Can subsidising green agricultural technology reduce smog? An experimental study

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- In response to escalating air pollution, particularly from crop residue burning, this study investigates the effectiveness of AgriPunjab's "Mechanised Management of Rice Crop Residue" (MMRCR) programme in Punjab, Pakistan, with a focus on mitigating the severe health and economic consequences of air pollution.
- Through a randomised controlled trial (RCT), subsidies for Rice Straw Shredders and Happy Seeders were distributed through a public lottery in major rice-growing districts.
- The study will examine how agricultural emissions contribute to air pollution in Punjab. The introduction of RSS-HS technology offers a promising solution, reducing greenhouse gas emissions by over 78% compared to burning. However, high upfront equipment costs pose a substantial barrier to technology adoption among farmers.

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Policy motivation for research

Our pilot study investigates the early-stage impacts of AgriPunjab's "Mechanised Management of Rice Crop Residue" (MMRCR) programme, with the aim of identifying opportunities for larger scale evaluation to lower costs and increase impacts. The programme was launched in 2020 and provides 80% subsidies for a bundle of equipment including Rice Straw Shredders and Happy Seeders to farmers through a public lottery in 15 major rice-growing districts in Punjab. These districts represent 80% of the 4.6 million acres of rice cultivation in the area. The equipment is manufactured locally by prequalified firms, establishing a local supply chain that can support future sustainability and scale.

Programme eligibility criteria include a commitment to rent the equipment to other farmers for at least four years. The programme trains lottery winners to use the equipment, while farmers are responsible for repair and maintenance. Take up of RSS-HS absent subsidies is negligible, with previous literature showing that high upfront costs of this equipment represent a major barrier to adoption (Shyamsundar et al. 2019), and AgriPunjab estimates that the majority of rice-wheat farmers clear their fields using fire.

Pakistan is one of the most polluted countries in the world, with air pollution levels far exceeding World Health Organization (WHO) guidelines and the country's own air quality standards. In Punjab province, home to 110 million residents, air pollution shortens life expectancy by an estimated 3 to 5 years (AQLI 2021). Premature deaths and morbidities arising from air pollution cost Pakistan up to 6.5% of its GDP annually (World Bank 2019).

Agricultural emissions are responsible for an estimated 20% of air pollution in Punjab (FAO 2020), primarily from the burning of rice stubble after harvest by farmers engaged in rice-wheat cropping. Mechanisation with combine harvesters allows farmers to harvest rice more efficiently than traditional methods, but leaves rice straw, or stubble, which must be managed or removed during a narrow two- to three-week time window between rice harvest and wheat planting (Ahmed et al. 2015). Farmers commonly burn the stubble, as other methods are more costly, time-consuming, and labour-intensive.

However, stubble burning releases harmful pollutants, and potentially negatively impacts soil quality and productivity (Porichha et al. 2021). Burning stubble emits smoke, particulate matter (PM10 and PM2.5) and other air pollutants harmful to human health, and black carbon and greenhouse gases contributing to climate change (Jain, Bhatia, and Pathak 2014).

The role of technology

A growing literature evaluates the consequences of crop residue burning and shows that burning has substantial impacts on human health (Rangel and Vogl 2019, Ferguson 2020, Pullabhotla 2018). A smaller literature investigates the determinants of farmers' decisions to burn, including the availability of local labour (e.g., Behrer 2020, Garg, Jagnani, and Pullabhotla 2020).

Several governments around the world have seized on the potential for a technology solution by creating awareness for and subsidising green equipment. However, the literature focuses on the equipment's efficacy among adopters (Porichha et al. 2021; Shyamsundar et al. 2019; NAAS 2017), with less direct evidence documenting the impacts of government programmes to promote or subsidise the technology (Aryal et al. 2020; Xia, Wang, and Yan 2014). Measuring the private returns to the technology is key for determining the optimal rate of subsidisation. Some studies suggest these may be positive. For example, in northwest India, RSS-HS use has been associated with increases in wheat yields, reductions in fertilizer, herbicide, and labour requirements, and fuel savings, as well as water savings and increased profits (Sidhu et al. 2015; Kharia et al. 2017). However, existing studies all suffer from selection into the technology, leaving the question of private returns to adoption unanswered.

Finally, measuring the private and social costs of adoption also informs the level of rental market activity necessary to justify equipment subsidies. Like many mechanised inputs to agriculture in LMICs, adopting farmers will utilise the equipment for a small fraction of the days during the relevant window of agricultural production. The literature on rental markets is growing (e.g., Caunedo and Kala 2021; Foster and Rosenzweig 2017).

A new generation of mechanised equipment promises to address the externalities from burning stubble. Rice Straw Shredders and Happy Seeders (which we refer to as RSS-HS), which shred and incorporate stubble into the soil, offer the potential to mitigate burning. In an analysis of alternatives to crop burning in India, Shyamsundar et al. (2019) find RSS-HS use reduces GHG emissions per hectare by more than 78% relative to burning. Adoption may also improve productivity through increased soil fertility (Kharia et al. 2017) and introduction of more efficient sowing techniques (Sidhu et al. 2015). However, upfront equipment costs represent a major barrier to adoption (Shyamsundar et al. 2019).

Description of research

Our research is premised on addressing air pollution and the associated impact on climate change as a result of crop residue burning practices by rice-wheat farmers in fifteen districts of Punjab province in Pakistan. The study considers whether government subsidies for green technology which provides an alternative to burning would be associated with a reduction in burning, in the context of the equipment's various external costs and benefits. In particular, our pilot—and its offshoots—are focused on gathering evidence to resolve three core questions:

1. What is the demand for RSS-HS take up and use?
2. Are take up and use responsive to equipment subsidies?
3. How can equipment use and its impact on stubble burning and agricultural yields be measured?

The questions above will help us evaluate the effectiveness of the past wave of the programme, and recommend improvements in the Programme design. Findings can potentially enhance the institutional capacity of AgriPunjab and improve the design of future waves of MMRCR.

Methodology

In 2020, the Punjab Agriculture Department (AgriPunjab) launched a programme to subsidise RSS-HS. Subsidy recipients were selected by lottery. We leverage this random assignment to evaluate the impact of the programme on crop burning and air pollution, and on crop yields. Our evaluation of this government programme thus offers the opportunity to measure impacts of the technology itself, and its private and social returns. While this evaluation is important in its own right, it also sets the stage for a set of complementary interventions, such as subsidies for equipment rental or direct payments for not burning.

As part of our larger RCT, utilising IGC support, we conducted random spot checks for a sample of treatment and control farmers to collect evidence on both equipment use and crop residue burning. Both equipment use and burning were measured using enumerator check lists. In particular, the enumerators were trained to observe a number of visual signs that may correlate with burning, including signs of smouldering, partially burnt vegetation/stalks, and baled straw, as well as indications of machine use for both the rice shredder and happy seeder machines.

Policy recommendations

Results from our complete pilot exercise will bear direct relevance for monitoring environmental externalities in agricultural activities. By the end of our study, we aim to (hopefully) develop a method to measure small-scale burning through an ML model validated via additional spot checks. This will allow us to evaluate Phase 1 of the MMRCR Programme, thereby delivering insights on the effectiveness of a “green” government subsidy on stubble burning in a developing country context. And more importantly, we might be equipped to predict crop fires with new and more precision.