

ECON 709 Midterm Cheatsheet

- $P(A) = 1 - P(A^c)$
- If $A \subseteq B$ then $P(A) \leq P(B)$
- Boole's inequality: $P(A \cup B) \leq P(A) + P(B)$
- Bonferroni's inequality: $P(A \cap B) \geq P(A) + P(B) - 1$
- Bayes' Rule: $P(B|A) = \frac{P(A \cap B)}{P(A)} = \frac{P(A|B)P(B)}{P(A)} = \frac{P(A|B)P(B)}{P(A|B)P(B) + P(A|B^c)P(B^c)}$
- A, B are independent if $P(A \cap B) = P(A)P(B)$. If $P(A) > 0$ this implies $P(B) = P(B|A)$.
- A group of events are jointly independent if for any subset $J \subseteq \{1, \dots, k\}$, $P(\cap_{j \in J} A_j) = \prod_{j \in J} P(A_j)$.

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- $\lim_{x \rightarrow \infty} F(x) = 1, \lim_{x \rightarrow -\infty} F(x) = 0$; F is non-decreasing; F is right-continuous.
 - $F_Y(y) = P(g(X) \leq y) = P(X \leq g^{-1}(y) = F_X(g^{-1}(y))$ if g is strictly increasing. Differentiate to find the pdf. If decreasing then the inequality sign flips and to flip back you get $F_Y(y) = 1 - F_X(h(y))$
 - Let X have PDF $f_X(x)$, $Y = g(X)$, where g is a monotone function. Suppose that $f_X(X)$ is continuous on X and that $g^{-1}(y)$ has a continuous derivative on Y . Then the PDF of Y is given by:

$$f_Y(y) = \begin{cases} f_X(g^{-1}(y)) \left| \frac{d}{dy} g^{-1}(y) \right| & y \in Y \\ 0, & \text{otherwise} \end{cases}$$

- $E(X) = \sum_{x \in X} f_X x$ or $\int_{-\infty}^{\infty} x f_X(x) dx$
- $M_X(t) = E[\exp(tX)]$ and $\frac{d^m}{dt^m} M(t)|_{t=0} = E(X^m)$

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- $f_{X,Y}(x, y) = \frac{\partial^2}{\partial x \partial y} F_{X,Y}(x, y)$
 - $f_X(x) = \int_{-\infty}^{\infty} f_{X,Y}(x, v) dv$
 - $f_{Y|X}(y|x) = \frac{f_{X,Y}(x, y)}{f_X(x)}$
 - A, B independent if $P(X \in A, Y \in B) = P(X \in A)P(Y \in B)$ or $F_{X,Y}(x, y) = F_X(x)F_Y(y)$ or $f_{X,Y}(x, y) = f_X(x)f_Y(y)$
 - X, Y independent then $E(g(X)h(Y)) = E(g(X))E(h(Y))$
 - $E[Y|X = x] = \int_{-\infty}^{\infty} y f_{Y|X}(y|x) dy$
 - $E[Y|X = x] = \frac{\int_{-\infty}^{\infty} y f_{X,Y}(x, y) dy}{\int_{-\infty}^{\infty} f_{X,Y}(x, y) dy}$
 - $E(E[Y|X]) = E(Y)$
 - $Var(Y) = E[Var(Y|X)] + Var(E(Y|X))$
 - $Cov(X, Y) = E((X - EX)(Y - EY)) = E(X(Y - EY)) = E(XY) - EXEY$
 - $Corr(X, Y) = \frac{Cov(X, Y)}{\sqrt{Var(X)Var(Y)}}$

- A variance-covariance matrix is symmetric and positive semi-definite.
- If g is one to one and $Y = g(X)$ then $f_Y(y) = f_X(g^{-1}(y))|J|$
- A matrix is psd if its eigenvalues are nonnegative and nsd if its eigenvalues are nonpositive.

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- An estimator of θ is unbiased if $E(\hat{\theta}) = \theta$.
 - Jensen's inequality: If X is a random variable and f is convex then $f(E[X]) \leq E[f(X)]$
 - $Var(\bar{X}_n) = \sigma_X^2/n$
 - $s^2 = \frac{n}{n-1} \sum_i (X_i - \bar{X}_n)^2$ is an unbiased estimator of the variance.
 - t statistic: $t = \sqrt{n}(\bar{X}_n - \mu)/s$
 - $I_n - n^{-1}1_n 1_n'$ is idempotent.

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- A sequence of random variables converges in probability to Z as $n \rightarrow \infty$ if $\forall \epsilon > 0$ we have $\lim_{n \rightarrow \infty} P(|Z_n - Z| \geq \epsilon) = 0$. Notated $Z_n \rightarrow_p Z$ as $n \rightarrow \infty$
 - WLLN: $\bar{X}_n \rightarrow_p \mu$ as $n \rightarrow \infty$.
 - If an estimator $\hat{\theta}_n$ for θ converges in probability to θ then $\hat{\theta}_n$ is consistent for θ .
 - Markov's inequality: $P(|X| \geq \lambda) \leq \frac{E(|X|)}{\lambda}$.
 - Chebychev's inequality: $P(|X - \mu| \geq \lambda) \leq \frac{Var(X)}{\lambda^2}$
 - CMT: If $Z_n \rightarrow_p z$ as $n \rightarrow \infty$ and g is continuous then $g(Z_n) \rightarrow_p g(z)$ as $n \rightarrow \infty$.
 - A sequence of random variables converges in distribution to Z if $P(Z_n \leq x) \rightarrow P(Z \leq x)$
 - CLT: If X_i iid with $E(X_i) = \mu, Var(X_i) \rightarrow_d N(0, \sigma^2)$ (multivariate version uses covariance matrix instead of σ^2).
 - Delta Method: If $\sqrt{n}(\hat{\theta}_n - \theta) \rightarrow_d N(0, \sigma^2)$ and g is continuously differentiable in an open neighborhood of θ . Then $\sqrt{n}(g(\hat{\theta}_n) - g(\theta)) \rightarrow_d N(0, V)$ where $V = (g'(\theta))^2 \sigma^2$.
 - multivariate: $V = H(\theta)\Sigma H(\theta)'$ where $H(\theta) = \frac{\partial}{\partial \theta'}$

$$h(\theta) = \begin{pmatrix} \frac{\partial h_1(\theta)}{\partial \theta_1} & \cdots & \frac{\partial h_1(\theta)}{\partial \theta_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial h_n(\theta)}{\partial \theta_1} & \cdots & \frac{\partial h_n(\theta)}{\partial \theta_n} \end{pmatrix}$$

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- Find MLE: write down log likelihood ($f(x|\theta)$) and take FOC, and check second order conditions to ensure negative!
 - $S = \frac{\partial}{\partial \theta} \log(f(X|\theta))$.
 - $I_0 = E[SS'] = -E \left[\frac{\partial^2}{\partial \theta \partial \theta'} \log f(X|\theta) |_{\theta=\theta_0} \right]$
 - Note: for intuition note that we have log likelihood and $\log''(x) = (\frac{1}{x})' = -\frac{1}{x^2}$ so $\log''(x) = -(\log'(x))^2$.
 - CRLB: $Var(\hat{\theta}_n) \geq (nI_0)^{-1}$ and CR efficient is when this holds with equality.

¹Michael Nattinger wrote this cheatsheet. Alex von Hafften tweaked it.