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## Problem Set 4: IV and Natural Experiments

Consider the following structural equation, which relates an outcome variable  $y$  with a treatment variable  $x$ :

$$y_i = \beta x_i + \epsilon_i$$

where  $i$  denotes observations associated with different economic agents  $i$ .

Below, I give you several variables  $z$ . For each  $z$ , give:

- An example of an outcome  $y$  and treatment  $x$  for which the variable  $z$  can be used as an instrumental variable in estimating the treatment effect  $\beta$ .
  - For the  $y$  and  $x$  you give, give one reason why  $x$  is endogenous (i.e., why  $x$  is correlated with  $\epsilon$ ).
  - Rigorously justify why  $z$  is a valid instrument (make sure it satisfies all the assumption that an IV must satisfy).
  - If the treatment effect  $\beta_i$  varied across agents  $i$ , the resulting linear IV estimate yields the average treatment effect for a particular subpopulation given an additional monotonicity assumption. State the monotonicity assumption for the given  $(y, x, z)$ , and also state the subpopulation which the estimate is applicable to.
  - For the  $(y, x)$  that you give, suggest *another instrument* that can be used to estimate  $\beta$ , and justify it.
1. The Vatican II council changed the language of the Catholic services from Latin to the vernacular (everyday) language.  $z_t = 0$  before the council, and  $z_t = 1$  afterwards.
  2.  $z_i = 1$  if household  $i$  lives in a rural setting (i.e., in the countryside), and  $z_i = 0$  if household  $i$  lives in a city.
  3.  $z_i = 1$  if household  $i$  lives above the 5th floor of a high-rise apartment building, and  $z_i = 0$  if above the 5th floor.
  4.  $z_i = 1$  if agent  $i$ 's language can be written in the Roman alphabet, and = 0 if not.
  5.  $z_i = 1$  if agent  $i$  has a last name in the range A–M, and = 0 otherwise.

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6.  $z_i = 1$  if agent  $i$  is left-handed,  $= 0$  otherwise.
  7.  $z_i = 1$  if the street address of household  $i$  is an even number,  $= 0$  otherwise.
  8.  $z_t = 1$  when one lane of Interstate Highway 10 is closed for repairs,  $= 0$  otherwise.