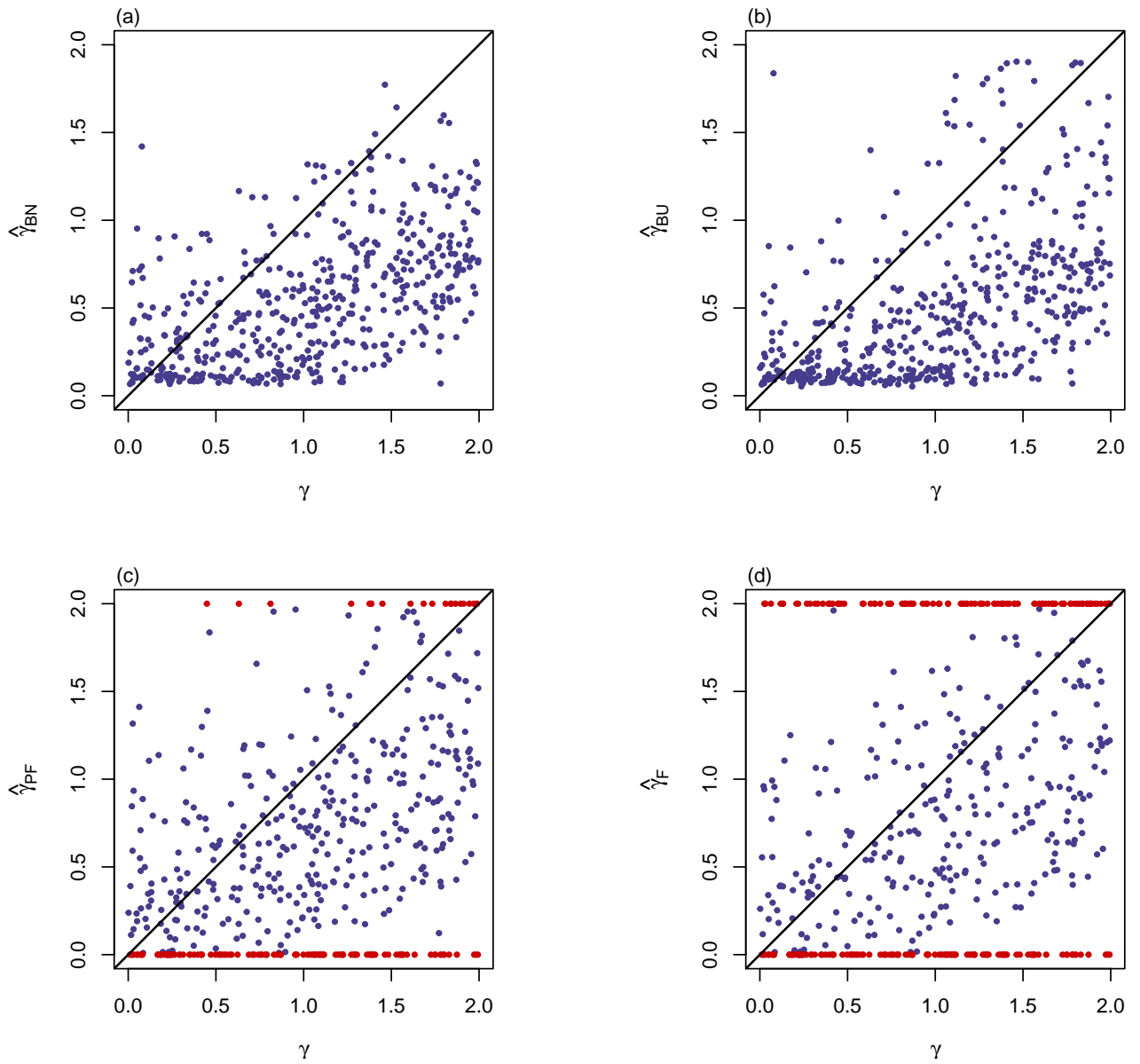
Supplementary Figure S1 Scatter plots of point estimates of γ against true value of γ for qualitative trait with $n = 500$, $MAF = 0.3$ and $\rho = -0.05$. The red points represent the extreme values (0 or 2). **(a)** $\hat{\gamma}_{BN}$; **(b)** $\hat{\gamma}_{BU}$; **(c)** $\hat{\gamma}_{PF}$; **(d)** $\hat{\gamma}_F$



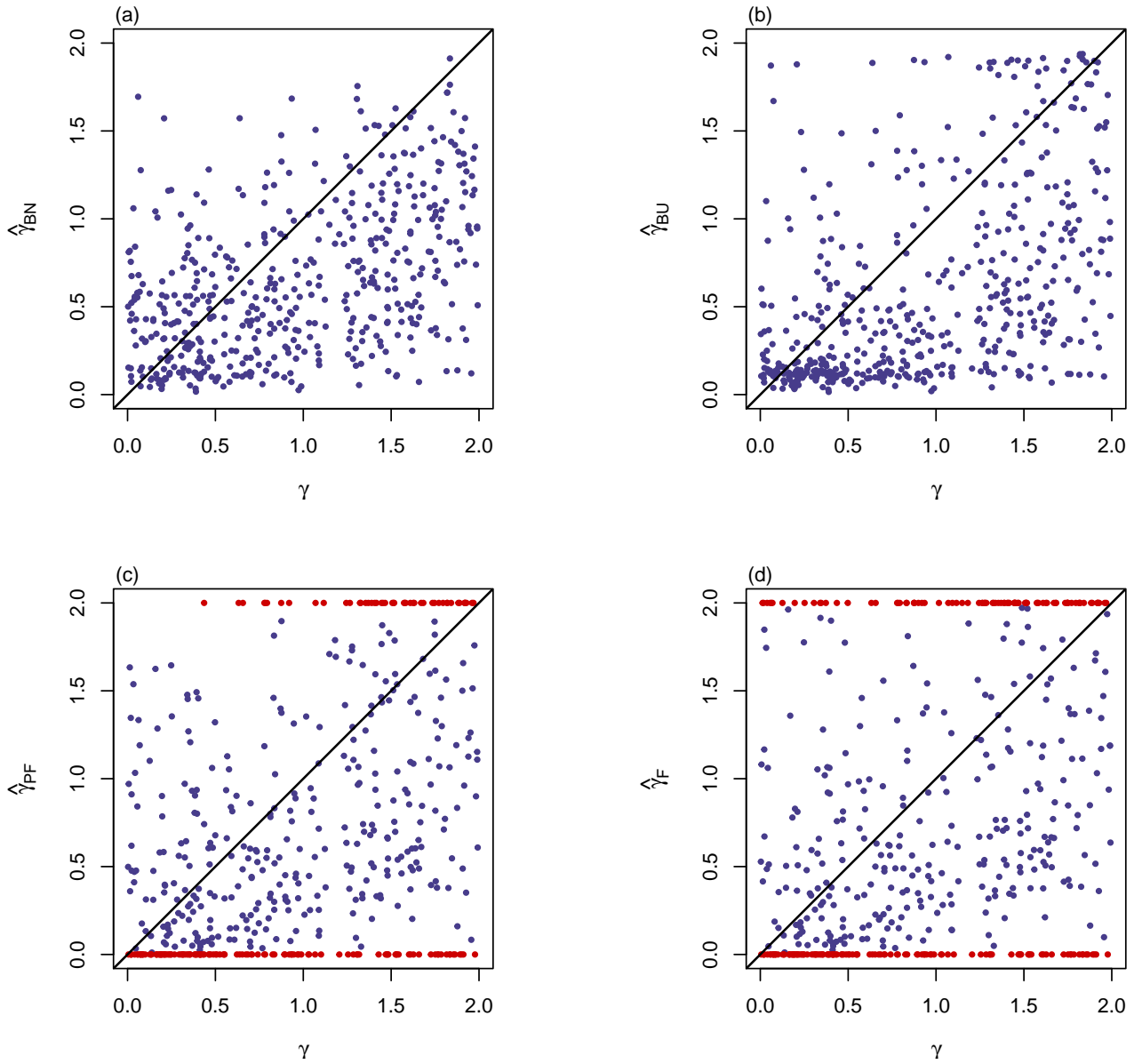
Supplementary Figure S2 Scatter plots of point estimates of γ are against true value of γ for qualitative trait with $n = 500$, $MAF = 0.3$ and $\rho = 0.05$. The red points represent the extreme values (0 or 2). **(a)** $\hat{\gamma}_{BN}$; **(b)** $\hat{\gamma}_{BU}$; **(c)** $\hat{\gamma}_{PF}$; **(d)** $\hat{\gamma}_F$



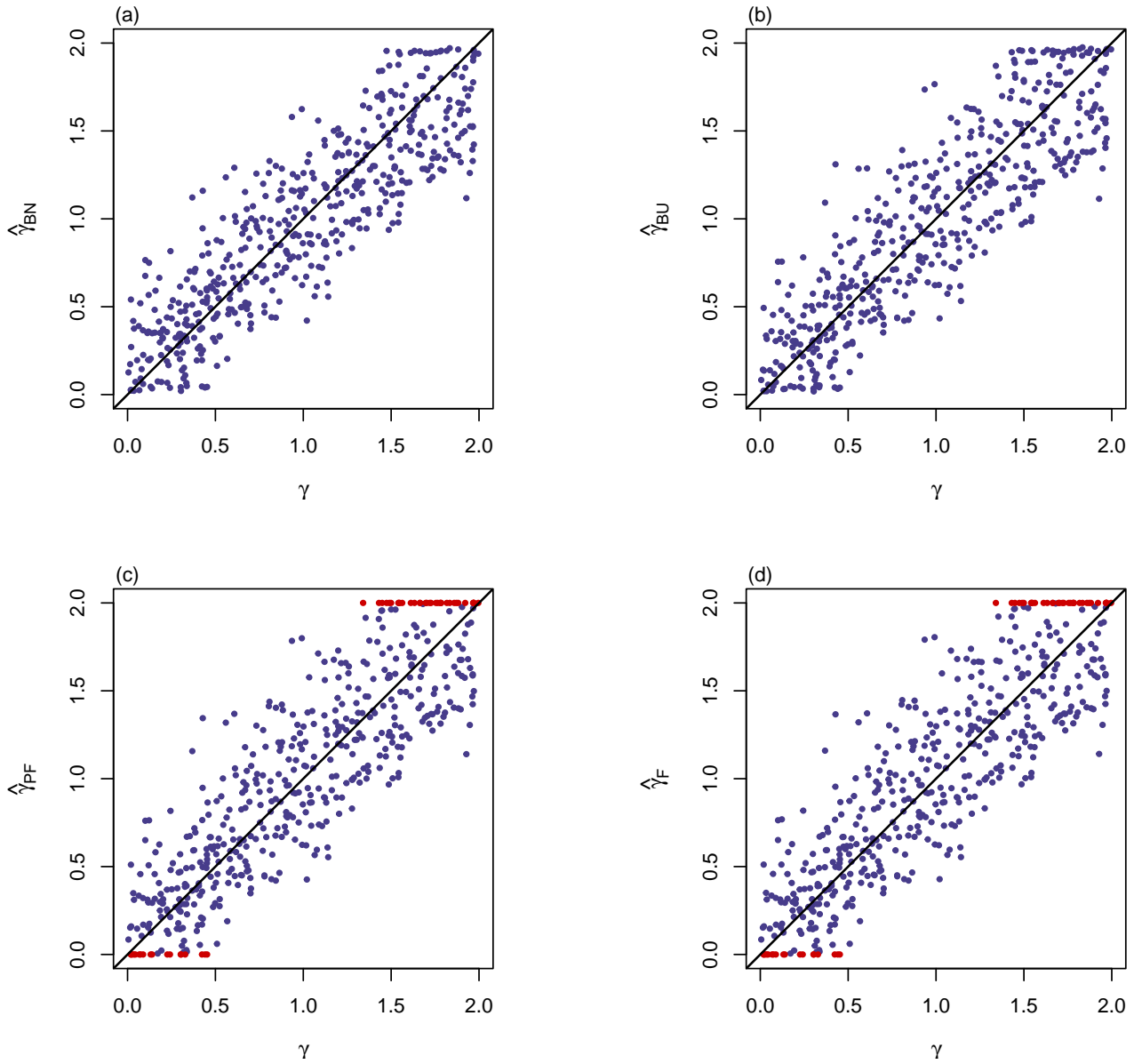
Supplementary Figure S3 Scatter plots of point estimates of γ against true value of γ for qualitative trait with $n = 500$, $\text{MAF} = 0.1$ and $\rho = 0$. The red points represent the extreme values (0 or 2). **(a)** $\hat{\gamma}_{BN}$; **(b)** $\hat{\gamma}_{BU}$; **(c)** $\hat{\gamma}_{PF}$; **(d)** $\hat{\gamma}_F$



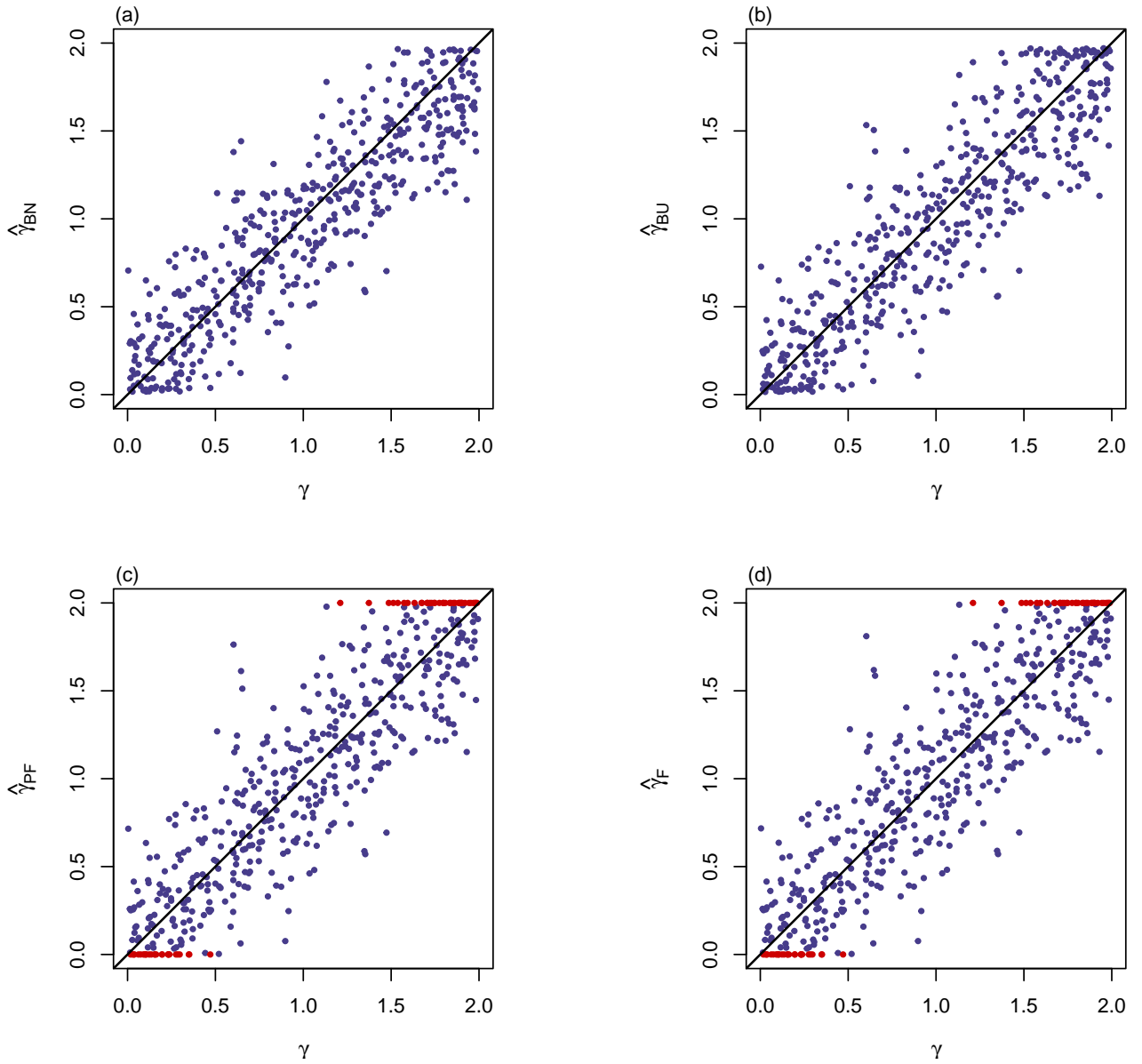
Supplementary Figure S4 Scatter plots of point estimates of γ against true value of γ for qualitative trait with $n = 500$, $MAF = 0.1$ and $\rho = -0.05$. The red points represent the extreme values (0 or 2). (a) $\hat{\gamma}_{BN}$; (b) $\hat{\gamma}_{BU}$; (c) $\hat{\gamma}_{PF}$; (d) $\hat{\gamma}_F$



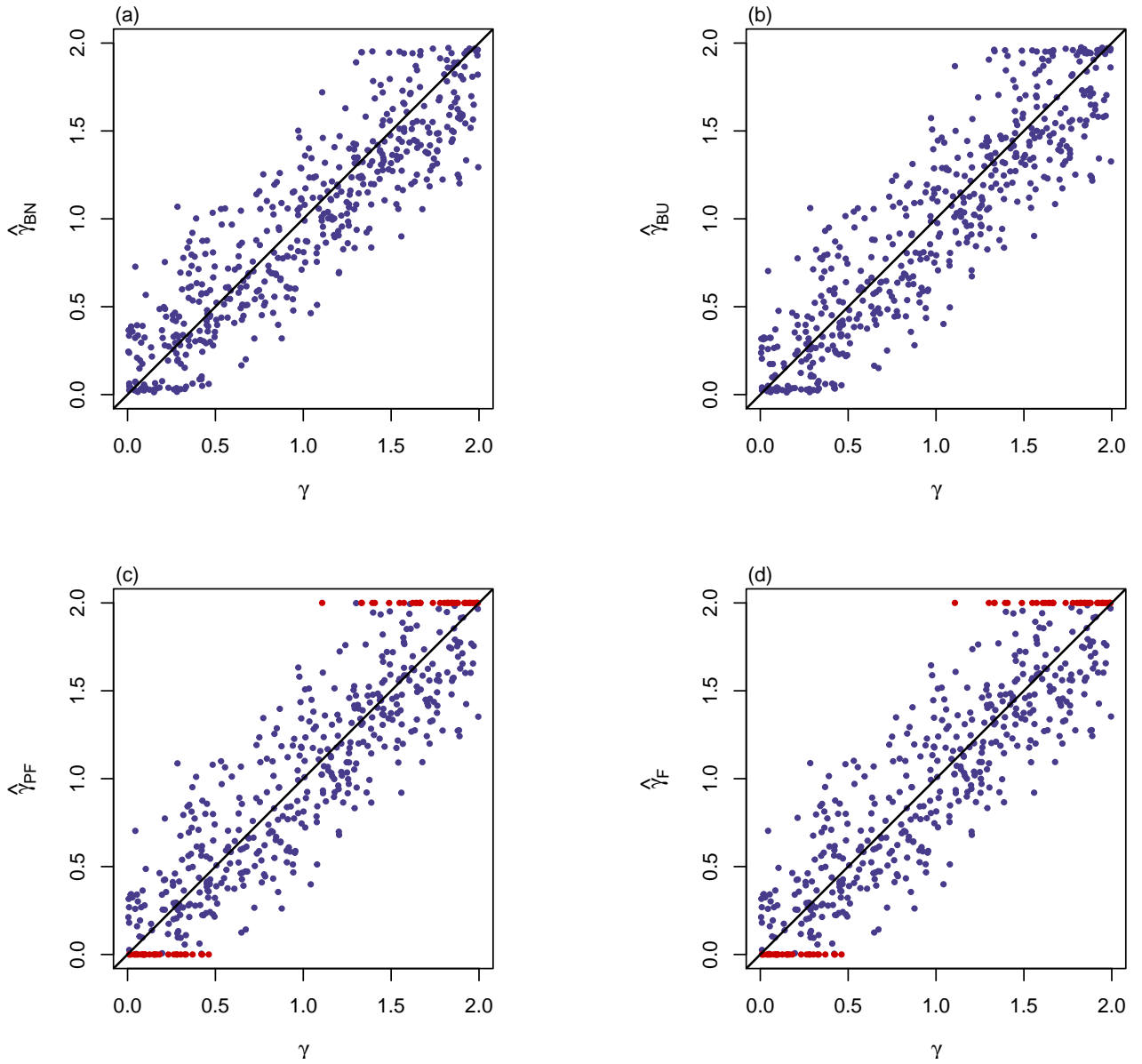
Supplementary Figure S5 Scatter plots of point estimates of γ against true value of γ for qualitative trait with $n = 500$, $\text{MAF} = 0.1$ and $\rho = 0.05$. The red points represent the extreme values (0 or 2). **(a)** $\hat{\gamma}_{BN}$; **(b)** $\hat{\gamma}_{BU}$; **(c)** $\hat{\gamma}_{PF}$; **(d)** $\hat{\gamma}_F$



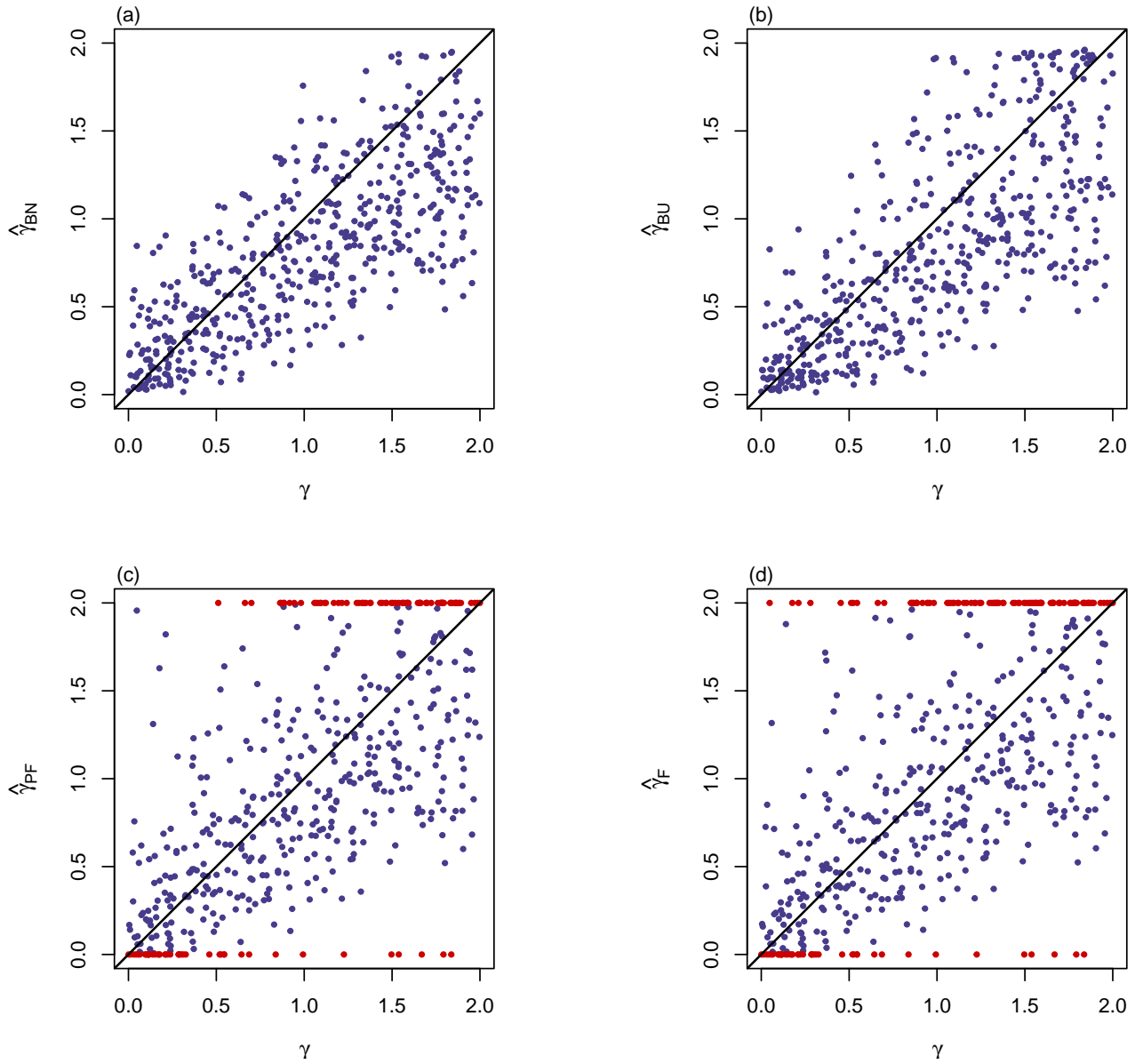
Supplementary Figure S6 Scatter plots of point estimates of γ against true value of γ for qualitative trait with $n = 2000$, $MAF = 0.3$ and $\rho = 0$. The red points represent the extreme values (0 or 2). (a) $\hat{\gamma}_{BN}$; (b) $\hat{\gamma}_{BU}$; (c) $\hat{\gamma}_{PF}$; (d) $\hat{\gamma}_F$



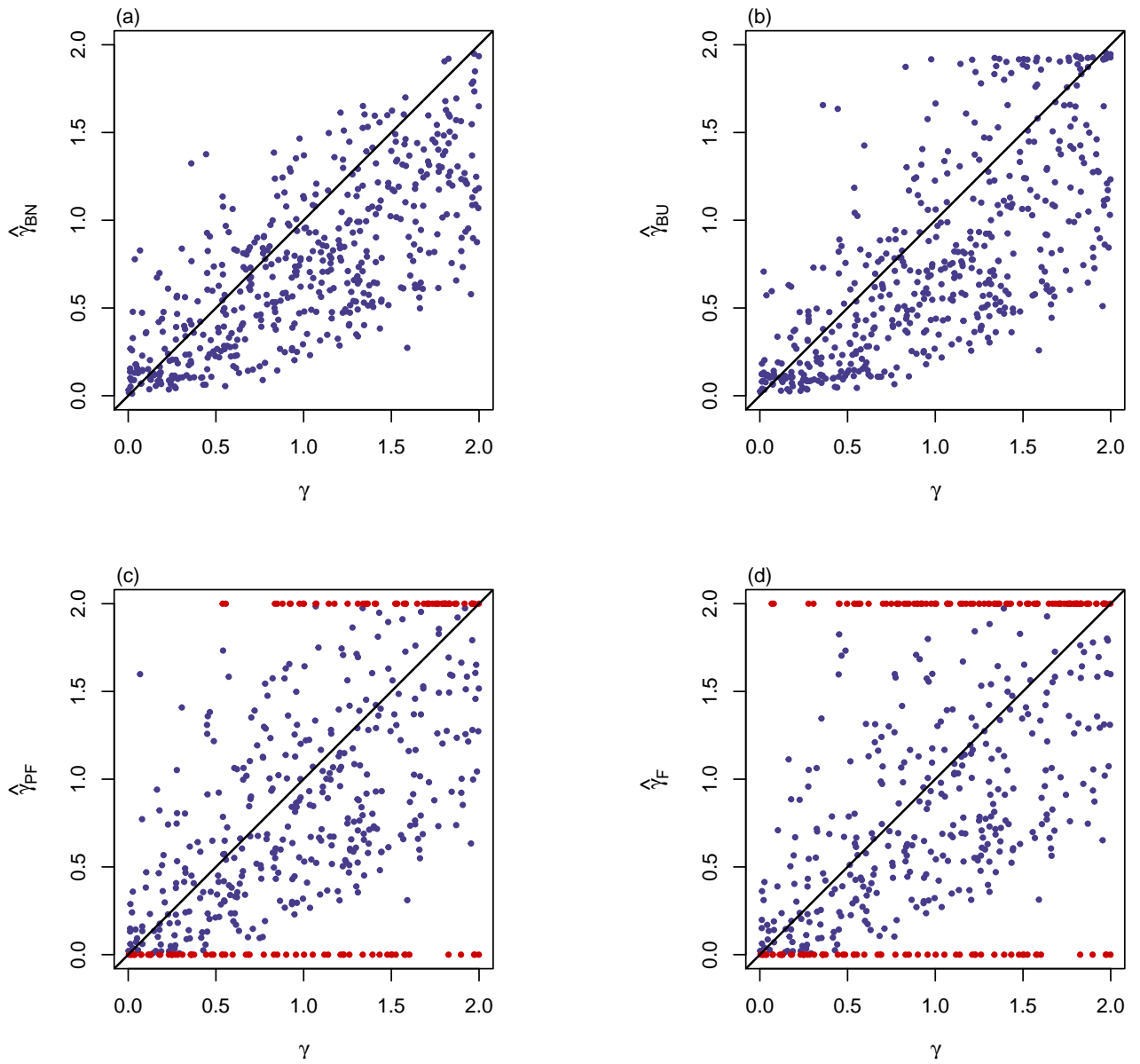
Supplementary Figure S7 Scatter plots of point estimates of γ against true value of γ for qualitative trait with $n = 2000$, $\text{MAF} = 0.3$ and $\rho = -0.05$. The red points represent the extreme values (0 or 2). **(a)** $\hat{\gamma}_{BN}$; **(b)** $\hat{\gamma}_{BU}$; **(c)** $\hat{\gamma}_{PF}$; **(d)** $\hat{\gamma}_F$



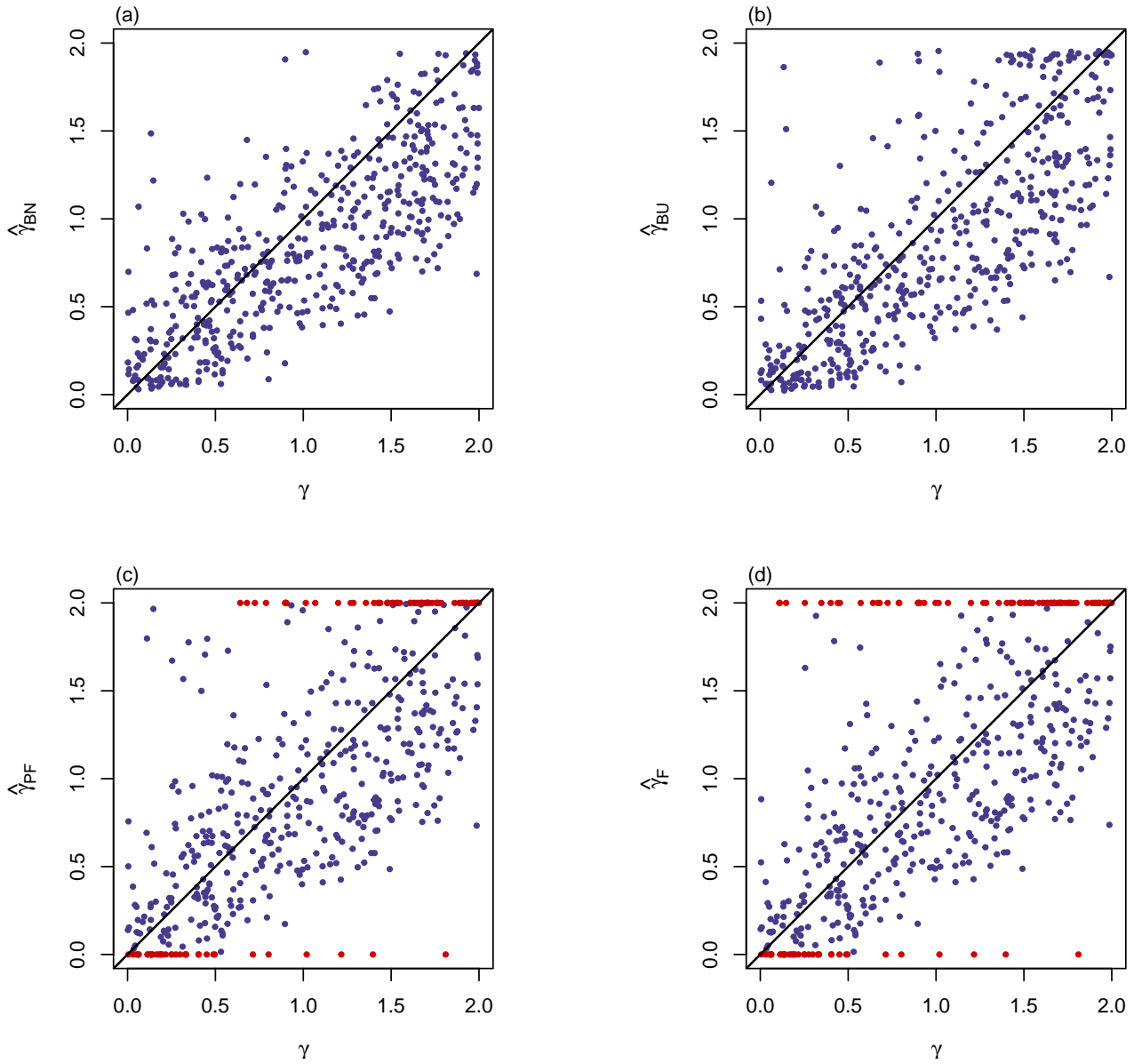
Supplementary Figure S8 Scatter plots of point estimates of γ against true value of γ for qualitative trait with $n = 2000$, $MAF = 0.3$ and $\rho = 0.05$. The red points represent the extreme values (0 or 2). (a) $\hat{\gamma}_{BN}$; (b) $\hat{\gamma}_{BU}$; (c) $\hat{\gamma}_{PF}$; (d) $\hat{\gamma}_F$



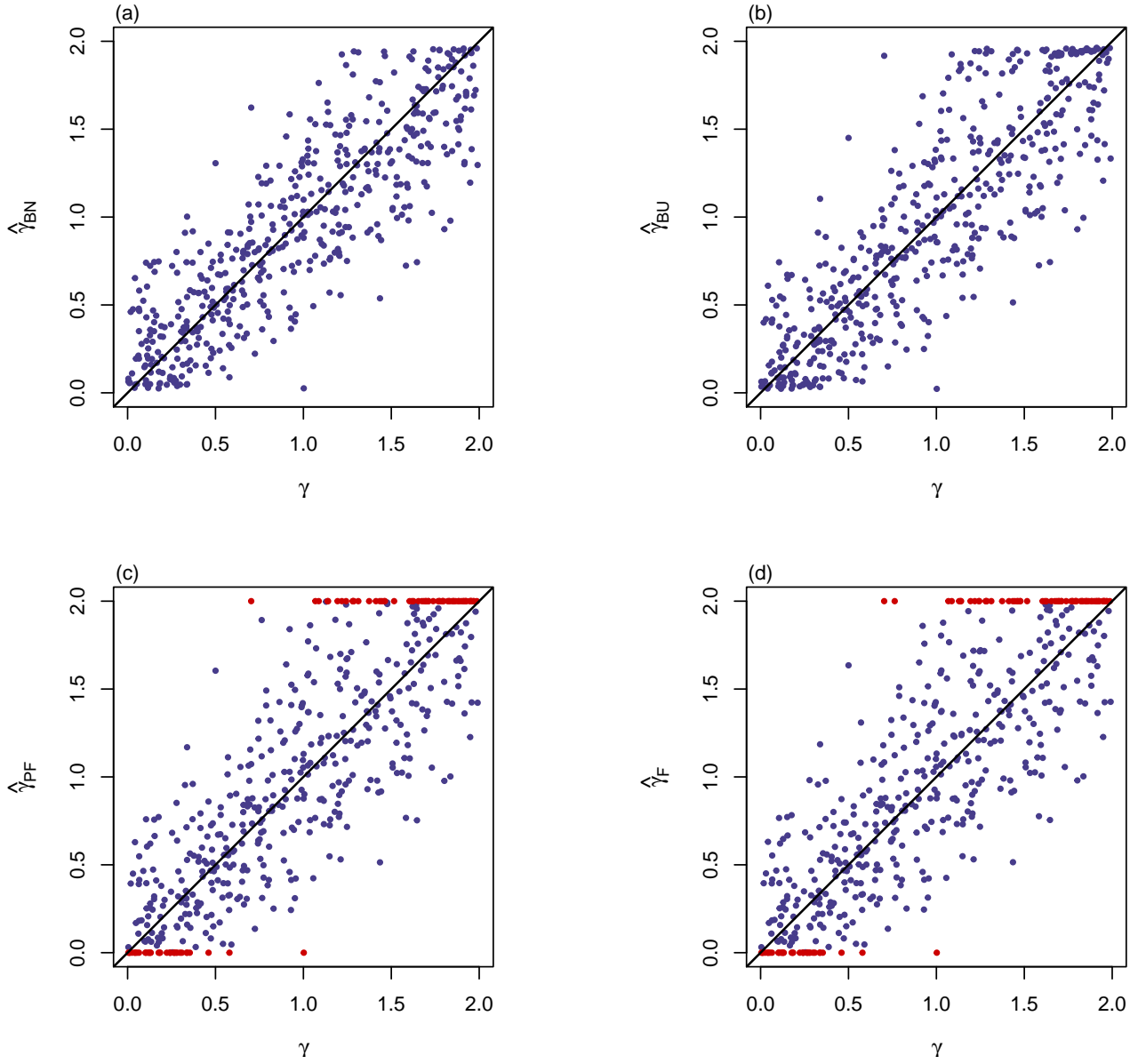
Supplementary Figure S9 Scatter plots of point estimates of γ against true value of γ for qualitative trait with $n = 2000$, $MAF = 0.1$ and $\rho = 0$. The red points represent the extreme values (0 or 2). (a) $\hat{\gamma}_{BN}$; (b) $\hat{\gamma}_{BU}$; (c) $\hat{\gamma}_{PF}$; (d) $\hat{\gamma}_F$



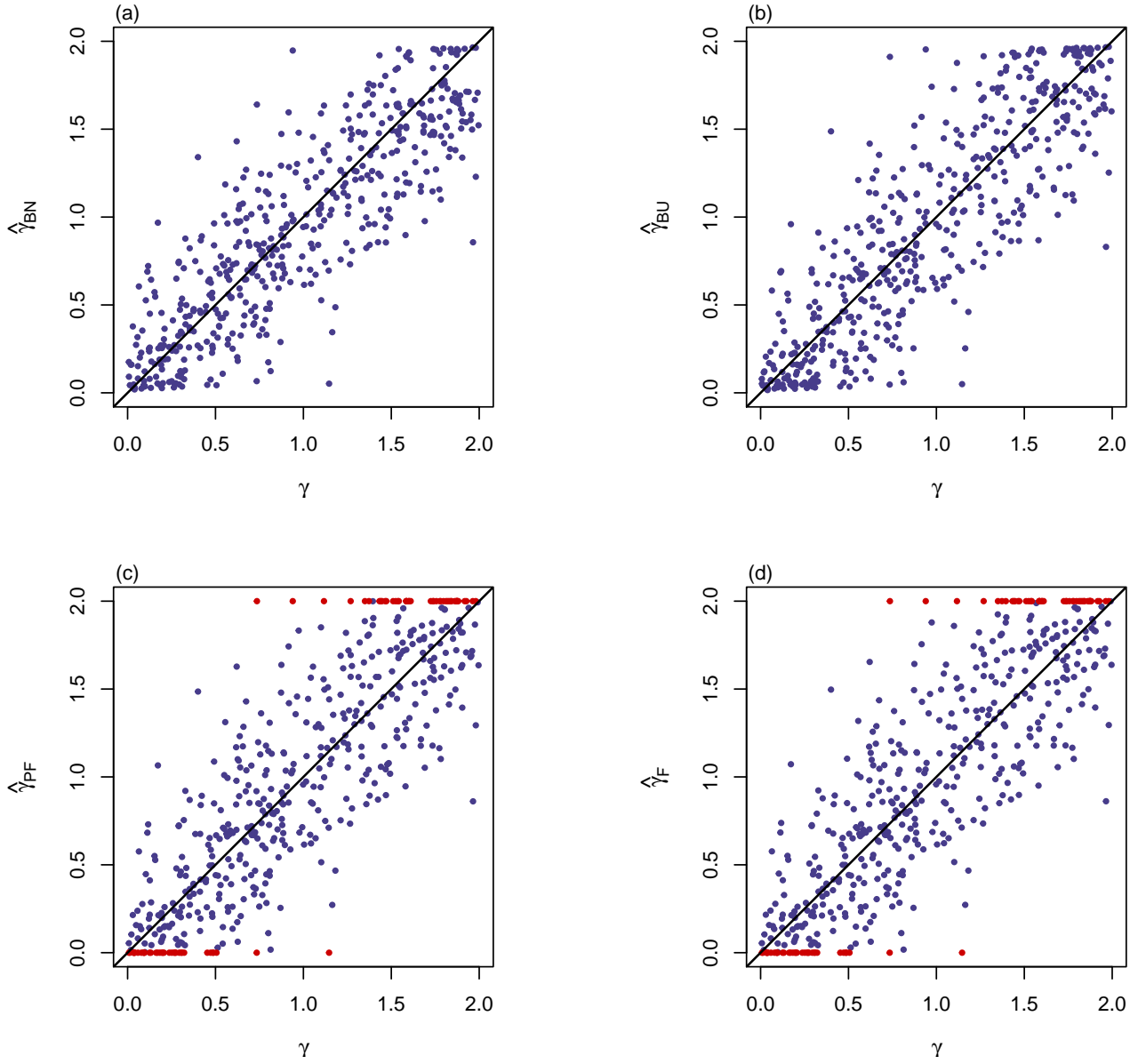
Supplementary Figure S10 Scatter plots of point estimates of γ against true value of γ for qualitative trait with $n = 2000$, $MAF = 0.1$ and $\rho = -0.05$. The red points represent the extreme values (0 or 2). **(a)** $\hat{\gamma}_{BN}$; **(b)** $\hat{\gamma}_{BU}$; **(c)** $\hat{\gamma}_{PF}$; **(d)** $\hat{\gamma}_F$



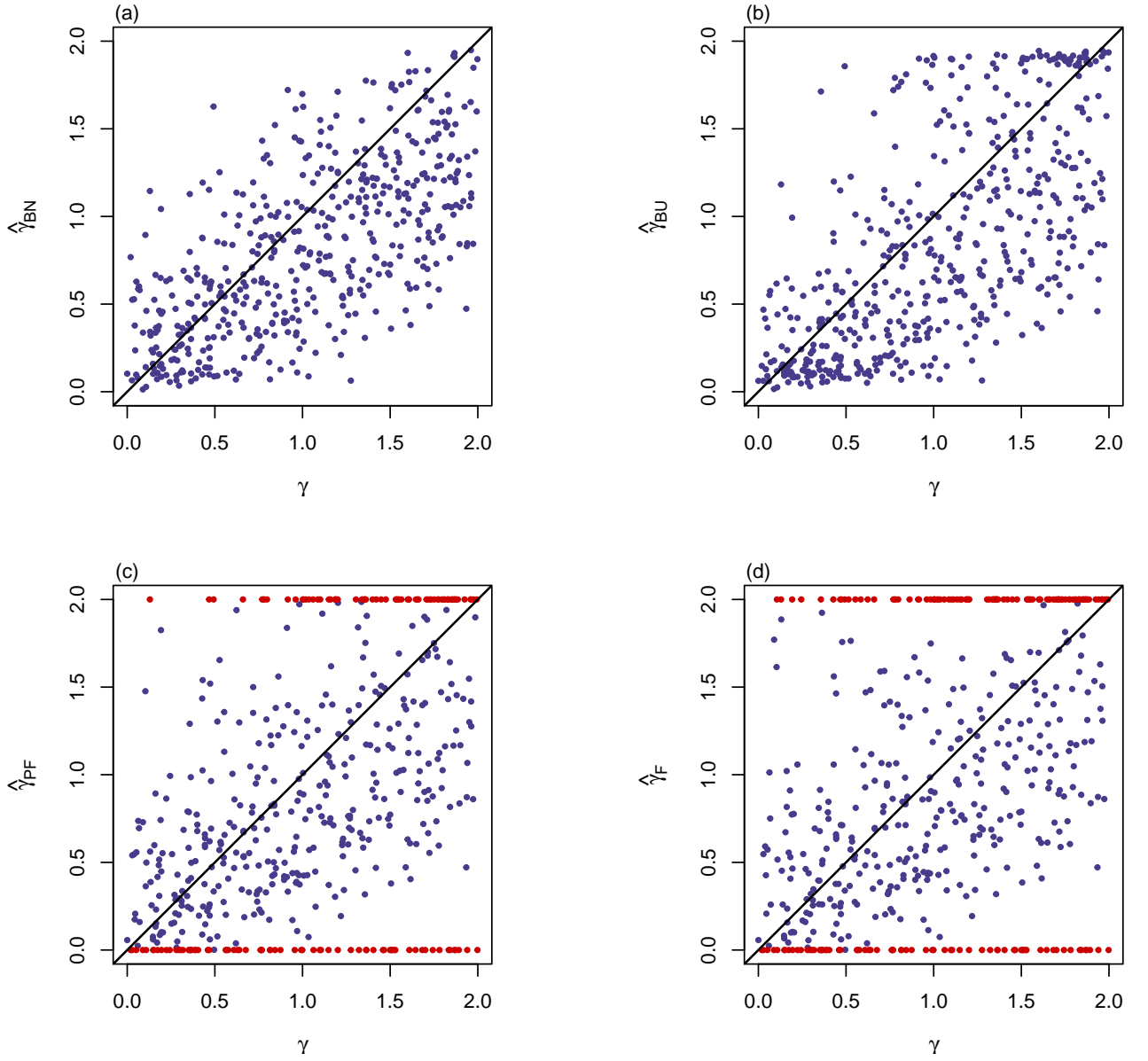
Supplementary Figure S11 Scatter plots of point estimates of γ against true value of γ for qualitative trait with $n = 2000$, $MAF = 0.1$ and $\rho = 0.05$. The red points represent the extreme values (0 or 2). (a) $\hat{\gamma}_{BN}$; (b) $\hat{\gamma}_{BU}$; (c) $\hat{\gamma}_{PF}$; (d) $\hat{\gamma}_F$



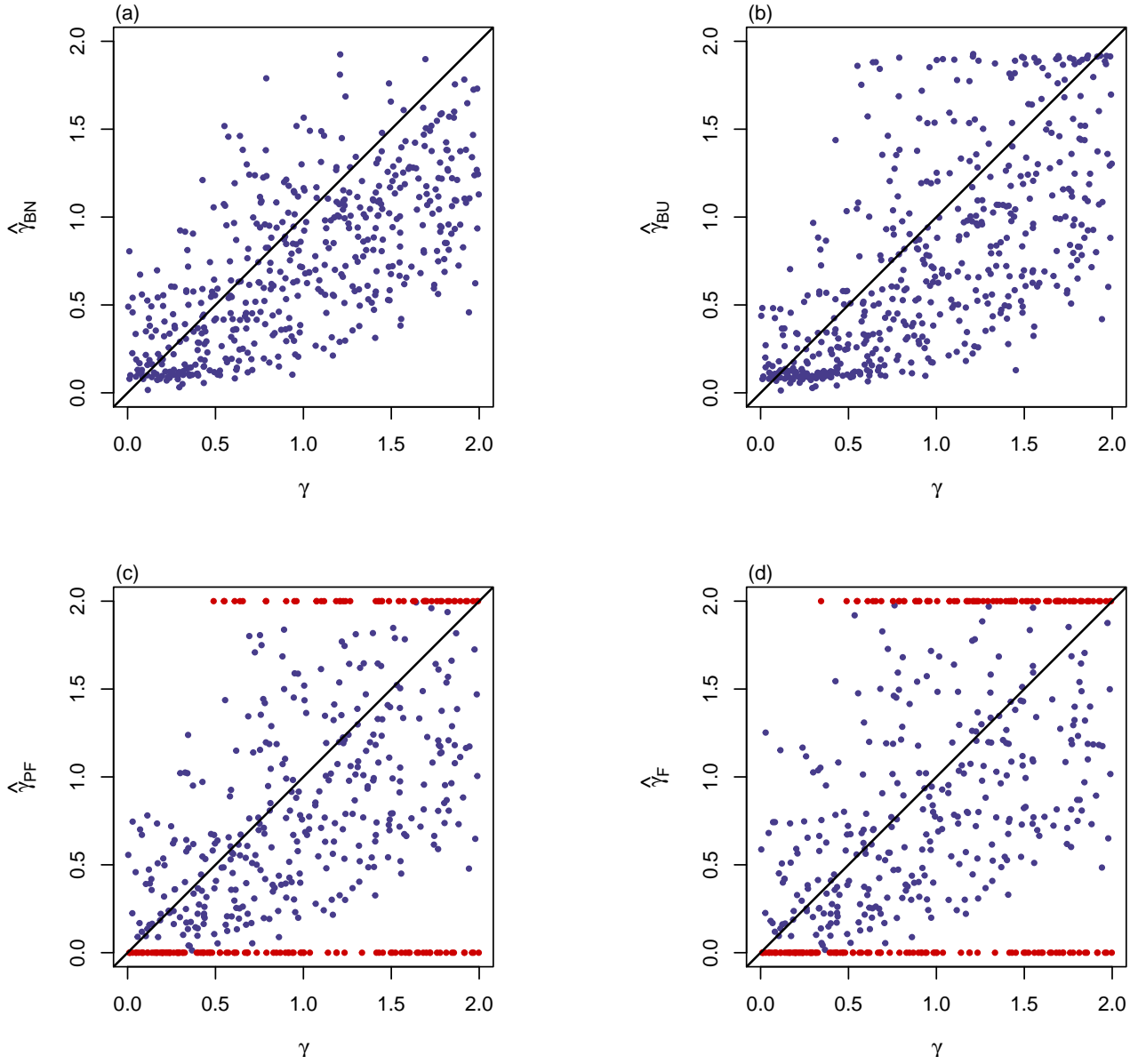
Supplementary Figure S12 Scatter plots of point estimates of γ against true value of γ for quantitative trait when $(\sigma_0^2, \sigma_1^2, \sigma_2^2) = (1, 1.2, 1)$ with $n = 500$, $\text{MAF} = 0.3$ and $\rho = -0.05$. The red points represent the extreme values (0 or 2). (a) $\hat{\gamma}_{BN}$; (b) $\hat{\gamma}_{BU}$; (c) $\hat{\gamma}_{PF}$; (d) $\hat{\gamma}_F$



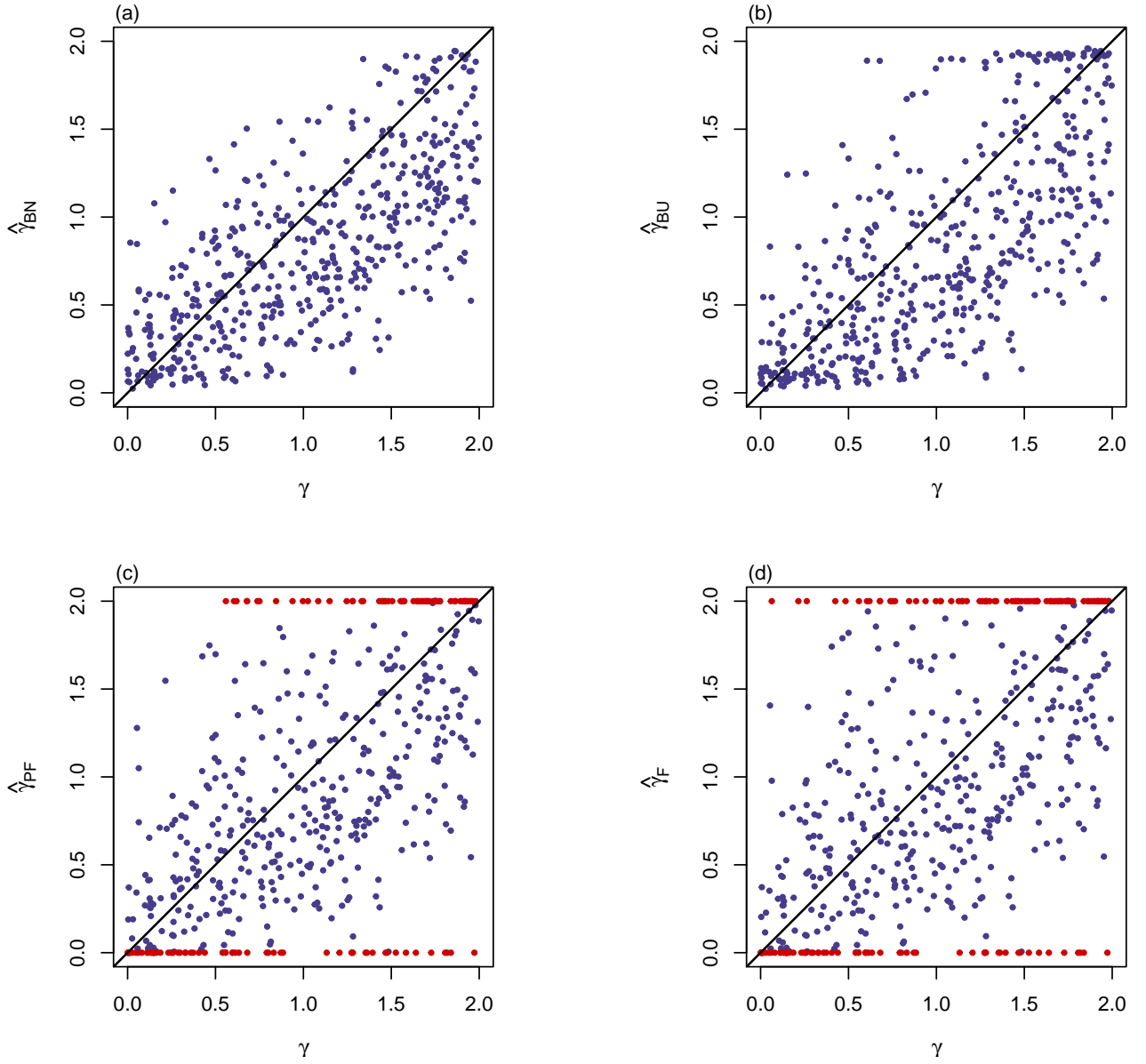
Supplementary Figure S13 Scatter plots of point estimates of γ against true value of γ for quantitative trait when $(\sigma_0^2, \sigma_1^2, \sigma_2^2) = (1, 1.2, 1)$ with $n = 500$, $\text{MAF} = 0.3$ and $\rho = 0.05$. The red points represent the extreme values (0 or 2). **(a)** $\hat{\gamma}_{BN}$; **(b)** $\hat{\gamma}_{BU}$; **(c)** $\hat{\gamma}_{PF}$; **(d)** $\hat{\gamma}_F$



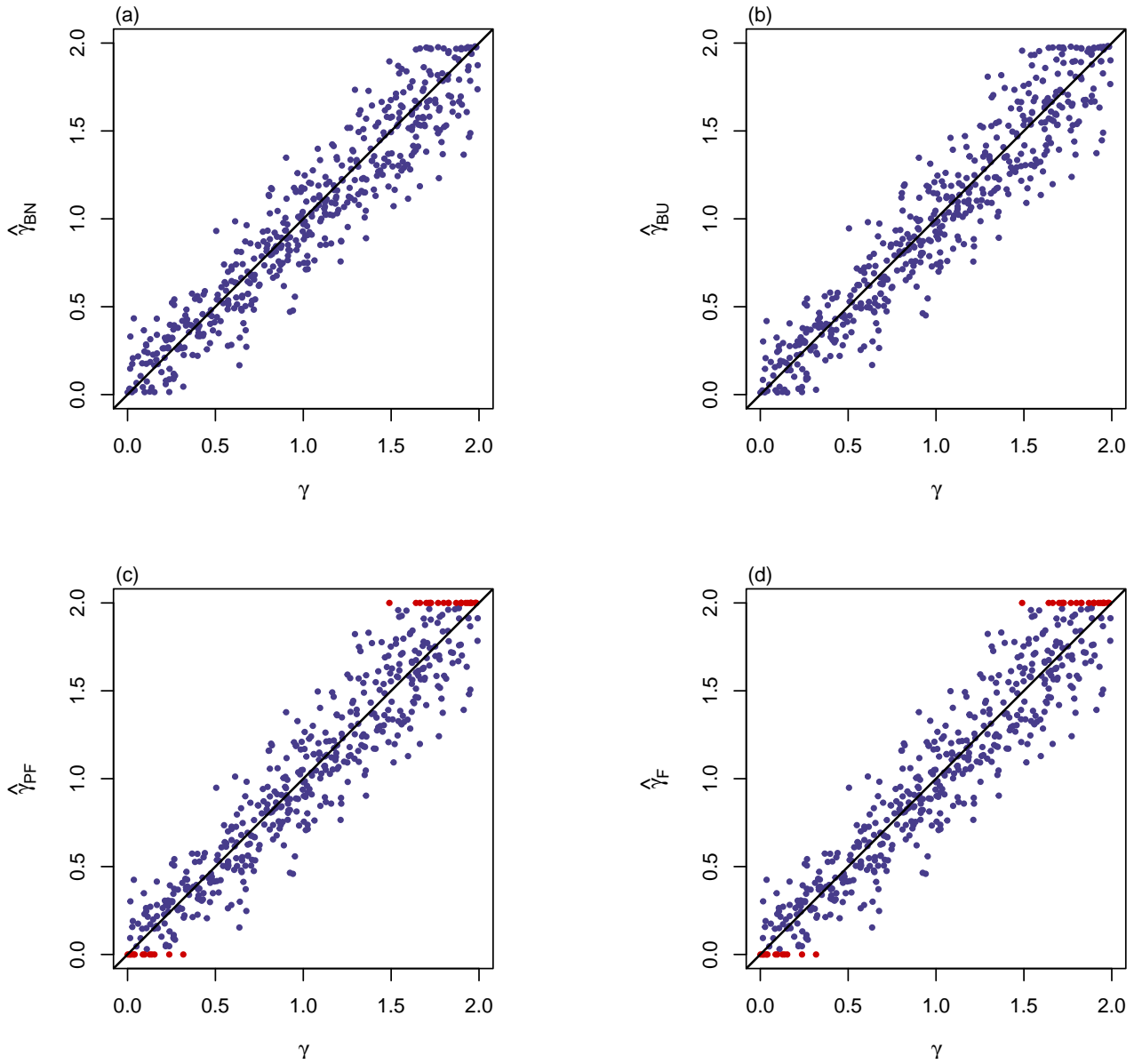
Supplementary Figure S14 Scatter plots of point estimates of γ against true value of γ for quantitative trait when $(\sigma_0^2, \sigma_1^2, \sigma_2^2) = (1, 1.2, 1)$ with $n = 500$, $\text{MAF} = 0.1$ and $\rho = 0$. The red points represent the extreme values (0 or 2). (a) $\hat{\gamma}_{BN}$; (b) $\hat{\gamma}_{BU}$; (c) $\hat{\gamma}_{PF}$; (d) $\hat{\gamma}_F$



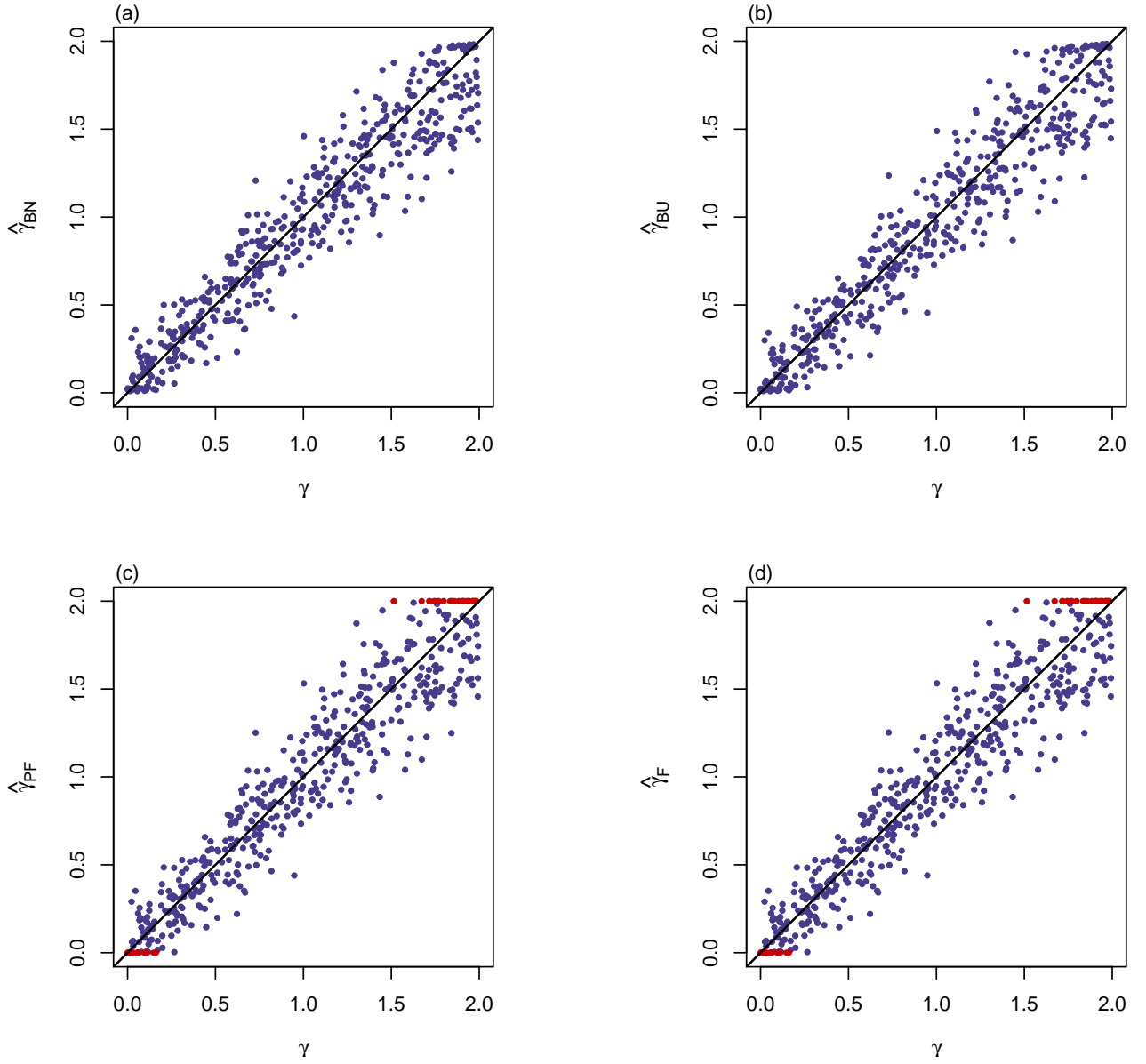
Supplementary Figure S15 Scatter plots of point estimates of γ against true value of γ for quantitative trait when $(\sigma_0^2, \sigma_1^2, \sigma_2^2) = (1, 1.2, 1)$ with $n = 500$, $\text{MAF} = 0.1$ and $\rho = -0.05$. The red points represent the extreme values (0 or 2). **(a)** $\hat{\gamma}_{BN}$; **(b)** $\hat{\gamma}_{BU}$; **(c)** $\hat{\gamma}_{PF}$; **(d)** $\hat{\gamma}_F$



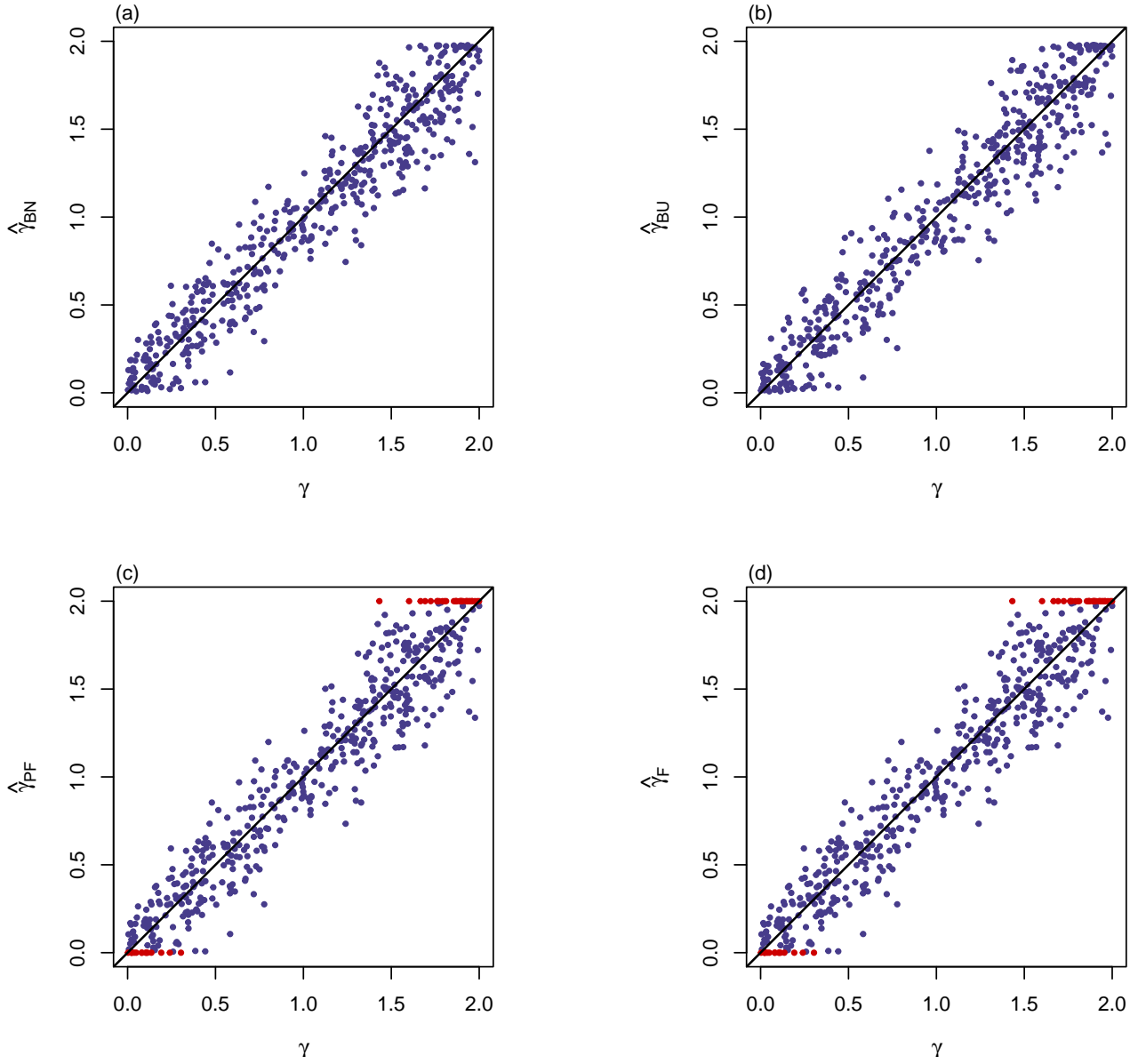
Supplementary Figure S16 Scatter plots of point estimates of γ against true value of γ for quantitative trait when $(\sigma_0^2, \sigma_1^2, \sigma_2^2) = (1, 1.2, 1)$ with $n = 500$, $\text{MAF} = 0.1$ and $\rho = 0.05$. The red points represent the extreme values (0 or 2). **(a)** $\hat{\gamma}_{BN}$; **(b)** $\hat{\gamma}_{BU}$; **(c)** $\hat{\gamma}_{PF}$; **(d)** $\hat{\gamma}_F$



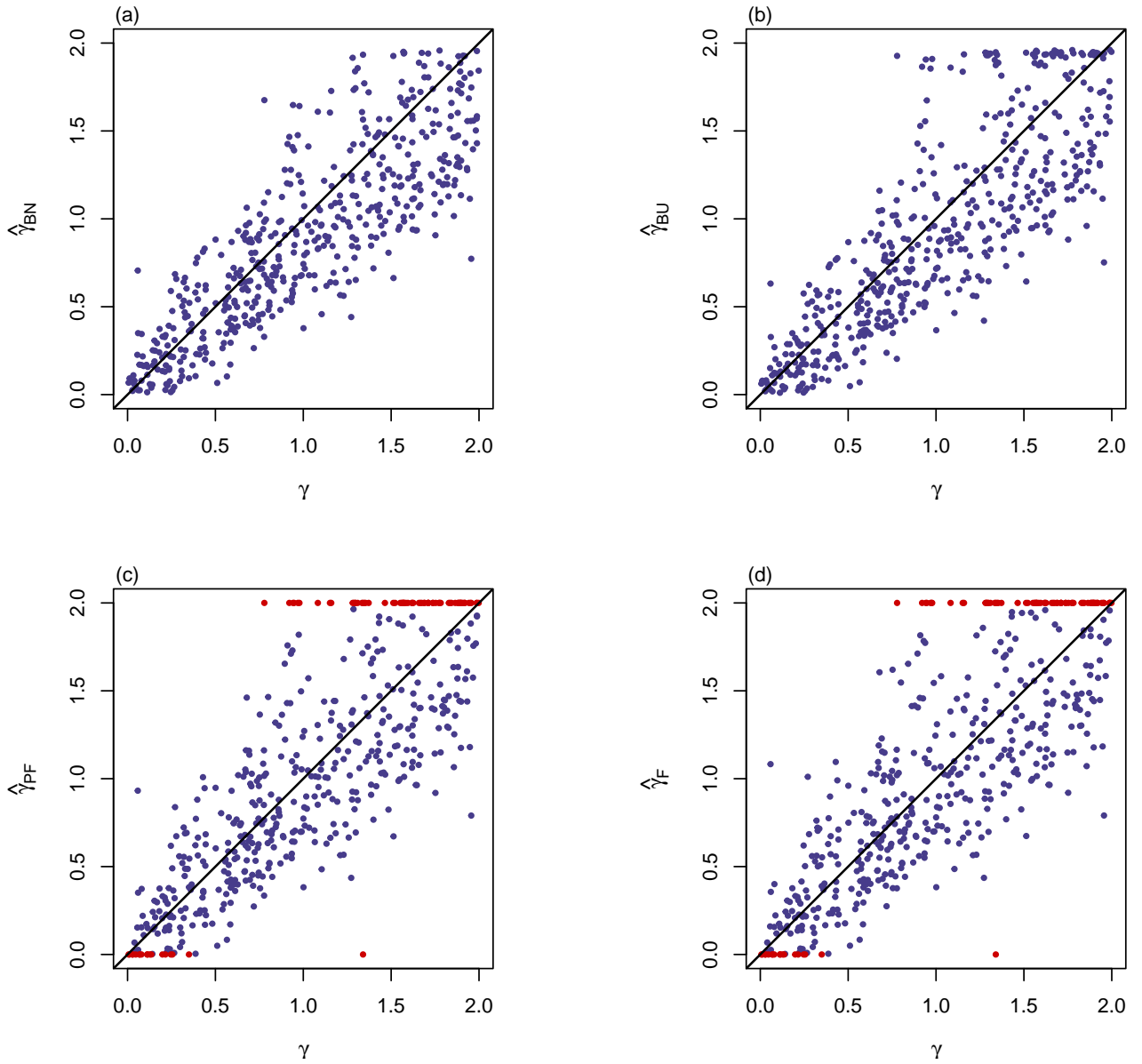
Supplementary Figure S17 Scatter plots of point estimates of γ against true value of γ for quantitative trait when $(\sigma_0^2, \sigma_1^2, \sigma_2^2) = (1, 1.2, 1)$ with $n = 2000$, $MAF = 0.3$ and $\rho = 0$. The red points represent the extreme values (0 or 2). (a) $\hat{\gamma}_{BN}$; (b) $\hat{\gamma}_{BU}$; (c) $\hat{\gamma}_{PF}$; (d) $\hat{\gamma}_F$



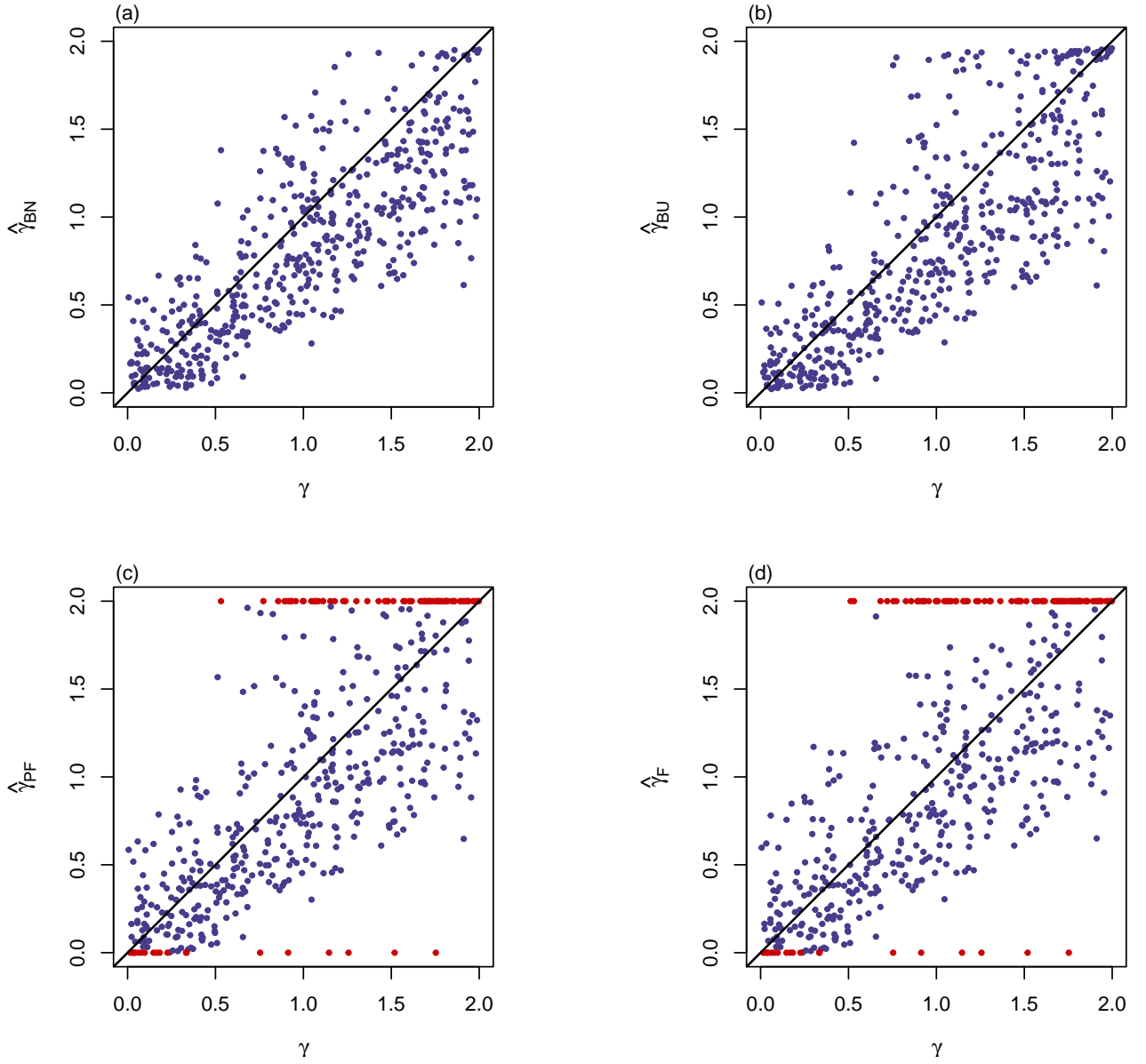
Supplementary Figure S18 Scatter plots of point estimates of γ against true value of γ for quantitative trait when $(\sigma_0^2, \sigma_1^2, \sigma_2^2) = (1, 1.2, 1)$ with $n = 2000$, $\text{MAF} = 0.3$ and $\rho = -0.05$. The red points represent the extreme values (0 or 2). (a) $\hat{\gamma}_{BN}$; (b) $\hat{\gamma}_{BU}$; (c) $\hat{\gamma}_{PF}$; (d) $\hat{\gamma}_F$



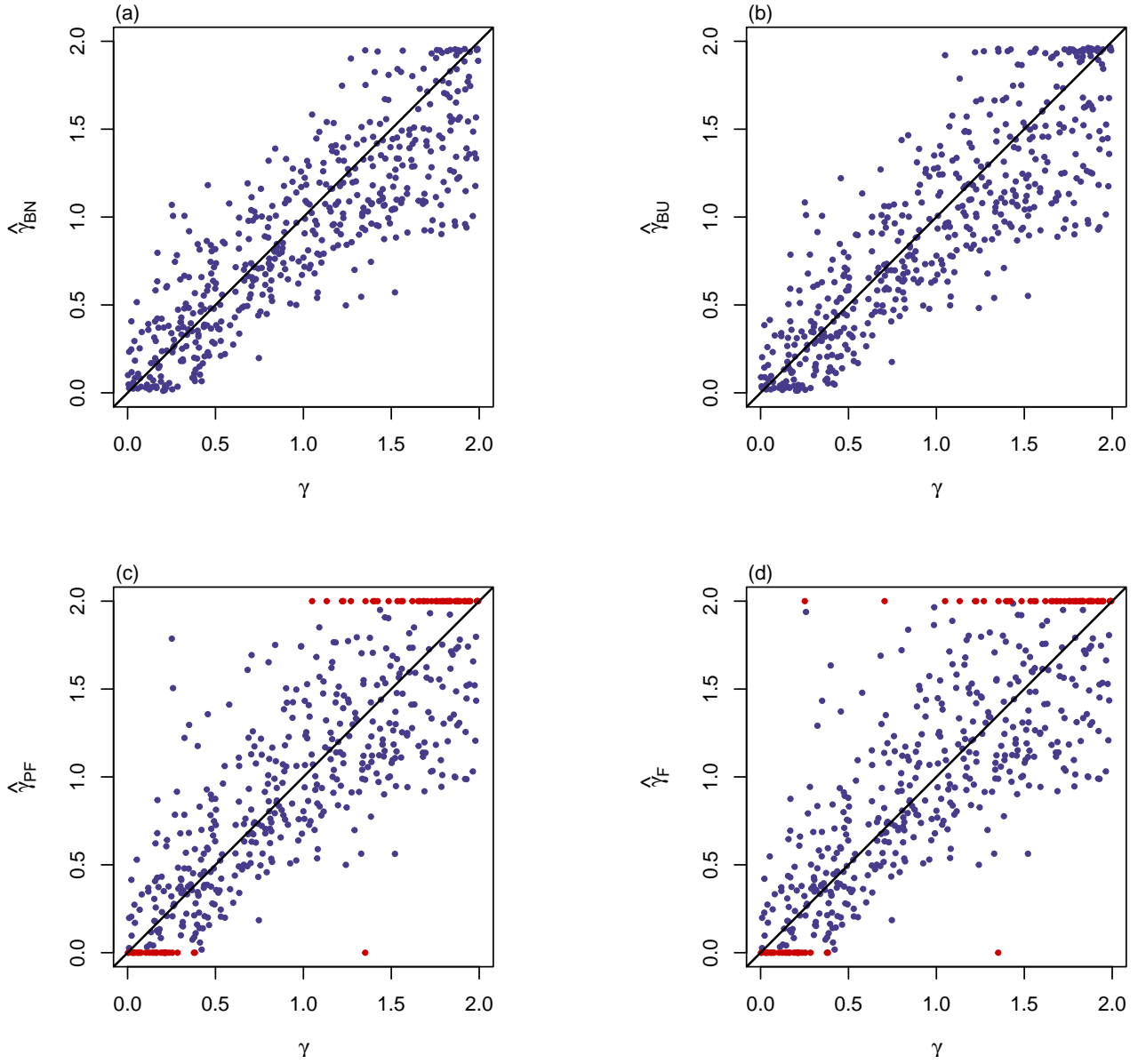
Supplementary Figure S19 Scatter plots of point estimates of γ against true value of γ for quantitative trait when $(\sigma_0^2, \sigma_1^2, \sigma_2^2) = (1, 1.2, 1)$ with $n = 2000$, $MAF = 0.3$ and $\rho = 0.05$. The red points represent the extreme values (0 or 2). **(a)** $\hat{\gamma}_{BN}$; **(b)** $\hat{\gamma}_{BU}$; **(c)** $\hat{\gamma}_{PF}$; **(d)** $\hat{\gamma}_F$



Supplementary Figure S20 Scatter plots of point estimates of γ against true value of γ for quantitative trait when $(\sigma_0^2, \sigma_1^2, \sigma_2^2) = (1, 1.2, 1)$ with $n = 2000$, $\text{MAF} = 0.1$ and $\rho = 0$. The red points represent the extreme values (0 or 2). (a) $\hat{\gamma}_{BN}$; (b) $\hat{\gamma}_{BU}$; (c) $\hat{\gamma}_{PF}$; (d) $\hat{\gamma}_F$



Supplementary Figure S21 Scatter plots of point estimates of γ against true value of γ for quantitative trait when $(\sigma_0^2, \sigma_1^2, \sigma_2^2) = (1, 1.2, 1)$ with $n = 2000$, $\text{MAF} = 0.1$ and $\rho = -0.05$. The red points represent the extreme values (0 or 2). **(a)** $\hat{\gamma}_{BN}$; **(b)** $\hat{\gamma}_{BU}$; **(c)** $\hat{\gamma}_{PF}$; **(d)** $\hat{\gamma}_F$



Supplementary Figure S22 Scatter plots of point estimates of γ against true value of γ for quantitative trait when $(\sigma_0^2, \sigma_1^2, \sigma_2^2) = (1, 1.2, 1)$ with $n = 2000$, $\text{MAF} = 0.1$ and $\rho = 0.05$. The red points represent the extreme values (0 or 2). **(a)** $\hat{\gamma}_{BN}$; **(b)** $\hat{\gamma}_{BU}$; **(c)** $\hat{\gamma}_{PF}$; **(d)** $\hat{\gamma}_F$