The Water Gap: Environmental Effects of Agricultural Subsidies in India*

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Work in progress

Abstract

A labyrinthine mix of input and output subsidies influence crop choices and farming practices in India. While some of these surely provide short-term benefits, their long-term impact on the environment is worrisome. In this paper we document the nefarious impact of output subsidies for the production of food grains on groundwater levels. Exploiting a policy change in 2007-08 as a natural experiment we examine the impact of explicit procurement incentives offered by the government for water intensive crops on groundwater extraction in the central state of Madhya Pradesh. Preliminary results suggest that a subsidy-induced shift towards intensive wheat cultivation away from pulse cultivation has a significant impact on groundwater level declines. We also map out a research agenda for a structural welfare analysis going forward.

1 The Question

There is growing anecdotal and statistical evidence that modern agricultural practices have adversely affected soil quality and fresh water supplies.[1] Policy design is key; it formulates the incentives for micro decisions made by farmers that aggregate to have a macro impact on the environment. For instance, Tilman et al. [2012] highlight that "new incentives and policies for ensuring the sustainability of agriculture and ecosystem services will be crucial if we are to meet the demands of improving yields without compromising environmental integrity or public health."

This paper seeks to provide a systematic causal link between the depletion of groundwater reserves and agricultural policy in India; the incentives offered to the farmers are making them take decisions that will have an adverse long-term environmental impact. India as a case study for this global phenomenon is important for three reasons: (i) breaking down the problem into smaller geographical regions of the world helps us understand the relationship between policy design and its environmental impact, (ii) one sixth of the world resides in India so every policy

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[1] See FAO [2015] on soil and FAO [2012] on water.

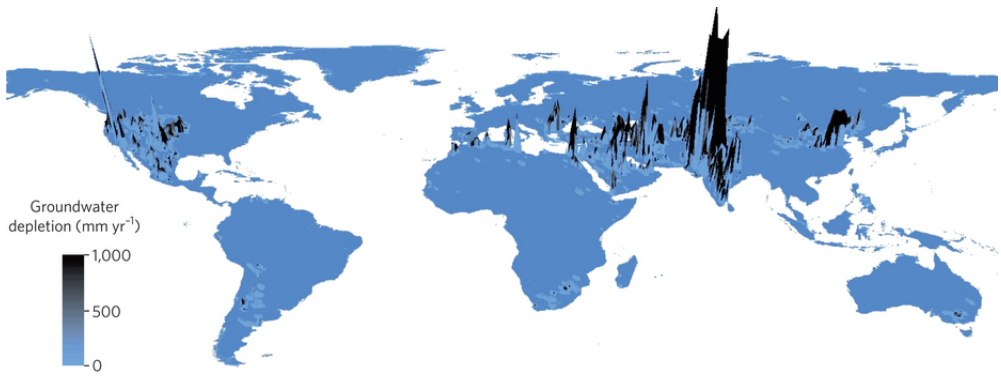


Figure 1: Intensive use of groundwater, India an outlier; Aeschbach-Hertig and Gleeson [2012]

decision has a large human impact, and (iii) groundwater depletion is a particularly acute problem in India from any global standards (see Figure 1).

The fulcrum of farming practices in many regions of India are state subsidies in their various guises. These can broadly be classified into input subsidies (free power, high yield seeds and fertilizers) and output subsidies (guaranteed procurement at set prices). Most, if not all, are well intentioned. But the externalities they have come to impose on the environment has broadly been ignored in policy design. Exploring the nature and extent of these externalities is the subject matter of our study.

Groundwater irrigation has increased by 500 percent over the past fifty years and there is widespread concern about the threat this trend forebodes in the face of a changing climate (Zaveri et al. [2016],Fishman et al. [2013]). Yet, few studies have assessed the impact of subsidies on groundwater extraction. A recent paper by Badiani and Jessoe [2015] focuses directly on input subsidies and finds a statistically significant impact of electricity subsidy on groundwater extraction with an implied price elasticity of -0.18. Farmers in many regions have almost free access to groundwater using electric tube wells which has led to an increase in the value of water-intensive crops, and hence the area on which these crops are grown.

To the best of our knowledge, ours is the first paper to evaluate the impact of output subsidies on groundwater levels in India. Every year before the sowing season the central government announces a minimum support price (henceforth MSP) at which it commits to procure any quantity of specified crops from farmers. The MSP has to be backed up by the state government procurement agencies, and this latter bureaucratic machinery acts as the true determinant of the efficacy of the policy. In some regions of the country (eg. Punjab and Haryana) and for certain crops (mostly food grains), MSP and procurement policies have heavily influenced crop choice and farming practices.[2]

Output subsidies are first-order important in that they influence the eventual revenue in the farmer's production function; so much so that (i) a highly fertile but not particularly overground water rich land like Punjab has been producing large amounts of paddy, and (ii) owing to the

[2]Chattrejee and Kapur [2016] document in detail the MSP and procurement policy as practiced across the country, and posit its optimal structure as a key research question going forward.

lack of price incentives, the per capita production of pulses has significantly declined nationally.[3] By skewing incentives for production decisions away from natural or replenishable endowments, output subsidies can potentially cause long-term environmental damage.

There are of course short-term benefits associated with agricultural subsidies- they have ensured India's aggregate food security, reduced import of grains, and enriched local farmers. A complete understanding of the varied underlying tradeoffs requires a structural model that parses out costs and benefits of the menu of policies at the government's disposal, and puts out numbers that allow for a welfare analysis.

The big picture question

Does agriculture policy have an (adverse) long term impact on the environment? Have output based agricultural subsidies in India led to the depletion of groundwater levels below replenishment? What are the general equilibrium effects of such policy choices?

2 Institutional background

Amidst serious food security concerns in the 1960s, the Green Revolution introduced high yielding varieties of various crops, in particular wheat- the staple food grain of a large number of Indians. It turned India from a net importer of food grains to a net exporter.[4] The high yielding varieties though demand more fertilizers and more water.

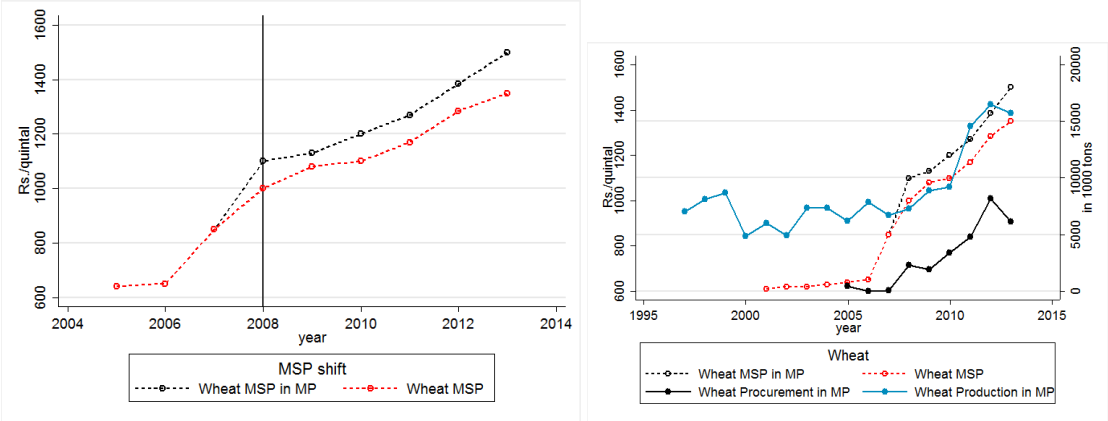
As a next step the central government introduced minimum support prices for the procurement of food grains. These had a dual role- to incentivize production and also to provide economic protection to the farmers. All this has culminated in an increase in the production and storage of food grains in India over the last few decades.

In part because of the success of the policy instrument, it has often been used as a pork-barrel to influence the electorate. This in turn introduces variation in farming decisions which can have a direct impact on measurable environmental parameters such as groundwater. In what follows, we exploit one such policy intervention by the state government of Madhya Pradesh that led to a spike in the production of wheat across the state.

3 A natural experiment in Madhya Pradesh

In the sowing season of 2007–08, the central government announced a major increase in minimum support prices for wheat. The Madhya Pradesh state government decided to top up this increase by a further ten percent, see Figure 2a. As described earlier, the potency of the MSP policy is driven in large part by the procurement machinery of the state at the local level; it became highly active in Madhya Pradesh in conjunction with the policy shift. Figure 2 reports a significant

[3] See for example Ministry of Agriculture, Government of India [2014].
[4] reference



(a) MSP for Wheat, all India and Madhya Pradesh (b) Wheat procurement by the government

Figure 2: MSP and Procurement of wheat in Madhya Pradesh

increase in the procurement of wheat by the state government which created new incentives for the farmers.

Krishnamurthy [2012] meticulously reports:[5]

> Given the FCI's meagre presence as a buyer in MP, there was no reason to expect that the rise in the centrally declared MSP in 2008 would significantly affect the structure and dynamics of wheat marketing in the state. This time, however, the move coincided with a major shift in the state government's wheat procurement policy. In the 2008 marketing season, preceding the assembly elections held in November that year, the state government announced a bonus of Rs 100 on top of the raised MSP, taking the state-declared procurement price of wheat in MP to Rs 1,100, higher than anywhere else in the country. Aware that the bonus could backfire if it was not effectively backed by actual buying, the MP government prepared to rapidly expand its procurement operations in the major wheat-producing regions of the state. In the previous decade, the largest volume of wheat purchased by the FCI and state agencies in MP in a year had been 0.54 mt in 1999-2000. In the 2007 marketing season, it had been a mere 0.057 mt. In the 2008 post-harvest period, this jumped many multiples to 2.4 mt, a figure that in a single season more than matched the state's entire procurement volume from 1999 to that point. Speculation that this might only have been an election-year sweetener was dispelled when the wheat bonus became a fixture in subsequent marketing seasons, each time coming on top of a higher MSP. Five years on, the volume of wheat procured by the state had burgeoned to the record figure..

The move led to a measurable changes in the cropping decision of the farmers. First, as the middle panel in Figure 3 shows, there has been a substitution away from gram and pulses as the main crop to wheat. Second, the right-most panel shows that it has also led to a significant increase in wheat production. Finally, Figure 4 plots the district-wise groundwater levels in Madhya Pradesh; a gradual increase in depth away from the surface is observable over time. We attempt to establish a casual link between these two regularities in the data.

[5]FCI is an acronym for Food Corporation of India; it oversees all procurement activities in the country.

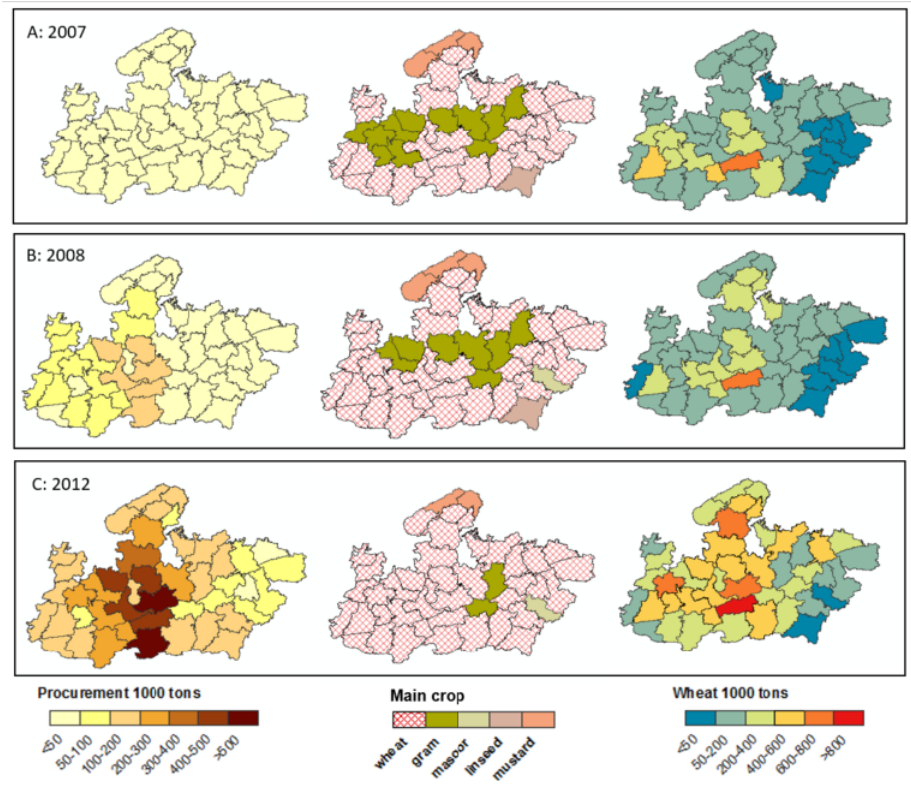


Figure 3: Wheat procurement and production

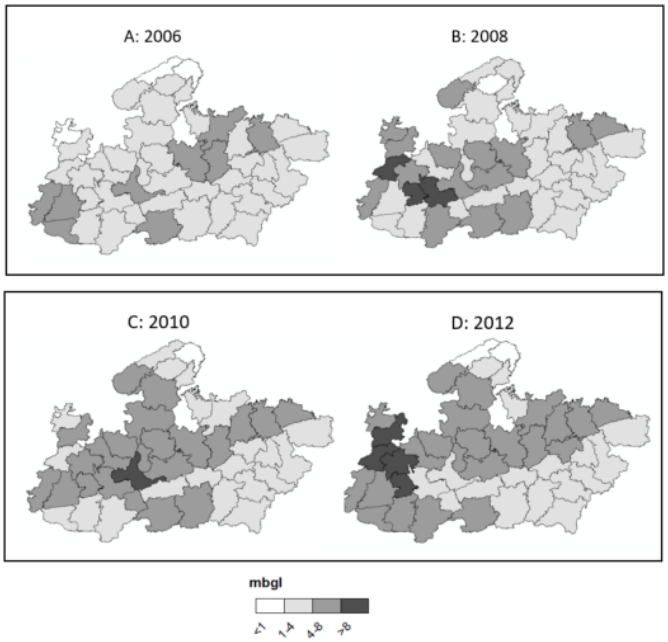


Figure 4: Groundwater level changes over the dry season (meters below ground level)

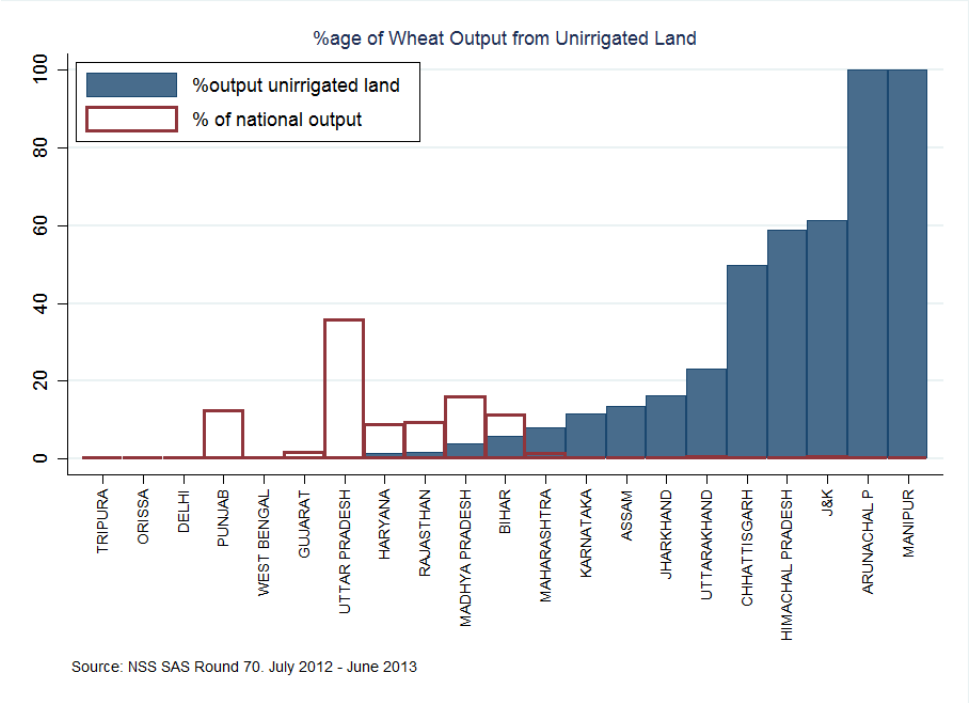


Figure 5: Wheat production and irrigation

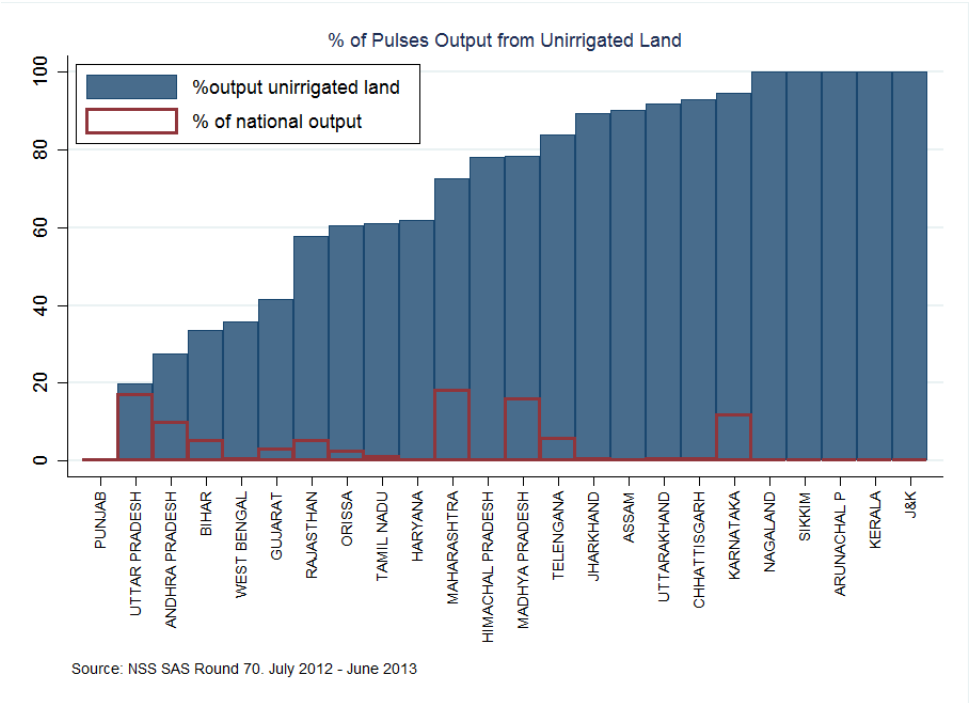


Figure 6: Pulses production and irrigation

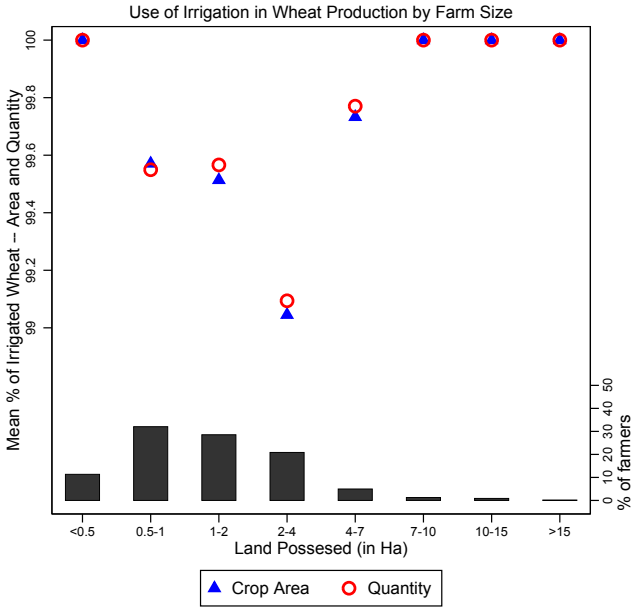


Figure 7: Land and Water: Wheat Area and Production

Unlike pulses, wheat is an irrigation-intensive crop in Madhya Pradesh. Figures 5 and 6 show that in contrast to pulses, the largest proportion of national wheat output is from irrigated land. Moreover, farmers across the land-ownership gradient engage in wheat irrigation in Madhya Pradesh (Figure 7).

Specific question on policy change in Madhya Pradesh

Did the policy switch to an increased minimum support price and greater procurement of wheat in the state of Madhya Pradesh have a causal effect on the groundwater levels?

4 Data

Our empirical analysis integrates FCI procurement data with agricultural data (production and area), groundwater levels and weather at the district-level.[6]

We make use of well-level data from the Central Groundwater Board of India within the Ministry of Water Resources for the years 2005-2013. For Madhya Pradesh, the data provides information for approximately 1,584 monitoring wells that record groundwater measurements four times in a year- in the pre-monsoon months of January and May, and in the monsoon and post-monsoon months of August and November. As Figure 8 shows the wells are fairly evenly spread. We aggregate this data to the district level using district boundaries corresponding to the 2001 Census, and use district-level changes in groundwater levels over the dry season in the

[6]Districts are administrative units within states and the administrative level at which detailed data is available. The average district area of 5000 sq. km. supports an average population of two million.

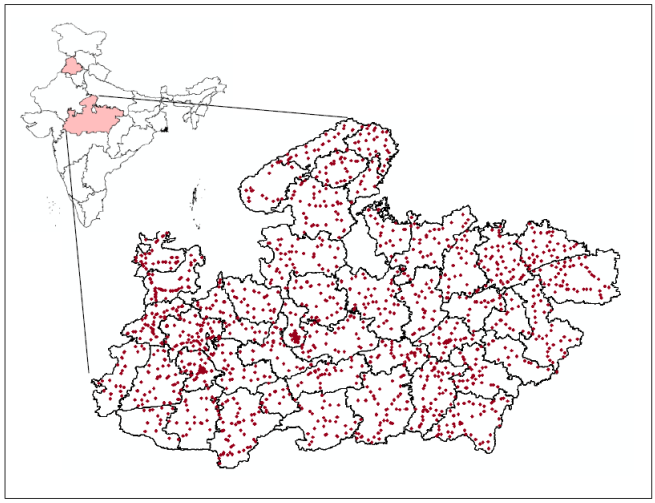


Figure 8: Well locations in Madhya Pradesh

empirical analysis.

Agricultural data come from the Directorate of Economics and Statistics within the Ministry of Agriculture. Data on procurement of wheat was obtained from the Food Corporation of India and is at the FCI district - month level. FCI districts are usually a union of 2-3 administrative districts. In order to use this at the district level, we distribute the amount procured in a FCI district - month to all the constitutent district in proportion of land area. This averages out a lot of useful spatial variation and therefore we are making efforts to obtain the same data at the sub-district level.

5 Methods

We employ the following statistical model:

$$W_{dt} = \alpha_d + \lambda_t + \theta \log(P_{dt}) + \eta \text{Post} \cdot \log(P_{dt}) + \beta X_{dt} + \varepsilon_{dt}$$

where W_{dt} is the difference in the depth of groundwater between sowing and harvesting periods for wheat in district d at time t. Post= $\mathbb{1}_{t>2007}$ is an indicator function that takes the value of 1 after 2007 and 0 before; it represents the exogenous increase in the minimum support price (MSP) for wheat and its level of procurement by the government in the state of Madhya Pradesh. P_{dt} represents the district level procurement of wheat in tons as recorded by the Food Corporation of India.

Our main coefficient of interest η, estimates the average effect of procurement on goundwaterlevels. Time-invariant heterogeneity at the district level are absorbed by district fixed effects α_d and state-level year specific shocks are captured by λ_t. X_{it} are time-varying characteristics of the districts that include contemporaneous and lagged rainfall and temperature to account for geographically driven changes in groundwater depth. In a variant of the specification, we also

control for agro-ecological zone (AEZ) specific trends to account for common regional trends affecting districts belonging to a particular AEZ. The standard errors are clustered at the level of districts. As is the case with all difference-in-difference studies, this approach does not identify the level effects of the MSP-procurement program but rather measures whether some districts suffered greater groundwater depletion relative to others.

To be precise, we seek to measure short- to medium- term effects of procurement on groundwater levels by relying on the space-time variation in the implementation of the MSP-procurement program in Madhya Pradesh and comparing groundwater levels in districts with greater procurement to districts with less procurement.

Identification assumption: The timing of the jump in procurement levels and subsequent phasing-in of the policy is not correlated with any other omitted variable that could also affect groundwater depth.

A common concern with difference-in-difference type estimators is to ensure that common trends hold. In future specifications, we will conduct an events study analysis and exploit the gradual phasing in of the policy. While MSP prices were hiked in years following 2007, procurement increased gradually after 2007 and varied across districts. Our hypothesis is that the main channels through which MSPs impact groundwater levels are: a) crop-switching from pulses to wheat since pulses remain the main competing crop grown in the Rabi or dry-season and b) concomitant increases in wheat production in predominantly wheat growing areas.

6 Results

Tables 1, 2 and 3 list the preliminary results. Table 1 shows that in general, the depth to groundwater increases after the policy-induced shift in procurement levels. Groundwater depth is measured in meters below the surface, so that a positive coefficient implies a worsening of the groundwater situation. Columns 1-4 in Table 1 indicate that a 10 percent increase in procurement post the policy change results in an additional level shift of groundwater of about 0.05 meters away from the surface over the rabi cycle. The coefficient is statistically significant. Since the within-district standard deviation is 2.09 meters, this represents 0.02 of a standard deviation increase in the depth to groundwater.

Further, we find that the dramatic increase in procurement post 2007 significantly increases wheat cropped area, while also depressing pulse area over time (Tables 2 and 3). This pattern is consistent with our hypothesis that procurement gradually altered cropping decisions in favor of wheat.

In subsequent work, we will use disaggregated procurement data at the village-level and match these directly to spatial location of wells to better measure local effects. While district-level procurement amounts serve as a proxy for the introduction of the MSP-procurement policy, it is influenced by the spread and number of villages in each district and can contaminate the true

Table 1: Spike in MSP & rise in procurement by the state lead to a decline in groundwater.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Difference between pre sowing and post harvest							
	GWL(mbgl)[a]				GWL(mbgl)[b]			
Log wheat procurement	0.023	-0.039	0.022	-0.034	0.148	0.118	0.151	0.123
	(0.163)	(0.148)	(0.164)	(0.151)	(0.130)	(0.117)	(0.135)	(0.123)
> 2007 x Log wheat procurement	0.572***	0.564**			0.479***	0.478***		
	(0.211)	(0.220)			(0.158)	(0.169)		
> 2008 x Log wheat procurement			0.476**	0.445**			0.298*	0.297*
			(0.213)	(0.207)			(0.176)	(0.170)
District FE	y	y	y	y	y	y	y	y
Year FE	y	y	y	y	y	y	y	y
AEZ-specific trends	n	y	n	y	n	y	n	y
Controls for weather	y	y	y	y	y	y	y	y
Cluster SE	District							
N	315.000	308.000	315.000	308.000	315.000	308.000	315.000	308.000
Adj. Rsq	0.516	0.529	0.515	0.527	0.578	0.615	0.573	0.610

Notes: Sample covers 45 districts in Madhya Pradesh from 2005-2013. GWL reflects depth changes over a rabi cycle of sowing and harvesting. [a] refers to level changes between November of the previous year and May of the current year. [b] refers to level changes between post-monsoon (August and November) of the previous year and pre-monsoon of current year (January and May). * p<0.10 ** p<0.05 *** p<0.01.

measure of the impact. Instead using village-level data will enable us to exploit the variation in policy introduction across villages in a standard DID framework.

7 Research agenda

Subsidies are a potent policy lever in agriculture, employed all over the world. They are, however, enmeshed in tradeoffs. The cost side of the bargain is particularly accentuated in developing countries due to weak implementation and severe stress on existing resources. Do these subsidies help the poor, or through the externalities they impose, ending up hurting them more?

Our research agenda going forward is twofold. First, we want to document the extent of environmental damage caused by agricultural subsidies. While anecdotal evidence exists aplenty, careful causal analysis have been meagre, especially for India. Our focus will be mainly on groundwater; soil quality as a dependent variable is also a fruitful agenda going forward.

Second, we want to understand the general equilibrium impact of intervention in the agricultural market in the form of input and output subsidies. At least three distortions are introduced due to such interventions: crop choice, price and trade, and these aggregate to affect the overall welfare in the economy.

In order to evaluate the general equilibrium effects, we plan to construct a model where farmers decide which crop to produce and what input mix to use; the government chooses the level of subsidies, procurement, and international trade policy; price and quantity are determined in equilibrium. The intensive use of groundwater today for high yielding varieties can have large

Table 2: Rise in procurement by the state increased wheat area.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Log cropped area							
	Wheat				Rabi Pulses			
Log wheat procurement	-0.043*	-0.050*	-0.044*	-0.050*	-0.040*	-0.044*	-0.040*	-0.045*
	(0.023)	(0.026)	(0.023)	(0.026)	(0.023)	(0.025)	(0.023)	(0.025)
> 2007 x Log wheat procurement	0.068***	0.070***			-0.046	-0.043		
	(0.023)	(0.024)			(0.031)	(0.031)		
> 2008 x Log wheat procurement			0.084***	0.079***			-0.045*	-0.044*
			(0.026)	(0.027)			(0.031)	(0.032)
District FE	y	y	y	y	y	y	y	y
Year FE	y	y	y	y	y	y	y	y
AEZ-specific trends	n	y	n	y	n	y	n	y
Controls for weather	y	y	y	y	y	y	y	y
Cluster SE	District							
N	315.000	308.000	315.000	308.000	315.000	308.000	315.000	308.000
Adj. Rsq	0.944	0.943	0.946	0.944	0.962	0.958	0.962	0.958

Notes: Sample covers 45 districts in Madhya Pradesh from 2005-2013. Agricultural data is from DES. * p<0.10 ** p<0.05 *** p<0.01.

Table 3: Rise in procurement by the state increased share of wheat area.

	(1)	(2)	(3)	(4)
	Share of district area			
	Wheat cropped area		Rabi Pulses cropped area	
Log wheat procurement	-0.004	-0.004	-0.004**	-0.004**
	(0.003)	(0.003)	(0.002)	(0.002)
> 2007 x Log wheat procurement	0.011***	0.011***	-0.006*	-0.006*
	(0.003)	(0.003)	(0.003)	(0.003)
District FE	y	y	y	y
Year FE	y	y	y	y
AEZ-specific trends	n	y	n	y
Controls for weather	y	y	y	y
Cluster SE	District			
N	315.000	308.000	315.000	308.000
Adj. Rsq	0.944	0.943	0.946	0.944

Notes: Sample covers 45 districts in Madhya Pradesh from 2005-2013. Agricultural data is from DES. * p<0.10 ** p<0.05 *** p<0.01.

(negative) welfare implications in the future.

The objective function of the farmer is to maximizes its profit, and that of the government is to maximize the welfare of the population internalizing the long-term externalities imposed on the environment through crop choice and other farming practices. Using this framework, we aim to make a quantitative assessment of impact of subsidies, do the short-term benefits justify the long-term costs, and evaluate if in fact there exists an optimal subsidy structure in the agricultural market in India.

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