The Equilibrium Impact of Agricultural Support Prices and Input Subsidies

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Abstract

We study the implications of agricultural minimum support price (MSP) programs, which offer a minimum price to staple crop farmers, and intermediate input subsidies for *misallocation* (productivity gap between agriculture and non-agriculture) and consumer welfare. We develop a dynamic general equilibrium model with heterogeneous agents, financial frictions and endogenous occupational sorting between two sectors: agriculture and non-agriculture, and two crops: staples and cash crops. The government procures staple crops at predetermined prices and distributes them as free rations while subsidising inputs for all farmers. The model is calibrated to match a mix of macro data and quasi-experimental evidence pertaining to the Indian economy. Our results suggest that if the MSP is removed, misallocation reduces, as labour reallocates from the agriculture to the non-agriculture sector, increasing agricultural labour productivity by 10%. A decrease in the input price subsidy exacerbates misallocation by reducing intermediate input intensity. Policies that replace the support price or input subsidy programs with budget-equivalent income transfers improve welfare.

JEL Codes: J43, Q18, O13, Q11, E24

Keywords: misallocation, welfare, agriculture, price support, input subsidies, general equilibrium, heterogeneous agents

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1 Introduction

Several studies argue that the low agricultural productivity in low-income countries is crucial for explaining cross-country differences in total factor productivity and living standards (Caselli, 2005; Gollin, Lagakos, & Waugh, 2014), especially since agriculture employs a substantial proportion of the workforce [1]. Both the less intensive use of inputs (capital, intermediate inputs, land and labour) and misallocation of these inputs (due to institutions or policies) in developing countries have been identified as important factors responsible for low agricultural productivity[2]. Given the importance of this sector, policymakers in these countries have rolled out various policies to assist farmers, often by directly influencing crop input and sale prices[3]. In this paper, through the lens of a quantitative general equilibrium (GE) framework, we investigate the extent to which these policies impact agricultural and non-agricultural productivity and consumer welfare.

The model features skill heterogeneity and financial market imperfections, both widely prevalent in developing countries (Restuccia & Rogerson, 2017). We calibrate our model to the Indian context that is consistent with macro data and quasi-experimental evidence. Model counterfactuals reveal that the removal of the minimum support price for staple crops increases overall agricultural productivity by 10%. On the other hand, the removal of input price subsidy by 110%, consistent with the quasi-experimental evidence, reduces agricultural productivity by 25.5%. We establish that *selection* effects (employment allocation across sectors), intermediate input use and general equilibrium forces play crucial roles in quantifying the impact of these policies on sectoral productivities. Furthermore, we show that these policies improve welfare for the poorest farmers given their limited insurance options (Giné & Yang, 2009; Mobarak & Rosenzweig, 2013); however, budget-equivalent transfers are even more beneficial.

We develop a dynamic general equilibrium model with two sectors (agriculture and non-agriculture) and two crops (staples and cash). All agents are heterogeneous with respect to their productivity in each occupation and can save in a risk-free asset, which induces a distribu-

[1] See Figures A1 and A2 in the Appendix

[2] See Buera et al. (2023), Gollin and Kaboski (2023), Herrendorf et al. (2014) and Restuccia and Rogerson (2013) for a review of the literature.

[3] In the US, as per the Farm Bill of 2014, the government pays the difference between the predetermined price floor and the market price, conditional on the market price being lower than the price support. FAO data shows that more than 43 countries had some form of output price support in agriculture in the last decade. Ramaswami (2019) estimated that input subsidies to power, fertilizer, irrigation, and credit in India together comprised 1.5% of GDP in 2017-18. Similarly, Holden (2019) discusses the prevalence of input subsidy programs in Africa.

tion of asset holdings in equilibrium in an environment with incomplete markets. Agriculture production requires intermediate input, which is available at reduced prices, but farmers face intra-period working capital constraints when purchasing them. Staple crops are protected by a minimum support price (MSP) policy that farmers can avail of subject to incurring a fixed cost. The government procures staple crops at a fixed price and then distributes them freely as rations to all households. These subsidies, hence, impact the occupational choices of agents. We calibrate the stationary equilibrium of the benchmark economy with the MSP and input subsidy policies.

The model is calibrated to match key moments of the Indian economy using a combination of quasi-experimental evidence and macro statistics. We leverage natural experiments to pin down two important parameters in the model: the elasticity of agricultural output to intermediate input and the working capital constraint in the agricultural sector. The former parameter is targeted by exploiting the deregulation of fertilizer prices; a 110% decrease in input subsidy reduced agricultural yield by 25.5%. The financial friction parameter is informative about the 8.5% adjustment in intermediate input intensity that we observe in the data when farmers received a cash transfer by the government equivalent to 6.25% of their annual income. As external validity, we show that the model replicates several untargeted aggregate and micro-data patterns, including the correlations between asset holdings, input intensity and agriculture output.

Using the calibrated model, we conduct counterfactual experiments to quantify the impact of each policy. In the first exercise, we remove the minimum support price and associated staple crop procurement and ration disbursal program. In the second exercise, we reduce intermediate input subsidy by increasing the effective price of inputs by 110%, matching the increase observed in the data. Our framework allows us to quantify the role of price adjustments in general equilibrium in evaluating the effect of these policies on individual occupational and input choices.

The removal of MSP has a positive impact on agricultural productivity through price adjustments that reallocate individuals to the non-agricultural sector. Under fixed prices, it has minimal effect as the salience of the program is limited (the government procures 30% of the staple output). However, in GE, the market price of staple crops falls as these crops formerly procured by the government are now released on the market. The demand for cash crops falls both due to the substitution effect and income effect through a reduction in farmers' income.

The loss of rations only partially offsets the fall in demand and price of staple crops. In equilibrium, the employment shares of cash crop and staple crop farmers reduce by 6.5 and 0.5 pp, respectively. Average agricultural productivity rises by 10%, while aggregate output increases only marginally as the average productivity in the non-agriculture sector falls. Misallocation, captured by the productivity gap between non-agriculture and agriculture, is reduced by 16%.

The reduction in input subsidy has a sizeable negative impact on agricultural productivity by substantially reducing the demand for intermediate inputs. Under fixed prices, the reduction in subsidy reduces intermediate input demand by almost 80% leading to a considerable shift out of agriculture. However, this leads to a substantial increase in crop prices, which increases both intermediate input demand and agricultural employment. Overall, employment shares change marginally relative to the benchmark economy. However, intermediate input demand and agricultural output are lower by 48% and 25.5%, respectively. Moreover, non-agricultural output cannot fully offset these losses due to income effects, implying that aggregate output falls by 10.5% and misallocation increases by 37%. In conclusion, the support price program for the staple crop affects relative labour productivity across sectors through its impact on sectoral employment shares (the *selection* effect), while input usage plays a significant role in shaping productivity when examining input subsidy policies[4].

These policies generate substantial consumer welfare, measured using consumption equivalent variation. The removal of the MSP policy results in lower consumer welfare relative to the benchmark economy, mainly due to the loss of free rations by at least 12%. Alternative budget-equivalent policies, wherein government expenditure on procurement is instead utilized to make either in-kind (mimicking a disbursal of rations) or income transfers to all households in the absence of an MSP, improve welfare for all agents. A reduction in input price subsidies also results in welfare losses (17%) relative to the benchmark as individual incomes are lower, market prices of both crops are higher and rations are lower than in the benchmark. A policy that compensates households with lump-sum transfers that are a fraction of the amount saved from the subsidy reduction can mitigate the welfare losses for all agents.

Finally, we corroborate the model prediction of higher prices and minimal employment effects in the data when reducing input subsidy. Furthermore, we leverage a natural experiment

[4]The price of the intermediate input is assumed to be exogenous in this framework since India is a large net importer of fertilisers (Gaulier & Zignago, 2010). However, this characterization is not unique to India as at least 50% of fertilizer consumption for approximately 75% of countries in the world (Hebebrand & Glauber, 2023). However, allowing for input price to change would mitigate some of the impact on agricultural productivity.

involving an increase in MSP, unrelated to productivity factors, to show a positive association between MSP and staple production in both the data and the model.

1.1 Related Literature

This paper contributes to three strands of literature. First, it contributes to the macro-development literature investigating the reasons behind large productivity gaps across countries. Low input intensity is widely regarded as an important contributor to these differences (Boppart et al., 2023; Caunedo & Keller, 2021; Restuccia et al., 2008), especially low intermediate input usage (Donovan, 2021; McArthur & McCord, 2017; Pietrobon, 2024; Rodríguez-Sala, 2023). Furthermore, input misallocation also plays a substantial role in contributing to productivity gaps across nations (Hsieh & Klenow, 2009; Restuccia & Rogerson, 2017)[5].

In this paper, we connect misallocation to specific agriculture input and output price subsidy programs. To the best of our knowledge, we are the first to study the distortionary impact of agriculture price support policies, both *within* agriculture and *between* sectors, in a quantitative framework. More broadly, our paper quantifies the role of selection (Adamopoulos et al., 2024; Hamory et al., 2021; Lagakos & Waugh, 2013) and input intensity in analysing input subsidy or output price policies. We demonstrate that selection accounts for the majority of the distortionary effects of MSP, while input intensity plays a more limited role. Conversely, input intensity is the primary driver of agricultural productivity, with selection playing a minor role when examining the effects of input subsidies.

Second, we contribute to the literature investigating the consequences of input subsidies and price support policies. Most of the literature on the agriculture price support program, in both developed and developing country contexts, focuses on the direct impact on agriculture or welfare (Alizamir et al., 2018; Demirdögen et al., 2016; Garg & Saxena, 2022; Krishnaswamy, 2018; Lichtenberg & Zilberman, 1986). We contribute new theoretical insights by developing a dynamic general equilibrium model with financial constraints. When the government procures goods from producers and reduces market supply, rather than simply compensating for price losses, it drives up the market price of the goods relative to other sectors, which in turn leads to farmers exiting from other sectors[6]. We show this mechanism is quantitatively im-

[5] Various institutions and policies can give rise to such misallocation, for example, labour market institutions (Donovan et al., 2023), financial market institutions (Buera et al., 2011), land market institutions (Adamopoulos et al., 2024; Manysheva, 2022) and spatial frictions (Chatterjee, 2023; Lagakos et al., 2023), among others.

[6] Narayanan and Tomar (2023) show that when the government compensates only for price losses, it creates excess supply and lowers market prices.

portant even when the salience of the program is limited (the government only procures 30% of staple output in the model), but financial constraints matter. Since farmers have to pay a fixed cost to avail procurement, intertemporal motives become important in their occupational choices. If there are no financial constraints and program salience is limited, this channel has little significance.

Our work complements both the empirical and quantitative studies on input subsidy programs. Our empirical result about the positive impact on agriculture output due to input subsidies is consistent with other studies (Beaman et al., 2013; Carter et al., 2021; Jayne et al., 2018). Moreover, our study complements the quantitative literature (Bergquist et al., 2019; B. Diop, 2023; Garg & Saxena, 2022; Ghose et al., 2023), which evaluates agriculture input subsidy programs mostly through static models[7]. We use the dynamic general equilibrium framework in our paper to quantify the contribution of selection versus input intensity, which adds to the literature on the productivity implications of subsidy reforms. Furthermore, our framework adds to the literature of analysing the impact of policies at scale (Muralidharan & Niehaus, 2017).

Our paper is most closely related to Mazur and Tetenyi (2023), who use a macroeconomic model to investigate the effect of the input subsidy program in Malawi. They find that input subsidies would make agriculture less productive due to strong selection effects. One of the reasons for the differences in the results is the presence of a fixed transaction cost in their model, which increases the purchasing price relative to the production of staple crops and generates a high proportion of unproductive farmers in that sector. Input subsidy makes staple production even more attractive, leading to inefficient sorting. This is unlikely to be a relevant channel in the Indian context as the government provides staples as in-kind transfers to households, diminishing farmers' incentives to produce staple crops (Gadenne, 2020; Li, 2023)[8,9]. This mechanism would also be less applicable in many other developing countries, as 44% of safety net recipients in the world benefit from in-kind transfers (Honorati et al., 2015).

[7] Bergquist et al. (2019); B. Diop (2023); Garg and Saxena (2022) study input subsidies in Uganda, Zambia and India, respectively.

[8] Mazur and Tetenyi (2023) also point out that the fixed transaction cost implies perfect competition among intermediaries. Chatterjee (2023) presents evidence of substantial intermediary market power in Indian agriculture, while Bergquist and Dinerstein (2019) and Casaburi and Reed (2022) offer similar findings for Kenya and Sierra Leone. Incorporating market power through a fixed reduction in price received as a farmer will not change the logic of our arguments.

[9] Another potential reason can be that our model does not impose sectoral mobility costs, unlike theirs. Mazur and Tetenyi (2023) interpret moving between sectors as migration between regions. Hnatkovska et al. (2024) show that rural-urban migration costs have reduced in India as the median rural-urban wage gap has fallen by 66 percentage points between 1983 and 2010.

Finally, we add to the body of research on anti-poverty initiatives and food security in low-income nations (Banerjee & Duflo, 2011; Barrett, 2002; Egger et al., 2022; Gadenne et al., 2024). One of the key objectives of the MSP program is to distribute grains to the poor. We exploit the rich heterogeneity by productivity and assets in our framework to analyse the welfare implications of these policies and their budget-neutral in-kind and in-cash replacements. The removal of these policies leads to substantial welfare losses across all occupation types. However, replacing these policies with budget-neutral income transfers generates higher welfare gains as income transfers help in overcoming financial market imperfections by a larger magnitude. Moreover, budget-neutral in-kind transfers also help the poor more in the model than providing rations through the MSP program, as the removal of MSP also reduces the market price, which benefits poor households. The model simulations illustrate that both types of transfers enhance welfare more than the agriculture subsidy programs[10].

The rest of the paper is as follows. Section 2 discusses the empirical evidence, whereas the details of the general equilibrium macroeconomic framework are described in Section 3. Section 4 details the calibration exercise, which explains the parameter choices used to solve the model. Section 5 presents the results from the quantitative exercises. Section 6 presents additional empirical validation of model counterfactuals and Section 7 concludes.

2 Background: Indian agriculture and agriculture policies

Indian agriculture is characterized by low productivity of workers, volatile yields and limited insurance options. First, 42% of the Indian workforce was engaged in the agriculture sector in 2019, yet labour productivity in the non-agricultural sector was four times higher than in agriculture (Appendix Figures A3a and A3b). The majority of farmers in India are small and marginal, with 85% cultivating less than 2 hectares of land (Bolhuis et al., 2021). Second, agriculture production is particularly volatile; the time-series standard deviation in the growth of value-added is 4.1% and 1.5% for agriculture and non-agriculture, respectively[11]. Crop insurance take-ups are quite low, with less than 10% of agricultural households holding any crop insurance (2019 Land and Livestock Survey). Lastly, food insecurity remains a critical issue in

[10] Our model is not designed to evaluate the benefits of in-kind versus in-cash transfers (Currie & Gahvari, 2008; Gadenne et al., 2024).

[11] Appendix Figure A4 shows the growth in valued added by sectors in India between 1980 and 2019. The mean (standard deviation) of growth in value added in agriculture and non-agriculture was 3.1% (4.1%) and 6.7% (1.5%), respectively.

India because 15% of the population (200 million) are still classified as undernourished[12].

Amidst these issues, various government initiatives were launched to boost agricultural production and enhance food security across the country. Ramaswami (2019) estimated that agriculture subsidies (input, credit and price support subsidies) amount to 2.25% of GDP in India. Additionally, the government distributes in-kind transfers to nearly 180 million households, costing almost 1% of the GDP (Balani, 2013). In this section, we discuss the institutional background of the two prominent types of government subsidies: (1) fertilizer subsidy, and (2) minimum support price.

2.1 Fertilizer subsidies

India's Green Revolution in the late 1960s boosted farm yields not only by introducing high-yield seeds but also through the extensive use of chemical fertilizers. The subsidies were mostly applied to urea, diammonium phosphate (DAP) and muriate of potash (MOP), which primarily deliver nitrogen (N), phosphate (P) and potassium (K) nutrients, respectively, to the soil. The fertilizer subsidies were implemented by controlling the retail price of fertilizers. The government either compensated manufacturers for the difference between production costs and retail prices or offered imported fertilizers at significantly reduced prices[13]. 40% of the total consumption of nitrogen, phosphorous and potassium fertilizers is imported in India (FAO, 2019). These facts will motivate the assumption in the model that fertilizer prices are fixed. Though fertilizer subsidies remain substantial, the government has sought to curb spending by deregulating non-urea fertilizer prices in 1991 and again in 2010. We will use the quasi-natural experiment in 2010 to estimate the elasticity of output to intermediate inputs (Section 4.1).

2.2 Minimum support price (MSP)

MSP was introduced in India during the time of the Green Revolution to ensure food security and stabilize farmer incomes. It entails the government announcing a price floor for 23 crops at which it commits to buy as much as a farmer is willing to sell. Though, in practice, the most amount of procurement happens in rice and wheat (Chatterjee & Kapur, 2016). Support price

[12] India ranked 102nd out of 117 countries in the 2019 Global Hunger Index.

[13] Comparing the international and the Indian retail price, the subsidy on a bag of urea, DAP and MOP was 89%, 61% and 29% respectively in 2022 (`https://govtschemes.in/fertilizer-subsidy-scheme-2022`).

programs are also common in other countries like China and US[14]. Below, we discuss some of the key aspects of the program.

First, the price floor is known to the farmers in advance, as it is announced nationally at the start of the agriculture season in June. The Commission for Agricultural Costs and Prices (CACP) is responsible for setting the support price. It considers several factors, including a minimum margin over anticipated production costs, expected monsoon patterns, food security concerns, demand and supply dynamics and international market prices. Thus, there is no uncertainty with regard to the support price for the farmer.

Second, penetration of the program is incomplete; in recent years, the government has procured around 30% of national rice and wheat production (Figure 1a). Furthermore, delays in procurement after harvest and payments imply that the richer farmers are more likely to access MSP. Figure 1b shows that farmers with higher production levels were more likely to take advantage of the MSP program[15]. Although access is imperfect, Chatterjee et al. (2020) argue that MSP has caused farmers to produce crops with lower yield and price risk. We also provide reduced-form evidence in Section 6.1 that MSP affects agricultural production[16].

Lastly, the government either stores the procured crops for food security purposes or distributes them to low-income households at markedly reduced prices. On average, highly subsidized rations account for 30% of household rice and wheat consumption (Gadenne, 2020)[17]. We integrate these features into a general equilibrium model in Section 3 and use simulated data to analyze the effects of agricultural input and output price subsidies.

3 Model

There are two sectors in the economy: agriculture and non-agriculture. The agricultural sector, in turn, comprises *staple* crops and *cash* crops. The non-agricultural good serves as the numeraire, and its price is normalized to 1 $\forall t$. The prices of the staple (s) and cash crops (r)

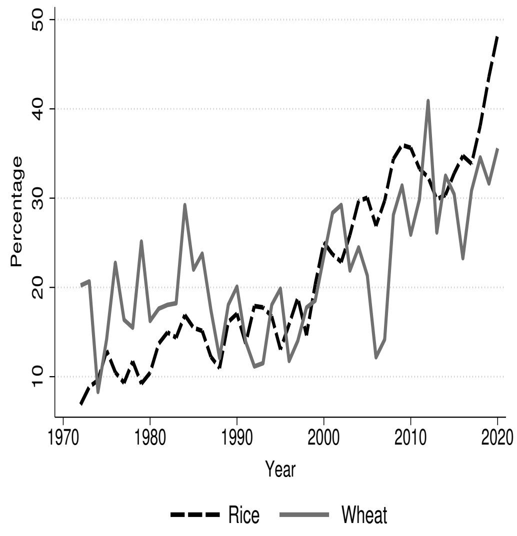
[14]Under the Price Loss Coverage program in the US, farmers are compensated for the difference between the market price and a pre-determined price if the latter falls below the market price (Alizamir et al., 2018).

[15]Some of this variation is explained by variation in procurement at state-level due to political cycles and local-level procurement infrastructure. But, this pattern holds even after controlling for state fixed effects, as shown in Appendix Figure A5a. Furthermore, we demonstrate that this pattern remains consistent when measuring a farmer's wealth by land area rather than output (Appendix Figure A5b).

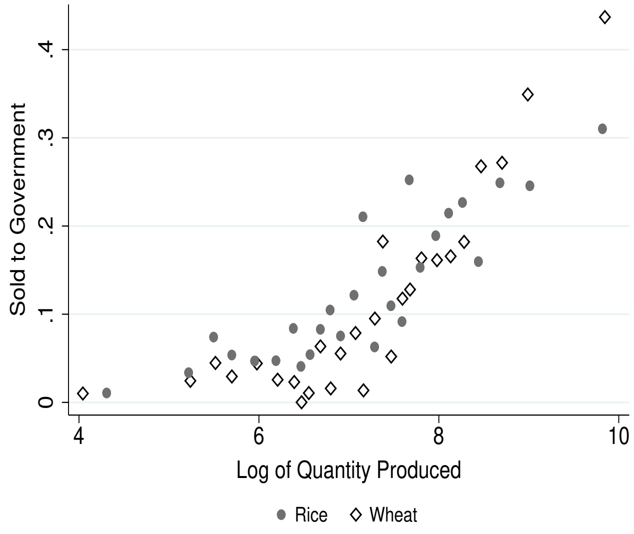
[16]Most of rice and wheat in India is produced in few states. Appendix Figures A6a and A6b show that there is little correlation between actual and potential yield for rice and wheat across Indian states. This suggests that differences in land quality cannot account for regional variation in cultivation patterns; however, policies like the MSP may play a role.

[17]The ratio of median market to PDS price is 10 and 3 for rice and wheat (Gadenne, 2020), respectively.

Figure 1: Incomplete penetration of MSP



(a) Proportion of procurement



(b) Heterogeneity in likelihood of MSP

Note: The figure on the left shows the fraction of output that is procured nationally. The figure on the right shows the a binscatter of the fraction of farmers selling to a government agency (y-axis) against log of total quantity produced. The Land and Livestock Survey of 77th NSS Round was used to construct the right-hand figure along with 30 quintiles for each crop.

are denoted by $\{p_{st}, p_{rt}\}$ respectively.

A measure 1 of individuals can choose to be either farmers of cash or staple crops, or workers in the non-agricultural sector. We do not permit an agent to allocate her unit labour endowment to multiple sectors in the same period. The resolution of all sources of uncertainty at the beginning of a period makes the role of labour supply in smoothing shocks discussed in, e.g. Donovan (2021), less relevant here.

Each farmer faces crop-specific idiosyncratic productivity shocks z_{jt}, drawn from a log-normal distribution Q_j with zero mean and s.d. σ_j. The realization of z_{jt} is i.i.d with respect to individuals, crops and time[18]. Workers in the non-agricultural sector draw idiosyncratic productivity shocks τ_t from a log-normal distribution with mean μ_τ and s.d. σ_τ.

Individuals make their occupational choices *after* the idiosyncratic shocks are realized. However, farmers of staple crops have the option to incur a fixed cost ρ that enables them to sell their produce to a procurement agency (the government) at the announced minimum support price (MSP), $\bar{p}$. We assume that cash crop farmers cannot avail of support prices. This is meant to parsimoniously capture the essence of the MSP program, wherein farmers of staple crops could choose to avail of above-market prices subject to certain costs. We do not specify

[18] Donovan (2021) shows that the auto-correlation of harvest realizations is low in Indian micro-data.

the objective of the policymaker in offering such a program but rather focus on the impact of the program on the agricultural productivity gap (the ratio of labour productivity in non-agriculture and agriculture) and welfare.

3.1 Technologies

The non-agricultural good is produced by a representative firm, which uses capital k_{nt} and labour n_{nt}, hired at interest rate $\tilde{r}_t$ and wage w_t respectively, as inputs:

$$y_{nt} = A n_{nt}^{\alpha} k_{nt}^{1-\alpha}, \;\; 0 < \alpha < 1 \tag{1}$$

where A is economy-wide total factor productivity (TFP) and α is labour's share of income in a Cobb-Douglas production function.

The agricultural good of each type ($j = \{r, s\}$) is produced by home-operated farms according to the following production function, which uses intermediate inputs (fertilisers) k_{jt} as the sole input:

$$y_{jt} = (A z_{jt}) \left[k_{jt}^{\zeta_j} \right] \tag{2}$$

where $\zeta_j < 1$ is the elasticity of production w.r.t intermediate inputs. We abstract from considering land as a choice variable and, thereby, do not consider the frictions associated with adjusting landholdings, which are the focus of a sizable literature, e.g., Adamopoulos and Restuccia (2014) and Bolhuis et al. (2021).

One unit of the intermediate input is produced by transforming p_k units of the non-agricultural good, hence p_k is the price of the intermediate input. Since the fertilizer prices are regulated by the Indian government, p_k is exogenous in the model. Expenditure on the intermediate input by a farmer of crop j is then $p_k k_{jt}$.

Expenditure on the intermediate inputs must be incurred prior to the harvest by intra-period borrowing from lenders at rate $\tilde{r}$, where $\tilde{r}$ is the return on saving discussed below. Let the gross interest factor be denoted by $\tilde{R} = 1 + \tilde{r}$.

Intra-period borrowing is subject to a working capital constraint that is a linear function of the asset holdings (a) of the borrower:

$$p_k k_j \equiv b \leq \phi a$$

The parameter $\phi > 0$ represents the degree of financial frictions, as in Buera et al. (2011) and Mazur and Tetenyi (2023).

3.2 Preferences

Individuals have preferences over the consumption of the two agricultural goods ($c_j,\ j \in \{s, r\}$) and the non-agricultural good (c_n) and maximize the expected discounted stream of utility from the consumption of the three goods:

$$\mathbb{E}_0\left[\sum_{t=0}^{\infty} \beta^t u(c_{st}, c_{rt}, c_{nt})\right]$$

The period utility function is non-homothetic and includes a subsistence requirement for staple crops following the literature on structural transformation (e.g. Herrendorf et al. (2014))[19]:

$$u(\mathbf{c}) = \frac{\left[\phi_s(c_s - \bar{c}_s)^{1-\theta} + \phi_r(c_r)^{1-\theta} + (1 - \phi_s - \phi_r)(c_n)^{1-\theta}\right]}{1 - \theta} \tag{3}$$

Here, $\mathbf{c} = (c_s, c_r, c_n)$ is the bundle of consumption goods. $\bar{c}_s$ measures the subsistence level of consumption of the staple crop, and ϕ_j is the weight that individuals assign to the agricultural good j. θ is inversely related to the elasticity of substitution across goods.

Households do not have access to insurance markets; thus, consumption can only be insured through saving in a risk-free asset that earns interest $\tilde{r}_t$, as in standard models with incomplete markets. Savings (a_t) is denominated in units of the non-agricultural good. Individuals cannot borrow to finance consumption, i.e. $a_t \geq 0$.

3.3 Role of Government: Procurement and Distribution of Staple Crops

We consider a support mechanism wherein staple crops are procured from farmers at a fixed price (the support price $\bar{p}_t$), and the procured crops are, in turn, freely distributed to all households. Finally, we assume that all agents obtain a ration of staple crops determined in equilibrium and denoted by c^{ration}.

[19] Lagakos and Waugh (2013) find that in poor countries, which are typically associated with low economy-wide efficiency, the subsistence requirement incentivizes the relatively unproductive farmers to inefficiently choose agriculture as their occupation

3.4 Profit maximization problems

The profit maximization problem of the representative firm (in units of the non-agricultural sector) is standard and yields first-order conditions that equate the marginal products of inputs to their factor prices:

$$\max_{n_{nt},k_{nt}} An_{nt}^{\alpha}k_{nt}^{1-\alpha} - w_t n_{nt} - \tilde{r}_t k_{nt} \tag{4}$$

$$w_t = \alpha A k_{nt}^{1-\alpha} n_{nt}^{\alpha-1} \tag{5}$$

$$\tilde{r}_t = (1-\alpha) A k_{nt}^{-\alpha} n_{nt}^{\alpha} \tag{6}$$

An individual observes their idiosyncratic productivity in each sector and MSP of staple crop before making occupational and farm input choices. Staple crop farmers differ from cash crop farmers in their ability to sell produce at the MSP.

A farmer of crop r with state vector $\{z_{st}, z_{rt}, \tau_t, a_t\}$ solves the following:

$$\max_{k_{rt} \leq \frac{\phi a_t}{p_k}} p_{rt}(Az_{rt})\left[k_{rt}^{\zeta_r}\right] - \tilde{R}_t p_k k_{rt} \tag{7}$$

Note that the problem above incorporates the working capital constraint, $k_{rt} \leq \frac{\phi a_t}{p_k}$.

The optimal unconstrained choice of farm input by a cash crop farmer is denoted by $k_{rt}^u = k_r^u(z_{rt})$.

Combining the first-order conditions of the problem above, one obtains:

$$k_r^u(z_{rt}) = \left(\frac{\zeta_r A z_{rt} p_r}{p_k \tilde{R}}\right)^{\frac{1}{1-\zeta_r}} \tag{8}$$

However, the actual amount of capital rented by a farmer is:

$$k_r(z_{rt}, a_t) = \min\{k_{rt}^u(z_{rt}), \frac{\phi a_t}{p_k}\} \tag{9}$$

Plugging this back into the production function and the profit expression yields:

$$\begin{aligned} y_r(z_{rt}, a_t) &= (Az_{rt})\left[k_{rt}^{\zeta_r}\right] && (10) \\ \Pi_r(z_{rt}, a_t) &= p_{rt}(Az_{rt})\left[k_{rt}^{\zeta_r}\right] - \tilde{R}_t p_k k_{rt} && (11) \end{aligned}$$

In the expressions above, the dependence on asset holdings is made explicit. This, in turn, arises from the collateral constraint affecting intermediate input choices.

A farmer of the staple crop is assumed to hold the option to sell her produce at the announced support price $\bar{p}_t$ subject to incurring a fixed cost associated with procurement, ρ. The staple farmer decides whether she wishes to sell her produce at the support price $\bar{p}_t$ as opposed to selling it at the market price p_{st}, based on a comparison of the value functions associated with the two options, that shall be defined below.

A staple crop farmer s with state vector $\{z_{st}, z_{rt}, \tau_t, a_t\}$ solves a similar optimization problem for input choices, with the difference that the staple crop farmer could sell her crop at the support price. Hence, there are two sets of equations for input choice, yield and profit, corresponding to the prices received by farmers.

A staple crop farmer receiving the market price chooses the intermediate input as per:

$$\max_{k_{st} \leq \frac{\phi a_t}{p_k}} p_{st}(Az_{st})\left[k_{st}^{\zeta_s}\right] - \tilde{R}_t p_k k_{st} \tag{12}$$

A staple crop farmer receiving the MSP chooses the intermediate input as per:

$$\max_{k_{st} \leq \frac{\phi a_t}{p_k}} \bar{p}_t(Az_{st})\left[k_{st}^{\zeta_s}\right] - \tilde{R}_t p_k k_{st} \tag{13}$$

The expression for k_{st}^u for a farmer receiving price $\hat{p}_{st} \in \{p_{st}, \bar{p}_t\}$ is analogous to the corresponding one derived above for cash crop farmers' intermediate input choices:

$$k_s^u(z_{st}, \hat{p}_{st}) = \left(\frac{\zeta_s A z_{st} \hat{p}_{st}}{p_k \tilde{R}}\right)^{\frac{1}{1-\zeta_s}} \tag{14}$$

The input choice for the staple crop farmer receiving price $\hat{p}_{st}$ is:

$$k_s(z_{st}, a_t; \hat{p}_{st}) = \min\{k_s^u(z_{st}, \hat{p}_{st}), \frac{\phi a_t}{p_k}\} \tag{15}$$

Henceforth, we shall denote the dependence of the input choice on received price $\hat{p}_{st}$ parsimoniously by $k_{st}(\hat{p}_{st})$. One obtains an expression for staple crop production that is similar to the corresponding expression derived for cash crop farmers.

The profit of a staple crop farmer with state vector $\{z_{st}, z_{rt}, \tau_t, a_t\}$, saving a_t and receiving price $\hat{p}_{st}$ is:

$$\Pi_s(z_{st}, a_t; \hat{p}_{st}) = \hat{p}_{st}(Az_{st})\left[k_{st}(\hat{p}_{st})^{\zeta_s}\right] - \tilde{R}_t p_k k_{st}(\hat{p}_{st}) - \mu(z_s, z_r, \tau, a)\rho \tag{16}$$

Depending on whether procurement is chosen or not, i.e. if $\mu(z_s, z_r, \tau, a) = 1$ or $\mu(z_s, z_r, \tau, a) = 0$, which shall be discussed below, one obtains the input choices, staple crop output and profit:

$$k_s(z_{st}, a_t) = \mu(z_s, z_r, \tau, a) \times k_s(z_{st}, a_t; \bar{p}) + \left(1 - \mu(z_s, z_r, \tau, a)\right) \times k_s(z_{st}, a_t; p_{st}) \tag{17}$$

$$y_s(z_{st}, a_t) = \mu(z_s, z_r, \tau, a) \times y_s(z_{st}, a_t; \bar{p}) + \left(1 - \mu(z_s, z_r, \tau, a)\right) \times y_s(z_{st}, a_t; p_{st}) \tag{18}$$

$$\Pi_s(z_{st}, a_t) = \mu(z_s, z_r, \tau, a) \times \Pi_s(z_{st}, a_t; \bar{p}) + \left(1 - \mu(z_s, z_r, \tau, a)\right) \times \Pi_s(z_{st}, a_t; p_{st}) \tag{19}$$

3.5 Utility maximization and Occupational choice

An individual can choose to be either a farmer of cash or staple crops in the agricultural sector or a worker in the non-agricultural sector. Workers in the non-agricultural sector face idiosyncratic productivity shocks denoted by τ_t, drawn from a lognormal distribution with mean μ_τ and standard deviation σ_τ. Thus, a worker with productivity τ_t who inelastically supplies one unit of labour effectively supplies τ units of labour, leading to labour earnings of $\tau_t w_t$. The relevant state vector is therefore $(z_{st}, z_{rt}, \tau_t, a_t)$. To ease notation, we shall denote the shock vector (z_{st}, z_{rt}, τ_t) by $\mathbf{z}$. We shall also use primes to denote variable values in the next period.

If the agent chooses to be a farmer in sector $j = r$, she obtains the profit from operating her farm, $\Pi_r(z_{rt}, a_t)$ specified in the equations above. Similarly, if the agent chooses to be a staple crop farmer, she obtains the profit $\Pi_s(z_{st}, a_t; \hat{p}_{st})$ depending on the received price $\hat{p}_{st}$.

Consider first the value associated with working in the non-agricultural sector.

$$V^w(\mathbf{z}, a) = \max_{c_r, c_n, c_s, a'} u(c^{\text{ration}} + c_s, c_r, c_n) + \beta \mathbb{E}_{\mathbf{z}'} V(\mathbf{z}', a') \tag{20}$$

subject to:

$$p_r c_r + p_s c_s + c_n + a' = \tau w + a(1 + \tilde{r})$$

Note that total staple crop consumption is the free ration c^{ration} plus the amount chosen, c_s.

Next, consider the value associated with becoming a farmer of the cash crop:

$$V^r(\mathbf{z}, a) = \max_{c_r, c_n, c_s, a'} u(c^{\text{ration}} + c_s, c_r, c_n) + \beta \mathbb{E}_{\mathbf{z}'} V(\mathbf{z}', a') \tag{21}$$

subject to:

$$p_r c_r + p_s c_s + c_n + a' = \Pi_r(z_r, a) + a(1 + \tilde{r})$$

Similarly, the value associated with becoming a farmer of the staple crop is the upper envelope of the value functions associated with receiving market or support prices:

$$V^s(\mathbf{z}, a, \hat{p}_s) = \max_{c_r, c_n, c_s, a'} u(c^{\text{ration}} + c_s, c_r, c_n) + \beta \mathbb{E}_{\mathbf{z}'} V(\mathbf{z}', a') \tag{22}$$

subject to:

$$p_r c_r + p_s c_s + c_n + a' = \Pi_s(z_s, a, \hat{p}_s) + a(1 + \tilde{r})$$

Hence, $V^s(\mathbf{z}, a) = \max\{V^s(\mathbf{z}, a, p_s), V^s(\mathbf{z}, a, \bar{p})\}$. This leads to associated procurement choices:

$$\mu(\mathbf{z}, a) = 1 \text{ if } V^s(\mathbf{z}, a, p_s) \leq V^s(\mathbf{z}, a, \bar{p}) \tag{23}$$

$$\mu(\mathbf{z}, a) = 0 \text{ if } V^s(\mathbf{z}, a, p_s) > V^s(\mathbf{z}, a, \bar{p}) \tag{24}$$

The value function $V(\mathbf{z}, a)$ for an agent with saving a and shocks $\mathbf{z} = \{z_s, z_r, \tau\}$ is the maximum of the choice-specific value functions:

$$V(\mathbf{z}, a) = \max\{V^s(\mathbf{z}, a), V^r(\mathbf{z}, a), V^w(\mathbf{z}, a)\} \tag{25}$$

This yields the occupational choice functions:

$$\omega(\mathbf{z}, a) = 1, \ \sigma(\mathbf{z}, a) = 0 \ \text{ if } V(\mathbf{z}, a) = V^w(\mathbf{z}, a) \tag{26}$$

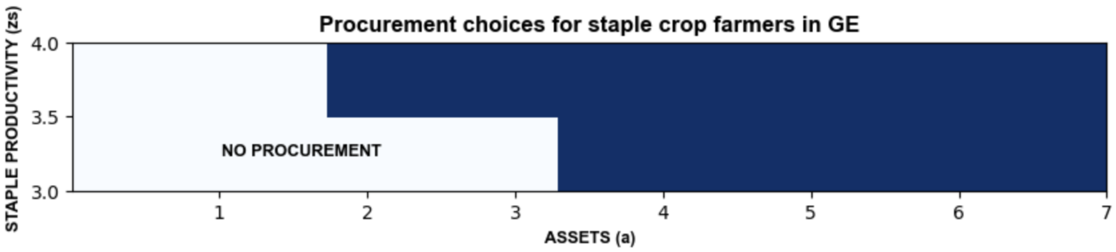
$$\omega(\mathbf{z}, a) = 0, \ \sigma(\mathbf{z}, a) = 1 \ \text{ if } V(\mathbf{z}, a) = V^s(\mathbf{z}, a) \tag{27}$$

$$\omega(\mathbf{z}, a) = 0, \sigma(\mathbf{z}, a) = 0 \ \text{ if } V(\mathbf{z}, a) = V^r(\mathbf{z}, a) \tag{28}$$

3.5.1 Procurement choice

Staple crop farmers have the option to sell their produce at the support price subject to incurring the fixed cost of procurement. As described in the model above, this boils down to a comparison of the value to a staple crop farmer of selling produce at the support price subject to the fixed cost of procurement against the value of selling produce at the market price. This suggests that farmers with profits above a certain threshold would choose to incur the fixed cost in order to sell at the MSP. Further, productive staple crop farmers with sizable assets, who are therefore less constrained, would tend to earn profits above the threshold for procurement to be chosen. These predictions are confirmed in Table 2, where the coloured region represents procurement choice. Note that relatively less productive staple crop farmers have a higher asset threshold for procurement choice.

Figure 2: Procurement choice for staple crop farmers



3.5.2 Selection effect of agricultural policies

Policies like the support price program may encourage individuals on the margin to shift toward working in the subsidized sector (staple crops), compared to what they would do in the program's absence. The sector-specific value functions reveal that conditional on asset, occupational choices depend on a comparison of the current payoffs (wages or profits) of agents across sectors. Suppose an agent with state vector $(\mathbf{z}, a)$ has the following payoff profile across sectors:

$$\Pi^s(z_s, a; \bar{p}) - \rho > \max\{w\tau, \Pi^r(z_r, a)\} > \Pi^s(z_s, a; p_s) \tag{29}$$

This represents a scenario where an agent who would have chosen either non-agricultural labour or cash crop farming over staple cultivation, but is induced by the support price program to choose staple cultivation. We refer to this as the *selection effect* of MSP program. To understand the selection effects better in the presence of financial frictions, first consider the case where the staple crop farmer with state vector $(\mathbf{z}, a)$ is unconstrained in input choice. Using the expressions for input choice described in the model above, equation (29) becomes:

$$\left(\frac{\zeta_s}{\tilde{R}p_k}\right)^{\frac{\zeta_s}{1-\zeta_s}}(1-\zeta_s)\left(\lambda p_s A z_s\right)^{\frac{1}{1-\zeta_s}} - \rho > \max\{w\tau, \Pi^r(z_r, a)\} > \left(\frac{\zeta_s}{\tilde{R}p_k}\right)^{\frac{\zeta_s}{1-\zeta_s}}(1-\zeta_s)\left(p_s A z_s\right)^{\frac{1}{1-\zeta_s}} \tag{30}$$

In the expression above, λ denotes the scaling factor linking the support price to the market price of staples. The support price leads to greater revenue given a certain output, but also increases output through higher demand of intermediate inputs. The inequalities representing sectoral misallocation of agents would typically tend to hold when z_s is neither too low (in which case the other sectors would be chosen even with a support price program in place) nor too high (in which case staple cultivation would be chosen regardless of the support price program)[20].

Next, we consider the benchmark model with working capital constraints. Input choice for constrained farmers is $\frac{\phi a}{p_k}$, and the misallocation inequalities become:

$$\left(\frac{\phi a}{p_k}\right)^{\zeta_s}\left(\lambda p_s A z_s\right) - \phi a - \rho > \max\{w\tau, \Pi^r(z_r, a)\} > \left(\frac{\phi a}{p_k}\right)^{\zeta_s}\left(p_s A z_s\right) - \phi a \tag{31}$$

Profits from cultivation fall when working capital constraint binds leading to sectoral misallocation over a larger range of staple crop productivity realisations (z_s). The MSP policy increases input demand leading to higher agricultural productivity, but reduces agricultural productivity through inefficient sorting of labour.

The input subsidy program similarly generates a selection effect by increasing farming profits through greater input intensity, making it more attractive than working in the non-agricultural sector. So far, we highlighted the selection effect in partial equilibrium i.e., keeping prices fixed. Below, we will quantify the strength of the selection effect and input intensity on agricultural productivity in general equilibrium.

3.6 Stationary equilibrium

A stationary competitive equilibrium is defined in the usual manner. It comprises an invariant distribution F, value functions $\{V^s, V^r, V^w, V\}$ with associated decision rules $\{\omega, \sigma, \mu, c_r, c_s, c_n, a'\}$ and prices $\{p_s, p_r, \bar{p}, w, \tilde{r}\}$ that solve the agents' and firm's optimisation problems detailed above. In the following, we list the market clearing conditions and the equation that updates the distribution of agents in the economy.

1. Markets clear:

[20] The fixed cost determines the degree of salience of the program. Keeping parameter values at their benchmark levels from the calibration in section 4, we find that selection effects are close to zero in an economy without financial constraints.

(a) Non-agricultural good:

$$\int_{\mathbf{z}\times A} c_n(\mathbf{z},a)\ dF(\mathbf{z},a) + \int_{\mathbf{z}\times A} \left(1-\omega(\mathbf{z},a)\right)\ \sigma(\mathbf{z},a) p_k k_s(z_s,a) dF(\mathbf{z},a) + \int_{\mathbf{z}\times A} \left(1-\omega(\mathbf{z},a)\right)\left(1-\sigma(\mathbf{z},a)\right)\ p_k k_r(z_s,a)\ dF(\mathbf{z},a) = y_n \quad (32)$$

(b) Cash crop:

$$\int_{\mathbf{z}\times A} c_r(\mathbf{z},a)\ dF(\mathbf{z},a) = \int_{\mathbf{z}\times A} \left(1-\sigma(\mathbf{z},a)\right)\left(1-\omega(\mathbf{z},a)\right)\ y_r(z_r,a)\ dF(\mathbf{z},a) \quad (33)$$

(c) Marketed staple crops: total staple crops purchased for an agent with state $(\mathbf{z},a)$ is given by $c_s(\mathbf{z},a)$. On the supply side, a fraction $1-\mu(\mathbf{z},a)$ of the amount produced is sold on the market.

$$\int_{\mathbf{z}\times A} c_s(\mathbf{z},a)\ dF(\mathbf{z},a) = \int_{\mathbf{z}\times A} \sigma(\mathbf{z},a)\left(1-\mu(\mathbf{z},a)\right)\ y_s(z_s,a)\ dF(\mathbf{z},a) \quad (34)$$

(d) Asset market:

$$\int_{\mathbf{z}\times A} a^{'}(\mathbf{z},a)\ dF(\mathbf{z},a) = k_n + \int_{\mathbf{z}\times A} \left(1-\omega(\mathbf{z},a)\right) p_k k_j(\mathbf{z},a)\ dF(\mathbf{z},a) \quad (35)$$

(e) Rationed staple crops: these are disbursed equally to all agents

$$c^{\text{ration}} = \int_{\mathbf{z}\times A} \sigma(\mathbf{z},a)\mu(\mathbf{z},a)\ y_s(z_s,a)\ dF(\mathbf{z},a) \quad (36)$$

(f) Labour market: Demand for workers by non-agricultural firms equals effective labour supplied to the non-agricultural sector:

$$n_n = \int_{\mathbf{z}\times A} \omega(\mathbf{z},a)\ \tau\ dF(\mathbf{z},a)$$

2. The distribution F evolves as per:

$$TF(z_s', z_r', \tau', a') \quad = \quad \int_{\mathbf{z}\times A} \mathbb{I}_{\{a'(\mathbf{z},a)=a'\}} \quad dF(\mathbf{z}, a) \qquad \forall (z_s', z_r', \tau', a') \quad \in \quad \mathbf{z} \ \times \ A \tag{37}$$

Here, $\mathbb{I}_{\{a'(\mathbf{z},a)=a'\}}$ is an indicator function that takes the value 1 when an agent with state $(\mathbf{z}, a)$ has saving a'. T is an operator that maps distributions into distributions.

4 Calibration

We calibrate some parameters of the model internally, either to match certain moments of the Indian economy, or to match quasi-experimental empirical evidence from the fertiliser deregulation and cash transfer programs discussed below. The rest of the parameters are chosen based on the literature.

4.1 Internally calibrated parameters

Working capital constraint estimation

To pin-down the key working capital constraint parameter ϕ, we bring to bear a permanent income transfer program in India that increased investment in intermediate inputs (fertilizers). The Pradhan Mantri Kisan Samman Nidhi (PMKSN) policy promises a perpetual cash transfer to landowning farmers of Rs 6000 (equivalent to 6.25% of their annual income). The government launched the program in 2019 to provide insurance against adverse income shocks given the low take-up of crop insurance by farmers. Ghosh and Vats (2022) finds that the program increases farmers' income through higher credit demand and investments on the farm. We argue that the program also helps in increasing fertilizer use by relaxing a farmer's financial constraints.

We employ a difference-in-differences (DiD) framework to estimate the impact of the program. Although the government attempted to implement the program nationwide, the state of West Bengal initially opted out due to disagreements with the federal government over how the transfers should be distributed to farmers. They eventually joined the program in May 2021. The regression specification we employ is:

$$Y_{dt} = \alpha + \phi_d + \phi_t + \beta^{-1} \times \mathrm{T}_s \times 1_{\{2016 \leq t \leq 2017\}} + \beta \times \mathrm{T}_s \times 1_{\{t=2019\}} + \varepsilon_{dt} \tag{38}$$

where Y_{dt} is the outcome of district d at time t, T_s is a dummy referring to the treated states, $\mathbf{1}_{t=2019}$ is a dummy variable that takes value 1 for the year 2019 and $\mathbf{1}_{2016\leq t\leq 2017}$ is a dummy variable that takes value 1 for years before 2018[21]. β measures the average treatment of the outcome of interest: the log of the total value of nitrogen, phosphorous and potash fertilizers[22].

The first column of Table 1 highlights the increase in output due to the policy, consistent with the findings in Ghosh and Vats (2022). The second column shows that some of the increase in output occurred through fertilizer consumption rising by 8.5%[23,24]. These results highlight the presence of financial frictions that limit the use of intermediate input use in the Indian context. The parameter ϕ in the working capital constraint is chosen to equal 1.275 to match the increase in aggregate intermediate input demand when cash-in-hand for farmers' increases by 6.25% of their annual income. This parameter value is similar to the parameterization for Asian economies (Moll, 2014; Itskhoki & Moll, 2019), and lower than typically assumed for advanced economies, like US (Morazzoni & Sy, 2022). This is intuitive as developing countries are likely to experience stronger financial barriers than developed economies.

Table 1: Effect of transfer program on output and fertilizer use

Dependent variables: Log Output or Log of Total Fertilizer value		
	Output (tonne) (1)	Total Fertilizer value (Rs.) (2)
Treatment Effect	0.121***	0.085**
	(0.044)	(0.036)
Pre-treated effect	0.061	-0.025
	(0.050)	(0.029)
Observations	2216	1960
R^2	0.965	0.966
Outcome Mean	22.915	19.826

Note: The coefficients show the average treatment and pre-treated effects. The sample size changes as we restrict regressions to a balanced panel in each case. Standard errors clustered at the district level are reported in parentheses. ***, ** and * represent the statistical significance at 1%, 5% and 10% levels respectively.

[21] We focus on the years between 2016 and 2019 to ensure our estimates are not driven by the pandemic period, or the anticipation of West Bengal joining the program in 2021.

[22] We use data from CMIE States of India. Appendix C contains details about the dataset.

[23] The insignificant pre-treated effects imply that there were no differences in fertilizer use between the treated and control states. Appendix Figures A7a and A7b shows the estimates using an event-study specification.

[24] Appendix Table B1 shows the cash transfer program increased demand of nitrogen and phosphorous. Our results are consistent with Ghosh and Vats (2022) and Varshney et al. (2021) on the effect of the policy on fertilizer consumption. Varshney et al. (2021) show that the program increased the likelihood of farmers in Uttar Pradesh to use fertilizer (extensive margin), while Ghosh and Vats (2022) shows the beneficial impact on input usage on more versus less treated areas through a continuous difference-in-differences specification.

Production function estimation

To estimate the ζ parameters, which are the intermediate input shares, we rely on a policy change following Garg and Saxena (2022) wherein the government deregulated prices of key fertilizers from its cost of production for fertilizer manufacturers. This reduction in the effective subsidy for non-urea fertilizers resulted in an approximate 110% increase in their weighted average price[25,26].

We utilize a DiD framework to isolate the impact of the deregulation on agricultural production and use it to estimate the elasticity of production to intermediate input in the model with a similar experiment. The regression specification is:

$$Y_{dt} = \alpha + \phi_d + \phi_t + \beta^{-1} \times \mathrm{T}_d \times 1_{\{2004 \leq t \leq 2008\}} + \beta \times \mathrm{T}_d \times 1_{\{2010 \leq t \leq 2017\}} + \varepsilon_{dt} \tag{39}$$

where Y_{dt} is the outcome of district d at time t, T_d is a dummy referring to the treated districts, $\mathbf{1}_{2010 \leq t \leq 2017}$ is a dummy variable that takes value 1 for the years from 2010 onwards and $\mathbf{1}_{2004 \leq t \leq 2008}$ is a dummy variable that takes value 1 for years before the last period from the year of implementation of the policy (2004 to 2008).

Garg and Saxena (2022) use this natural experiment in a continuous DiD setting to demonstrate that agricultural production fell more in areas with a higher fertilizer use. We use a discrete DiD specification, as the reduced-form coefficient corresponds to the impact of reducing fertilizer subsidy in the model counterfactual. Callaway et al. (2024a) show that the standard two-way fixed effect with a continuous treatment does not capture the level treatment effect[27].

Our outcomes of interest are the natural log of the value of agricultural output and natural log of yield (output per unit of area)[28]. To determine treatment and control groups, we construct a measure of fertilizer use intensity by taking a weighted average of phosphate and

[25] Appendix Figure A8a shows the median nominal price per kilogram paid by farmers for each fertilizer type from 2004-2017. Prices of phosphate and potassium rose significantly after 2009 until 2012 before stabilizing at a higher level. Appendix Figure A8b shows that this led to a substantial reduction in consumption of non-urea fertilizers at the district-level

[26] The price of urea rose moderately in 2011 and 2012 but then did not change in spite of the sharp price increase in the international market (Bansal & Rawal, 2020)

[27] To do so in a continuous treatment setting, one needs to aggregate the causal response parameter over the entire distribution of treatment intensity. This requires either making parametric assumptions or building non-parametric estimators (Callaway et al., 2024b). On the other hand, Callaway et al. (2024a) show that even in a setting with no untreated districts, if the control group is defined as districts with the lowest treatment intensity and the change in outcome of the least treated unit is close to zero, then the β coefficient in the discrete DiD captures the 'true' treatment effect.

[28] The Ministry of Agriculture & Farmers Welfare provides district-level production and area cultivated data from 2004 to 2017 covering 20 major Indian states and 48 crops. The sample data covers 88% of national gross area sown.

potash fertilizer consumption per unit of area at the district level between 2005 and 2009[29]. We assign districts below the 5th percentile of fertilizer usage to the control group[30].

Table 2: Effect of fertilizer deregulation on agricultural production

Dependent variables: Log Output or Log Yield or Log Area			
	Output (tonne) (1)	Yield (tonne per ha) (2)	Area (hectare) (3)
Treatment Effect	-0.27***	-0.26***	-0.00
	(0.10)	(0.09)	(0.03)
Pre-treated effect	-0.09	-0.10	0.03
	(0.08)	(0.08)	(0.02)
Observations	7056	7056	7056
R^2	0.92	0.88	0.94
Outcome Mean	19.93	7.54	12.39

Note: The coefficients show the average treatment and pre-treated effects. Standard errors clustered at the district level are reported in parentheses. ***, ** and * represent the statistical significance at 1%, 5% and 10% levels respectively.

Table 2 shows that both output and yield (columns 1 and 2, respectively) decreased by nearly 26%, indicating that the policy had no impact on the amount of land allocated to agriculture production (column 3). The results are consistent with the reduced-form findings by Garg and Saxena (2022) in the Indian context and with studies in other countries on the impact of fertilizer subsidies on agricultural output (Beaman et al., 2013; Carter et al., 2021; B. Z. Diop, 2022; Ghose et al., 2023)[31]. Furthermore, Table 2 highlights that districts in the control and treated groups display no significant differences[32,33].

The agricultural production function parameters ζ_s and ζ_r are chosen to match the reduced-

[29] The formula to compute fertilizer intensity at district-level is:

$$\text{Fertilizer Usage Intensity}_d = \frac{1}{6}\sum_{t=2004}^{2009}\frac{p_P F_{Pdt} + p_K F_{Kdt}}{\text{Area Sown}_{dt}} \tag{40}$$

where p_i and F_{idt} are price and consumption of fertilizer $i = \{P, K\}$, respectively. ICRISAT provides data on district-level fertilizer consumption, and the median price paid by a farmer in the CCS survey is used to compute fertilizer price.

[30] Appendix Figures A9a and A9b show a binned scatter plot of the change in log average production and log average yield, respectively, before (2005-2009) and after (2010-2016) the policy against fertilizer use intensity. Agricultural output and yield fell much more in districts that were exposed more to the policy, which validates our empirical approach. Moreover, the change in output is the lowest after the policy for the districts below the 5th percentile, which leads us to assign those districts as the control group.

[31] Our magnitudes are also comparable with B. Z. Diop (2022); B. Z. Diop (2022) finds that a 50% rebate on purchase of fertilizers in Zambia increased yields by 15%, while we show that yields fell by 26.4% given an increase in effective fertilizer price of 110%.

[32] Appendix Figures A10a and A10b show the treatment and pre-treatment effects using an event-study design.

[33] Appendix Table B2 shows the average treatment and pre-treated response of log output and log yield using the baseline (5th), 10th, 15th, and 20th percentiles to create control groups. The average treatment impact is similar using the alternate cutoffs values, but pre-trends exist among each of the alternate cutoffs.

form estimate of the fall in agricultural production following the 110% increase in fertilizer price[34]. Since, we cannot rule out general equilibrium effects in our empirical analysis as they were based on regional-level analysis, we target the general equilibrium effect of raising input price in the model. Moreover, Appendix Table B3 shows that the effect of the policy on cash and staple production is not very different from each other. Hence, we assume that the share of intermediate input is equal in cash and staple crops. We estimate $\zeta_s = \zeta_r = 0.43$, implying a residual labour share of 57%. This is consistent with both the empirical labour share of value added in agriculture in India (55% in 2009, RBI India KLEMS Database) and commonly observed values for developing countries (Bolhuis et al., 2021; Chen et al., 2022).

Other internally calibrated parameters

The standard deviations of crop-specific shocks, η_r, η_s, are assumed to be equal and are chosen to match household-level variation in average crop harvest across all crops, which is 0.58 from wave one (2004) of the Indian Human Development Survey (IHDS). Only the first wave of IHDS contains information about the type and value of crops grown and inputs used in agriculture production. We estimate the household-level variance in crop harvest by removing the variation that we do not model here, following Donovan (2021) and others. We regress household level harvest on dummies of family size, married males, married females, religion and caste, gender of household head and education, total types of crops grown, harvest season, intermediate inputs usage, labour usage, district, and age.[35] These factors explain 62% or roughly two-thirds of the total variation in log agricultural harvest. We match the variance of the residual term in the above regression, implying that $\eta_r = \eta_s = 0.425$. The model implied standard deviation in harvest is similar to the estimate of 0.32 by Donovan (2021).

The standard deviation of the idiosyncratic productivity shock, η_n, in the non-agricultural sector is chosen to match the 2012 agricultural employment share in India of 48%. The resulting value of η_n is 0.6.

The subsistence requirement, $\bar{c}$, is chosen to match the ratio of staple to cash production value of 1.17 from IHDS-I.

The fixed cost of procurement, ρ, is chosen to match the share of staple crops procured,

[34] The effect of the working capital constraint will also be accounted in affecting intermediate input demand as these parameters are estimated jointly.

[35] Dummies for intermediate inputs and labour usage includes irrigation used or not, fertilizers used or not, pesticides used or not, machinery used or not, and four categories of labour employed (0, 1-10, 11-100 and greater than 100).

Table 3: Targeted Moments

Parameter	Value	Target/Source	Data	Model
Standard dev. of agricultural shocks $\{\eta_s, \eta_r\}$	0.425	Variance of all crops (IHDS-I)	0.58	0.58
Standard dev. of non-agri shock η_n	0.6	Agricultural employment share in 2012	48%	48%
Fixed cost of procurement ρ	0.205	Share of staple crops procured in 2011 (RBI, IndiaStat)	32%	32%
Subsistence requirement $\bar{c}$	0.01	Value of staple relative to cash crop production (IHDS-I)	1.17	1.59
Agriculture production function $\{\zeta_s, \zeta_r\}$	0.43	$\frac{\Delta(\sum_j k_j)}{\Delta p_k}\vert_{\Delta p_k=1.1}$ (Table 2)	–26.4%	–25%
Working capital constraint ϕ	1.275	$\frac{\Delta(\sum_j k_j)}{\Delta \text{Income}}\vert_{\Delta \text{Income}=6.25\%}$ (Table 1)	8.5%	6%

which is around 32% in 2011 (Reserve Bank of India).

4.2 Externally chosen parameters

We normalize the sector-neutral TFP A to 1. We calibrate the preference parameters to the US as a benchmark, setting $\phi_s = 0.13$ and $\phi_r = 0.06$. Staple includes food, whereas expenditure on beverages, clothes, personal care and tobacco captures spending on cash crops. Using the consumption shares for the US economy implies that preferences are not changing along the development path, which is standard practice in the literature. In the benchmark equilibrium that is calibrated to the Indian economy, this results in an equilibrium staple crop price that exceeds the equilibrium cash crop price. θ, the risk-aversion coefficient, which is also inverse of the elasticity of substitution across crops, is set at 2.

The discount factor, $\beta = 0.9$, is chosen to lie between the $\beta = 0.85$ value chosen by Buera et al. (2021) and the $\beta = 0.96$ chosen by Donovan (2021). Moreover, we show below that the model-implied saving rates are quite close to their empirical counterparts. The labour share of income, $\alpha = 0.67$, as is standard. The intermediate input price is exogenously set at $p_k = 2.77$, following Donovan (2021) and Restuccia and Rogerson (2008).

The support price $\bar{p}$ is set to be $1.07 * p_s$, based on the empirical ratio of MSP to market price[36].

[36] We use the nationally representative Land and Livestock Holding Survey of 2018 (NSS 77th Round) to determine the price received by the farmer for rice or wheat. Price is equal to the average value divided by the quantity sold. We compare the price received with the national support price. Appendix Figure A11 shows the distribution of market price to support price. Chatterjee et al. (2020) also reports that market price can fall below the support price in regions with low procurement of grains.

4.3 External validity: comparing the model's predictions against the data

We now consider a couple of external validity tests of the model. In the first set of tests, we compare the model's predictions about the relationship between asset holdings, intermediate input usage and harvest value at the household level. Finally, we compare the model's performance in the aggregate versus the data. Overall, the model and the data match well.

4.3.1 Relationship between assets, intermediate input usage and harvest value

We estimate the relationship between asset holdings and intermediate input usage or harvest value using simulated data obtained from the model and in the data. To compute the regressions in the model, we simulate 500,000 households in the stationary equilibrium of the calibrated model. Standard errors are computed by bootstrapping 1000 samples of populations equal to the ICRISAT sample size. As households in the simulated data can switch across sectors, the regressions are run using simulated data for households in periods where they choose the agricultural sector.

We follow Donovan (2021) to obtain these relationships in the data. We use the ICRISAT Village Level Studies (VLS) panel from India over the period 2009 to 2014. The regression specification is:

$$y_{i,t} = \alpha + \beta \times a_{i,t-1} + \gamma X_{i,t} + \epsilon_{i,t} \tag{41}$$

where $y_{i,t}$ is the dependent variable at time t for household i. The outcomes considered are intermediate expenditures $p_k k_j$, $\{j = s, r\}$ and the harvest value $(p_j y_j)$. Asset holdings are lagged to limit any risk of observing the empirical counterpart of the savings choice in period t, $a'(\mathbf{z}, a)$, instead of asset holdings in period t, a. To make the data more comparable to the model, the data regressions include controls $X_{i,t}$, such as village and year dummies, and village-level time trend[37]. In all regressions, both dependent and independent variables are normalized by their respective means.

Table 4 demonstrates that the model predictions and data generally match well. There is a strong positive association between asset holdings and input expenditure (columns 1 and 2). Unlike the model in Donovan (2021), there is an implied relationship between input usage and asset holdings for constrained farmers that would serve to increase the dependence of the outcomes considered on asset holdings. Indeed, agents with low asset holdings do not sort into

[37]Other controls include number of adult men, adult women and kids in the household, and gender, education, age and age squared of the household head.

Table 4: Savings and agricultural outcomes: model and data

	Input expenditure		Harvest value	
	Data (1)	Model (2)	Data (3)	Model (4)
Saving	0.414***	0.586***	0.382***	0.293***
	(0.066)	(0.021)	(0.080)	(0.025)
Observations	2390	n.a.	2390	n.a.
R^2	0.335	0.352	0.334	0.07

Significance at 0.01, 0.05 and 0.1 levels are denoted by ***, ** and * respectively. Standard errors shown in parentheses. Standard errors in the data are clustered at household level. Standard errors in the model are bootstrapped using 1000 samples of 478 individuals. Dependent and independent variables are normalized by sample mean.

agriculture owing to the working capital constraint. Finally, the association between harvest value and savings is significant (columns 3 and 4), but the model slightly under-predicts the relationship.

4.3.2 Non-targeted moments

In Table 5, we report some over-identifying moments that have not been targeted in the calibration. First, the implied aggregate saving rate of the economy equals 28.6%, which is close to the 26% saving rate in 2010 obtained from the World Development Indicators. Our model also replicates the pattern of savings rates by occupation. The model implied agricultural saving rate is 16.5% is very close to the saving rate in the data 15.9% (IHDS-I); while the model implied non-agricultural saving rate 39.6% is a bit higher than in the data (29.4%). Second, the model also matches the share of staple crop farmers relative to cash crop farmers. The model implied share of staple crop farmers is 63%, while the empirical counterpart is 65.2%[38]. Third, the model generates a ratio of labour productivities of the non-agricultural to the agricultural sector (net of intermediate input usage) that exceeds one but is lower than the ratio of 4.33 for 2010 estimated using the India KLEMS database. Fourth, we also compute the relative income of agriculture to non-agriculture to be equal to 0.79, which is almost equal to the corresponding ratio of 0.78 from IHDS-II.

[38] Appendix Figure A12 shows the distribution of output devoted to staple crop farming in the IHDS-I data. Farmers with more than 75% of output devoted to staple crop farming are defined as staple crop farmers.

Table 5: Non-targeted moments

Moment/Source	Data	Model
Aggregate saving rate	26%	28.6%
Agricultural saving rate	15.9%	16.5%
Non-agricultural saving rate	29.4%	39.6%
Share of staple crop farmers in agriculture	65.2%	63%
Relative labour productivity of non-agriculture to agriculture	4.33	1.13
Relative income of agriculture to non-agriculture	0.78	0.79

5 Results

In this section, we discuss the results of various counterfactual exercises conducted using the calibrated general equilibrium model presented above. Our benchmark model is one in which the minimum support price policy is present. First, we examine the implications of the support price program. This involves a counterfactual exercise wherein we evaluate equilibrium outcomes when the support price program is removed, followed by a decomposition of the channels driving the results so obtained. Second, in order to investigate the role of the input price subsidy, we conduct a counterfactual exercise wherein we increase the price of the intermediate input, p_k, by 110% (mimicking the fertiliser price deregulation episode discussed in section 4.1) from its benchmark value of 2.77 and then evaluate resulting equilibrium outcomes. Third, we discuss the welfare implications of these policies. Finally, we discuss the role of the working capital constraint, the fixed cost of procurement and the subsistence requirement on outcomes relative to the calibrated benchmark.

5.1 Counterfactual exercise: removing the MSP

Figure 3 depicts the impact on occupational choices for marginal agents when prices adjust in general equilibrium, i.e. we focus on agents who are likely to switch occupations in general equilibrium following a change in the minimum support price policy[39]. While agents with low realizations of z_s and z_r remain as workers in the non-agricultural sector, agents with high $z_s(z_r)$ and low $z_r(z_s)$ choose staple (cash) crop farming.

[39]The partial equilibrium outcomes of the counterfactual exercises conducted here, wherein all prices are kept fixed, are listed in Table B4 in the appendix. They are essentially unchanged from the benchmark, indicating that the share of marginal staple crop farmers that are induced away from another sector (Section 3.5.2) is negligible and that the loss of rations does not influence occupational choice when prices are kept fixed. Further, a sizable share of the farmers who choose procurement in the benchmark equilibrium are constrained. Hence, the removal of procurement only slightly affects their production, as their input choice is determined by the working capital constraint. The unconstrained farmers opting for procurement tend to be those with relatively low staple crop productivity, hence their input demand is not significantly affected by the removal of procurement.

As compared to the benchmark case, in the absence of the minimum support price policy, which served to raise received crop prices for staple farmers and boosted their demand for the intermediate input, individuals with relatively low productivity in the staple crop sector are incentivised to move out of staple crop farming toward the non-agricultural sector. In Table 3, the band labelled 'ΔWORKERS' represents those agents who switch to the non-agricultural sector upon the removal of the MSP.

Figure 3: Occupational choices: removing MSP

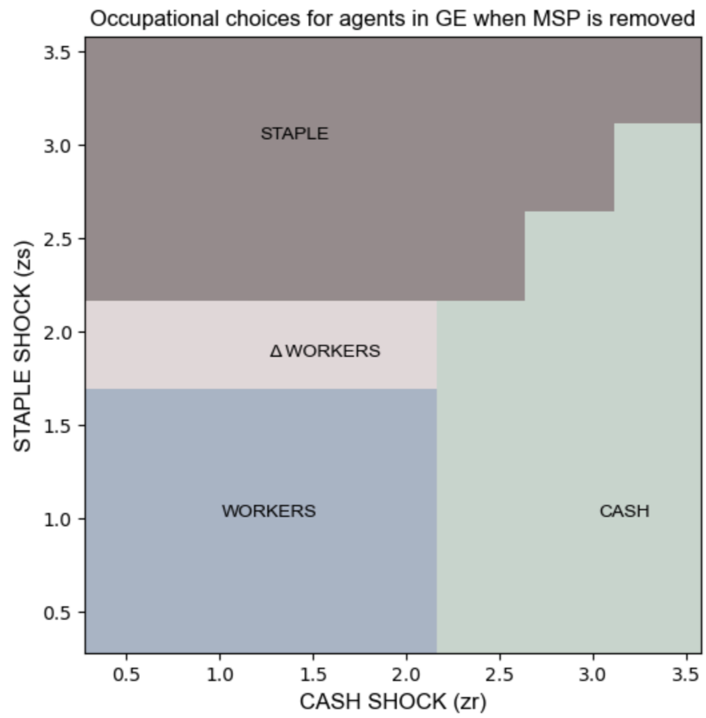


Table 6 displays the quantitative results obtained in general equilibrium from this counterfactual exercise (Column 2) to the benchmark (Column 1). In general equilibrium, an outflow of staple crop farmers to the non-agricultural sectors raises the share of non-agricultural workers. This influx of labour into the non-agricultural sector drives wages down, with the increased capital demanded by non-agricultural firms outweighing the reduction in intermediate input usage, leading to a slightly higher interest rate. There is a decline in the staple crop price, p_s. This is because staple crops hitherto procured by the government are now supplied to the market, which brings down the market price of staple crops. The resulting fall in staple farmers' incomes lowers their demand for both crops, while substitution away from the cash crop to the cheaper staple crop brings the price of the cash crop down as well. This, in turn, leads to an income effect, thereby lowering demand for crops even further. Lower profitability of cash crop producers leads to a sizable outflow from that sector to the non-agricultural sector. The absence of procurement reduces intermediate input demand and, hence, production for farmers of staple crops. A lower cash crop price also reduces intermediate input usage and production of cash crops. However, this reduction in the value of agricultural production is countered by a rise in non-agricultural production as more agents switch toward that sector. The overall value of production, $\sum_j p_j y_j$, falls slightly. Real output, which is calculated using benchmark equilibrium prices, rises slightly as the production of both crops doesn't fall enough to offset the increased production of the non-agricultural good.

The labour productivity of the non-agricultural sector relative to the agricultural sector (the *labour productivity gap*) falls, while the labour productivity of cash relative to staple crops rises. These ratios are computed using prices in the benchmark equilibrium, $\{p_s^*, p_r^*\}$. In the case of the former, we note that the labour productivity gap is given by $\frac{y_n}{p_s^* y_s + p_r^* y_r} \frac{\text{Employment}_{\text{agri}}}{\text{Employment}_{\text{nonagri}}}$. The decline in the labour productivity gap is driven by the sizable rise in non-agricultural employment, which offsets the reduction in intermediate input usage (leading to a fall in production) by the agricultural sector. In the case of the cash-staple labour productivity ratio, the rise is mainly driven by the sharp fall in the employment share of the cash crop sector.

5.1.1 Decomposing the effects of removing the MSP

The results above highlight three effects associated with the removal of MSP, viz. (a) the loss of support prices received by staple crop farmers, (b) the loss of staple crop rations by all agents in the economy, and (c) the release of formerly procured staple crops on the market. We disentangle these effects by taking away one of these three attributes of the support price program at a time and evaluating equilibrium outcomes. This will allow us to consider the importance of the dropped attribute in explaining the equilibrium outcomes listed in column 2 of Table 6.

We begin by considering an environment where the MSP policy is retained, but all (or a significant fraction of) procured crops are disposed of or thrown away [40,41]. We shall refer to this as the 'procure-disposal' program. This program retains two facets of the support price program: (i) procurement at support prices and (ii) the limited supply to the market. However, rations are replaced (reduced). We find that such a program results in a higher staple crop

[40]The outcomes associated with the decomposition are reported in Table B5 in the appendix.

[41]In Table B5, we report outcomes for the case when a quarter of the procured staple crops are disposed of, with the remainder being used as rations. The results are qualitatively similar when a larger fraction of the procured crops are thrown away.

Table 6: Equilibrium Outcome Comparison

	Benchmark	Removing MSP	Reducing Input Subsidy*
	(1)	(2)	(3)
Aggregate Quantities			
Aggregate Output, $\sum_j p_j Y_j$	2.47	2.426	2.61
Real Output†, $\sum_j p_j^* Y_j$	2.47	2.474	2.21
Non-agricultural Good, y_n	1.37	1.43	1.375
Cash Crop, y_r	0.19	0.17	0.142
Staple Crop, y_s	0.27	0.264	0.21
Rations, c^{ration}	0.087	0	0.069
Intermediate input demand, $k_s + k_r$	0.133	0.122	0.069
Capital demand, k_n	3.53	3.47	3.63
Labour productivity of non-agri sector‡	2.62	2.42	2.67
Labour productivity of agricultural sector	2.31	2.54	1.72
Labour productivity of cash crop sector	2.37	3.33	1.775
Labour productivity of staple crop sector	2.25	2.22	1.68
Prices			
Non-agricultural Good (normalized)	1	1	1
Cash Crop, p_r	2.25	2.15	3.18
Staple Crop, p_s	2.48	2.36	3.76
Support Price, $\bar{p}$	2.65	-	4.02
Interest rate, r	0.082	0.085	0.079
Wage, w	1.07	1.06	1.09
Employment Shares			
Non-agricultural Sector	0.52	0.59	0.515
Cash Crop Farmers	0.18	0.115	0.18
Staple Crop Farmers	0.3	0.295	0.305

Note: *For this exercise we increase the price of input, p_k from 2.77 to 5.82
†p^* represents prices in the benchmark
‡Labour productivity in sector j computed using benchmark equilibrium prices as $\frac{p_j^* Y_j}{\text{Employment share}_j}$

price, as the loss of rations boosts staple crop demand which dovetails with a reduction in the supply of staple crops to the market. This also leads to a rise in the employment share of both crops.

Next, we consider an environment with support prices where the government retains a scaled-down rations program and transfers the remainder of the procured crops to the market. We shall refer to this as the 'procure-rations-market sale' program. This program retains some facets of the support price program: (i) procurement at support prices and (ii) rations.

However, the reduction in market supply of staple crops that would be associated with procurement and rations disbursal is now diminished, as the rations program is scaled down and all procured crops that are not distributed as rations are transferred to the market. This allows us to approximate a thought experiment wherein we retain the procurement and rations aspects of the support price program without necessarily diverting all of the procured staple crops away from the market. We find that such a program results in lower staple and cash crop prices. It also leads to a slight decline in the employment share of both crops. Both patterns are consistent with the results in column 2 of Table 6.

Finally, we consider an environment with no procurement by the government (and therefore no support prices for staple crop farmers) but with a scheme wherein the government purchases a quantity of staple crops at market prices equivalent to the rations provided in the benchmark equilibrium, and redistributes them to all agents in the economy. We shall refer to this as the 'market redistribution' program. This program retains the (i) rations disbursal and (ii) reduced supply to the market features of the support price program. However, procurement at the support price is dropped. We find that there is no difference in outcomes relative to the benchmark equilibrium.

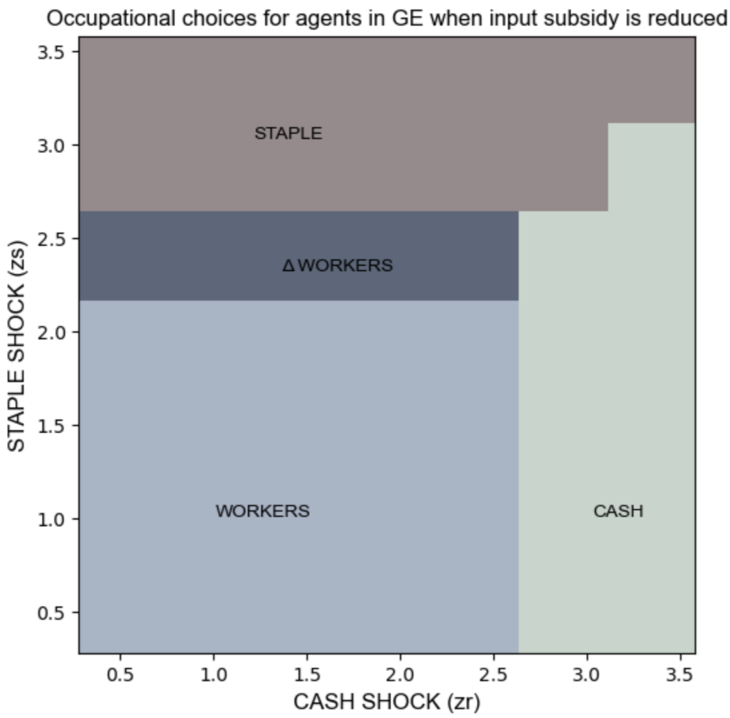
These results suggest that the key feature whose removal aligns equilibrium outcomes with the counterfactual outcomes in column 2 of Table 6 is the supply of hitherto procured crops to the market, which we considered in the 'procure-rations-market sale' exercise. The additional market supply drives down staple crop prices, pushing agents away from staple crop production toward the non-agricultural sector. Falling staple crop prices shift demand away from cash crops toward staple crops, resulting in a fall in cash crop prices and the employment share of the cash crop sector.

In the 'procure-disposal' and 'market redistribution' programs, note that the supply of staple crops to the market is reduced, either because the procured crops are thrown away or because they are purchased by the government. The 'procure-disposal' program results in a sizable increase in crop prices, but there is no change in crop prices under the 'market redistribution' program. Furthermore, in either program, the non-agricultural sector's equilibrium employment share either declines or is unchanged. Hence, we conclude that the effects of MSP removal arise from the increased supply of staple crops to the market.

5.2 Counterfactual exercise: reducing the input subsidy

A reduction in input subsidies is captured by an exogenous 110% increase in the price of the intermediate input, p_k, that is based on the policy change that deregulated fertiliser prices in India in 2009. Figure 4 depicts how occupational choices respond to a reduction in the input subsidy in general equilibrium. This lowers the expected profits for farmers by reducing their demand for intermediate inputs. Marginal agents respond to this reduction in profits by switching to the non-agricultural sector. The fall in agricultural production is 25%, which is quite close to the quasi-experimental evidence in Figure A10b.

Figure 4: Occupational choices: reducing input subsidy



The quantitative results in GE are listed in Column 3 of Table 6. A rise in input prices significantly lowers intermediate input usage and, thereby, farm profits, moving farmers away from crop production toward non-agriculture. However, preferences for agricultural goods consumption mandate an upward adjustment in crop prices to incentivise crop production. The net effect is that sectoral employment shares are effectively unchanged relative to the benchmark. The staple crop price rises sufficiently to actually induce a slight increase in the employment share of the staple crop sector.

While the rise in crop prices offsets to a large degree the effect of higher intermediate input prices on crop production, the overall effect is a fall in crop production relative to the benchmark. This also results in a fall in real output, calculated using benchmark equilibrium prices. However, the value of crop production rises as the prices of both crops rise. Non-agricultural production rises slightly, as the lower interest rate resulting from lower intermediate input usage boosts capital demand and hence production of the non-agricultural sector.

The labour productivity of the non-agricultural sector relative to the agricultural sector and the labour productivity of cash relative to staple crops both rise, albeit marginally, for the latter ratio. As the sectoral employment shares are largely unchanged, the increases are driven by the relatively greater fall in agricultural production in the case of the former ratio[42] and the relatively greater fall in staple crop production as opposed to cash crop production in the case of the latter ratio.

5.2.1 Discussion of the impact of input subsidies on misallocation

Our results on misallocation ensuing from the reduction of the input subsidy differ from corresponding results in Mazur and Tetenyi (2023). The model environment in their paper differs from the one presented above: notably, we do not consider transaction costs associated with staple crop purchases, nor do we consider correlated shocks across rural and urban areas, although their environment does not feature crop-specific productivity shocks. They also permit cash crop farmers to allocate shares of their land toward both crops.

As we have noted above, the impact of price subsidy programs on the agricultural labour productivity gap, $\frac{y_n}{p_s^* y_s + p_r^* y_r} \frac{\text{Employment}_{\text{agri}}}{\text{Employment}_{\text{nonagri}}}$, can be decomposed into the impact on sectoral employment shares and sectoral production. Mazur and Tetenyi (2023) obtain a *rise* in the ratio of non-agricultural (manufacturing) to agricultural production following the introduction of input subsidies, whereas the corresponding ratio declines in our setup (compare columns 1 and 3 in table 6). Furthermore, the sectoral employment shares (the urbanization rate in their setup) rise in favour of agriculture upon the introduction of an input subsidy. Both effects tend to raise the non-agricultural productivity relative to agricultural productivity upon the introduction of an input subsidy.

While sectoral employment shares in our paper rise in favour of agriculture upon the introduction of an input subsidy, this change is small (0.5 pp). Hence, the net effect of input subsidies on the agricultural productivity gap in our setup is driven by the increase in agricultural

[42] Recall that the labour productivity gap is given by $\frac{y_n}{p_s^* y_s + p_r^* y_r} \frac{\text{Employment}_{\text{agri}}}{\text{Employment}_{\text{nonagri}}}$. Hence, with limited changes in the employment shares, the gap is driven by falling agricultural production

production of both crops, compared to the slight increase in non-agricultural production.

As Mazur and Tetenyi (2023) note, the transaction cost associated with market purchases of staple crops makes staple crop production relatively more attractive, hence the introduction of the input subsidy leads to a large inflow into the staple crop sector in their paper. Cash crop farmers allocate more of their land toward cultivating staple crops, hence cash crop production actually declines following the introduction of the input subsidy, although overall agricultural production does rise. As our model does not feature transaction costs associated with market purchase of staple crops, we obtain neither a large inflow into the agricultural sector nor a negative effect on cash crop production upon the introduction of the input subsidy. Finally, Mazur and Tetenyi (2023) argue that the rise in non-agricultural production upon the introduction of the input subsidy in their setup is due to greater saving by agents as incomes rise. In our setup, the incentive to reduce saving upon introduction of the input subsidy, due to a looser working capital constraint, dominates and results in a fall in saving. Consequently, capital and labour employed by the non-agricultural sector fall, as does non-agricultural production[43].

5.3 Role of frictions

Other than the single risk-free asset and no inter-temporal borrowing assumptions that are common to standard incomplete markets models, the model presented above has three frictions or constraints whose effect on target outcomes is the focus of this section. In each of these exercises, we remove the friction in question alone, keeping the rest of the model unchanged.

We first consider the impact of the subsistence requirement ($\bar{c}$) on target outcomes relative to the calibrated benchmark. The results are listed in Column (2) of Table 7. We find that removing the subsistence requirement has no effect on any of the target outcomes, which is intuitive as the calibrated $\bar{c}$ is small and because rations are sizable and hence reduce the salience of the subsistence requirement.

Next, we consider the role of the fixed cost of procurement. We lower the fixed cost ρ to 0.05 from its calibrated value of 0.205. According to intuition, Column (3) of Table 7 indicates that this leads to nearly all staple crops being procured, which reduces the market supply of staple crops and raises staple crop prices. Higher incomes also boost demand for

[43]Prior research has also shown that other channels through which fertilizer subsidy can positively impact agricultural productivity, such as learning externality (B. Z. Diop, 2022), higher calorie intake (Strauss, 1986) and decentralized subsidy targeting (Basurto et al., 2020). Incorporating these channels will strengthen our conclusions even more about the productivity impact of input subsidy.

Table 7: Changes in certain outcomes without frictions

Outcome	Benchmark	$\bar{c} = 0$	$\rho = 0.05$	$\phi = \infty$
	(1)	(2)	(3)	(4)
Employment share in agriculture	48%	48%	59%	35.5%
Share of staple crops procured in 2011	32%	32%	100%	44%
Value of staple relative to cash crop production	1.17	1.57	1.47	1.56
Intermediate input usage	0.133	0.132	0.225	0.164
Labour productivity of non-agri sector†	2.62	2.61	2.975	2.077
Labour productivity of agricultural sector*	2.31	2.31	2.55	3.53
Labour productivity of cash crop sector	2.37	2.375	2.5	4.21
Labour productivity of staple crop sector	2.25	2.25	2.55	3.2

Note: †Labour productivity in sector j computed using benchmark equilibrium prices as $\frac{p_j^* Y_j}{\text{Employment share}_j}$
* Labour productivity of the agricultural sector computed using benchmark equilibrium prices as $\frac{p_r^* Y_r + p_s^* Y_s}{\text{Agricultural employment share}}$

cash crops, raising cash crop prices, while the employment shares of both crops rise at the expense of non-agricultural employment. Intermediate input usage rises with farmer income, which boosts the labour productivity of agriculture. Non-agricultural labour productivity is also higher, driven mainly by the lower non-agricultural employment share.

Finally, we consider the role of the working capital constraint. Relaxing the constraint, we find in Column (4) of Table 7 that the employment share of agriculture falls. Intermediate input consumption by farmers rises, which boosts crop production and supply to the market. This, in turn, drives down crop prices relative to the benchmark, lowering profit margins for farmers, inducing greater procurement and leading to outflows from agriculture. Greater intermediate input usage and a falling agricultural employment share raise the labour productivity of agriculture and the two crops. However, labour productivity in the non-agricultural sector is lower as the employment share rises more than output in that sector.

5.4 Welfare

The welfare measure that we shall focus on first is based on Buera and Shin (2011), which is an aggregate consumption equivalent measure.

We first define the aggregate welfare function of the benchmark stationary equilibrium, defined as:

$$W^{j*} = \int V^*(\mathbf{z}, a)\ \mathbb{I}_j^*\ dF^*(\mathbf{z}, a) \tag{42}$$

In the expression above, $\mathbb{I}_j^*$ is an indicator for an individual belonging to sector j in the benchmark stationary equilibrium (here, with MSP and the input price subsidy). This welfare measure is defined for each sector $j \in \{s, r, w\}$. This measures the welfare of an individual belonging to group j under the 'veil of ignorance', i.e. the welfare calculation of a planner who weights every agent of group j in the stationary distribution equally.

Similarly, define the welfare of a model economy, using the stationary distribution of agents $F^*(\mathbf{z}, a)$ in the benchmark model, under the counterfactual equilibrium:

$$\hat{W^j} = \int \hat{V}(\mathbf{z}, a)\ \mathbb{I}_j^*\ dF^*(\mathbf{z}, a) \tag{43}$$

Note that we are considering the welfare of agents who belonged to group j in the benchmark stationary equilibrium. Hence, we are tracking the welfare of agents belonging to group j in the benchmark stationary equilibrium in the new stationary equilibrium under the counterfactual policy.

The welfare cost reported is in units of permanent consumption compensation necessary to make an individual of group j indifferent between the status quo (the benchmark stationary equilibrium) and the counterfactual equilibrium:

$$\chi^j = \left[\frac{W^{j*}}{\hat{W^j}}\right]^{\frac{1}{1-\theta}} - 1 \tag{44}$$

To obtain the above expression, we scale up subsistence consumption levels $\bar{c_s}$ by χ^j as well[44]. A negative value for χ^j would indicate that agents of group j are better off in the new stationary equilibrium corresponding to the counterfactual exercise.

We construct this welfare measure to consider changes in welfare from the two exercises discussed above, viz. removing the MSP and reducing the input subsidy, where the benchmark in each case is an economy with the MSP and input subsidy.

Consider first the counterfactual exercise entailing removing the MSP. Noting from the discussion in section 5.1.1 that removing the MSP also removes rations disbursed to all agents,

[44]Given the small calibrated value of $\bar{c_s}$, one could also think of the welfare measure as approximating the exact consumption equivalent measure in the absence of a subsistence requirement

Table 8: Welfare changes under counterfactual policies

Group	No MSP	No MSP (balanced)	No MSP (in-kind)	Higher p_k	Higher p_k (transfer)	Higher p_k (fixed ration)
	(1)	(2)	(3)	(4)	(5)	(6)
Workers	12.36%	−0.51%	−0.375%	17.3%	−12.33%	7.7%
Staple crop farmers	13.1%	−0.75%	−1.03%	16.1%	−14.47%	6.2%
Cash crop farmers	12.85%	−0.74%	−0.65%	17.03%	−14.51%	7.1%

a policy that removes the MSP without compensating agents by means of an alternative policy (such as an income transfer) is unlikely to improve welfare. This insight is confirmed in column 1 of Table 8.

A more reasonable comparison is with welfare in environments where the MSP is replaced by alternative policies that support farmers. We begin by considering income transfers to all agents in the economy, where the total amount available for disbursal is the expenditure of the government on procurement, $\bar{p} * c^{\text{ration}}$. We refer to this as a *balanced budget* transfer policy. Equilibrium outcomes under various replacement policies are listed in Appendix Table B6. Briefly, we note that income transfers, by boosting the resources of agents, boost demand, production and prices relative to the no MSP counterfactual. Sectoral employment shares revert to the benchmark equilibrium levels; hence, the agricultural labour productivity gap widens. In terms of welfare, column 2 of Table 8 shows that there are small welfare gains from replacing the MSP program with an income transfer. A replacement policy that is a natural contrast to income transfers is a balanced budget program that uses the amount spent on the MSP program to purchase staple crops on the open market that are then disbursed to all agents as rations; an *in-kind* policy. Column 3 of Table 8 shows that this also results in welfare gains compared to the no MSP counterfactual (column 1) and equilibrium outcomes similar to the benchmark economy, suggesting that the provision of rations or in-kind transfers is valued by agents. However, the amount of staples provided under the in-kind transfer policy is lower than the rations provided under MSP in the benchmark, while both equilibrium crop prices are also higher in this counterfactual than the benchmark equilibrium.

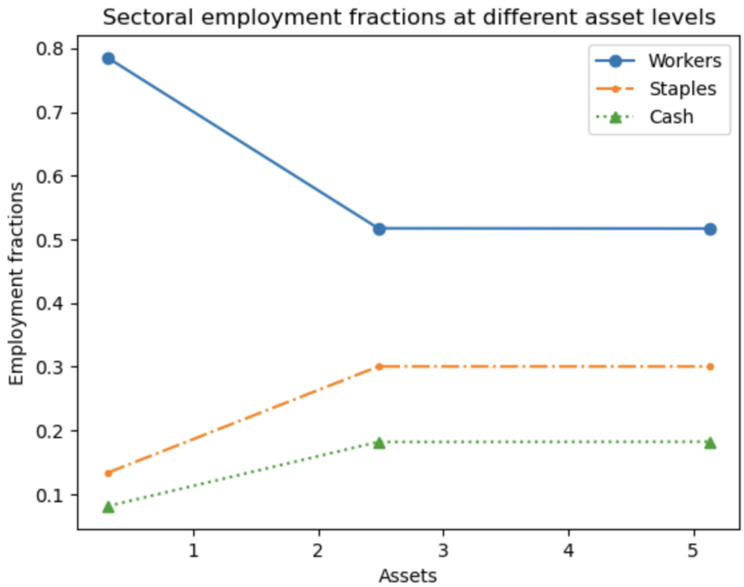
The second counterfactual we consider is a reduction of the input subsidy, keeping the MSP policy in place. Noting from Table 6 that the real income of farmers falls and prices of staple and cash crops rise significantly in the counterfactual that reduces the input subsidy, the welfare of all agents should fall in the counterfactual economy, which is confirmed in column 5 of Table 8. In this case, we consider an alternative policy that reduces the input subsidy but transfers a fraction (10%) of the amount saved to agents in the form of an income transfer. Equilibrium outcomes under this alternative are listed in column (2) of Table B7 in the appendix. We note that the income supplement boosts intermediate input demand and crop production relative to the counterfactual with a reduced input subsidy sans transfers. However, it reduces the outflow of agents from agriculture, thereby lowering non-agricultural good production, and hence overall output is unchanged. The falling employment share of the non-agricultural sector also raises the agricultural productivity gap slightly by boosting non-agricultural labour productivity more than the rise in agricultural labour productivity. The policy also results in welfare gains in the counterfactual economy. These gains arise because the income transfer boosts consumption despite the rise in prices, but primarily because the rations disbursed nearly triple relative to the benchmark.

A final alternative policy we consider that acts as a replacement when the input subsidy is reduced is to keep the quantity of rations disbursed fixed at the benchmark equilibrium level of 0.087. Equilibrium outcomes under this alternative are listed in column (3) of Table B7 in the appendix. The fixed rations policy raises crop prices and intermediate input demand relative to the reduced subsidy counterfactual, and although the outflow of agents from agriculture is slightly lowered, the increase in intermediate input usage boosts crop production, and hence, overall output rises slightly. The falling employment share of the non-agricultural sector also raises the agricultural productivity gap slightly by boosting non-agricultural labour productivity while agricultural labour productivity falls slightly. The policy also results in lower welfare losses in the counterfactual economy relative to those arising when the input subsidy is reduced without an alternative program in place. The welfare losses are lower relative to the reduced subsidy counterfactual as rations rise adequately to counter the rise in crop prices.

5.4.1 Variation with assets

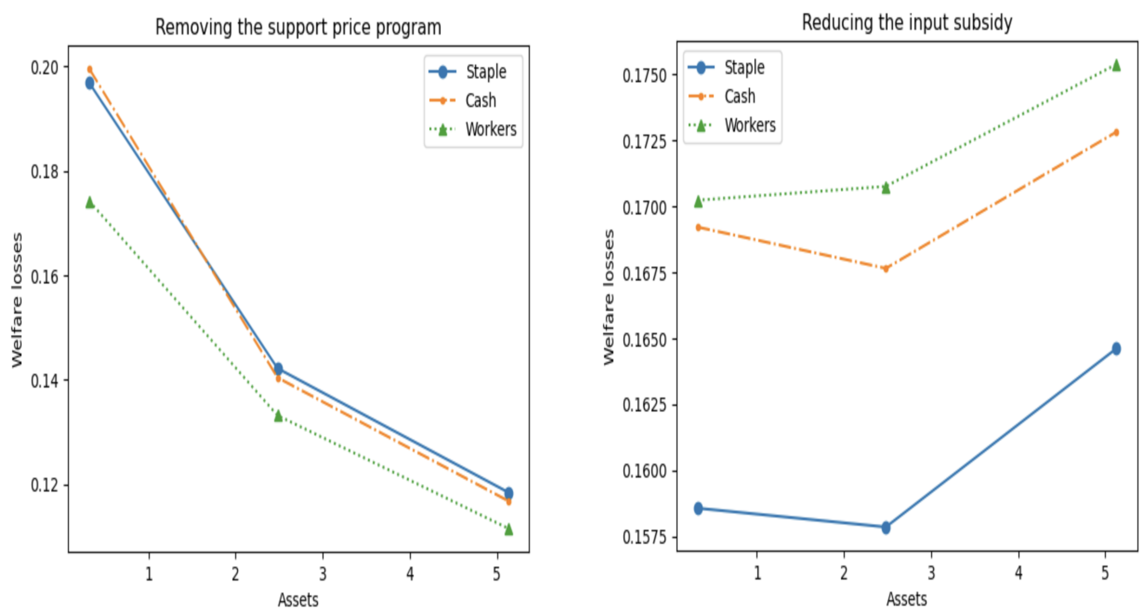
We also compute the consumption equivalent welfare losses across asset levels associated with removing the support price program and reducing the input subsidy. Specifically, we compute the consumption equivalent variation measure of welfare loss relative to the benchmark equilibrium at three asset levels (low, medium and high) for the equilibrium arising from either the removal of the support price program or the reduction of the input subsidy. As before, we use the benchmark equilibrium occupational choice and distribution functions in order to construct the welfare measure. At each asset level, we depict the employment fractions by sector (summing up to 1 at each asset level) in Table 5. Note that since the working capital constraint tends to bind at lower asset levels, most agents with low asset levels are workers in the non-agricultural sector. As asset levels rise, agents move toward agriculture as the working capital constraint becomes less salient.

Figure 5: Sectoral employment fractions: variation across asset levels



Figures 6a and 6b depict that both policy changes result in welfare losses for all agents in the absence of a compensatory scheme such as an income or in-kind transfer. Welfare losses differ by occupation and asset levels. However, while welfare losses are lower across occupations for agents with greater asset holdings in the counterfactual equilibrium without support prices, the opposite pattern holds in the counterfactual equilibrium with a lower input subsidy. When the support price program is removed, welfare losses arise from the loss of rations, and agents with more assets are better able to compensate for the loss of rations through market purchases at the lower equilibrium prices. When the input subsidy is reduced, welfare losses arise from lower rations relative to the benchmark equilibrium and significantly higher crop prices. Agents with low asset holdings in the benchmark equilibrium have low levels of consumption and, hence, do not drastically reduce their consumption levels as prices rise following the subsidy reduction. However, agents with high asset holdings and a higher benchmark equilibrium level of consumption do cut back significantly on consumption following the reduction of the input subsidy and concomitant price rise. Moreover, the variation in welfare losses by asset levels for any given occupation are much smaller in magnitude with the reduction in input subsidy than the removal of the MSP. Finally, welfare losses for staple and cash crop farmers are nearly equal when the support price program is removed, but they are higher for cash relative to staple crop farmers when the input subsidy is reduced. This is because staple crop prices, and hence incomes, of staple crop farmers rise proportionally more relative to the corresponding outcomes for cash crop farmers.

Figure 6: Welfare losses by asset levels and occupations



(a) Removal of MSP (b) Removal of input subsidy

6 Empirical validation of model counterfactuals

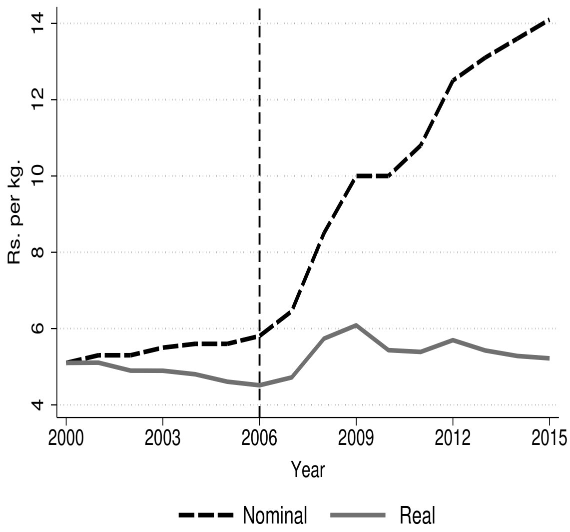
In this section, we present empirical evidence that supports the model's counterfactual predictions. First, we illustrate the impact of the MSP on agricultural production, and then we demonstrate the effect of fertilizer subsidy reduction on non-agricultural output.

6.1 MSP

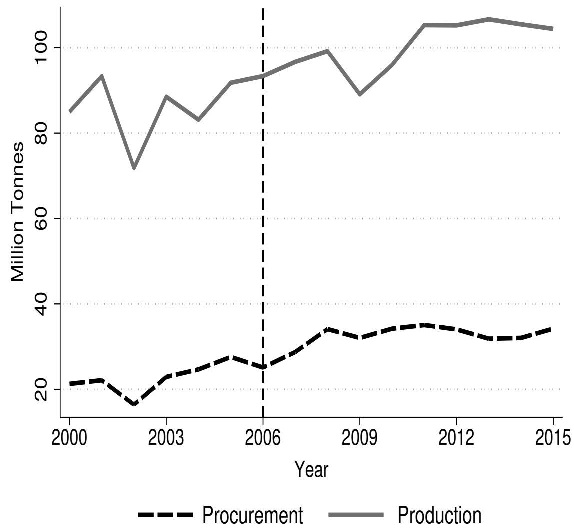
We will use two key factors in our empirical approach to test the effect of price support on agricultural production. First, the support price is announced at the beginning of the cultivation season, making it known to the farmer in advance. Second, the quantity procured varies at the sub-national level.

Typically there are many factors, such as, minimum margin over anticipated production costs, expected monsoon patterns and international market prices, that are taken into account to determine MSP each year. Before 2007, though the support price of rice in nominal terms was rising, the support price in real terms had stagnated (Figure 7a). But, over reliance of imports during the global spike in international food prices (De Hoyos & Medvedev, 2011) and falling stocks of surplus grains (Saini & Gulati, 2016), led to higher support prices for three consecutive years (2007-2009). Consequently, rice production also increased during this period (Figure 7b).

Figure 7: Minimum Support Price and Production over time of Rice



(a) Nominal and Real MSP



(b) Quantity of Production and Procurement

Though, national trends may be confounded by many factors. We exploit the intensity of procurement across states to overcome this issue. States like Punjab, Haryana and Chhattisgarh procure at least 40% of locally produced output, whereas states like Gujarat and Assam do not engage in procurement[45]. We employ a difference-in-differences framework to understand the effect of price support. The regression specification we use is:

$$Y_{dt} = \alpha + \phi_d + \phi_t + \beta^{-1} \times \mathrm{T}_s \times \mathbf{1}_{\{2003 \leq t \leq 2005\}} + \beta \times \mathrm{T}_s \times \mathbf{1}_{\{2007 \leq t \leq 2009\}} + \varepsilon_{dt} \quad (45)$$

where Y_{dt} is the outcome of district d at time t, T_s is a dummy referring to the treated states, $\mathbf{1}_{2007 \leq t \leq 2009}$ is a dummy variable that takes value 1 for years from 2007 onwards, $\mathbf{1}_{2003 \leq t \leq 2005}$ is a dummy variable that takes value 1 for years before 2006. The period of analysis is restricted until 2009 to not contaminate the coefficient of interest with the fertilizer price deregulation program. We classify states with minimum procurement above 15% as "treated", and those

[45]Appendix Figure A13 shows that the minimum proportion of output procured at the state level before (2003-2006) and after (2007-2009) the sudden increase in support price is similar.

below “15%" as control. The 15% cutoff ensures stability of treatment and control units across periods, apart from one state (Tamil Nadu) which we drop from the analysis[46,47].

The outcomes of interest are the natural log of output (rupees), area (hectare) and yield of rice cultivation at the district level, where yield is defined as output divided by area[48]. Column 1 of Table 9 presents that higher MSP increased production. The increase in output is driven entirely by higher yield, indicating a higher use of intermediate inputs, which is consistent with the model simulations[49].

Table 9: Effect of change in support price

Dependent variables: Log Output, Log Area and Log Yield			
	Output (1)	Area (2)	Yield (3)
Treatment Effect	0.11***	0.02	0.10***
	(0.03)	(0.02)	(0.02)
Observations	1869	1869	1869
R^2	0.98	0.99	0.88
Mean of Dependent variable	4.47	3.99	7.38

Note: The coefficient shows the average treatment effect. Standard errors clustered at the district level are reported in parentheses. ***, ** and * represent the statistical significance at 1%, 5% and 10% levels respectively.

6.2 Input subsidy program

Table 6 illustrates that a decrease in fertilizer subsidy leads to higher prices of agricultural goods, and thereby significantly mitigates the impact on non-agricultural production and employment. We exploit the fertilizer price deregulation, which we had used to determine the elasticity of output to intermediate input in Section 4.1, to test these hypothesis in the data: (1) the effect on prices of agricultural goods, and (2) the effect on non-agricultural production.

Table 10 shows the results from applying a similar DiD framework on the log price of 16

[46] Treated states include Chhattisgarh, Haryana, Orissa, Punjab, Uttarakhand and Uttar Pradesh. They accounted for 45% of total production before the sharp increase in support price. The control group includes major rice-producing states like West Bengal and Andhra Pradesh that engage in limited procurement.

[47] Direct spillovers are unlikely as Agriculture Produce and Marketing Committee (APMC) Acts restrict farmers from selling across state boundaries (Chatterjee, 2023).

[48] The support price of wheat also rose between 2006 and 2008 (Saini & Gulati, 2016), but there is far lesser variation in procurement to causally estimate its impact.

[49] Appendix Figure A14 displays the pre-treated and treatment effects using an event-study specification. Although there exist some pre-trends with regards to yield, the estimated treatment effects are still much higher than the pre-treated effects.

agricultural crops, and separately for the group of staple and cash crops[50]. The reduction in fertilizer subsidy led to an increase in price of agricultural goods, consistent with the model predictions. Prices of both staple and cash crops increased following the government deregulation of fertilizer prices, but the effect is stronger among staple crops[51].

Table 10: Effect of fertilizer deregulation price on price of agricultural goods

Dependent variables: Log Price per quintal			
	All (1)	Staples (2)	Cash (3)
Treatment Effect	0.05***	0.05***	0.03
	(0.02)	(0.02)	(0.04)
Pre-treated effect	0.01	0.01	0.01
	(0.02)	(0.02)	(0.03)
Observations	44064	28048	16016
R^2	0.93	0.92	0.79
Outcome Mean	7.50	7.20	8.01

Note: The coefficients show the average treatment and pre-treated effects. Standard errors clustered at the district level are reported in parentheses. ***, ** and * represent the statistical significance at 1%, 5% and 10% levels respectively.

Applying the same DiD specification as in equation (39), Table 11 demonstrates that the decrease in fertilizer subsidy had no discernible impact on output of manufacturing and service sectors, which is consistent with the model-generated dynamics[52]. Appendix Table B8 shows that the policy change had no significant effect on employment in either the agriculture or non-agriculture sectors, aligning with the dynamics predicted by the model[53]. In conclusion, the model's predictions align closely with the observed data patterns.

[50]The regression specification is:

$$Y_{cdt} = \alpha + \phi_{cd} + \phi_{ct} + \beta^{-1} \times T_d \times 1_{\{2004 \leq t \leq 2008\}} + \beta \times T_d \times 1_{\{2010 \leq t \leq 2016\}} + \varepsilon_{dt} \tag{46}$$

where Y_{cdt} is price of crop c at time t in district d. Crops include cereals (barley, jowar, maize, ragi, rice, sorghum and wheat), pulses and legumes (chickpea and pigeonpea), oilseeds (castorseed, groundnut, linseed, rapeseed, sesame), sugarcane and cotton. Cash crops include oilseeds, sugarcane and cotton.

[51]Appendix Figure A15 shows the estimates for all years from an event-study specification

[52]Some of the imprecision in the estimates may stem from the limited availability of data on manufacturing and service sector output, which covers only a few periods (2007 to 2013). Appendix Figures A16a and A16b display the estimates for all periods.

[53]We use employment data from the NSS survey for the years 2004-05, 2005-06, 2007-08, 2009-10 and 2011-12 (61st, 62nd, 64th, 66th and 68th, respectively).

Table 11: Effect of fertilizer deregulation price on non-agriculture production

Dependent variables: Log Output		
	Manufacturing	Service
	(1)	(2)
Treatment Effect	0.03	-0.00
	(0.04)	(0.02)
Pre-treated effect	0.01	0.03
	(0.01)	(0.02)
Observations	3528	3528
R^2	0.99	1.00
Outcome Mean	9.38	10.10

Note: The coefficients show the average treatment and pre-treated effects. Standard errors clustered at the district level are reported in parentheses. ***, ** and * represent the statistical significance at 1%, 5% and 10% levels respectively.

7 Conclusion

This article studies the productivity and welfare consequences of policies that offer price support to farmers of certain crops, as well as subsidies to input prices, in the context of India. To do so, we develop a dynamic quantitative model that features heterogeneous agents, occupational choice, financial frictions, and input and output price subsidies. Our results indicate that staple crop production falls, aggregate output rises marginally, and the agricultural productivity gap shrinks in the absence of the support price policy. Using our framework, we also show that with a reduction in the input subsidy, agriculture and non-agriculture output falls while the agricultural productivity gap widens. These outcomes arise through the interaction of occupational flows, intermediate input usage and crop price changes in general equilibrium following the change in policy. The model results are consistent with the quasi-experimental evidence on the relationship between input and output agriculture subsidies and agriculture production. Welfare gains arise when the support price and input subsidy programs are replaced with budget-neutral income or in-kind transfers.

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Appendix

A Additional Figures

Figure A1: Employment shares across sectors in rich and poor countries

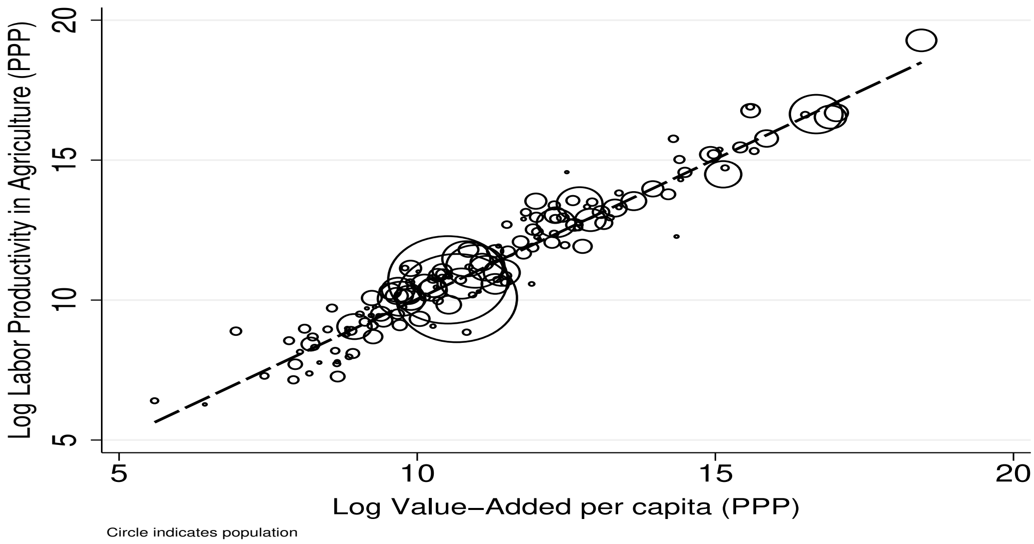


Figure A2: Employment shares across sectors in rich and poor countries

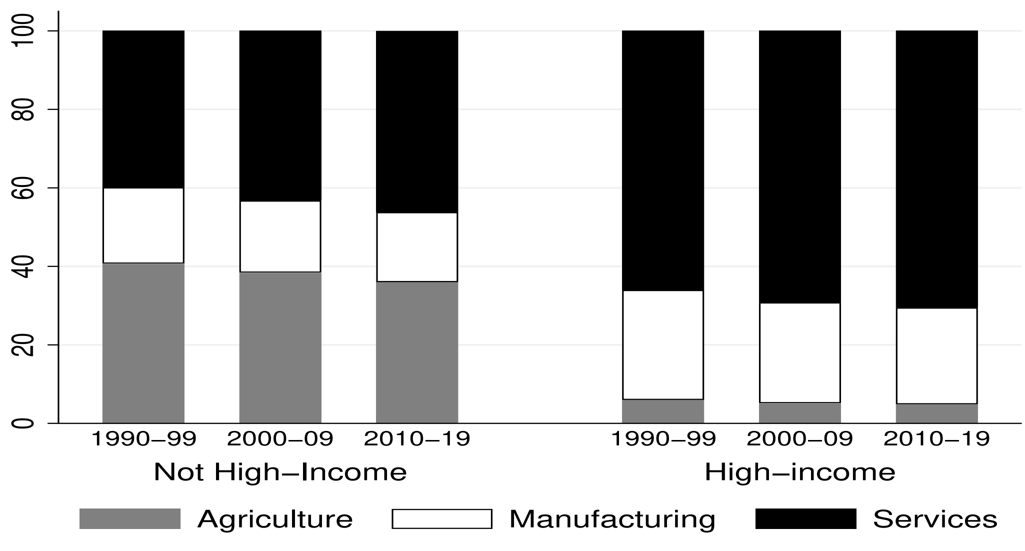
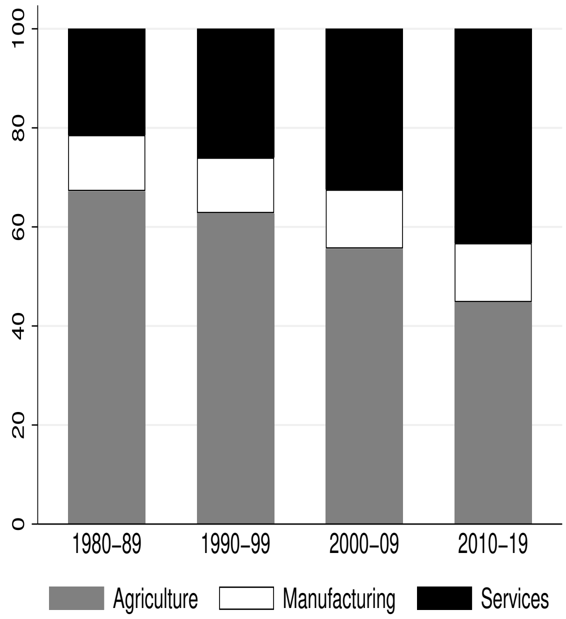
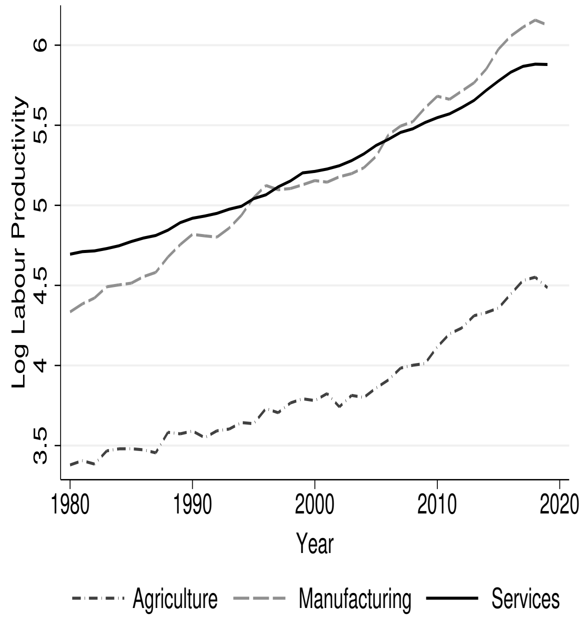


Figure A3: Employment shares and labour productivity in India by sectors



(a) Employment Shares



(b) Labour Productivity

Note: Data on sectoral employment shares and value added were sourced from the RBI India KLEMS Database.

Figure A4: Growth in value added by sectors in India

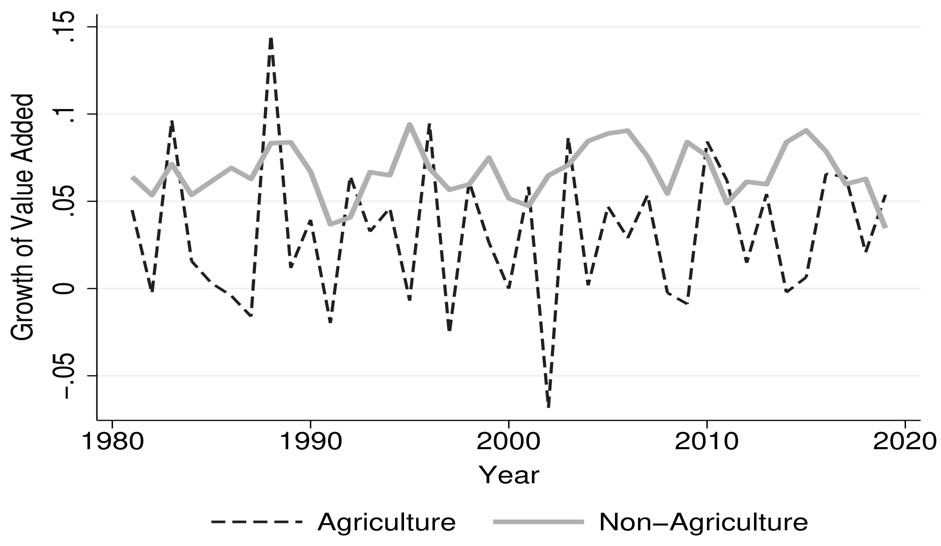
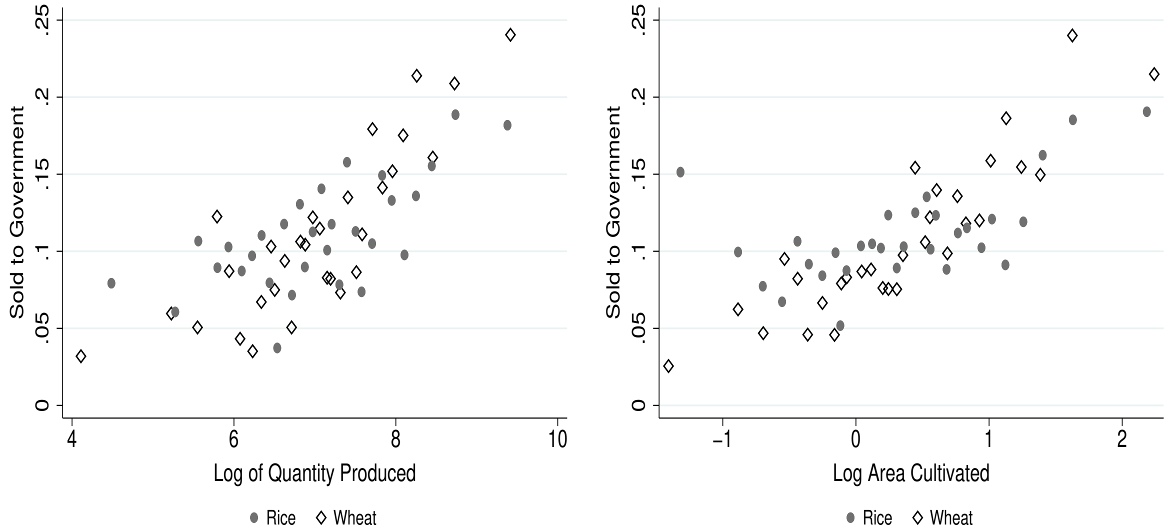


Figure A5: Incomplete penetration of MSP: controlling for state fixed effects

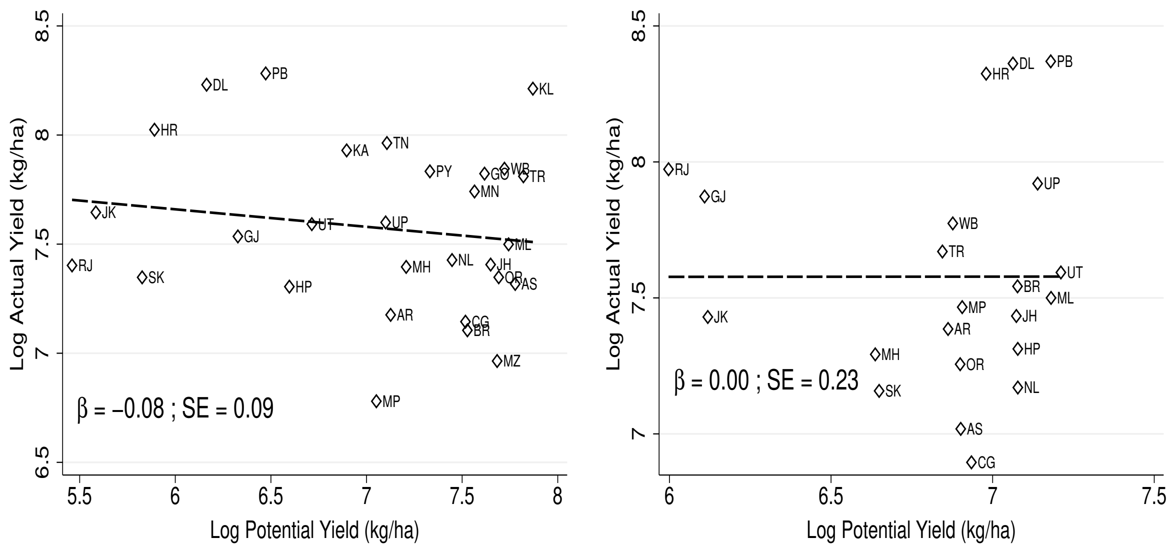


(a) Log quantity produced

(b) Log area cultivated

Note: The y-axis is an indicator variable taking the value 1 if output sold to a government agency. The x-axis is log quantity produced and log total area cultivated for left- and righ-hand side, respectively. Both plots control for state dummies and use 30 quintiles for each crop. The figure uses the Land and Livestock Survey of 77$^{\text{th}}$ NSS Round.

Figure A6: Relationship between actual and potential yield for rice and wheat across Indian states

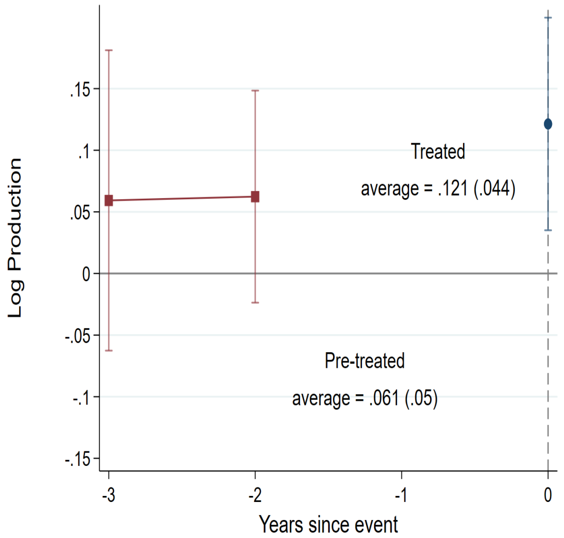


(a) Rice

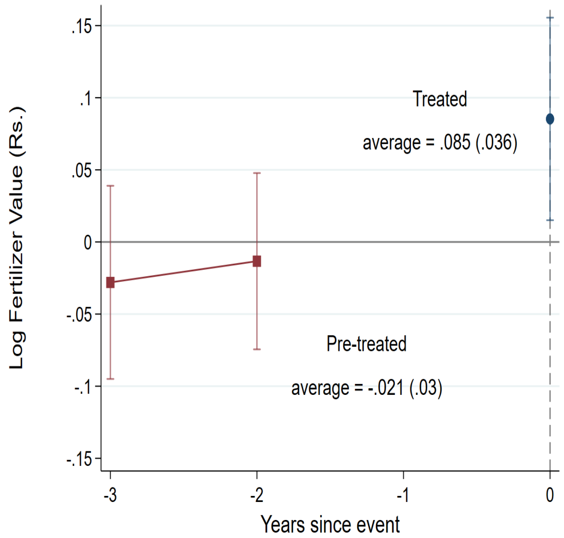
(b) Wheat

Note: Data on actual and potential yield are from Reserve Bank of India Handbook of Statistics on Indian States and GAEZ FAO, respectively. Actual and potential yield are averaged between 2004 and 2009 for each state. Standard errors are robust to heteroscedasticity.

Figure A7: Effect on log output and log fertilizer consumption to cash transfer program



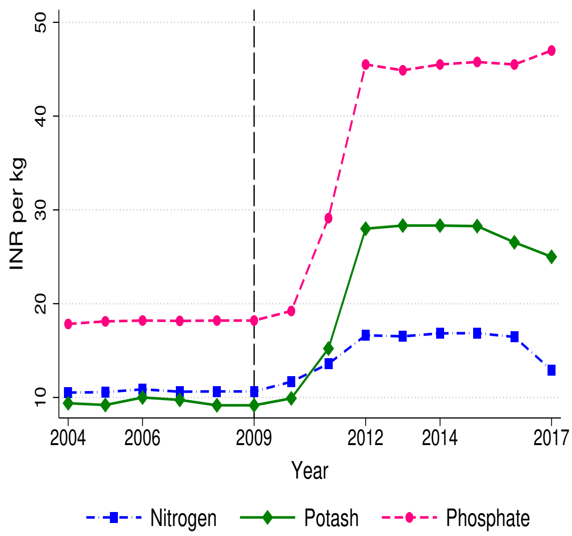
(a) Output



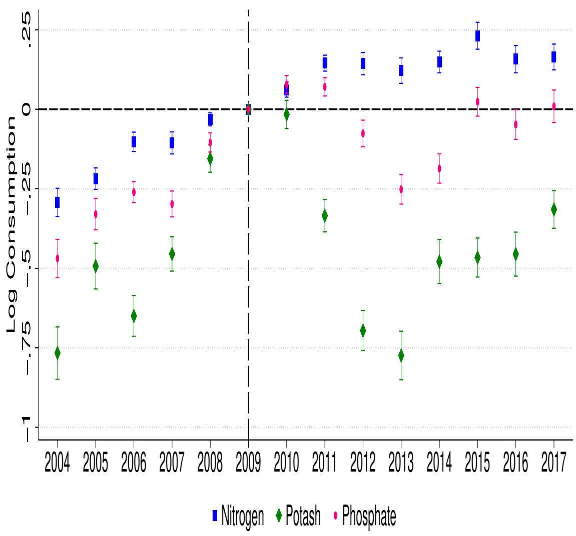
(b) Fertilizer

Note: Figure reports treatment and pre-treatment effect averages and 95% confidence intervals in response to the cash transfer program. Standard errors in parentheses are clustered at the district level.

Figure A8: Fertilizer price and consumption over time

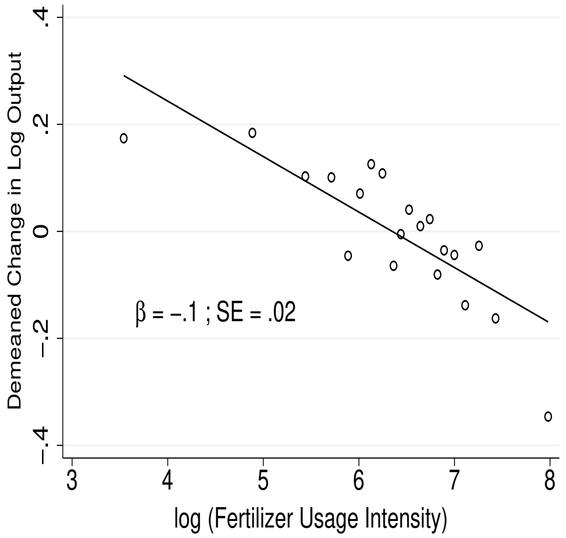


(a) Price of N, P and K

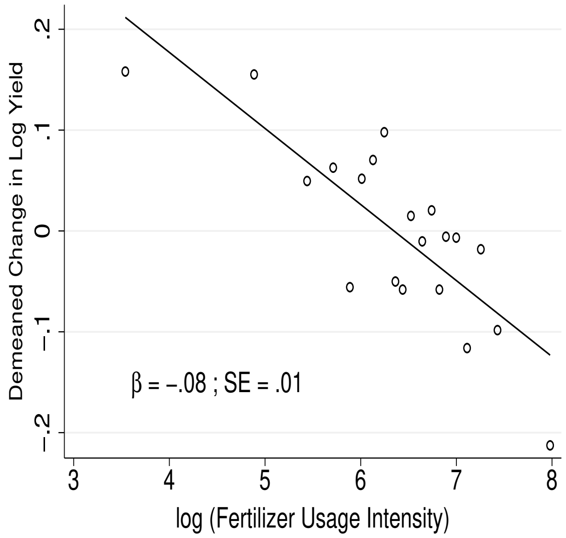


(b) Consumption of N, P and K

Figure A9: Binscatter of change in agricultural production and yield before and after the policy by quantiles of fertilizer usage

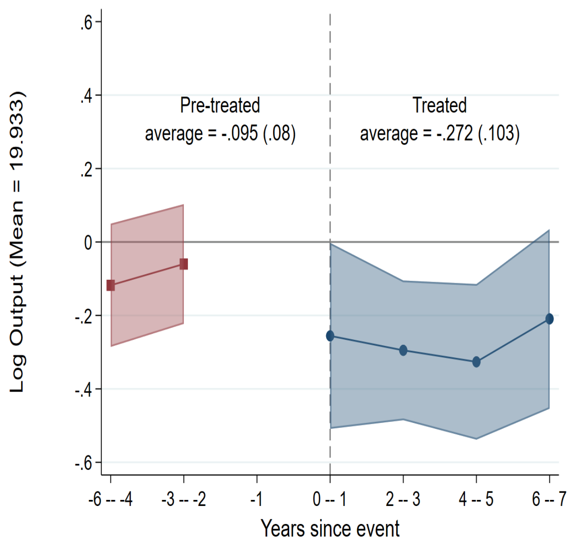


(a) Production

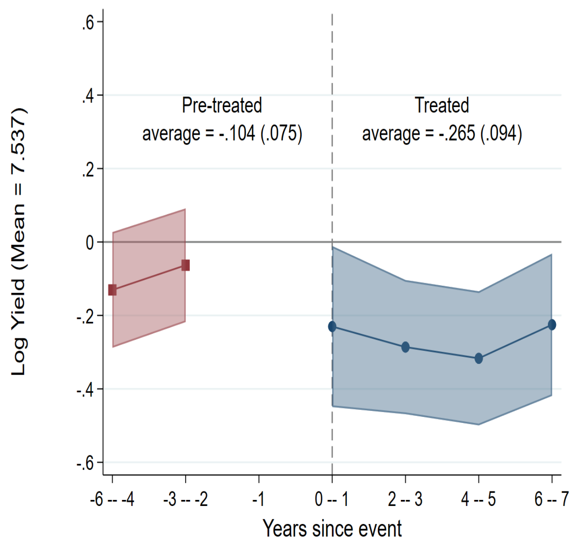


(b) Yield

Figure A10: Effect of fertilizer price deregulation on log output and log yield



(a) Log Output



(b) Log Yield

Note: Figure reports treatment and pre-treatment effect averages and 95% confidence intervals in response to the change in fertilizer subsidy policy. Treatment and pre-treatment effects combined into 2-year bins. Standard errors in parentheses are clustered at the district level.

Figure A11: Distribution of market price of rice and wheat to MSP

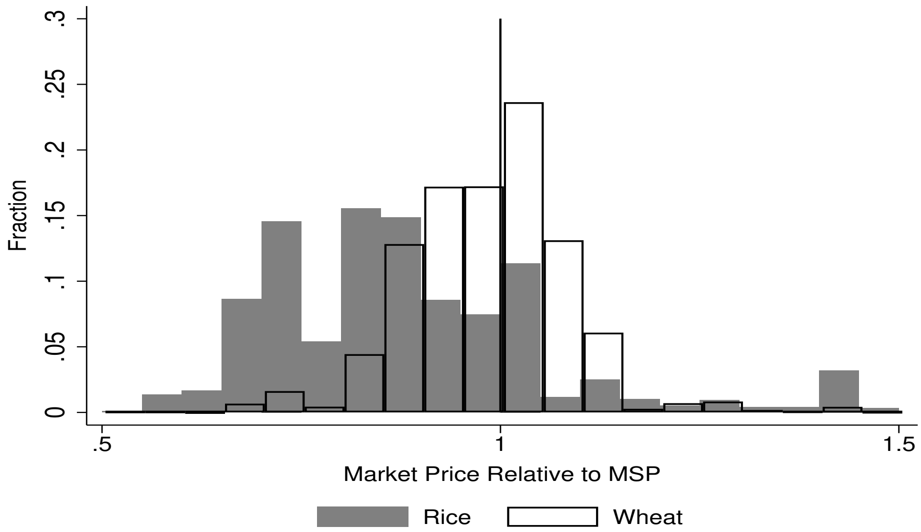


Figure A12: Distribution of staple crop share

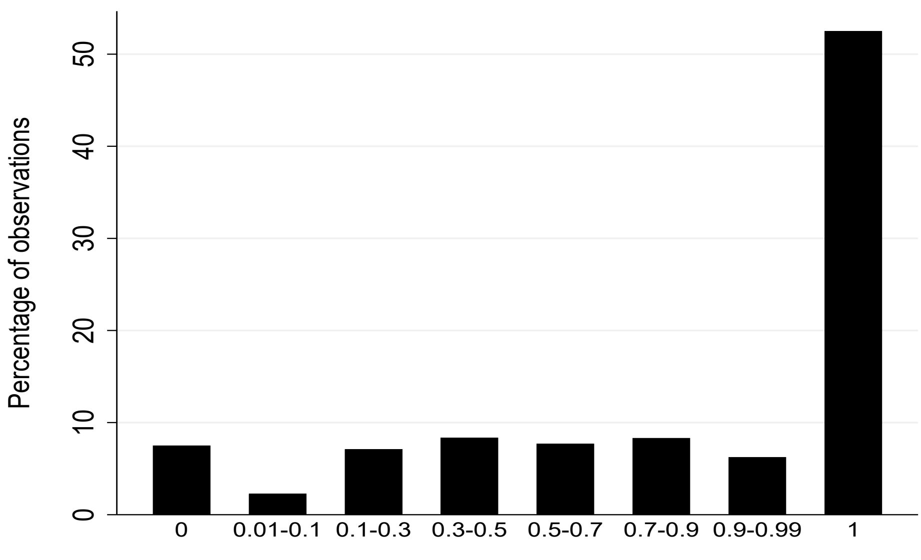
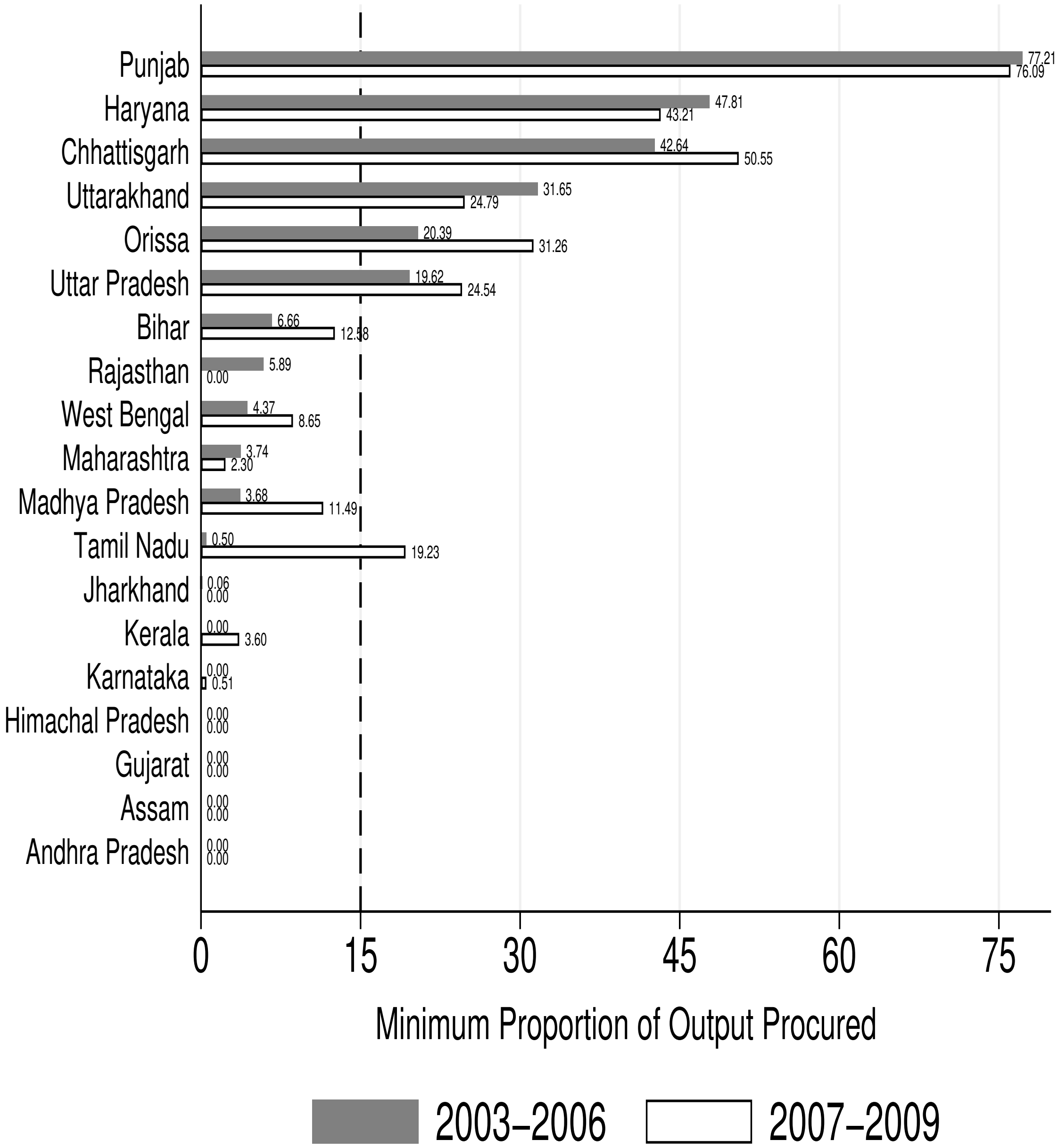
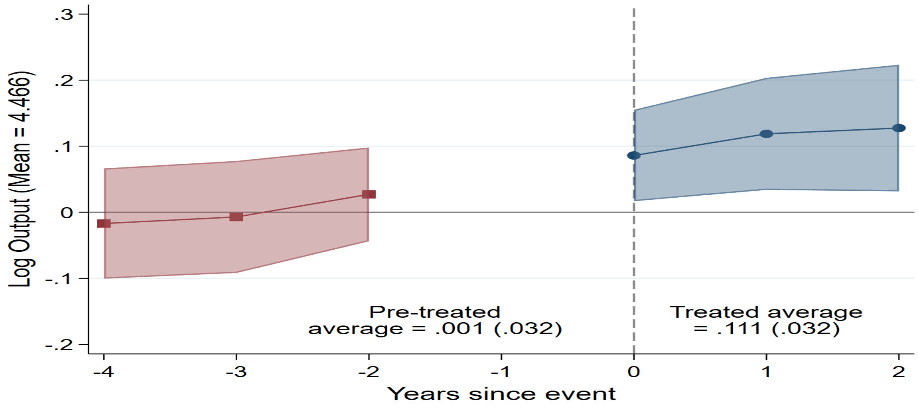


Figure A13: Variation in minimum proportion of output procured

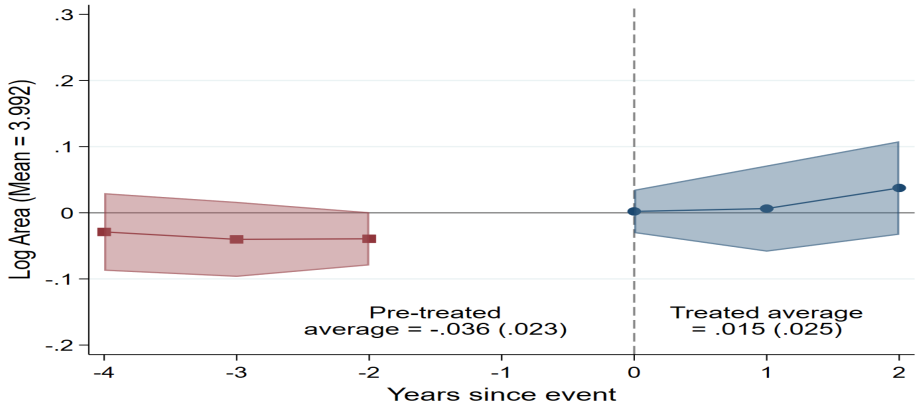


Note: Figure reports the minimum share of output procured before (2003-2006) and after (2007-2009) after MSP policy change. States with more than 15% minimum procurement are defined as “treated" (Chhattisgarh, Haryana, Orissa, Punjab, Uttarakhand and Uttar Pradesh). Tamil Nadu is removed from analysis due to change in treatment status.

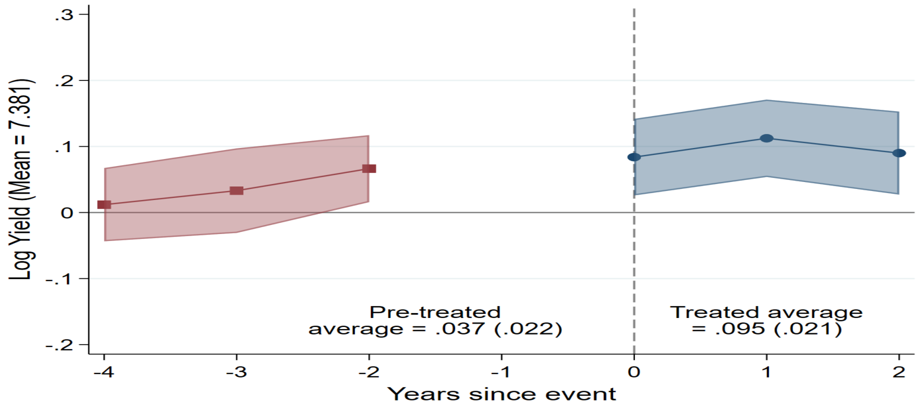
Figure A14: Effect of MSP on agriculture



(a) Log Output



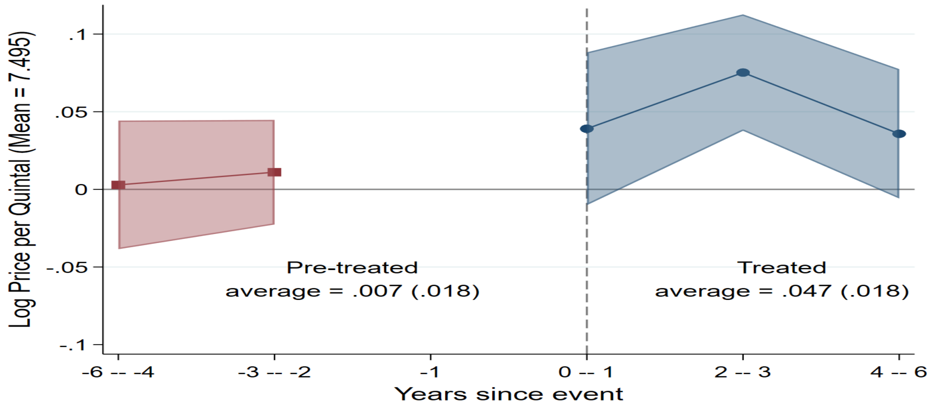
(b) Log Area



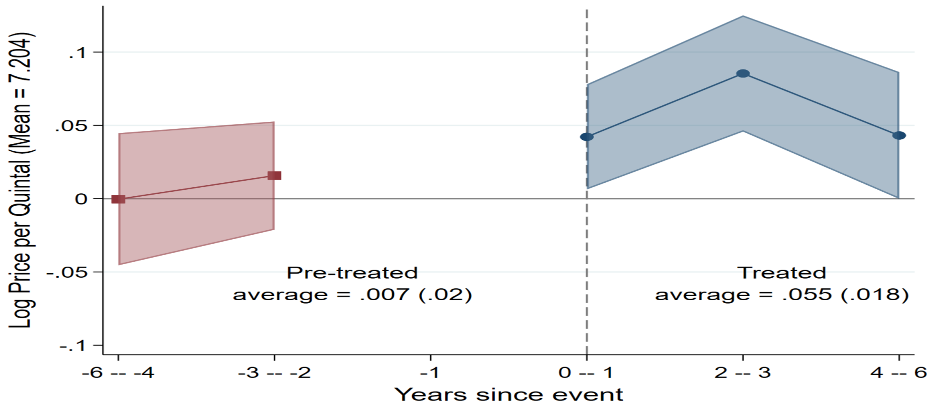
(c) Log Yield

Note: Figure reports treatment effects and pre-treatment averages and 95% confidence intervals in response to change in support price policy. Standard errors in parentheses are clustered at the district level.

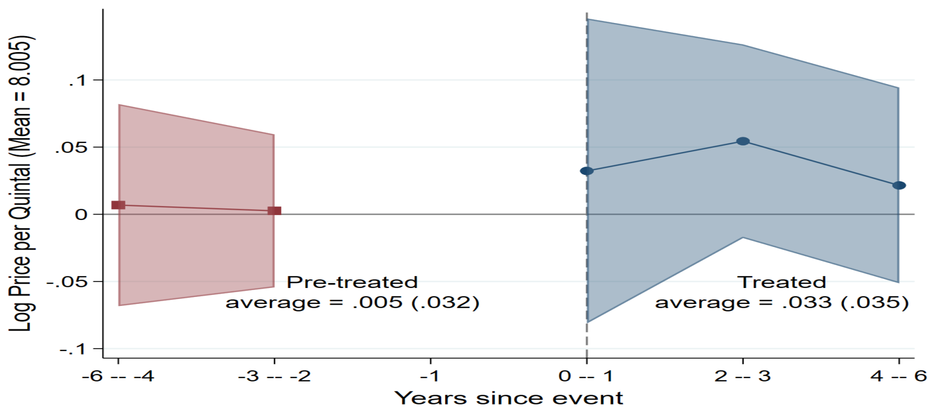
Figure A15: Effect of fertilizer price deregulation on agriculture prices



(a) Overall



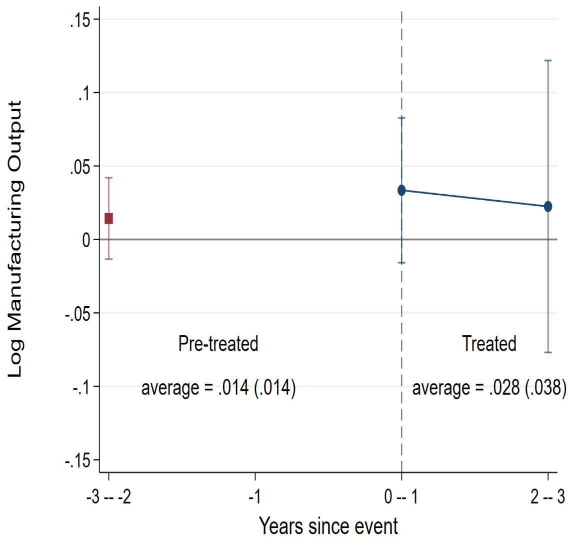
(b) Staples



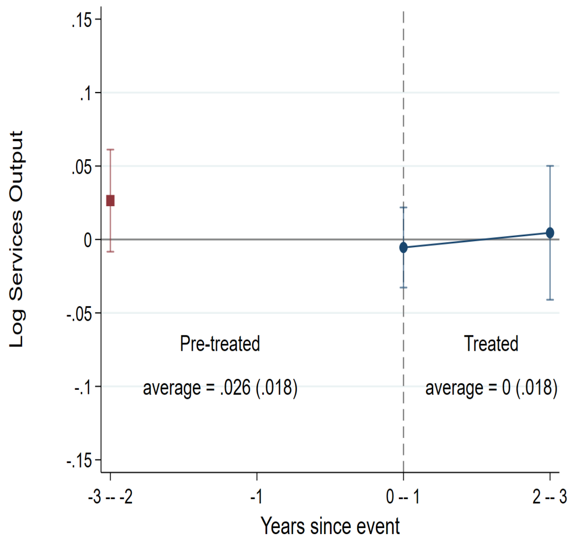
(c) Cash

Note: Figure reports treatment and pre-treatment effect averages and 95% confidence intervals in response to the change in fertilizer subsidy policy. Treatment and pre-treatment effects combined into 2-year bins. Standard errors in parentheses are clustered at the district level.

Figure A16: Effect of fertilizer price deregulation on log output in the manufacturing and services sectors



(a) Manufacturing



(b) Services

Note: Figure reports treatment and pre-treatment effect averages and 95% confidence intervals in response to the change in fertilizer subsidy policy. Treatment and pre-treatment effects combined into 2-year bins. Standard errors in parentheses are clustered at the district level.

B Additional Tables

Table B1: Effect of transfer program on different fertilizers use

Dependent variables: Log of Total Fertilizer value or Log Quantity				
	Total value (Rs.)	Nitrogen (kg)	Phosphorous (kg)	Potash (kg)
	(1)	(2)	(3)	(4)
Treatment Effect	0.08**	0.08***	0.08**	0.01
	(0.04)	(0.02)	(0.04)	(0.05)
Pre-treated effect	-0.02	-0.07	-0.01	-0.03
	(0.03)	(0.04)	(0.04)	(0.04)
Observations	1960	1956	1952	1908
R^2	0.97	0.97	0.96	0.93
Outcome Mean	19.83	16.67	15.71	14.36

Note: The coefficients show the average treatment and pre-treated effects. The sample size changes as we restrict regressions to a balanced panel in each case. Standard errors clustered at the district level are reported in parentheses. ***, ** and * represent the statistical significance at 1%, 5% and 10% levels respectively.

Table B2: Effect on log output and log yield using different control groups of fertilizer deregulation price

Dependent variable: Log Output or Log Yield				
	Baseline (5)	10	15	20
	(1)	(2)	(3)	(4)
	A: Output			
Treatment Effect	-0.27***	-0.26***	-0.25***	-0.23***
	(0.10)	(0.07)	(0.05)	(0.05)
Pre-treated effect	-0.09	-0.16**	-0.13**	-0.11**
	(0.08)	(0.07)	(0.05)	(0.04)
Observations	7056	7056	7056	7056
R^2	0.92	0.92	0.92	0.92
Mean Dependent	19.93	19.93	19.93	19.93
	B: Yield			
Treatment Effect	-0.26***	-0.30***	-0.25***	-0.23***
	(0.09)	(0.07)	(0.05)	(0.04)
Pre-treated effect	-0.10	-0.14**	-0.13***	-0.12***
	(0.08)	(0.06)	(0.05)	(0.04)
Observations	7056	7056	7056	7056
R^2	0.88	0.88	0.88	0.88
Mean Dependent	7.54	7.54	7.54	7.54

Note: The coefficients show the average treatment and pre-treated effects. Standard errors clustered at the district level are reported in parentheses. ***, ** and * represent the statistical significance at 1%, 5% and 10% levels respectively.

Table B3: Effect of fertilizer deregulation price on cash and staples agricultural production

Dependent variables: Log Output or Log Yield				
	Staples		Cash	
	Output (tonne)	Yield (tonne per ha)	Output (tonne)	Yield (tonne per ha)
	(1)	(2)	(3)	(4)
Treatment Effect	-0.31***	-0.32***	-0.22*	-0.18**
	(0.11)	(0.11)	(0.11)	(0.09)
Pre-treated effect	-0.14	-0.18*	-0.03	-0.09
	(0.10)	(0.09)	(0.09)	(0.07)
Observations	7056	7056	6790	6790
R^2	0.88	0.84	0.93	0.87
Outcome Mean	19.51	7.41	18.16	7.91

Note: The coefficients show the average treatment and pre-treated effects. Standard errors clustered at the district level are reported in parentheses. ***, ** and * represent the statistical significance at 1%, 5% and 10% levels respectively.

Table B4: Partial Equilibrium Outcome Comparison*

	Benchmark	Removing MSP	Reducing input subsidy
	(1)	(2)	(3)
Aggregate Quantities			
Aggregate Output	2.47	2.47	2.15
Real Output	2.47	2.47	2.15
Non-agricultural Good, y_n	1.37	1.37	1.75
Cash Crop, y_r	0.19	0.189	0.075
Staple Crop, y_s	0.27	0.27	0.095
Rations, c^{ration}	0.087	0	0.022
Intermediate input demand, $k_s + k_r$	0.133	0.132	0.025
Capital demand, k_n	3.53	3.53	4.52
Employment Shares			
Non-agricultural Sector	0.52	0.52	0.77
Cash Crop Farmers	0.18	0.18	0.095
Staple Crop Farmers	0.3	0.3	0.135

Note: *In these exercises, all prices are kept at the baseline level.

Table B5: MSP decomposition: outcomes

	Procure-disposal*	Procure -rations-market sale	Market redistribution
	(1)	(2)	(3)
Aggregate Quantities			
Aggregate Output	3.32	2.41	2.47
Real Output	2.74	2.45	2.47
Non-agricultural Good, y_n	1.26	1.38	1.37
Cash Crop, y_r	0.25	0.183	0.19
Staple Crop, y_s	0.37	0.264	0.27
Rations, c^{ration}	0.23	0.041	0.087
Intermediate input demand, $k_s + k_r$	0.22	0.125	0.132
Capital demand, k_n	3.92	3.5	3.51
Prices			
Non-agricultural Good (normalized)	1	1	1
Cash Crop, p_r	3.09	2.19	2.25
Staple Crop, p_s	3.48	2.37	2.48
Support Price, $\bar{p}$	3.7	2.53	-
Interest rate, r	0.058	0.0835	0.082
Wage, w	1.19	1.07	1.07
Employment Shares			
Non-agricultural Sector	0.42	0.53	0.52
Cash Crop Farmers	0.22	0.175	0.18
Staple Crop Farmers	0.36	0.295	0.3

Note: *A quarter of the procured staple crops are disposed of in this exercise, with the remainder being disbursed as rations.

Table B6: Equilibrium outcomes under replacement policies when MSP is removed

	No MSP	No MSP (balanced)	No MSP (in-kind)
Aggregate Quantities			
Aggregate Output	2.426	2.52	2.57
Real Output	2.474	2.484	2.506
Non-agricultural Good, y_n	1.43	1.368	1.369
Cash Crop, y_r	0.17	0.193	0.195
Staple Crop, y_s	0.264	0.275	0.281
Rations, c^{ration}	0	0	0.07
Intermediate input demand, $k_s + k_r$	0.122	0.136	0.141
Capital demand, k_n	3.47	3.54	3.575
Labour productivity of non-agri sector[‡]	2.42	2.635	2.66
Labour productivity of agricultural sector	2.53	2.33	2.34
Labour productivity of cash crop sector	3.33	2.412	2.4375
Labour productivity of staple crop sector	2.22	2.273	2.286
Prices			
Non-agricultural Good (normalized)	1	1	1
Cash Crop, p_r	2.15	2.3	2.32
Staple Crop, p_s	2.36	2.55	2.66
Interest rate, r	0.085	0.0813	0.08
Wage, w	1.06	1.077	1.082
Employment Shares			
Non-agricultural Sector	0.59	0.52	0.515
Cash Crop Farmers	0.115	0.18	0.18
Staple Crop Farmers	0.295	0.3	0.305

Table B7: Equilibrium outcomes under replacement policies when input subsidy is reduced

	Higher p_k	Higher p_k (balanced)	Higher p_k (fixed ration)
	(1)	(2)	(3)
Aggregate Quantities			
Aggregate Output	2.61	2.09	2.695
Real Output	2.21	2.21	2.23
Non-agricultural Good, y_n	1.375	1.244	1.34
Cash Crop, y_r	0.142	0.184	0.154
Staple Crop, y_s	0.21	0.27	0.212
Rations, c^{ration}	0.0689	0.2215	0.0876
Intermediate input demand, $k_s + k_r$	0.069	0.106	0.075
Capital demand, k_n	3.63	3.9	3.63
Labour productivity of non-agricultural sector	2.67	2.974	2.79
Labour productivity of agricultural sector	1.72	1.862	1.69
Labour productivity of cash crop sector	1.775	1.85	1.61
Labour productivity of staple crop sector	1.683	1.87	1.72
Prices			
Non-agricultural Good (normalized)	1	1	1
Cash Crop, p_r	3.18	4.406	3.3
Staple Crop, p_s	3.76	4.75	3.91
Support Price, $\bar{p}$	4.02	5.076	4.18
Interest rate, r	0.079	0.0582	0.077
Wage, w	1.09	1.19	1.1
Employment Shares			
Non-agricultural Sector	0.515	0.36	0.48
Cash Crop Farmers	0.18	0.215	0.215
Staple Crop Farmers	0.305	0.424	0.305

Table B8: Effect of fertilizer deregulation price on employment

Dependent variables: Dummy or Number of days			
	Main Activity Agriculture (1)	Agri Days (past week) (2)	Non-Agriculture Days (past week) (3)
Treatment Effect	0.02	0.16	-0.06
	(0.02)	(0.12)	(0.12)
Pre-treated effect	-0.02	0.14	-0.09
	(0.02)	(0.12)	(0.10)
Observations	700172	700172	700172
R^2	0.37	0.57	0.61
Outcome Mean	0.36	2.62	3.82

Note: The coefficients show the average treatment and pre-treated effects. Column 1 is an indicator variable with value 1 if main activity is All regressions are weighted as per weights provided in NSS. Standard errors clustered at the district level are reported in parentheses. ***, ** and * represent the statistical significance at 1%, 5% and 10% levels respectively. Regressions exclude individuals who indicated that they did not work or seek work in the past week. All regressions control for age and dummies for district, year, fmonth of year, household size, marital status, gender, education, social group, religion and rural area. Columns 2 and 3 additionally include dummies for household type.

C Data

This section describes the various datasets used for empirical analysis and calibrating the model. Additionally, we describe the sample selection undertaken for the various empirical exercises.

Ministry of Agriculture & Farmers Welfare

District level area, production, yield and price data for 48 crops covering 20 major states comes from the Ministry Of Agriculture and Farmers Welfare, Govt. Of India[54]. We focus on the states: Andhra Pradesh, Assam, Bihar, Chhattisgarh, Gujarat, Haryana, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Telangana, Uttar Pradesh, Uttarakhand and West Bengal. Quantity of all crops is reported in tonne, but only in units for coconut. We convert units into metric tonne by converting coconut production into copra[55]. Moreover, data on cotton, jute and mesta is available in bales. We convert it into metric tonne using the factor suggested by the Ministry of Agriculture[56]. We also categorize the crops into staple and cash varieties.

Table C1: List of staple and cash crops

Staple	Cash
Cereals: Bajra, Barley, Jowar, Maize, Ragi, Rice, Small Millets, Wheat	Oilseeds: Castor seed, Coconut, Groundnut, Linseed, Niger seed, Rapeseed, Safflower, Sesamum, Soyabean, Sunflower
Pulses: Arhar, Bengal Gram, Horse Gram, Khesari, Masoor, Moong, Moth, Pea, Urad	Fibre: Cotton, Jute, Mesta, Sannhemp
Spices: Arecanut, Black Pepper, Cardamom, Coriander, Dry Chillies, Garlic, Ginger, Turmeric	Miscellaneous: Guarseed, Sugarcane, Tobacco
Fruits and Vegetables: Banana, Cashew nut, Onion, Potato, Sweet Potato, Tapioca	

We do not consider output, area and yield for a crops where its yield is greater than 500. For the fertilizer subsidy exercise in Section 4.1, we only consider districts with observations for all

[54] https://aps.dac.gov.in/APY/Index.htm

[55] 5000 units of coconut = 1 metric tonne of copra. Source: https://documents1.worldbank.org/curated/en/309941468180567229/pdf/FAU4.pdf

[56] The conversion for cotton, jute and mesta is: 1 bale = 170, 180 and 180kg, respectively.

periods in the sample. After harmonizing some of the districts across time and other datasets, we are left with a sample of 504 districts. Our sample contains 7056 district-year observations with 14 periods (2004-2017).

For the MSP exercise in Section 6.1, we drop districts that had zero rice production during the sample period. Moreover, we consider only districts with positive area cultivation for all periods of analysis. Moreover, we drop Tamil Nadu from the analysis because there was a stark difference in its procurement policy before and after 2006. With 7 years (2003-2009) and 267 districts leads to 1869 district-year observations.

CEDA

In order to aggregate output and yield over crops, we weight them using prices. Monthly price data by crop is available at (CEDA, 2023). We use the price of the crop Sannhemp as the price of Mesta given they are both closely related fibre crops. In order to remove seasonality and time trends, we first average over the monthly data. Use the exponent of the constant in the regression of log of prices on time and time squared.

ICRISAT–TCI

Annual district-level data on manufacturing and service output at constant 2004 prices, covering the period from 2007 to 2013, were obtained from the ICRISAT–TCI (Tata-Cornell Institute of Agriculture and Nutrition). Annual district-level prices for 16 agricultural crops from 2004 to 2016 also came from this source. These data were used to understand the predictions of the model relating to the input subsidy program in Section 6.2. Furthermore, district-level annual consumption of N, P and K fertilizers from 2004 to 2017 was also provided by ICRISAT–TCI. This helped in the creation of a measure of fertilizer intensity at the district-level.

Cost of Cultivation Survey (CCS)

The Cost of Cultivation is a nationally representative survey on the input usage and costs faced by the farmers in India to grow various crops.

We use the years 2004-2009 to compute the area weighted median nominal price of fertilizers N, P and K per kg in Section 4.1. The median nominal prices are quite stable over the years due to the government's intervention in the fertilizer market. Hence, we use nominal rather than real prices across years.

We use the years between 2016-2018 to compute the area weighted nominal median price of fertilizers N, P and K per kg. Though, median nominal prices across years change with the level of inflation after the fertilizer policy change. We deflate them using the annual CPI and use the real prices to aggregate fertilizer consumption, which we use in Section 4.1 while investigating the impact of the cash transfer program on intermediate input use.

Land and Livestock Holding Survey (NSS 77$^{\text{th}}$ Round)

The Land and Livestock Holding Survey by the National Sample Survey (NSS) is a survey to collect information about the asset holdings, income and expenditure of rural households. We use both the visits of the 77$^{\text{th}}$ Round to compute the ratio of market price of rice and wheat to the national support price for the year 2018-19. We only consider rice and wheat as they are the two crops with the highest amount of procurement. Market price is defined as the value of the crop sold divided by the quantity. We keep the 20 major Indian states and drop the smaller states and union territories.

CMIE States of India

Annual data on fertilizer use of Nitrogen, Phosphorus and Potash and production and area data for 44 crops from 2017 to 2020 comes from this source. ICRISAT–TCI only provides data until 2017. Hence, this led to the use of a different data provider. We use the median real prices from CCS to construct the total value of fertilizer consumption at the district level. We use districts with 4 years of observations in all the regressions related to the cash transfer program. We are left with 490 districts and 1960 district-year observations for the regression on log total fertilizer. Moreover, we have 554 districts and 2216 district-year observations for the production and yield regressions.

India Human Development Survey

The India Human Development Survey (IHDS) is a national- and state-level representative data. There are two waves of the data corresponding to the years 2004-05 and 2010-11. It provides detailed information on household income and consumption in both waves. Additionally, it contains detailed questions on the kinds and value of crops grown and agricultural production inputs in the first wave. The second wave provides individual level data on income from agriculture and non-agricultural activities.

We focus on the 19 major Indian States while computing any statistic from the IHDS dataset. When estimating the variance of crop harvest, we winsorize the top and bottom 1% of the crop harvest distribution. Moreover, we focus on households living in rural areas with non-missing information on education and positive net land (land holdings minus land rented out plus land rented in) used in agriculture.

Employment Survey (NSS)

The Employment Survey by NSS is a cross-sectional survey on individual employment status, which representative at the district level. We use the 61^{st}, 62^{nd}, 64^{th}, 66^{th} and 68^{th} rounds, which correspond to the years 2004-05, 2005-06, 2007-08, 2009-10 and 2011-12 over a 12 month period (July to June). The survey provides daily information on labour supply over a week at the individual-industry level. We drop individuals with missing information on religion, caste, household size, marital status, education, gender and date of survey. We focus on individuals between age 16-64 living in the 19 major Indian states and exclude individuals with no response about their household type.

Other Data

Some of the other data sources are listed below in Table C2.

Table C2: List of other data sources

	Variable	Source
1	Annual CPI	World Development Indicators
2	MSP Procurement Price	Reserve Bank of India Handbook of Indian Statistics
3	National and State Level Procurement	IndiaStat
4	Sectoral employment shares and value added for India	RBI India KLEMS Database
5	Worldwide sectoral employment shares	International Labour Organization (ILO)
6	Worldwide sectoral value added	World Development Indicators
7	Actual yield of rice and wheat by states	Reserve Bank of India Handbook of Statistics on Indian States
8	Potential yield	GAEZ FAO