Final Exam
Energy Economics with Geography Focus 567A
Winter 2025
Professor: Geoffrey Barrows

Please write your answers in the exam books provided

You have 3 hours for this exam and can reach a maximum of 100 points

Do not turn this page before you are asked to start.

Good Luck!

Part I (30 points)

Market demand for a good is given by $Q = 60 - \frac{1}{2}P$, where Q is the quantity demanded and P is the price. The marginal private cost of supplying the good is given by $MPC = 40 + Q$. Suppose that scientists estimate that the production of the good generates total environmental cost of $TEC = 20 + \frac{1}{2}Q^2$, which are not taken into account by the producers.

1. What are the marginal social costs of producing the commodity? (5 points)
2. Calculate and illustrate graphically (10 points)
   (a) The socially optimal output level Q^* and associated price P^*
   (b) The unregulated competitive equilibrium output level Q_c and associated price P_c
   (c) The resulting inefficiency (i.e. deadweight) loss DWL
   (d) The optimal tax per unit of Q
3. Now suppose that the scientists made a mistake in evaluating the total externality costs associated with production. The true total externalisty costs are given by $TEC = 20Q + \frac{1}{2}Q^2$. Recalculate (10 points)
   (a) The socially optimal output level Q^* and associated price P^*
   (b) The deadweight loss in the unregulated competitive equilibrium
4. Calculate the deadweight loss associated with the mis-estimation of total externality costs, assuming that the government taxes optimally given it's (incorrect) information (5 points)

Part II (40 points)

In a recent paper, Allcott et al (2016)[1] study the relationship between electricity "blackouts" (when a portion of the grid stops working for a period) in India and firm-level output, input, and productivity. If grid-based electricity is a necessary input in production, then electricity blackouts will lower inputs, outputs and potentially productivity as well. However, if firms have their own electricity generators, or they can substitute away from electricity towards other inputs, then blackouts might not have much effect on manufacturing firms. Hence, the effect of blackouts on manufacturing outcomes is an empirical question.

To estimate the effect, Allcott et al (2016) gather data on state-level electricity shortages and firm-level manufacturing outcomes in India between 1992 and 2010. Electricity shortage in Indian state s at time t is defined as the share of energy needs in the state that cannot be met by capacity plus net imports. Energy needs are computed by the government as the counterfactual energy demand of the state if there were no blackouts "Assessed Demand". Formally, electricity shortage in state s at time t is calculated as

$$S_{st} = \frac{\text{Assessed Demand}_{st} - \text{Energy Available}_{st}}{\text{Assess Demand}_{st}}$$

where Energy Available$_{st}$ is the sum of capacity and net imports of electricity. Allcott et al (2016) take S_{st} as a proxy for blackouts in state s in year t. In fact, the variable S_{st} correlates strongly with self-reported data from manufacturing firms in India with respect to electricity. In Figure 1, Allcott et al (2016) regress each of the dependent variables reported in columns 1-4 on the shortage variable S_{st}. In Figure 1, Allcott et al (2016) find that when S_{st} is higher in an Indian state, firms in that state are more likely to report that electricity is the primary barrier to growth (column 1), lower power quality (column 2) , and higher share of electricity

Figure 1: Shortage and Firm Response

	1(Largest ~~barrier~~ growth) (1)	Power quality (2)	Self-gen share (3)	Capacity factor (4)
Shortage	1.107	−8.378	0.699	0.167
	(0.492)**	(3.383)**	(0.213)***	(0.062)**
Observations	2,280	2,265	1,124	1,286
Dependent variable mean	0.31	6.38	5.9	0.64
Sample	WBES firms	WBES firms	WBES firms	Coal plants

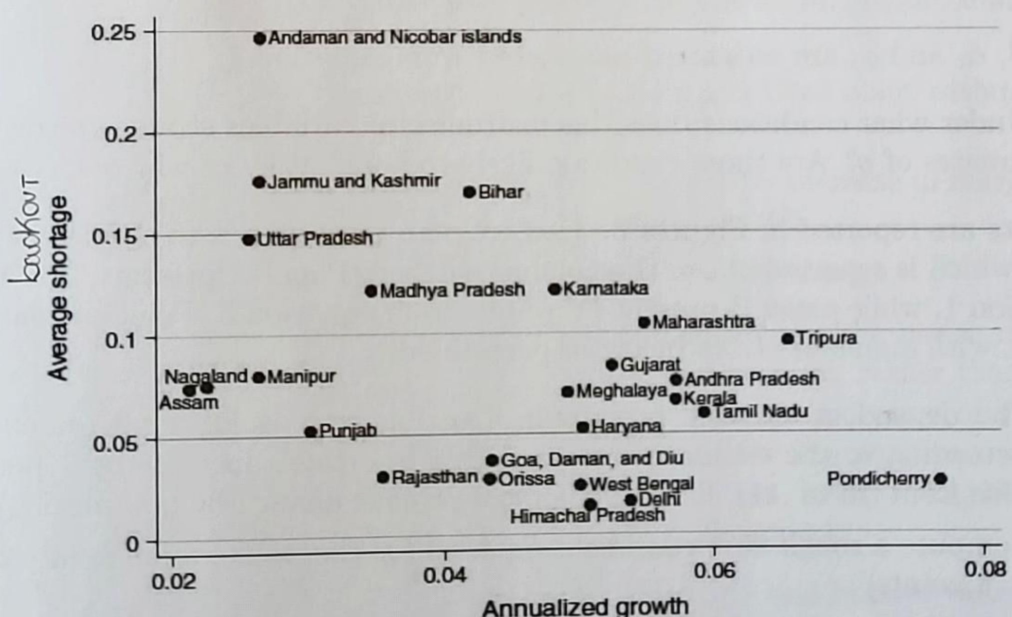
Notes: Sample for columns 1, 2, and 3 is the 2005 World Bank Enterprise Survey (WBES). Dependent variables in columns 1–3 are, respectively, an indicator for whether the firm's manager reports that electricity is the primary barrier to growth, the manager's rating of grid power quality (from 1 (extremely bad) to 10 (excellent)), and Self-Generation Share (omitting plants that do not own generators). Sample for column 4 is panel data on all Indian coal power plants from 1994–2009. Columns 1–3 condition on industry indicators, and column 4 conditions on year indicators and plant fixed effects. Robust standard errors, clustered by state.

*** Significant at the 1 percent level.
** Significant at the 5 percent level.
* Significant at the 10 percent level.

generated on site (column 3). These results indicate that the shortage variable indeed correlates with firm-level electricity supply problems (i.e. "blackouts").

1. Allcott et al (2016) start with aggregate analysis at the state level. In Figure 2, Allcott et al (2016) plot average shortage S_{st} for each state over the period 1992-2010 against the annualized per-capita GDP growth over the same period. The correlation is clearly negative. Does this analysis indicate that shortages reduce GDP growth? Why or why not? (5 points)

Figure 2: Shortage and Growth



2. Allcott et al (2016) next relate firm-level outcomes to state-level shortage. Let Y_{ist} represent an outcome variable (sales, energy input, material input, productivity, etc.) for firm i in state s in year t. Allcott et al (2016) estimate by OLS

$$Y_{ist} = \rho S_{st} + \theta_t + \phi_i + \epsilon_{ist} \tag{1}$$

[1] Allcott, Hunt, Allan Collard-Wexler, and Stephen D. O'Connell. "How do electricity shortages affect industry? Evidence from India." American Economic Review 106.3 (2016): 587-624.

where θ_t is a year fixed effect, ϕ_i is a firm fixed effect, and ϵ_{ist} is an error term.

(a) The Indian government is aware of the blackout problem, and has been building electricity capacity nationally, especially in years in which demand is high. Would this government action bias estimates of ρ in Equation 1? Why or why not? (5 points)

(b) Some firms are inherently more productive than others, and these firms might endogenously sort into states with low average blackout rates. Would this sorting behavior bias estimates of ρ in Equation 1? Why or why not? (5 points)

(c) Temperature likely affects state-level energy demand because the demand for air conditioning is higher when it is warmer. Temperature likely also affects firm output because people are less productivity when it is hotter. Would omitting state-specific temperature bias estimates of ρ in Equation 1? Why or why not? (5 points)

3. To address potential endogeneity of electricity shortages, Allcott et al (2016) propose an instrumental variable strategy. Allcott et al (2016) note that a substantial share of electricity in India is generated from hydroelectric power (about 20%), which depends on water availability. Allcott et al (2016) compute the amount of water inflows to hydroelectric power reservoirs each year aggregated across the state Z_{st} and use it to predict S_{st}

$$S_{st} = \beta Z_{st} + \alpha_t + \phi_s + \epsilon_{st} \tag{2}$$

where α_t is a year fixed effect, ϕ_s is a state fixed effect, and ϵ_{st} is an error term.[2] Allcott et al (2016) then estimate by instrumental variables the relationship between Y_{ist} and predicted shortages

$$Y_{ist} = \rho \hat{S}_{st} + \gamma \mathbf{W_{st}} + \theta_t + \phi_i + \epsilon_{ist} \tag{3}$$

where $\mathbf{W_{st}}$ is a vector of state-year controls (which include rainfall and weather) and $\hat{S}_{st}$ is defined as

$$\hat{S}_{st} = \hat{\beta} Z_{st} + \hat{\alpha}_t + \hat{\phi}_s \tag{4}$$

and $\hat{\beta}$, $\hat{\alpha}_t$ and $\hat{\phi}_s$ are estimated parameters from equation 2.

(a) Under what conditions does this instrumental variables strategy recover unbiased estimates of ρ? Are these condition likely to hold? Why or why not? (5 points)

4. Results are reported in Figures 3. Each column corresponds to a different outcome variable, which is reported above the column number. Panel A presents OLS estimates from equation 1, while panel B present IV results from equation 3. Point estimate are reported above, with standard errors below in parentheses.

(a) The dependent variable in column 4 of Figure 3 is log total revenue of the firm. According to the estimates in panel B, if shortages increase by 1 percentage point (like from .10 to .11), firm-level annual revenue change by how much? (5 points)

(b) Compute a rough 95% confidence interval for the point estimate in panel B, column 4 (5 points)

(c) What explains the difference between the OLS and IV results? (5 points)

[2] The actual strategy in Allcott et al (2016) is a bit more complicated than this, but for the purposes of the exam, suppose the strategy were precisely as described here.

Figure 3:

log ranipal

	ln(Materials) (1)	ln(Workers) (2)	ln(Earnings/worker) (3)	ln(Revenue) (4)	ln(TFPR) (5)
Panel A. OLS					
Shortage	−0.00711	−0.0138	0.161	0.116	0.0543
	(0.0631)	(0.0461)	(0.0421)***	(0.0631)*	(0.0387)
Panel B. IV					
Shortage	−1.137	−0.243	−0.267	−1.091	−0.304
	(0.511)**	(0.339)	(0.218)	(0.536)**	(0.259)
Observations	495,043	502,724	456,443	501,130	479,313
Clusters	115,040	116,803	110,213	116,231	112,371
Clusters (2)	536	536	482	536	536
First stage *F*-statistic	14.23	14.19	14.63	14.17	14.90

Notes: This table presents estimates of equation . Panel B instruments for Shortage using hydro availability. *F*-statistic is for the heteroskedasticity and cluster-robust Kleibergen-Paap weak instrument test. Robust standard errors, with two-way clustering by plant and state-year.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

Part III (30 points)

Answer the following questions with a brief explanation, or in the case of question 3, some math and a figure.

1. Based on the evidence we saw in class, give the approximate magnitude for (10 points):
   (a) percent increase in housing prices in Brazil resulting from electrification
   (b) percent increase in consumers' electricity bill after switching to automatic bill payment in the US
   (c) percent decline in housing rents caused by having a Coal plant within 2 miles in the US
   (d) percent decrease in electricity consumption for a 10% increase in marginal electricity price, conditional on average electricity price, in the US
   (e) percent decrease in welfare world-wide due to climate change
2. Rebecca Diamond (2016) argues that local amenities like public parks, clean air, transportation infrastructure, and crime are endogenous outcomes, rather than fixed features of a city. If this is true, how could it lead to increased concentration of high-skill people in high-wage/high-rent cities as opposed to a model in which amenities are fixed features? Does Diamond find that the well-being gap is higher or lower than the real-wage gap between high-skill and low-skill people in the US? (10 points)
3. Suppose there are two goods in the economy – food (f) and bottled water (w). A representative consumer has preferences that can be summarized by the Cobb-Douglas utility function $U = f^{1-\alpha}w^{\alpha}$. The price of food is p_f, the price of bottled water is p_w, and income is y. Derive an equation for the marginal willingness to pay for bottled water in terms of α, w, and y. Graph this marginal willingness to pay curve against bottled water consumption w. (10 points)