Ryan and Sudarshan 2020 - Rationing the Commons

Yixin Sun

November 3, 2020

EEE Presentation

Introduction

Motivation

- Economic development often has led to the mass depletion of natural resources

- Economic development often has led to the mass depletion of natural resources (fisheries, hunting, forests, and of course water)
- India is now the largest user of groundwater in the world
- Economists have tools that should lead to efficient outcomes, which Ryan has introduced to us through Pigou and Coase

Motivation

- Economic development often has led to the mass depletion of natural resources
- India is now the largest user of groundwater in the world

- Economic development often has led to the mass depletion of natural resources (fisheries, hunting, forests, and of course water)
- India is now the largest user of groundwater in the world
- Economists have tools that should lead to efficient outcomes, which Ryan has introduced to us through Pigou and Coase

Motivation

- Economic development often has led to the mass depletion of natural resources
- India is now the largest user of groundwater in the world
- Economists have tools that should lead to efficient outcomes

- Economic development often has led to the mass depletion of natural resources (fisheries, hunting, forests, and of course water)
- India is now the largest user of groundwater in the world
- Economists have tools that should lead to efficient outcomes, which Ryan has introduced to us through Pigou and Coase

Motivation

- Economic development often has led to the mass depletion of natural resources
- India is now the largest user of groundwater in the world
- Economists have tools that should lead to efficient outcomes
- But do we balance equity and efficiency?

- Economic development often has led to the mass depletion of natural resources (fisheries, hunting, forests, and of course water)
- India is now the largest user of groundwater in the world
- Economists have tools that should lead to efficient outcomes, which Ryan has introduced to us through Pigou and Coase

Motivation

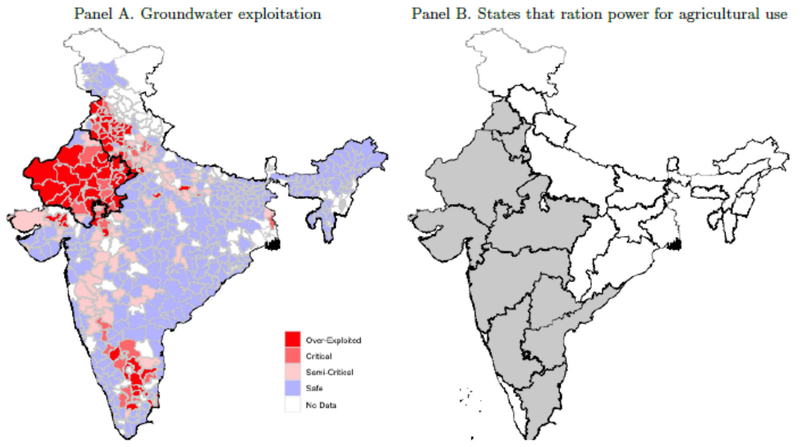
- Economic development often has led to the mass depletion of natural resources
- India is now the largest user of groundwater in the world
- Economists have tools that should lead to efficient outcomes
- But do we balance equity and efficiency?

Research question: how does the current groundwater rationing system in India balance the trade-off between efficiency and equity?

- Economic development often has led to the mass depletion of natural resources (fisheries, hunting, forests, and of course water)
- India is now the largest user of groundwater in the world
- Economists have tools that should lead to efficient outcomes, which Ryan has introduced to us through Pigou and Coase

Context: Common Pool Problem in Indian Groundwater

Figure 1: Groundwater Depletion in India



- The spread of groundwater irrigation was instrumental in ushering in the Green Revolution of the 1960s and 1970s. This led to huge productivity growth in India, but also huge depletions of groundwater
- Rajasthan, the area of study in this paper, has an extraordinary concentration of districts withover-exploited groundwater and as a state is extracting groundwater at 137% of the rate that can naturally be recharged. (Point to Rajasthan, which is the area outlined in black on the left hand side)
- Primary method government oversight is Use rationing of electricity to limit how much water farmers can extract. We can see this on the left hand panel, which shades the states in India that use a rationing regime in supplying power for farmers

Weitzman Detour

Weitzman (1977): Is the Price System or Rationing More Effective in Getting a Commodity to Those Who Need It Most?

"There is a class of commodities whose just distribution is sometimes viewed as a desirable end in itself, independent of how society may be allocating its other resources. While it is always somewhat arbitrary where the line should be drawn, such "natural right goods" as basic food and shelter, security, legal aid, military service, medical assistance, education, justice, or even many others are frequently deemed to be sufficiently vital in some sense to give them a special status. The principal of limited dimensional equity in the distribution of a commodity is an open violation of consumer sovereignty."

- We've seen Weitzman's famous Prices vs. Quantities paper in class, but Weitzman actually also has a paper called "Is the Price System or Rationing More Effective in Getting a Commodity to Those Who Need It Most". And I'll just share with you the quote from the paper that outlines why he sets up this other framework to think about "natural right goods"

Weitzman Detour: Model

1. Measures each consumer's relative need vs. ideal allocation based on that need.

- Measures each consumer's relative need vs. ideal allocation based on that need. Note he uses "need" rather than "preference" because he is specifically thinking about goods such as water rather than widgets, because these are goods where distributional issues are important
- The second is the social objective function, which is the quadratic loss between ideal and actual allocations
- Limited-information assumption: government needs to choose an allocation system without perfect information on where individuals lie on a distribution. Since everyone has read the paper, this definitely sounds like the setting that Ryan and Sudarshan are studying.

Weitzman Detour: Model

1. Measures each consumer's relative need vs. ideal allocation based on that need.
2. Social objective function: quadratic loss between ideal and actual allocations

- Measures each consumer's relative need vs. ideal allocation based on that need. Note he uses "need" rather than "preference" because he is specifically thinking about goods such as water rather than widgets, because these are goods where distributional issues are important
- The second is the social objective function, which is the quadratic loss between ideal and actual allocations
- Limited-information assumption: government needs to choose an allocation system without perfect information on where individuals lie on a distribution. Since everyone has read the paper, this definitely sounds like the setting that Ryan and Sudarshan are studying.

Weitzman Detour: Model

1. Measures each consumer's relative need vs. ideal allocation based on that need.
2. Social objective function: quadratic loss between ideal and actual allocations
3. Limited-information assumption: government needs to choose an allocation system without perfect information on where individuals lie on a distribution

- Measures each consumer's relative need vs. ideal allocation based on that need. Note he uses "need" rather than "preference" because he is specifically thinking about goods such as water rather than widgets, because these are goods where distributional issues are important
- The second is the social objective function, which is the quadratic loss between ideal and actual allocations
- Limited-information assumption: government needs to choose an allocation system without perfect information on where individuals lie on a distribution. Since everyone has read the paper, this definitely sounds like the setting that Ryan and Sudarshan are studying.

Weitzman Detour: Results

If people's needs are more widely dispersed or if the society is relatively egalitarian $\rightarrow$ price mechanism

- If people's needs are more widely dispersed or if the society is relatively egalitarian, then a pricing mechanism works better
- If people's needs are quite uniform or there is great income inequality, then a rationing mechanism is better.
- I think it's important to think about how this differs from a direct applicaiton of Prices vs. Quantities framework. If I were to think about this problem after I watched Ryan's lectures but before I read the rationing the commons paper, I think my train of thought would've been, "demand elasticity of water tends to be pretty big in the literature, so the marginal benefits curve is pretty flat, so if I apply Weitzman 1974, then we should use a pricing mechanism to solve the common resource problem in India".
- But that's not the conclusion you'd probably reach using Weitzman 1977 (don't ask me about the math though). I think the intuition here is that Weitzman's notion of need is affected by income and your own idiosyncratic need for a good. So when there is no income inequality, prices are effective at allocating the good because willingness to pay is an efficient measurement of the need of an individual. However, when there is huge income inequality, a rationing scheme essentially prevents those with larger incomes from monopolizing consumption of the commodity in question

Weitzman Detour: Results

If people's needs are more widely dispersed or if the society is relatively egalitarian $\rightarrow$ price mechanism

If people's needs are quite uniform or there is great income inequality $\rightarrow$ rationing mechanism

- If people's needs are more widely dispersed or if the society is relatively egalitarian, then a pricing mechanism works better
- If people's needs are quite uniform or there is great income inequality, then a rationing mechanism is better.
- I think it's important to think about how this differs from a direct applicaiton of Prices vs. Quantities framework. If I were to think about this problem after I watched Ryan's lectures but before I read the rationing the commons paper, I think my train of thought would've been, "demand elasticity of water tends to be pretty big in the literature, so the marginal benefits curve is pretty flat, so if I apply Weitzman 1974, then we should use a pricing mechanism to solve the common resource problem in India".
- But that's not the conclusion you'd probably reach using Weitzman 1977 (don't ask me about the math though). I think the intuition here is that Weitzman's notion of need is affected by income and your own idiosyncratic need for a good. So when there is no income inequality, prices are effective at allocating the good because willingness to pay is an efficient measurement of the need of an individual. However, when there is huge income inequality, a rationing scheme essentially prevents those with larger incomes from monopolizing consumption of the commodity in question

Model of agricultural production under rationing

Modelling the Optimal Ration

$$\underbrace{\sum_i \frac{d\widetilde{\Pi}_i\left(W_i\left(\bar{H}^*, D_i\right)\right)}{d\bar{H}^*}}_{\text{Marginal benefit}} = \underbrace{\sum_i c_E P_i + \rho\frac{P_i}{D_i}\lambda_W}_{\text{Marginal social cost}}$$

Farmer profits = Direct cost of elec. + Opportunity cost

- Paper begins by modelling agricultural production with groundwater.
- Farmers are heterogeneous in productivity and in factor endowments.
- Under rationing, markets clear on quantity
- Here we are considering the state's problem: they are maximizing total surplus, taking as given the price of electricity, and they have to choose a ration, $\bar{H}$. So we get the familiar FOC for the optimal ration in the slide
- Efficient ration balances the marginal social benefit of increasing the ration against the marginal social cost
- The benefits are the additional profits farmers earn when the state increases the ratio, which allows farmers to extract more water
- The marginal cost has two parts. The first is the cost of generating and distributing the additional electricity that farmers use when the state increases the ration. The second is the opportunity cost of water extraction due to the externality: if a farmer uses water today, the water level will fall, and the cost of water extraction tomorrow will rise.
- An important result here is that even an optimal ration distorts allocation of water and lowers surplus because it is forcing heterogeneous farmers to have the same level of power use.

Sufficient Statistic for Electricity Ration

$$W_i\left(H_i, D_i\right) = \rho \frac{P_i H_i}{D_i}$$

$$\sum_i \frac{d\widetilde{\Pi}_i\left(W_i\left(\bar{H}, D_i\right)\right)}{d\bar{H}} = \sum_i -\frac{d\widetilde{\Pi}_i}{dD_i}\frac{D_i}{H_i}$$

- The above equation is intuitive - we want to balance marginal benefits and marginal cost
- But we can't measure marginal benefit directly because the ration does not vary. Also, as shown by their agricultural survey, the ration binds for almost all farmers, so we can't see marginal willingness-to-pay
- But they know that water extraction is dictated by this water extraction function. So they can replace the increase in water due to a change in the ration with the increase in water due to a change in depth. So the marginal return to depth is a sufficient statistic for the benefit of an increased electricity ration. They use plausibly exogenous variation in groundwater conditions, based on the geology of aquifers, to estimate farmer's return to water.

Calculating Marginal Benefits v Costs

Hedonic IV Regression to Estimate Marginal Benefits

$$\Pi_{ic} = \beta_o + D_i\beta_1 + X'_{ic}\beta_2 + \alpha_s + \alpha_p + \epsilon_{ic}$$
$$D_i = \delta_0 + Z'_i\delta_1 + \eta_{ic}$$

Coefficient of interest: $\beta_1 = \frac{d\Pi}{dD}$

Discussion

- To estimate the marginal benefit of more water, the authors regress profits on well depth, along with controls for farmer and crop characteristics, and fixed effects.
- However, OLS could suffer from endogeneity or omitted variable bias, say if more profitable farmers are able to get land with less water depth.
- Solution: use geological characteristics as an instrument for well depth

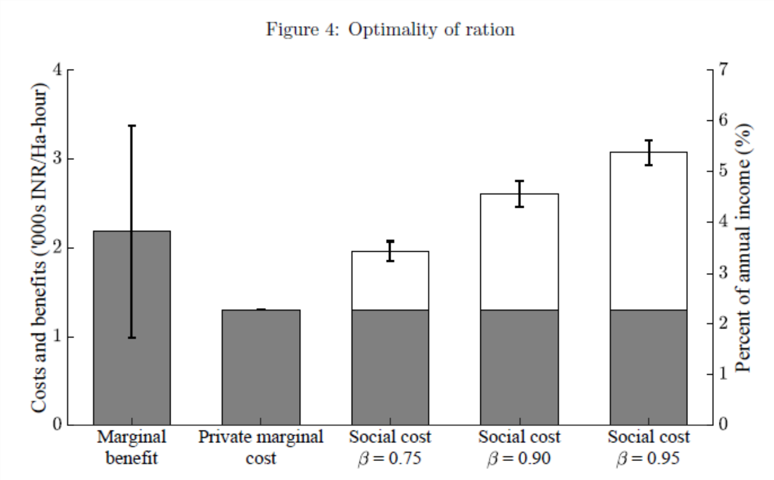
Results of Hedonic Regressions

Table 2

	OLS (1)	OLS (2)	IV-PDS (3)	IV-PDS (4)
Well depth (1 sd = 187 feet)	0.69	-2.71^{*}	-8.87^{***}	-7.01^{***}
	(1.25)	(1.56)	(2.47)	(2.70)

- In their preferred specification, they find that a one standard deviation increase in depth decreases profit by 8,900 rupees per hectare in the dry season
- This reduction is about 14% of output per hectare, or 15% of household income for the average farmer
- So by these estimates, the amount of water is incredibly valuable for farmers

Comparing Marginal Benefits and Costs of Ration



Discussion

- The next step is to estimate the opportunity cost. This was the λ_w that we saw from before, which depends on how water extraction today affects groundwater levels tomorrow as well as on the returns to water in agriculture and the discount rate.
- They use a simplified dynamic version of their production model to estimate this
- Figure 4 translates these comparisons into comparisons of marginal benefits nad marginal costs.
- The first bar translates the results from the regression, the β_1 they found, and finds that a one-hour increase in power supply increases farmer profits by 2,200 rupees per hactare. The remaining bars show the costs, where the gray region is the direct cost of power, and the top white bar is the cost of water for three different discount factors
- This figure implies that on average, farmers are not using too much water, and that the ration is roughly efficient

Structural Estimation and Counterfactuals

Structural Model of Agricultural Production

$$y_{ic} = \alpha_L l_{ic} + \alpha_X x_{ic} + \alpha_K k_{ic} + \alpha_W w_{ic} + \omega_{Yic}$$

farmer i planting crop c

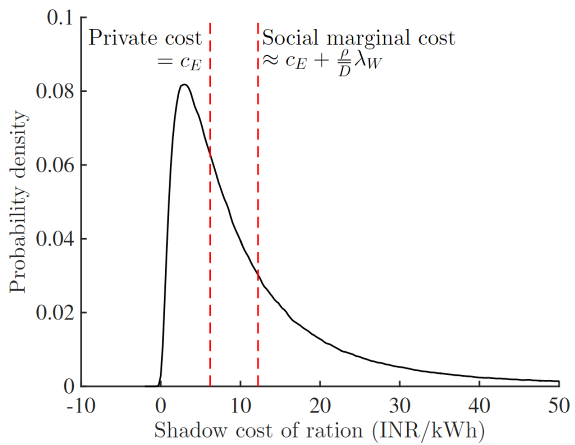
$$\omega_{Yic} = \underbrace{\overbrace{W_{Eic}\beta_E}^{\text{known output shifters}} + \overbrace{\omega_{ic}}^{\text{farmer-specific shock}}}_{\text{obs. by farmer}} + \underbrace{\epsilon_{Yic}}_{\text{unobs. shock at harvest}}$$

Questions

- Even though the rationing may be about right, we discussed on a previous slide that even a perfectly set ration imposes allocative inefficiencies, because everyone has the same ration, regardless of productivity.
- To compare rationing to Pigouvian pricing, they estimate a structural model of agricultural production
- Assume a Cobb-Douglas function shown here, with yields a residual that has several components. The first term consists of known output shifters. The second is a farmer-specific shock. Both these are observed by the farmer early in the season and hence input choies are endogenous to these terms. The third is an unobservable shock at harvest. The econometrician only observes W_{Eic}.
- They run this production function as a regression, again using an instrumental variable approach to account for endogeneity of input choices to productivity.
- From the residuals of their regression, the authors can calculate the implied TFP for farmers.

Model Estimates and Dispersion of Shadow Costs

Figure 6: Shadow cost of the status quo ration



- The model estimates then allow the authors to calculate the shadow cost of ration for each farmer
- This shadow cost is the price of electricity such that each farmer, if unconstrained, would optimally choose to use the rationed amount of water.
- They graph these shadow costs in figure 6. We see that about 2/3 of the farmers have a shadow cost less than social marginal cost. But we have this long right tail of farmers with extremely high shadow costs.
- This high dispersion gives us an illustration of there being a high degree of misallocation of water across farmers

Running Counterfactual Regimes and Transfers

Counterfactual Regimes

1. Ration set at optimal, rather than 6 hours
2. Pricing regimes instead of ration, sets price of electricity at private marginal cost
3. Pigouvian regime $\rightarrow$ sets price of electricity at social marginal cost

Transfer Methods

1. Flat (uniform) transfers across farmers
2. Transfers on basis of land size
3. Transfers on basis of pump capacity

Equations

Counterfactual Regimes Results

Table 4
Counterfactual Production and Social Surplus

	Rationing		Pricing	
	Status quo (1)	Optimal (2)	Private cost (3)	Pigouvian (4)
Surplus (INR 000s)	10.13	10.26	12.29	14.77
Water (liter 000s)	1592.37	1322.45	2853.76	1548.15
Power (kWh per season)	1011.60	840.86	1572.73	806.97
Hours of use (per day)	5.96	4.95	10.99	6.12
Output (INR 000s)	54.61	52.00	68.67	59.21
Gain in output from status quo (pp)		-5	26	8
Gain in output due to input use (pp)		-5	19	2
Gain in output due to productivity (pp)		-0	7	6

- Column 1 is status quo 6 hour ration Column 2 is the optimal ration. Column 3 is pricing at private costs, and column 4 is Pigouvian pricing.
- We see that the ration is at roughly the efficient level - column two here sets the optimal ration at 5 hours
- We see large efficiency costs with rations. If you look at the mean surplus in column 1, we can get a 50% increase under Pigouvian pricing. The authors calculate that this gain in surplus would equal 12% of the annual household income, so these potential gains are huge!
- The other thing to note here is that the surplus gains under Pigou are because of increases in productivity rather than water conservation. We see that average water extraction is nearly the same under Pigou. But if we look at gains in output in the last section of rows, 6 of the 8 percentage point increases in output are due to higher productivity rather than input use
-

Distributional Impacts of Pigouvian Reform

Table 5
Distributional Effects of Pigouvian Reform

	Rationing	Pigouvian			
Transfers:	None (1)	None (2)	Flat (3)	Pump (4)	Land (5)
A. Inequality under different transfer schemes					
Mean profit (INR 000s)	45.36	32.90	32.90	32.90	32.90
+ Mean transfer (INR 000s)	0.00	0.00	22.24	22.24	22.24
Mean net profit (INR 000s)	45.36	32.90	55.13	55.13	55.13
Share who gain		0.10	0.74	0.68	0.61
Share who lose		0.90	0.26	0.32	0.39

- But this is potential surplus gain is not the end of the story. The author ends this paper by studying the distributional impacts of Pigouvian reform.
- Column 1 here gives status quo results, and the next four compares the status quo to the Pigouvian regime under the different transfer mechanisms we discussed in the previous slide.
- We see that without transfers, most farmers lose out under Pigouvian pricing
- With flat transfers, 74% of farmers gain, which is substantial but not a Pareto improvement. And what's important to note is that those who lose tend to be farmers with high ex ante profits, land, and productivity, and deeper wells. So this scheme actually mostly harms productive, moderate landholders in areas with severe groundwater depletion.
- And in the last two columns, we see that targetting transfers based on pump capacity or land size actually hurts more farmers than the flat fee transfer scheme. The intuition here is that targeting mainly shifts the burden of losses, because they end up spending a large part of the budget on large farmers who would've been profitable even without transfers.
- This highlights one of the paper's key points: productivity is the key determinant of gains from reform, but the state cannot target transfers on productivity, which means Pigouvian regimes still leave a large number of farmers worse off.

Summary

- On average, the current 6-hour ration is set at the roughly efficient level
- With farmer heterogeneity, even the optimal ration produces allocative inefficiency
- Pigouvian pricing would lead to large increases in social surpluses, but about 90% of farmers would lose out if no transfers are given
- Even with transfers, significant portions of farmers would still be worse off

Discussion

Musings

- Appreciate a comparison between efficiency and distribution
- Comparing current policy to realistic policies that government could take $\rightarrow$ Coase would be proud!
- Extremely well written and easy to understand, even with all the moving parts
- Agricultural survey is very impressive

Importance of This Paper

- Agriculture is 16% of India's GDP, but a huge portion of consumer surplus
- 60% of Indian population works in the agriculture sector
- India's agricultural output accounts for about 7% of world agricultural output
- How we use water today has many feedback components that are made worse with climate change
- Direct Benefit Transfers (DBT) of Electricity subsidies

Then climate change is bringing in a new slew of issues surrounding water and agriculture.

- earlier spring melt - lost storage from snow pack
- More variable precipitation; makes existing storage of water less usable, and more frequent and severe drought
- These issues lead to groundwater depletion and less groundwater recharge
- implication is that irrigation and technology improvements are very unlikely to be the adaptation strategy for climate change *rightarrow* we need to think about what government intervention looks like

Indian government proposed a Direct Benefit Transfers of Electricity plan, where farmers would pay the bill for the power consumed for farming. After that, they get the subsidy in their bank accounts for the hours they do not use electricity. So farmers can select into using all of their electricity ration, or cut back and receive a cash transfer, thereby implicitly selecting on productivity.

How Should We Think About the Future?

- Found that the rationing status quo seems close to being efficient, but "Rajasthan as a state is extracting groundwater at 137% of the rate that can naturally be recharged."

- This model doesn't interact at all with the weather or climate, which the authors adress in their appendix, and say is because they could not get granular enough data. Fair enough, but interacting with the climate will likely speed up the rate of depletion

How Should We Think About the Future?

- Found that the rationing status quo seems close to being efficient, but "Rajasthan as a state is extracting groundwater at 137% of the rate that can naturally be recharged."
- Are they picking the right discount rate? Fig. 4

- This model doesn't interact at all with the weather or climate, which the authors adress in their appendix, and say is because they could not get granular enough data. Fair enough, but interacting with the climate will likely speed up the rate of depletion

How Should We Think About the Future?

- Found that the rationing status quo seems close to being efficient, but "Rajasthan as a state is extracting groundwater at 137% of the rate that can naturally be recharged."
- Are they picking the right discount rate? Fig. 4
- Method of estimating costs does not incorporate the feedback components discussed Dynamic Model

- This model doesn't interact at all with the weather or climate, which the authors adress in their appendix, and say is because they could not get granular enough data. Fair enough, but interacting with the climate will likely speed up the rate of depletion

To estimate marginal benefits from more water, authors use geological features as an instrument for water depth. IV

How does this get rid of the endogeneity concern?

- I think I have a hard time thinking about the exclusion restriction here because there are so many instruments, and they use a double lasso approach to pick the instruments. But generally I am thinking that the same selection behavior that would cause a farmer to choose a piece of land with low water depth would be the same selection behavior that would cause them to choose land with certain geological features
- And I know there's not a contemperanous selection issue since land markets are thin, but my thought is that if powerful families own land for many generations, then the reason they own that land is perhaps due to all these geological reasons. So this wouldn't get rid of simultaneity or endogeneity concerns.

Possible Extension

- What are the implications if we take into account that farmers can adapt or switch crops when the government sets a high enough ration? Put another way, what other dimensions can we learn if we use panel data?

- What if we were to use panel data to estimate marginal benefits? This paper estimated marginal benefits using cross-sectional data because "it can recover long-run elasticities of profit with respect to water, net of farmer adaptation".
- Does quality of electricity matter here? What I am wondering is if there are constant outages in some regions but not others, and that is probably interacting with geological features. This gets lumped into productivity right now, but I wonder if we can break that out, or even produce an estimate of how much agricultural profit is lost due to outages.

Possible Extension

- What are the implications if we take into account that farmers can adapt or switch crops when the government sets a high enough ration? Put another way, what other dimensions can we learn if we use panel data?
- Does quality of electricity matter here?

- What if we were to use panel data to estimate marginal benefits? This paper estimated marginal benefits using cross-sectional data because "it can recover long-run elasticities of profit with respect to water, net of farmer adaptation".
- Does quality of electricity matter here? What I am wondering is if there are constant outages in some regions but not others, and that is probably interacting with geological features. This gets lumped into productivity right now, but I wonder if we can break that out, or even produce an estimate of how much agricultural profit is lost due to outages.

Questions

1. Do most farmers pay their electricity bills?
2. Are microgrids or alternative energy sources used to get around the ration?
3. In equation (9), why is it important to include W_{Eic} in the residual if those are observable? Structural Eqn

- Do most farmers pay their electricity bills? I am thinking that another reason pricing electricity is not a good idea is simply that people just won't pay
- Are microgrids or alternative energy sources used to get around the ration? Is that something that is monitored?
- Technical question

Extra Slide: Pigouvian vs Rationing

Pigouvian Regime: $p_E^* = \underset{p_E}{\arg\max} \sum_i \mathbb{E}\left[\widetilde{\Pi}_i\left(p_E\right) - c_E P_i H_i\left(p_E\right) - \rho_i \frac{H_i(p_E)}{D_i} \lambda_W\right]$

Rationing Regime: $\bar{H}^* = \underset{\bar{H}}{\arg\max} \sum_i \left[\widetilde{\Pi}_i\left(W_i\left(\bar{H}, D_i\right)\right) - c_E P_i \bar{H} - \rho \frac{P_i}{D_i} \bar{H} \lambda_W\right]$

Counterfactuals

Extra Slide: Dynamic Model (Appendix E)

Farmer's Problem: $\max_{H_t \leq \bar{H}} \Omega \left(W_t \left(H_t, D_t\right)\right)^{\alpha_W} - p_E P H_t$

$$H_t^* = \min \left\{ \left(\frac{\Omega \alpha_W}{p_E}\right)^{\frac{1}{1-\alpha_W}} \left(\frac{\rho}{D_t}\right)^{\frac{\alpha_W}{1-\alpha_W}} \frac{1}{P}, \bar{H} \right\}$$

$$W_t^* = \rho \frac{P H_t^*}{D_t}$$

LOM: $D_{t+1} = D_t + \gamma \left(W_t - R\right)$

Discussion