United on Divisive Waters: Decentralization of Irrigation and Conflict in India*

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Abstract

Arguments for decentralizing local public goods often emphasize productivity gains, but such reforms can also shape social cohesion, particularly in diverse communities and for high-stake resources. Exploiting the staggered roll-out of irrigation decentralization across Indian states, we show that these reforms reduce riots and perceived village-level conflicts. Our mechanism analysis points at reform-induced increases in the opportunity cost of conflict and highlights increased labor supply in agriculture and strengthened cooperation, which expand irrigation access and ultimately boost agricultural productivity.

Keywords: Agriculture, conflict, public goods, irrigation management

JEL Codes: Q12, Q18, O11

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1 Introduction

Irrigation plays a pivotal role in agricultural landscapes worldwide, significantly contributing to food security and increasing the sector's productivity (Evenson and Gollin 2003). Its role is likely to become even more important in face of current climate change trends elevating the risks of water shortages (World Bank 2016). As a major local common pool resource, irrigation's functioning depends heavily on good governance, regulations and well-defined property rights. In most developing countries with weak enforcement powers of the state, ineffective state-run formal institutions usually overlap with informal institutions run by local communities.[1] It is well known that problems with water access[2] and food insecurity[3] spark conflict, and that both civil conflict and local cooperation are affected by group heterogeneity.[4] However, little is yet known about the effects of formalizing the informal irrigation institutions through administrative, fiscal and political decentralization on civil conflict in diverse societies. We investigate this issue in the empirical context of India, a unique setting characterized by multitude of castes, eight major religions, a plethora of languages and dialects spoken, all intertwined in recurring conflicts.

Historically, rulers of ancient Indian kingdoms acted as custodians of water resources with a high effective degree of administrative decentralization. This tradition shifted under British colonial rule who centralized all key irrigation decision making with the focus on building vast irrigation networks in order to increase agricultural productivity. The British legacy of centralized irrigation management continued in the post-independence India up until the end of 20th century, generating inefficiencies, inequities and associated conflicts due to ineffective governance, regulations and incomplete property rights.

Towards the end of the century, the central government of India began recommend-

[1] See e.g. Wade (1988), Ostrom (1990), Greif (1993), McMillan and Woodruff (1999), and Macchiavello and Morjaria (2015).

[2] See e.g. Devoto et al. (2012) for the case study in Morocco and Sekhri (2014) in India.

[3] See e.g. the special issue on food security and violent conflict in *World Development* (Brück and d'Errico 2019).

[4] See e.g. Arbatlı et al. (2020), Alesina and Spolaore (2005), and Habyarimana et al. (2007).

ing restructuring irrigation governance[5] through creation of *Water User Associations* (WUAs) endowed with property rights for constructing, running and maintaining the infrastructure. In what follows, we explore whether instituting WUAs shifting these property rights from central authorities to local communities affected the incidence of civil conflicts.

In order to guide our empirical work, we set off by developing a conceptual framework stressing the high-stake nature of irrigation for rural livelihoods. We show that a decentralization reform directly reduces the incidence of conflict by altering the opportunity cost of time devoted to conflict. Furthermore, these effects become reinforced by positive income effects unleashed by increases in the agricultural productivity.

Equipped with testable hypotheses from our conceptual framework, we build a novel panel of Indian states, districts, villages and households drawing on the Minor Irrigation Census (MIC), Indian Human Development Survey (IHDS), Indian Population Censuses, National Crime Records Bureau (NCRB), Reserve Bank of India, ERA5 from the European Centre for Medium-Range Weather Forecasts, and remote-sensed satellite biomass images from NASA. Our identification strategy relies on the federal structure of Indian government endowing states with autonomy over water politics, which generates an arguably quasi-natural variation in adoption times of WUAs reforms by state legislatures. This allows us to employ a staggered difference-in-differences (DiD) analytical framework for a comparative analysis between regions that have adopted decentralized model of water management and those that have not. We show that adoption of the laws has first stage impact on the government-managed share of irrigation recorded in MIC data and, based on this, devise a further instrumental variable (IV) strategy corroborating robustness of our results.

The findings reveal a significant reduction in the incidence of riots and perceived village-level conflicts following the implementation of these reforms, indicating an overall improvement in social stability. Our mechanism analysis confirms that the reform improves the subjective measure of cooperation over water among local communities, and increases labour supply in agriculture, access to irrigation and agricultural pro-

[5]First recommendations for country-wide decentralization of irrigation appeared in the 2002 update of the National Water Policy issued by the Indian Ministry of Water Resources.

ductivity. Importantly, we show that these effects do not simply arise due to increased public spending on irrigation infrastructure or being correlated with changes in general crime patterns. Finally, the positive effects of reform are observed consistently across both more and less culturally diverse regions.

Our study contributes to three strands of the literature. First, our work speaks to the literature on conflict due to water access, which are a recurrent issue in India, often exacerbated by the country's diverse socio-cultural landscape. Wade (1988) provides a foundational analysis of irrigation socio-economic dynamics in Indian village communities, including discussion of water conflicts, highlighting the importance of local institutions and caste networks in regulating and monitoring irrigation water use and resolving water disputes. Devoto et al. (2012) and Sekhri and Hossain (2023) offer more recent empirical evidence, showing how problems with accessing water lead to disputes and violence. Similarly, Sekhri (2014) and Miguel, Satyanath, and Sergenti (2004) show that poverty induced by water scarcity leads to violent conflict. We complement these papers by documenting the effectiveness of a scalable solution entrusting local communities with the property rights over irrigation infrastructure, thereby promoting cooperation and more efficient and equitable resource allocation.

Second, we contribute to the literature on impact of decentralization reforms across domains. Existing literature often finds conflicting and inconclusive results evaluating various decentralization reforms (Bardhan and Mookherjee 2006, Treisman 2007, Faguet and Pal 2023). Examples of positive evaluations of decentralization reforms are in Dahis and Szerman (2024), Narasimhan and Weaver (2024), and of negative ones in Cassidy and Velayudhan (2022), Malesky, Nguyen, and Tran (2014). In the context of irrigation, Mazur (2023) structurally estimates a model of risk sharing and irrigation cooperation on a panel data from 3 Indian villages and shows that decentralization reforms benefited these communities by unleashing dynamic complementarities between the two institutions. In this paper, we provide country-wide causal evidence that irrigation decentralization reforms in India not only improve the efficiency of irrigation systems but also foster a more resilient and cooperative community structure, leading to reduction in civil conflict. Focusing on different type of public goods, Chaudhary and Iyer (2024) shows that incomplete devolution of administrative responsibilities

over local health care institutions (without decentralizing associated fiscal responsibilities) in India has worsened the mortality rate of children. We find positive outcomes in case of arguably more complete decentralization of irrigation infrastructure, in line with their hypothesis about differential impacts of complete and incomplete decentralization reforms.

Third, we contribute to the literature on conflict-reducing interventions, which often focus on fostering meaningful exposure to outgroup members alongside leadership appeals for peace. For example, Weiss, Ran, and Halperin (2023) show that debates about inter-group tensions in schools and exposure to outgroup perspectives via televised appeals effectively counter prejudice among adolescents in Israel. Similarly, Blair et al. (2021) find that peace-promoting messages from trusted authorities in Nigeria reduce belligerent attitudes, while Chang and Peisakhin (2021) report similar results from spiritual leaders in Lebanon. However, these interventions are often artificial, have only short-term effects, and are difficult to scale. To address this, some studies explore inter-group interdependencies in more natural settings. Lee and Pyun (2016) find that bilateral trade integration fosters peace between neighboring countries, and Gartzke (2007) shows that economic development, shared policy interests, and financial integration reduce conflict, a pattern confirmed by Martin, Mayer, and Thoenig (2008). We build on this cross-country evidence by establishing a causal link between economic integration and peace at the micro level. We add to the works of Jha and Shayo (2019), who show that incentivizing Israelis and Palestinians to participate in financial markets fosters peace-oriented attitudes, and Garg et al. (2024), who leverage the competitive nature of Indonesia's Community Driven Development program to demonstrate that inter-village competition reduces conflict by promoting cohesion within villages. In the context of India, Varshney (2003)'s primarily qualitative work on Hindu and Muslim relations demonstrates similar cooperation-promoting effects arising from economic interdependence.

2 Institutional setting

2.1 Historical Context of Irrigation in India

Irrigation has always been a critical commodity for ensuring food security and sustaining rural livelihoods in India. Historically, irrigation systems in ancient and medieval India were largely managed in a decentralized fashion. Local communities, often under the trusteeship of regional kings (Cullet and Gupta 2008, Siddiqui 1992), were responsible for regulating water resources based on local geographical and physical conditions (Vani 1992, Joseph 2021 and Bhat, Basalalli, and Bhogse 2021). This decentralized model allowed communities to adapt their practices to local needs, ensuring sustainable water management.

However, this model underwent significant changes during the colonial period. The British colonial administration sought to assert control over India's natural resources, including water, to facilitate agricultural production and extract rents. The colonial government viewed irrigation as a tool for both economic development and famine prevention (Commission Of Inquiry On Indian Famines 1880). This led to the construction of an extensive network of irrigation canals, which continues to benefit India today (Asher et al. 2023).

Legally, the British introduced the concept that local communities held only usufructuary rights over water, meaning they could use the water flowing through their lands but did not own the water resource itself nor any particular volume of it (Puthucherril 2011, Jacob and Singh 1972, Cullet and Gupta 2008). This principle marked a significant shift from the customary rights previously enjoyed by local communities. The 1919 Government of India Act adjusted this highly centralized model of water management by introducing a quasi-federal system granting provincial governments the authority to propose and carry out irrigation projects with central approval (Singh 2003, Jain 1971). The 1935 Government of India Act extended this autonomy by granting regions' control over all domains of water management with the exception of the central government retaining the authority to resolve interstate water disputes (Jain 1971). This legal framework has persisted with the post-independence constitution

maintaining the federal structure guaranteeing all the 29 state governments autonomy over water issues (with exception of 8 Union Territories where the central government retains control over this domain).[6]

2.2 Emergence of WUAs and Decentralized Irrigation Management

Several scholars argue that under the centralized institutions of irrigation management, the state governments (represented by regional offices of Ministry of Water's Irrigation Department (ID)) often struggled to effectively monitor, regulate, and maintain irrigation infrastructure (Wade 1982, 1988, 2000, Chambers 1988, Wade and Chambers 1980, and Brewer et al. 1999). The reasons for this mismanagement range from corruption to lack of human or financial resources, motivation, expertise or information about local settings. Going beyond the setting of India, but for similar reasons, the 2004 World Development Report has similarly argued for reforms decentralizing public service delivery:

> Too often services fail poor people in access, in quality, and in affordability ... this year's World Development Report argues that services can be improved by putting poor people at the center of service. How? By enabling the poor to monitor and discipline service providers, by amplifying their voice in policy making, and by strengthening the incentives for providers to serve the poor. (World Bank 2004)

Arguably, trying to address these issues, India has started in 1990s the gradual implementation of Water User Association (WUA) laws across its states and union territories. The first states to enact these laws were Andhra Pradesh and Goa in 1997 and, as of today, 16 Indian states have implemented such institutions (for the timeline of WUAs implementation years see Table A11 in Online Appendix).

The WUA reforms establish Farmers Organizations, which are organized into three hierarchical levels: Project Committees, Distributory Committees, and Water User

[6]The central government may to some extent exercise control over states' water politics through the Article 282 of Constitution granting it a discretionary power to provide grants for financing irrigation projects (Puthucherril 2022).

Associations (in the order of subjacency). At the core and the lowest level of this system are the Water User Associations, which consist of all landowners living typically in an areas encompassing one or two villages. These associations hold group property rights over local water resources and are responsible for maintaining, expanding, and improving local irrigation systems, regulating and monitoring equitable water supply schedules, managing their budgets (with power to levy water fees), providing extension services to its members, and resolving water disputes within their membership.[7]

The structures of WUAs often build upon or co-operate with Panchayats, decentralized village-level governments, established in 1993 through the Panchayati Raj Acts as 73rd and 74th amendments to the constitution of India. Accounts in Wade (1988), Sengupta (1991) and Gandhi et al. (2020) also show that already in 1970s and 1980s some Indian village communities managed to independently develop their own successful local-level water management institutions. Thus, while WUAs are not direct successors of the early, sporadically distributed decentralized irrigation institutions, the reforms establishing WUAs represent a significant and coordinated effort to decentralize water management and involve farmers on a large scale.[8] By decentralizing water management through WUAs, these reforms aim to enhance the sustainability and effectiveness of water use in agriculture. This approach aligns with broader goals of the Panchayati Raj Acts aiming at improving efficiency and accountability in public services, fostering a sense of ownership among farmers, and addressing long-standing issues of resource access and equity in India's diverse rural landscape.

[7]The Distributory Committees delineate all WUAs within a specific distributory area, serving as a coordinating body and resolving conflicts across WUAs. The Project Committees delineate larger swathes of project areas into respective distributory areas, and similarly coordinate works and resolve conflicts across Distributory Committees.

[8]Ghatak and Ghatak (2002) argue that the Panchayati Raj Acts served as similar role as although there were some panchayats already before the 1990s, most of them were generally ineffective, did not play any active role in public service provision and held no regular elections.

2.3 Examples of experiences with WUAs

In what follows, we synthesize micro-level studies shedding further light on the causal roots of the effects we establish in our conceptual framework and empirical results below. First, inception and spread of decentralized water management institutions in India varies from case to case, but their common denominator are the local farmer communities with genuine interest and initiative in establishing those institutions.[9] In some of the cases these efforts were initially supported by trainings and extension services provided by NGOs (as in cases from Gujarat in Mukherji, Verma, and Rath (2002) and Bhatt (2013)). In others, local farmers took up the initiative on their own either under the desperation of dismal state of local infrastructure abandoned by state-level institutions or upon learning about successful experiences of WUAs established in other communities (as in cases from Assam and Bihar in Gandhi et al. (2020)).[10] In general, joining WUAs is voluntary and farmers can become members by purchasing shares in the institution.

From the political angle, virtually all WUAs reviewed have executive committees involving around a dozen of members (including the chairman, secretary, treasurer and their assistants), who are in principle independent from the committees of local Panchayats. They are appointed through elections or consensus by WUA members. Usually, one of each WUA's executive committee members is elected to become a member of the higher level Distributory Committees' executive committee, and so on. To the extent that the degree of the members' voluntary involvement in these democratic processes depends on the actual performance of their own WUAs, this political decentralization further contributes to the sense of ownership over the common in-

[9]Exception from this is the state of Maharashtra, where the 2005 Maharashtra Management of Irrigation systems by Farmers Act stipulates that the provision of irrigation water can be done exclusively via WUAs.

[10]Many of the early WUAs, i.e. those established in years preceding the large reforms passed by state parliaments and studied in this paper, were experimental and informal in the sense of not receiving any financial or institutional support from their state's ID. However, after confirming their usefulness in improving local irrigation affairs, the managing communities usually formalized their institutions by signing formal agreements with the state's authorities (see e.g. Mukherji, Verma, and Rath (2002)).

frastructure. Moreover, Bhatt (2013) finds evidence that these local institutions have not been captured by local elites. Importantly, in state with laws recognizing women as landowners or providing reservation quotas for women in local institutions, executive committees of WUAs consequently include women and thereby also contribute to gender integration (e.g. the case of WUAs in Bihar reviewed in Gandhi et al. (2020) and in Andhra Pradesh and Madhya Pradesh reviewed in Raju, Dayal, and Chatterji (2008)).

While the laws passed by some state government (Table A11) contain provisions for WUAs to be equally involved in groundwater irrigation, most of the reviewed WUAs were principally engaged in operations and management of surface irrigation systems charged by canals. In cases from Gujarat in Bassi, Rishi, and Choudhury (2010) and Mukherji, Verma, and Rath (2002) and from Andhra Pradesh in Raju, Dayal, and Chatterji (2008), the availability of and equity in access to water have significantly improved post-WUA establishment, inducing sectoral transformations from cultivation of rain-fed rice or pulses to wheat, moong, groundnuts, sugarcane and other vegetables (Mukherji, Verma, and Rath (2002)). Moreover, Mukherji, Verma, and Rath (2002) provides accounts of communities where agricultural productivity impacts have been so large as to reduce seasonal migration of farmers in lean seasons, thereby arguably contributing to social cohesion in the village.

The villages reviewed included those located at both the heads or tails of particular canals. In such a setting, if a tragedy of the commons occurs, the tail-end users may be entirely deprived of water, being a great recipe for sparking inter-village conflicts. To this end, Bassi, Rishi, and Choudhury (2010) and Raju, Dayal, and Chatterji (2008) provide accounts of numerous villages sharing one canal where they have recorded improvements in water availability or equity after establishing WUAs, and especially so for the tail-end communities. The complexity of irrigation made head-users realize that they cannot maintain the canal well without the help of end-users. The head-users reciprocated by sharing water with end-users according to promises, expecting that they would need their help again in the future.

More generally, while every task related to operation and management of local irrigation had to be coordinated and implemented by the WUA's executive committee,

no work could be done without active participation of the rest of community or even cooperation with other communities sharing the resource. This is further confirmed by accounts in Gandhi et al. (2020) of WUA members respecting the leadership of local chairman and providing voluntary labor whenever called upon for repairing irrigation infrastructure.

Fiscal decentralization is a critical component of any such reform allowing to strengthen the sense of ownership. Before establishing of WUAs, irrigation water fees were collected directly by ID with very poor collection rates. After these decentralized institutions have been established, collection rates have significantly improved, often because of social network interlinkages, norms and customs (as reported by e.g. Mukherji, Verma, and Rath (2002), Raju, Dayal, and Chatterji (2008) and Bhatt (2013)).[11]

Nonetheless, WUAs are not entirely independent from state's ID as they share their water fees with ID. On this account, ID supplies water to the canals and sometimes, but not always, assists the communities in large repairs by providing manpower, equipment and financing. Improved collection of fees has also contributed to increased availability and reliability of water from ID to WUAs. This happened not only because of reduced frequency of ID's punishments for non-payments, but also due to improvements in communication between the community and ID allowing for better water demand forecasting (Mukherji, Verma, and Rath (2002)).

As a result of the socio-economic dynamics triggered by WUAs discussed above, many of the case studies based on interviews with farmers in Gandhi et al. (2020),

[11]Further evidence on such institutions can be found on pages 6 and 75 in Wade (1988), where he discusses "common irrigators" appointed by local village councils and paid using contributions from all benefiting farmers. They are responsible for watering fields, ensuring fair allocations, organizing groups for repairing infrastructure and (together with village councils) fining households abusing common resources. Furthermore, on p. 193 Wade (1988) documents widespread use of financial, reputational and ostracising sanctions imposed by local population or councils for not co-operating over or abusing the irrigation water. On p. 104, Sengupta (1991) describes a similar institution of impartial "neerpaichys" in Kandadevi village of Tamil Nadu working as common water distributors, guards and repairers paid by all cultivators.

Bassi, Rishi, and Choudhury (2010), Raju, Dayal, and Chatterji 2008 and Bhatt (2013) provide explicit evidence of significant reductions in water conflicts over water. Bassi, Rishi, and Choudhury (2010) find this even in cases of communities with WUAs performing relatively worse.

Further studies by Wade (1988) and Bardhan (2000) document higher degrees of social co-operation in Indian villages with WUAs as opposed to the ones where irrigation affairs are mostly regulated by the state-level ID. Meta-analyses of 21 cases of WUAs in Gujarat, Maharashtra and Tamil Nadu by Brewer et al. (1999) and Kolavalli and Brewer (1999) similarly conclude that these transfers of ownership and management were usually associated with development and strengthened enforcement of rules for irrigation water and infrastructure management and, importantly, reductions in conflict.

Going beyond the case of India, many of the positive effect discussed above are confirmed in a Food and Agriculture Organization's (FAO's) cross-country report on irrigation management transfers by Garces-Restrepo, Vermillion, and Munoz (2007). In most global case studies reviewed (including WUAs from Andhra Pradesh, Karnataka and Madhya Pradesh in India), they find improvements in the efficiency of water fee collection, quality of infrastructure maintenance, timeliness and equity of water delivery, area of land irrigated, yields and income.

3 Conceptual Framework

3.1 Static Environment

We begin with a one-period economy inhabited by 2 identical farming households with linear preferences over consumption $c \geq 0$ and a constant relative risk aversion (CRRA) preferences over leisure:

$$u\left(c_i, l_i\right) = c_i + \alpha \frac{l_i^{1-\frac{1}{\epsilon}}}{1-\frac{1}{\epsilon}} \tag{1}$$

where $\epsilon > 0$ governs the Frisch elasticity. Both households $i \in \{1, 2\}$ are endowed

with 1 unit of time and with resources $w_i = w$, over which they may fight. We denote by f_i the amount of time household i devotes to fighting over resources of the other household $-i$. We assume that household i takes the fighting decision of the other household as given.

Furthermore, households decide about the time devoted to working on the field n_i to produce agricultural output using the following technology:

$$y\left(n_i; f_1, f_2, \theta^j\right) = \theta^j \left(1 - \frac{1}{2}\left[f_1 + f_2\right]\right)^{(1-\gamma)\cdot\zeta} n_i^{\gamma} \tag{2}$$

where $\gamma \in (0, 1)$ so that the production technology exhibits decreasing returns to scale in labor. The term $\theta^j \left(1 - \frac{1}{2}\left[f_1 + f_2\right]\right)^{(1-\gamma)\cdot\zeta}$ captures the overall productivity of irrigation in the village. The first term introduces common pool externalities (typical for public goods such as irrigation) by assuming that the endogenous part of irrigation productivity is increasing in the village-wide time spent non-fighting. For tractability, we assume that it is taken as given by households when choosing f. As such, we also interpret increases in conflict as reductions in cooperation. We will highlight the importance of irrigation's common pool resource nature by comparing the model with ($\zeta = 1$) and without externalities ($\zeta = 0$).

The variable θ^j captures the productivity of irrigation that is exogenous to fighting time f, but endogenous to the choice of management model $j \in \{\mathbf{c}entralized, \mathbf{d}ecentralized\}$. The centralized model assumes that the government agency external to the village is fully responsible for operations and maintenance of the irrigation infrastructure, i.e. it requires no time investment of households ($x_c = 0$). On the other hand, under the decentralized management of irrigation, villagers need to invest a fixed amount of time $x > 0$ to maintain and manage the infrastructure. We provide a dynamic extension of the model allowing for endogeneous choice of the degree of cooperation in Section 3.2 below.

Characterization We start with making the following assumption:

Assumption 1. *The amount of resources w is large relative to the irrigation mainte-*

nance time x in the sense of:

$$1 - \left(\frac{\max\{\theta^d, \theta^c\} \cdot \gamma}{w} \right)^{\frac{1}{1-\gamma}} - \left(\frac{\alpha}{w} \right)^{\epsilon} \geq x \tag{3}$$

which implies that the amount of time devoted to fighting satisfies $f_i \geq 0$ (we establish this below in Proposition 1).

Second, the labor supply will be positive $n_i > 0$ due to the production function (2) exhibiting decreasing return to scale. This implies $l_i < 1 - 1_{j=d} \cdot x$, where $1_{j=d}$ denotes the indicator function taking value of 1 if the policy maker chooses to decentralize irrigation management ($j = d$). Similarly, as the CRRA utility function of leisure satisfies Inada condition[12] at 0, $l_i > 0$. Thus, we know that endogenous choices will be interior: $0 < l_i < 1 - 1_{j=d} \cdot x$, $0 < n_i < 1 - 1_{j=d} \cdot x$ and $0 < f_i < 1 - 1_{j=d} \cdot x$.[13] We interpret f_i as the share of household $-i$'s resources controlled by household i after fighting takes place. The symmetry implies $n_1 = n_2$ and $f_1 = f_2$.[14]

In equilibrium, households maximize individual utility given by (1), taking the irrigation management model $j \in \{c, d\}$ as given, subject to:

1. the following budget constraint:

$$c_i \leq \theta^j \left(1 - \frac{1}{2} \left[f_1 + f_2 \right] \right)^{(1-\gamma)\cdot\zeta} n_i^{\gamma} + w_i \left(1 - f_{-i} \right) + w_{-i} f_i \ \forall i \in \{1, 2\} \tag{4}$$

2. the total amount of time spent on working, fighting, leisure and irrigation maintenance (under decentralized management) satisfying the following constraint:

$$l_i + n_i + f_i + x \cdot 1_{j=d} = 1 \tag{5}$$

The following proposition characterizes optimal decisions of households:

[12]The marginal benefit of leisure is infinity at $l_i = 0$.

[13]Strictly speaking, time devoted to fighting will be positive if we rule out the generic case of $1 - \left(\frac{\max\{\theta^d, \theta^c\} \cdot \gamma}{w} \right)^{\frac{1}{1-\gamma}} - \left(\frac{\alpha}{w} \right)^{\epsilon} = x$.

[14]In order to sidestep the issue of uncertainty about the outcome of fighting (which would affect the optimal labor choice), we implicitly assume that the labor supply decision takes places after the result of fighting is realized.

Proposition 1. *Households in regime $j \in \{c, d\}$ maximizing utility function* (1) *subject to* (4) *and* (5) *devote the following amount of time to fighting and working:*

1. with externalities ($\zeta = 1$):

$$f^* = 1 - \frac{x \cdot 1_{j=d} + \left(\frac{w}{\alpha}\right)^{-\epsilon}}{1 - \left(\frac{w}{\theta^j \gamma}\right)^{\frac{1}{\gamma-1}}} > 0 \tag{6}$$

$$n^* = \left(\frac{w}{\theta^j \gamma}\right)^{\frac{1}{\gamma-1}} \cdot \frac{x \cdot 1_{j=d} + \left(\frac{w}{\alpha}\right)^{-\epsilon}}{1 - \left(\frac{w}{\theta^j \gamma}\right)^{\frac{1}{\gamma-1}}} \tag{7}$$

2. without externalities ($\zeta = 0$):

$$f^* = 1 - \left(\frac{w}{\alpha}\right)^{-\epsilon} - x \cdot 1_{j=d} - \left(\frac{w}{\theta^j \gamma}\right)^{\frac{1}{\gamma-1}} \tag{8}$$

$$n^* = \left(\frac{w}{\theta^j \gamma}\right)^{\frac{1}{\gamma-1}} \tag{9}$$

Proof. See Appendix A.1. □

Notice that conflict is a socially wasteful zero sum game. This and the assumption that households do not internalize the impact of conflict[15] on productivity, imply that the the equilibrium with households maximizing individual utility is generally inefficient relative to the first best benchmark, where the planner would choose no conflict and internalize all externalities.

In any case, comparative statics associated with optimal decisions in Proposition 1 show that utility-maximizing households fight less and work more when their agricultural productivity increases. Furthermore, they work less and fight more when the amount of resources in the village increases. Intuitively, these dynamics reflect optimal responses of households to changes in opportunity cost of their time. We summarize these comparative statics in the following proposition:

Proposition 2. *Under Assumption 1, the following hold:*

[15] Under Assumption 1, conflict is positive in equilibrium unless $1 - \left(\frac{\max\{\theta^d, \theta^c\} \cdot \gamma}{w}\right)^{\frac{1}{1-\gamma}} - \left(\frac{\alpha}{w}\right)^{\epsilon} = x$.

1. *Conflict f decreases with productivity θ:* $\frac{\partial f}{\partial \theta} < 0$.

2. *Conflict f decreases with time required for maintaining irrigation x:* $\frac{\partial f}{\partial x} < 0$.

3. *Conflict f increases with amount of resources w:* $\frac{\partial f}{\partial w} > 0$.

4. *Labor supply n increases with productivity θ:* $\frac{\partial n}{\partial \theta} > 0$.

5. *Labor supply n weakly increases in time cost of irrigation maintenance x:* $\frac{\partial n}{\partial x} \geq 0$*:*

   (a) *With externalities, this relationship is strict:* $\frac{\partial n}{\partial x} > 0$.

   (b) *Without externalities, n is independent of x:* $\frac{\partial n}{\partial x} = 0$.

6. *Labor supply n decreases with amount of resources w:* $\frac{\partial n}{\partial w} < 0$.

Proof. See Appendix A.1. □

The effect of time cost of maintaining irrigation x on conflict and labor supply in the model with externalities is akin to the effects of exogenous productivity θ. As x increases, the opportunity cost of fighting increases (since production exhibits decreasing returns to scale and the function governing share of controlled resources after fight[16] is linear). In the model with externalities, these reductions in conflict further increase the endogenous part of productivity, translating into increased incentives for labor supply.

We now proceed to results of our main interest - the effects of decentralization on conflict and economic outcomes:

Proposition 3. *Under Assumption 1, there exists a productivity threshold value $\bar{\theta} \leq \theta^c$ such that for $\theta^d \geq \bar{\theta}$, decentralization reduces conflict, and increases irrigation's productivity, output and welfare. In the economy with externalities this threshold satisfies $\bar{\theta} < \theta^c$, and in the economy without externalities this threshold satisfies $\bar{\theta} = \theta^c$.*

Proof. See Appendix A.1. □

[16] Or the underlying probability of winning fight.

Although decentralization effectively taxes the amount of time at households' disposal, it leads to welfare improvements by reducing conflict over resources, and increasing among of output produced. These effects are particularly strong in the economy with productivity externalities. In this case, as the pressure of time required for maintaining irrigation reduces conflict, it also increases the productivity of farmers through the externality channel. This further increases opportunity cost of fighting, generating increases in labor supply and overall output. Ultimately, the welfare, as measured by the sum of utility functions (1) for both agents, also increases.

Finally, the model generates interesting predictions about heterogeneous effects of decentralization as summarized below:

Corollary 1. *Under (i) Assumption 1, and (ii) $\theta^d \geq \bar{\theta}$ established in Proposition 3, conflict reduction triggered by decentralization is larger in places with a higher productivity θ^d and a higher time cost of irrigation maintenance x.*

Proof. See Appendix A.1. □

3.2 Dynamic Environment

We now introduce a discrete choice of the degree of cooperation in a two period extension of the static model above. The protocol of the framework is largely similar to the above one with two key differences. First, households live now for two periods $t = 1, 2$ and discount future at the rate of $\beta \in [0, 1]$. For simplicity, we assume that in each period households have the same endowment $w > 0$.

Second, if irrigation management is decentralized, households may now also choose the level of cooperation high (H) or low (L), which translates into two levels of exogenous productivity $\theta^{d,L} < \theta^{d,H}$. We normalize the cost of low cooperation to zero and assume that the cost of high cooperation is a linear function increasing at the rate of $\chi^H > 0$ in the last period's total amount of time devoted to fighting $f_{t-1} = f_{1,t-1} + f_{2,t-1}$, with initial condition $f_0 \geq 0$ being given. The last assumption captures the theoretical mechanism in Rohner, Thoenig, and Zillibotti (2013) and, more importantly, is supported by the rich evidence discussed therein suggesting that

the history of conflict affects current social cohesion, generating dynamic effects on current and future cooperation patterns.

If decentralization takes place in period 1, each household $i \in \{1, 2\}$ faces the following dynamic problem:

$$\sum_{t=1}^{2} \beta^{t-1} \max \left\{ \max_{c,f,n,l} c_{i,t}^{L} + \frac{l_{i,t}^{L\,1-\frac{1}{\epsilon}}}{1-\frac{1}{\epsilon}}, \max_{c,f,n,l} c_{i,t}^{H} + \frac{l_{i,t}^{H\,1-\frac{1}{\epsilon}}}{1-\frac{1}{\epsilon}} - \chi^{H}\left(f_{1,t-1} + f_{2,t-1}\right) \right\} \tag{10}$$

$$s.t. \tag{11}$$

$$c_{i,t} \leq \theta^{d,l} \left(1 - \frac{1}{2}\left[f_{1,t} + f_{2,t}\right]\right)^{(1-\gamma)\cdot\zeta} n_{i,t}^{\gamma} + w_i\left(1 - f_{-i,t}\right) + w_{-i} f_{i,t} \;\forall l \in \{H, L\} \tag{12}$$

$$l_{i,t} + n_{i,t} + f_{i,t} + x \cdot 1_{j=d} = 1 \tag{13}$$

$$f_0 \; given \tag{14}$$

Characterization Upon imposing the following restriction on productivity levels under decentralization:

Assumption 2. *The productivity parameters θ^L and θ^H satisfy:*

$$\frac{1}{1 - \left(\frac{w}{\theta^{d,H}\gamma}\right)^{\frac{1}{\gamma-1}}} < \frac{2}{1 - \left(\frac{w}{\theta^{d,L}\gamma}\right)^{\frac{1}{\gamma-1}}} - \frac{x}{x + w^{-\epsilon}} \tag{15}$$

we can show that:[17]

Proposition 4. *Under Assumptions 1 and 2 in the model with externalities ($\zeta = 1$), there exists a region of the initial level of conflict $(\bar{f}_0, 1)$ and the slope of the cost of high cooperation $(\underline{\chi}^H, \bar{\chi}^H)$ s.t. the level of cooperation in period 1 is low (L) and in period 2 is high (H). The level of conflict in period 1 is higher than that in period 2.*

Proof. See Appendix A.1. □

Similarly as in Proposition 3, we can also find a threshold for $\theta^{d,L}$ s.t. conflict in period 1 under decentralization is lower than conflict without decentralization. Intuitively, if the cost of high cooperation is not too low or too high, and the level of initial

[17] Proposition 5 in Appendix A.1 proves the version of Proposition 4 under the no-externality case.

conflict is high enough, beneficial effects of decentralization may propagate over time unleashing dynamic complementarities. On impact of decentralization, conflict drops for reasons described in the static framework, increasing output and welfare in the very same period. This implies that the social cohesion proxied by the level of past conflict increases in the next period (relative to the centralized management benchmark). This in turn reduces the cost of choosing high cooperation patterns, increasing productivity and the opportunity cost of conflict even more, and so on.[18]

3.3 Discussion

Overall, the theoretical mechanism relies on reform-induced changes in the opportunity cost of time. Pre-decentralization, households rely on the external government actor to maintain the irrigation. After the reform, households need to devote a fraction of their time to maintain irrigation, which increases the relative time cost of fighting. We now summarize the testable implications of our model.

First, Propositions 3 and 4 from the static and dynamic models predict reductions in conflict following the introduction of decentralization reforms (H1) and that these declines increase over time (H1a).

Second, Proposition 3 implies that conflict reduction will be accompanied by increases in labor supply in agriculture (H2a) and the productivity of irrigation infrastructure (H2b). We interpret the latter as improvements in cooperation over water resources and, consequently, increases in access to irrigation. Finally, the two latter effects translate into increases in agricultural productivity and income (H2c).

Third, Corollary 1 generates non-trivial predictions about the reform's heterogeneous impact. On one hand, it predicts that reductions in conflict will be larger in areas where pre-reform productivity was higher (H3a). Intuitively, the increases in opportunity cost of fighting launched by the reform of these areas are greater, generating larger declines in conflict. On the other hand, it predicts that conflict reduction

[18]This effect is a dynamic counterpart of the typical income effect studied in the conflict literature, such as Chassang and Padró-i-Miquel (2009), Gawande, Kapur, and Satyanath (2017), Miguel, Satyanath, and Sergenti (2004), and Dube and Vargas (2013).

will be more pronounced in communities where decentralization requires higher time investment for maintaining and managing irrigation (H3b). We operationalize this by identifying areas where irrigation infrastructure was more neglected prior to the reform, requiring extensive communal effort to restore. As such, we posit that the necessity of greater collective action to rehabilitate the high stake local public good reduces conflictual relations and, in turn, reinforces cooperation.

4 Data sources and measures

Our empirical analysis rests on a novel panel dataset combining records on irrigation governance, conflict dynamics, agricultural productivity, socio-economic characteristics of Indian population and government expenditures. For construction of our main outcome variable, we employ two measures of conflict: district-level riot-incidence statistics and household-level perceptions of inter-group strife and cooperation. Our treatment variable is constructed using two measures of irrigation decentralization based on the timing of decentralization legislations enacted by state parliaments and a district-level records of irrigation infrastructure management structure. Our mechanism analysis exploits village-level data on irrigation access and agricultural productivity. Finally, we deploy further socio-economic and government data for robustness and heterogeneity analysis.

Table 1 provides overview of sources and summary statistics of the main variables employed. The number of observations varies across metrics due to differences in temporal coverage and units of analysis. As described below, our variables are measured at the district, village, and household levels. In the forthcoming analyses, we will specify the unit of analysis for each regression reported in the tables.

Conflict and cooperation measures Our principle measure of inter-group conflict is the incidence of riots constructed using data from the National Crime Records Bureau (NCRB), which has been collecting annual district-level number of complaints filed under various titles defined in the Indian Penal Code (IPC) since 1953. This approach follows previous studies that identified riots as a common expression of com-

munal violence in India (Wilkinson 2006, 2009; Iyer and Shrivastava 2018; Bulutgil and Prasad 2023). Our variable *Riots* reflects the frequency of riots at the district-year level between 1990 and 2016.[19] Our 13,804 district-year observations have a mean of 123 and a standard deviation of 213. Given the large size of average Indian district, these events may be relatively rare (especially compared to other types of crimes). However, as is the case in many places and especially so in India, these events usually involve many people and often cause devastating consequences for social and economic life (Gupte, Justino, and Tranchant 2014; Thomas and John Sergenti 2010). For our placebo exercise, we use the same data source to construct a complementary measure of *Thefts*.

Since the only district-level population data available comes from the 1991, 2001, and 2011 Population Censuses, we lack the frequency needed to compute precise number of annual riots in per capita terms. For robustness, we estimate yearly population figures for the studied period of 1990-2016, interpolating the data between years 1991-2011 and extrapolating for years 1990 and 2012-2016. As shown in columns 1 and 2 of Table 2, this transformation does not affect our results. Finally, for analyses using district-wave observations from the 4 waves of MIC (columns 3-5 of Table 2), we use the normalized riots variable, as the population census data aligns more closely with the MIC years.[20]

We use further complementary measures of communal conflict and cooperation at the household level derived from the 2005 and 2014 waves of the Indian Human Development Survey (IHDS) covering around 40,000 household-year observations. The first variable, *Conflict in Village (%)*, represents the percentage of households perceiving that their villages experience conflict. The data is collected for two periods of

[19]We end our analyses in year 2016 because the classification of crimes in the NCRB data changes in subsequent years, making it hard to create comparable metrics across years. Data on riots in 2011 is missing in the crime statistics records. Therefore, we impute the 2011 figures using the mean of riots in 2010 and 2012 for each district.

[20]The data from MIC is available for years 1993, 2000, 2006, and 2013. We match the 1991 population figure with the 1993 irrigation census, the 2001 population with the 2000 irrigation, the 2011 population with 2013, and for the 2006 irrigation data, we take the average between the 2001 and 2011 population figures.

2005 and 2014 survey waves, covering 40,058 household-year observations. The second variable, *Conflict Between Castes (%)*, captures the average household-level perception of prevalence of inter-caste conflicts in a village. As opposed to the district-year level data, these two measures provide a more fine-grained snapshot of local conflicts that could interact with distribution of public resources and so with water management dynamics. With mean values of 45% and 37% (respectively), these measures are consistent with a high average level of tensions and unrest present in the Indian society.

Last, the IHDS data also allows us to measure village-level cooperation. *Cooperative Water Problem Solving (%)* variable measures the percentage of households which declare that their communities engage in cooperative (as opposed to individualistic) solutions to problems with water supply. With a mean of 67%, this variable shows that in spite of a generally high level of violence, Indian communities also exhibit high degrees of cooperation, and particularly so in the critical domain of water management.

Effective decentralization measure We complement our records of the timing of WUA reform introductions with a proxy measure for the *effective* district-level decentralization derived from 2,213 district-year observations in the 2nd (1993), 3rd (2000), 4th (2006) and 5th (2013) waves of the Minor Irrigation Census (MIC) conducted by the Ministry of Jal Shakti.[21] Our key indicator of *Share Decentralized Irrigation (%)* captures the proportion of minor irrigation systems (i.e. those covering areas up to 2,000 ha) owned and managed by individuals, groups of farmers, cooperatives and local village panchayats (i.e. non-governmental entities) as opposed to being owned and managed by government. In absence of a direct measure of this, we define it as follows for district i at time t:

$$\begin{aligned} Share\ Dec.\ Irrig_{i,t} = \sum_j & \frac{Number\ of\ j-type\ units\ gov-owned_{i,t}}{Total\ number\ of\ units\ of\ type\ j} \\ & \times \frac{Irrigation\ potential\ of\ all\ units\ of\ type\ j}{Total\ irrigation\ potential\ of\ all\ irrigation\ units_{i,t}} \end{aligned} \tag{16}$$

[21] Note that the MIC data is not available at the village level, see https://micensus.gov.in/.

where j indexes all categories of irrigation unit types in MIC data (dugwells, shallow and deep tubwells, surface lift and flow irrigation). Although the minor irrigation systems in India represent approximately half of the India's irrigation potential and contain a high share of private groundwater wells, its mean of 81.2% (with a standard deviation of 24.6%) shows that decentralized management of irrigation is quite prevalent. For the very same reasons, this variable may reflect both actual decentralization efforts and entirely private investments. Since this measurement error is very likely non-random (e.g. affecting more districts with a higher groundwater potential), we address it through the instrumental variable strategy outlined below.

Irrigation access and agricultural productivity measures We construct the variable *Agricultural Land with Irrigation (log Ha)* measuring the village-level access to irrigation based on the 1991, 2001 and 2011 Population Censuses provided by SHRUG (Asher et al. 2021). The 1,039,602 village-year observations with a mean of 4.2 log hectares of irrigated land in a village (and a standard deviation of 1.7) confirm the widespread use of irrigation infrastructure in India.

As directly measured village-level data on agricultural yields is not available, we construct the widely used proxy for agricultural productivity *Yields* based on the Enhanced Vegetation Index (EVI), a satellite-derived indicator of biomass from NASA (Rasmussen 1997, Son et al. 2014, Asher et al. 2023). Using the GPS coordinates of the 2011 census villages from SHRUG, we estimate the village-level agricultural productivity for the main growing monsoon (kharif) season, spanning late May to early October following Rasmussen (1997) and Labus et al. (2002). In particular, we calculate this measure by subtracting the average EVI during the first six weeks of kharif from the highest EVI value observed during the entire season. This adjusted measure is more accurate for estimating yields compared to raw biomass data, which can reflect non-agricultural land, such as forests, that have high biomass but less seasonal fluctuation. For our analysis, we compute the productivity for the period from 2000 to 2016, covering 8,249,919 village-year observations.

Weather shocks To construct our measure of weather shocks, we use the ERA5 data on annual quantities of rainfall since 1950 till 2016 at GPS coordinates of all the 2011 census villages. We focus on drought events defined as years with total amount of rainfall falling below the 20th percentile of the long-run 1950-2016 distribution. Given this, we construct variable $Drought\ Year\ (\%)_{i,t}$ as the percentage of villages in district i that experienced drought in year t or $t-1$. We end up with 12,408 district-year observations between 1990 and 2016 with a mean of 39% and a standard deviation of 30%. We control for the incidence and scale of drought in the forthcoming village- and district-level analyses. However, our results are robust to the exclusion of this control variable, as reported in Appendix A.5.

Other socio-economic indicators In order to assess the impact of social status and the distribution of specific social groups across villages and districts on our outcomes, we utilize again the Population Census and IHDS data to identify the two most marginalized groups within the Indian caste system: Scheduled Castes and Scheduled Tribes. We create two key variables from this data: *Share Scheduled*, which measures the percentage of Scheduled Castes and Tribes households from Population Census at the district or village level, and *Scheduled HH* indicating whether the household surveyed in IHDS is classified as Scheduled Caste or Scheduled Tribe.

Finally, we use the panel on 1990-2016 state finances (Appendix Tables II and IV) provided by the Reserve Bank of India to rule out the competing explanation of our results being driven by increased subsidization of irrigation after implementation of decentralization reforms. Our logged measure of $Public\ Expenditures\ on\ Irrigation_{i,t}$ in state i and year t is a sum of total expenditures and total capital disbursements on all irrigation related items (minor, medium and major irrigation and flood control).

Table 1: Summary statistics

Variable	Mean	Std. Dev.	N	Data source
Riots	123.908	213.228	13804	NCRB '90-'16
Riots per 100k pop.	8.052	10.924	10,065	NCRB '91-'11
Theft	396.288	577.271	13301	NCRB '90-'16
Theft per 100k pop.	24.980	27.114	9587	NCRB '91-'11
Public Irrigation Expenditures (log INR ten lakh)	5.967	1.539	16792	RBI '90-'16
Drought Year (%)	0.386	0.3	12408	ERA5 '90-'16
Share Dec. Irrig. (%)	0.812	0.246	2209	MIC '93/'00/'06/'13
Land with Irrigation (log Ha)	4.213	1.682	1039602	Pop Census '91/'01/'11
Yields (log)	-2.547	0.844	8249919	NASA '00-'16
Village conflict (%)	0.450	0.498	40009	IHDS '05/'14
Intergroup conflict (%)	0.372	0.483	40009	IHDS '05/'14
Village Coop. (%)	0.671	0.47	40080	IHDS '05/'14

5 Empirical framework

5.1 Difference-in-differences approach

To identify the impact of irrigation decentralization reforms on our outcomes of interest established in the proposed model, we first employ the following staggered difference-in-differences design that compares the average change in the number of riots before and after the reform with the same change for areas not yet or not at all affected by the WUA reform transferring the management of irrigation infrastructure to local communities at the state level:

$$\text{Outcome}_{it} = \beta_0 + \beta_1(\text{Treat}_{it} \times \text{Post}_{it}) + \beta_2 \text{Drought Year}_{it} + \gamma_i + \delta_t + \epsilon_{it} \tag{17}$$

where Outcome_{it}, the outcome variable of interest (measures of conflict, cooperation, irrigation access or productivity) at the relevant unit (district, village or household) i and year t level. The binary treatment variable Treat_{it} takes value of 1 in unit i in year t if this unit resides in state s that has introduced the legislation recommending decentralized irrigation governance; Post_{it} is a post-reform dummy; and γ_i and δ_t are the relevant unit and time fixed effects. We cluster standard errors at districts.[22]

[22]In regressions using IHDS data, we do not control for drought shocks as locations of the surveyed villages have been anonymized.

Provided that the levels of conflict in treated and untreated areas would have followed the same trajectory in the absence of the decentralization reforms—the parallel trends assumption—β_1 in Equation (1) identifies the average treatment effect of the WUA reform on the outcome of interest in the treated group.

5.2 Instrumental variable approach

We further probe robustness of our analysis by using the timing of WUA reform introduction as an IV for the two measures of *effective* irrigation decentralization. The first measure uses data from MIC collected in 1993, 2000, 2006, and 2013. Furthermore, in the mechanism analysis, we also leverage an alternative indicator of effective irrigation decentralization available in the 2001 and 2011 population censuses: the share of village land irrigated by private canals. Instrumenting variations in these measures over time and space by reform introductions allows us to address the underlying measurement error (whereby the variations in our measures of effective decentralization are also affected by some infrastructure becoming destroyed or being entirely private in nature like many wells,[23] as also discussed in Section 3).

In the first step, we regress in the OLS model with unit and time fixed effects the time of introducing WUA reforms on either of the decentralized irrigation measures. Table A5 with results of this exercise not establishes the relevance of our instrument, but also shows that the WUA reform introduction had actual impact on the management structure of irrigation.

Secondly, we estimate 2SLS instrumental variable models with unit and time fixed effects using as the instrument the indicator variable of whether the decentralization reform was in force in a given year in the relevant unit of observation. Our approach relies on typical assumptions guaranteeing validity of the instrument, which we discuss in Appendix A.2.

[23]Notice that expansions in private wells may to some extent be also triggered by establishment of WUAs, as these associations also provide advisory and extensions services to local farmers.

6 Results

6.1 Decentralization and conflict

We begin with our main result: the left panel of Figure 1 presents the results of the Callaway and Sant'Anna 2021 event study analysis of the impact of WUA reforms' introduction on the difference in the annual number of riots between treated and not yet (or never) treated districts of India.[24] Validating the parallel trends assumption, we observe no systematic differences in riots in the pre-treatment periods between the two groups of Indian districts. Thus, although implementation of these reforms was clearly an endogenous decision of individual states, it is plausible to assume that the level of social cohesion or communal violence was not a variable influencing these choices. In terms of the reform's impact, we find a significant and long-lasting reduction in the number of riots occurring in a year in line with the key prediction of the model and summarized in H1. The point estimate in 10 years after the reform's introduction suggests that the number of riots taking place dropped by 60, equivalent to 50% of the average level of riots in our sample (see Table 1). Importantly, 1 shows that the estimated effect in 10 years after the reform almost doubles the effect estimated for the first 2-3 years after the reform. This pattern aligns with the dynamic effects predicted by the two-period model and summarized in H1a.

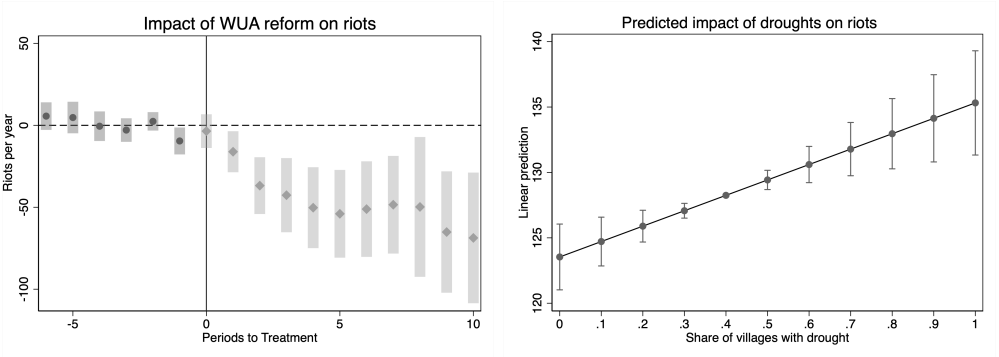
One potential concern with our analysis could be that implementation of the WUA reforms need not be followed by actual implementation of the decentralized institutions. Such a concern would, however, bias our results towards null effect and so suggests that our estimates may constitute a lower bound on the actual impact of the reform.

We also document that droughts, events leading to excess demand for irrigation water and food scarcity in places with insufficient access to irrigation, are one of drivers of riots. In the right panel of Figure 1 we plot the linear prediction of the impact of our measure of negative weather shocks on riots after controlling for district and year fixed effects. As the share of villages in a district experiencing drought increases

[24]We implement this design in Stata using command CSDID by Rios-Avila, Callaway, and Sant'Anna (2021).

from 0% to 100%, the number of riots increases by 13 (around 10% of the long run mean in our sample). This evidence suggests that our outcome measure—at least to some extent—captures conflicts either over access to water or due to insufficient food supply, both of which are plausibly most intense during drought years. This correlation lends further support to our main hypothesis that more efficient irrigation governance structures contribute to reductions in communal violence. Since the impact of reforms on conflict reduction significantly exceeds the predicted impact of droughts on riots, Figure 1 suggests that the conflict-reducing effects of irrigation decentralization go beyond their direct impact in drought years.

Figure 1: Event study evidence: reforms lower incidence of riots



Notes: The left plot shows Callaway and Sant'Anna (2021) event-study estimates with 95% confidence intervals from regressing annual number of riots on WUA reform implementation years and the control variable of the share of villages experiencing droughts. The assumed control group is states not yet (or never) treated by the reform. (Figure A1 shows that the pattern is substantively unchanged across different estimation strategies.) The right plot shows the predicted impact of the share of villages experiencing droughts in a given district-year on riots, controlling for year and district fixed effects.

Table 2 presents further results corroborating our main finding focusing on different measures of conflict, leveraging different levels of analysis and identification methods. In columns 1 and 2 with standard difference-in-differences district level analyses, we first confirm the result from our event study and also show that expressing riots in per capita terms does not change the qualitative nature of our findings. The latter estimate of -4.38 (significant at the 1% level) suggests that the reform reduces the incidence of riots per 100,000 people by 0.4 of standard deviation (the event study analysis in per capita terms leads to qualitatively identical results, see Figure A1 in Online Appendix).

In columns 3-5, we leverage the variable measuring the effective share of decentralized irrigation constructed from MIC data. In column 3, we find that the share of decentralized irrigation negatively predicts riots in the OLS framework, with a coefficient of -3.42 (significant at the 5% level). In column 4, estimating the IV-2SLS model, we find that the share of decentralized irrigation (instrumented with the introduction of WUA reforms) has a much larger negative effect on riots, with a coefficient of -26.06 (significant at the 5% level). This large change of the point estimate arises as the instrumentation addresses the noisy nature of *Share Dec. Irrig* as a proxy of decentralization (discussed in Section 3). Last, column 5 reports the reduced-form model akin to the event study reported in column 2 but relying on the same sample used in the IV regressions. In spite of a significantly smaller sample size, the negative relationship between irrigation decentralization and communal violence is firmly confirmed. The results are also robust to the inclusion of extended set of control variables (see Appendix A.4). Table A12 shows that socioeconomic variables do not predict the extent to which the decentralization reform is effectively implemented at the district level.

We uncover the same patterns using yet another data source: household-level data from IHDS. Column 6 shows that the reform reduces by 28 p.p. the likelihood that households' report presence of conflict within their villages. In column 7, we confirm this pattern using another indicator of communal conflict: the perceived prevalence of conflict between *jatis* (castes) in a village. A similar negative effect of the reform is seen on this inter-group conflict indicator, with a coefficient of -0.19 (significant at the 1% level). Both regressions rely on linear probability models as the IHDS data does not provide any proxies for irrigation decentralization nor their geographical location (which could allow us to overcome this data limitation using other data sources).

6.2 Mechanism analysis

Our results above deliver a consistent picture of irrigation decentralization reforms reducing the prevalence of communal conflict in a very ethnically and religiously diverse society of India. We now move on to answering the question of how precisely has

Table 2: Decentralization and conflict

	(1) Riots	(2) Riots (per 100k)	(3) Riots (per 100k)	(4) Riots (per 100k)	(5) Riots (per 100k)	(6) Village conflict	(7) Intergroup conflict
Decentralization Reform	-43.050***	-4.379***			-1.247**	-0.282***	-0.185***
	(9.146)	(0.614)			(0.515)	(0.062)	(0.063)
Share Dec. Irrig.			-3.418**	-26.062**			
			(1.663)	(12.289)			
Model	OLS	OLS	OLS	IV-2SLS	IV-Reduced	OLS	OLS
Unit of analysis	District	District	District	District	District	Household	Household
Unit + Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Share drought control	Yes	Yes	Yes	Yes	Yes	No	No
Mean of Dep. Var.	123.908	8.052	7.510	7.510	7.510	0.450	0.372
SD of Dep. Var.	213.228	10.924	9.948	9.948	9.948	0.498	0.483
R-squared	0.624	0.641	0.646	-0.127	0.646	0.505	0.531
Sample	'90-'16	'91-'11	'93/'00/'06/'13	'93/'00/'06/'13	'93/'00/'06/'13	'05/'14	'05/'14
N	10140	7779	1428	1428	1428	39546	39546

Standard errors clustered at the district level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

the decentralization of irrigation led to these outcomes. Our model proposes that the observed reduction in conflict is due to improved cooperation, captured by the provision of the relevant public good—irrigation infrastructure—and its downstream effects on agricultural productivity.

We find strong evidence consistent with these predictions, summarized in H2a and H2b. Reforms appear to reduce communal violence through improving the enforcement and monitoring technologies of local communities, allowing them to reduce free riding and improve cooperation patterns. These effects are further compounded by the critical role of irrigation infrastructure for the local food production and the forgone "irrigation's maintainer of last resort" function of external government. Taken together, these effects unleash powerful dynamic complementarities: on one hand, decentralization of irrigation pushes local communities to cooperate more, on the other (and as a result) - it increases the agricultural productivity and the average income in the communities, further reducing local conflict through the income effect (see Dube and Vargas 2013). The latter effects feed back into further improvements in cooperation patterns and so on.

In what follows, we document systematic evidence of these patterns. We use the same specifications as introduced in the previous section, estimating reduced-form models for all mechanisms outcomes and IV-2SLS models where possible (some datasets do not allow us to measure the availability or use of decentralized irrigation). Table 3 shows the results.

First, household-level data from IHDS shows that the decentralization reform in-

creases respondents' perceptions that their communities collectively cope with water scarcity (and other communal resource-related problems). The point estimates suggests that the reform increases by 9 p.p. (or 20% relative the the sample mean) the likelihood that households report approaching the water problems collectively. The same data also shows that households impacted by the reform spend 16% more time working in agriculture (column 2) and generate 11% higher income from this work (column 3; additional evidence available in Table A13).

Second, we use village-level data from Population Census to evaluate the extent to which these improvements in cooperation patterns induced by the reform translated into more efficient provision of irrigation. In line with H2a, column 4 of Table 3 suggests that the decentralization reform increased the area of irrigated land within villages by up to 32%.

Third, consistent with H2b, we show that decentralization leads to greater village-level productivity, as proxied by EVI derived from NASA satellite imagery. Column 5 reports the results from reduced-form model, using the full sample covering the entire 2000-2016 period. The estimate points to the positive effect of decentralization reforms on agricultural productivity.

Table 3: Decentralization and local cooperation, work, irrigation, and productivity

	(1) Water Coop.	(2) # Agric. Workers	(3) Agric. Income (log)	(4) Irrig. Land (log)	(5) Yields (log)
Dec. Reform	0.087*	0.186***	0.116*	0.321***	0.067***
	(0.050)	(0.052)	(0.060)	(0.051)	(0.023)
Model	OLS	OLS	OLS	OLS	OLS
Unit of analysis	Household	Household	Household	Village	Village
Unit+Time FEs	Yes	Yes	Yes	Yes	Yes
Drought control	No	No	No	Yes	Yes
Mean of Dep. V.	0.671	1.131	9.732	4.213	-2.547
SD of Dep. V.	0.470	1.409	1.590	1.682	0.844
R-squared	0.534	0.742	0.733	0.862	0.448
Sample	'05/'14	'05/'14	'05/'14	'91/'01/'11	'00-'16
N	39686	39900	18726	959182	8154696

Standard errors clustered at the district level in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

6.3 Heterogeneous effects implied by the model

The proposed model implies two sources of heterogeneous effects. First, it predicts that the largest reductions in conflict will occur in areas where pre-reform productivity was highest, as these regions had the greatest potential for cooperative gains, making them more likely to experience decline in conflict. Second, conflict reduction is expected to be most pronounced in communities that had to invest significant effort in cooperating on public goods provision. In our context, these are areas where irrigation infrastructure was most neglected before the reform: the necessity of extensive communal efforts to restore it should reinforce cooperation, ultimately leading to a decline in conflictual relations.

To empirically test these heterogeneous effects, we first analyze pre-reform agricultural productivity at the district level. We aggregate village-level yield data, measured using the Enhanced Vegetation Index (EVI), and weight village observations by their agricultural potential, as proxied by the hectarage of agricultural land reported in the 1991 population census. This allows us to construct a district-level measure of pre-reform agricultural productivity (log-transformed), which we then interact with the reform variable. Observations from districts where the reform was implemented before 2000—when our EVI data from NASA satellite imagery begins—are excluded to ensure temporal consistency. Table 4 (column 1) confirms that conflict reduction due to the reform is larger in districts with higher pre-reform productivity, supporting our model's predictions (H3). In Column 2, we confirm the positive effect of the reform on yields also holds after aggregating the village-level yields data to the district level.[25]

Second, we test for heterogeneity related to pre-reform investment in public goods using MIC data on the share of abandoned irrigation infrastructure, available from the 1993 and 2001 MIC waves. We construct a pre-reform measure of abandoned irrigation infrastructure at the district level and interact it with the reform variable. Our results indicate that conflict reduction is greatest in districts with the highest levels of abandoned irrigation infrastructure, where cooperation-intensive restoration

[25]The smaller sample size compared to previous analyses is due to two factors: the shorter time horizon (about 62% of the original period) and the incomplete overlap between the two datasets used in these analyses, which necessitated dropping some observations.

Table 4: Decentralization and conflict: Heterogeneous effects implied by the model

	(1) Riots (per 100k)	(2) Yields (log)	(3) Riots (per 100k)	(4) Share Abandoned
Reform	-10.039***	0.034***	-3.515***	-0.017**
	(3.578)	(0.013)	(0.624)	(0.006)
Reform x Pre-Reform Yields	-1.069***			
	(0.371)			
Reform x Pre-Reform Abandoned			-12.391**	
			(5.652)	
Model	OLS	OLS	OLS	OLS
Unit of analysis	District	District	District	District
Unit + Time FE	Yes	Yes	Yes	Yes
Share drought control	Yes	Yes	Yes	Yes
Mean of Dep. Var.	5.584	-8.850	7.743	0.011
SD of Dep. Var.	7.515	1.084	11.045	0.062
R-squared	0.750	0.974	0.527	0.503
Sample	'00-'16	'00-'16	'93/'00	'93/'00
N	3611	4356	11297	880

Standard errors clustered at the district level in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

efforts were most necessary. Table 4 (column 3) presents this interaction effect, which aligns with the model's predictions (H4). Additionally, column 4 shows that the share of abandoned irrigation decreases after the reform, further supporting the assumption that decentralized governance improved public goods provision.

Overall, our findings provide empirical evidence consistent with the heterogeneous effects predicted by the model, reinforcing the link between decentralization, cooperative efforts, and conflict reduction.

6.4 Alternative explanations and falsification tests

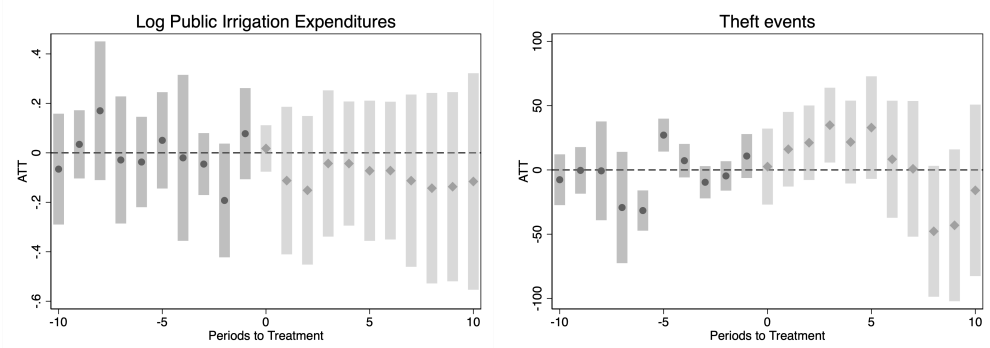
If decentralization reforms are accompanied with increased public spending on irrigation infrastructure, these reforms may reduce conflict merely through income effects not involving improvements in cooperation patterns. In the left panel of Figure 2, we again employ the Callaway and Sant'Anna 2021 event study design and show that there is no evidence of greater public expenditures on irrigation around the introduction of the decentralization reform. This is also true for other types of public expenditures (see Figure A2).

Secondly, even though we provide convincing validation of the parallel trends as-

sumption in Figure 1, it is still plausible that introduction of reforms coincides with a broader decline in crime that is not so much relevant to competition over common pool resources. To explore this possibility, we examine the reform's impact on the incidence of theft, one of the most common types of crime in India (National Crime Records Bureau 2023), which does not reflect inter-group strife. Results in the right panel of Figure 2 allow us to rule out this explanation by showing that the incidence of crime is not related to the introduction of WUA reforms.[26] Conversely, this result also suggests that the reforms have not led to an overall decrease in crime simply by increasing the opportunity costs of engaging in illegal activities, but they rather led to a decrease in inter-group conflict achieved through stimulating more cooperation.[27]

These results reaffirm us that irrigation decentralization reforms address deeper structural issues, such as inefficient resource allocation, poor governance, and inequitable access to essential services. By improving efficiency and creating a more transparent and accountable system, decentralization reforms can alleviate underlying tensions related to resource distribution and governance, thereby reducing conflict in a more sustainable and comprehensive manner.

Figure 2: Decentralization reform, public expenditures and placebo crime outcome



Notes: The plot shows event-time coefficients and 95% confidence intervals constructed using the estimator by Callaway and Sant'Anna (2021). Water theft is reported only from 2016 and these events account for less than 0.1% of all theft events.

[26] While there is some weak indication of a delayed decline in theft, it lacks consistency across various time periods.

[27] The theft patterns in pre-treatment periods reassure us again that the reform has not been targeted to states with lower incidence of overall crime.

6.5 Discussion on other potential sources of heterogeneous effects

Works of Shah et al. (2006), Banerjee and Somanathan (2007), Anderson (2011), and Bros and Couttenier (2015) document significant disparities in access to both drinking and irrigation water for Muslims, Scheduled Castes and Scheduled Tribes in India. Motivated by this literature, we investigate in Section A.3 of Online Appendix whether the effects of irrigation decentralization depend on either the share of scheduled group members in the village or the scheduled group membership of individual households.

We find suggestive evidence that the reforms have differential effects in places with larger caste diversity. More heterogeneous districts experience greater reduction in conflict, while more homogeneous villages see larger increases in productivity. This apparently contradictory pattern could be explained by the fact that scheduled groups may have inferior production technology or lower skills, which is why the increase in yields is lower in more heterogeneous areas. However, in such cases, peace improves more significantly because disparities in the access to irrigation narrows—a pattern we document in Table A6 and which is consistent with prior evidence (see Rao 2017).

As irrigation decentralization reforms have taken place relatively recently, this finding could reflect effects of prior reforms introduced in India with the goal of reducing such discriminatory practices (e.g. the ban of practicing untouchability adopted in Article 17 of the Indian Constitution or the introduction of reservations for women and members of scheduled groups in local panchayats in 73rd Amendment). However, as we believe that answering this question requires finer micro-level data, we take these results with a grain of salt and hope that future research can investigate this important issue more carefully.

7 Conclusion

Our study provides compelling evidence that WUA reforms introduced in many states of India with the goal of decentralizing irrigation management lead to a significant reduction in violence and conflict within rural communities. The core mechanism driving these outcomes appears to work through improved assignment of property

rights, which have been shifted from state government institutions plagued by weak enforcement and problems with motivation and corruption among their workers to local communities. This shift has enhanced local cooperation in managing this common pool resource, boosting agricultural productivity, local food security and, ultimately, alleviating economic pressures that often underlie conflicts. We developed a conceptual model to theorize these changes and empirically validate its predictions using multiple datasets, diverse units of analysis, and robust estimation strategies.

The involvement of local communities in managing public goods, such as irrigation systems, offers several key advantages. First, local stakeholders possess superior information about the unique needs and challenges of their environment, enabling them to make more informed and context-specific decisions. Second, local communities posses superior enforcement capacities, which allow them to better handle water disputes, ensure compliance with water access rules and improve overall reliablity of water supply. Obviously, the success of such initiatives depends heavily on the active participation of local communities, effective governance structures, and supportive policy environments, highlighting both the benefits and the challenges of decentralization in public goods management.

Our results also indicate that the positive impact of irrigation decentralization is immune to the high degree of ethnic and social diversity in India. As such, the external validity of our findings should be high for other regions facing similar challenges. These consideration may be particularly important in the context of Sub-Saharan Africa (SSA). Although in most of the region's countries irrigation infrastructure is still largely underdeveloped, these public investments will have to be made in the near future if the agricultural productivity of the region is to catch up with other regions of the world. The principles demonstrated by our study—community engagement allowing for more efficient common pool resource management—will be very likely equally applicable in the many diverse and conflicted areas of SSA, thereby contributing to broader goals of sustainable development and social stability.

We admit that our analysis of the irrigation decentralization reforms covers their short-run, or at best mid-run, impact. Nonetheless, we believe that in the long-run well-conducted decentralization reforms of such "high stakes" public goods have a high

potential to push communities into a better steady state characterized by lower incidence of conflict and free riding, better cooperation and higher productivity and income. These effects are likely to dominate the impacts of subsidies or cash transfers, which arguably would produce only short-lived effects in absence of the ownership and management rights transfers.

Finally, we believe that our paper provides a starting point for analyzing the impact of decentralization reforms of high stakes public goods on social cohesion. In our future work, we plan to test the implications of this reform on conflict and cooperation patterns across different religious and caste groups using randomized control trials.

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Online Appendix

A.1 Proofs

Proposition 1. *Households in regime $j \in \{c, d\}$ maximizing utility function* (1) *subject to* (4) *and* (5) *devote the following amount of time to fighting and working:*

1. *with externalities ($\zeta = 1$):*

$$f^* = 1 - \frac{x \cdot 1_{j=d} + \left(\frac{w}{\alpha}\right)^{-\epsilon}}{1 - \left(\frac{w}{\theta^j \gamma}\right)^{\frac{1}{\gamma-1}}} > 0 \tag{1}$$

$$n^* = \left(\frac{w}{\theta^j \gamma}\right)^{\frac{1}{\gamma-1}} \cdot \frac{x \cdot 1_{j=d} + \left(\frac{w}{\alpha}\right)^{-\epsilon}}{1 - \left(\frac{w}{\theta^j \gamma}\right)^{\frac{1}{\gamma-1}}} \tag{2}$$

2. *without externalities ($\zeta = 0$):*

$$f^* = 1 - \left(\frac{w}{\alpha}\right)^{-\epsilon} - x \cdot 1_{j=d} - \left(\frac{w}{\theta^j \gamma}\right)^{\frac{1}{\gamma-1}} \tag{3}$$

$$n^* = \left(\frac{w}{\theta^j \gamma}\right)^{\frac{1}{\gamma-1}} \tag{4}$$

Proof. Rewrite the problem of the household as:

$$V_i^j = \max_{c_i, f_i, n_i} \theta^j \left(1 - \frac{1}{2}(f_1 + f_2)\right)^{(1-\gamma)\zeta} n_i^\gamma + w(1 + f_i - f_{-i}) + \alpha \frac{(1 - x \cdot 1_{j=d} - n_i - f_i)^{1-\frac{1}{\epsilon}}}{1 - \frac{1}{\epsilon}} \tag{5}$$

For household i, given f_{-i}, the FOC for f reads:

$$\alpha(1 - f - n - x \cdot 1_{j=d})^{-\frac{1}{\epsilon}} = w \tag{6}$$

The FOC for n reads:

$$\alpha(1 - f - n - x \cdot 1_{j=d})^{-\frac{1}{\epsilon}} = \gamma\theta \left[1 - \frac{1}{2}(f_1 + f_2)\right]^{(1-\gamma)\zeta} n^{\gamma-1} \tag{7}$$

Also, in equilibrium symmetry implies that:

$$f_1 = f_2 = f > 0 \tag{8}$$

So the optimal f^* satisfies the following equation (combine (6), (7), (8)):

$$(1-f) - \left(\frac{w}{\gamma\theta}\right)^{\frac{1}{\gamma-1}} \cdot (1-f)^{\gamma_2} = x \cdot 1_{j=d} + \left(\frac{w}{\alpha}\right)^{-\epsilon} \tag{9}$$

and the optimal n^* satisfies the following equation:

$$n = \left(\frac{w}{\gamma\theta}\right)^{\frac{1}{\gamma-1}} \left[n + x + \left(\frac{w}{\alpha}\right)^{-\epsilon}\right]^{\gamma_2} \tag{10}$$

Case 1: $\zeta = 1$

Let $\zeta = 1$ in eq(9), we obtain the following optimal decisions:

$$f^* = 1 - \frac{x \cdot 1_{j=d} + \left(\frac{w}{\alpha}\right)^{-\epsilon}}{1 - \left(\frac{w}{\theta\gamma}\right)^{\frac{1}{\gamma-1}}} > 0 \tag{11}$$

$$n^* = \left(\frac{w}{\theta\gamma}\right)^{\frac{1}{\gamma-1}} \cdot \frac{x \cdot 1_{j=d} + \left(\frac{w}{\alpha}\right)^{-\epsilon}}{1 - \left(\frac{w}{\theta\gamma}\right)^{\frac{1}{\gamma-1}}} \tag{12}$$

Case 2: $\zeta = 0$

Let $\zeta = 0$ in eq(9), then we get:

$$f^* = 1 - \left(\frac{w}{\alpha}\right)^{-\epsilon} - x \cdot 1_{j=d} - \left(\frac{w}{\theta\gamma}\right)^{\frac{1}{\gamma-1}} \tag{13}$$

$$n^* = \left(\frac{w}{\theta\gamma}\right)^{\frac{1}{\gamma-1}} \tag{14}$$

□

Proposition 2. *Under Assumption 1, the following hold:*

1. *Conflict f decreases with productivity θ: $\frac{\partial f}{\partial \theta} < 0$.*
2. *Conflict f decreases with time required for maintaining irrigation x: $\frac{\partial f}{\partial x} < 0$.*
3. *Conflict f increases with amount of resources w: $\frac{\partial f}{\partial w} > 0$.*
4. *Labor supply n increases with productivity θ: $\frac{\partial n}{\partial \theta} > 0$.*
5. *Labor supply n weakly increases in time cost of irrigation maintenance x: $\frac{\partial n}{\partial x} \geq 0$:*
   (a) *With externalities, this relationship is strict: $\frac{\partial n}{\partial x} > 0$.*

(b) Without externalities, n is independent of x: $\frac{\partial n}{\partial x} = 0$.

6. *Labor supply n decreases with amount of resources w: $\frac{\partial n}{\partial w} < 0$.*

Proof. We will use the implicit function theorem on equations 9 and 10 to derive partial derivatives of f and n.

Define implicit functions:

$$G(f;\theta,w,x) = (1-f) - \left(\frac{w}{\gamma\theta}\right)^{\frac{1}{\gamma-1}} \cdot (1-f)^{\gamma_2} - x - \left(\frac{w}{\alpha}\right)^{-\epsilon} \tag{15}$$

$$K(n;\theta,w,x) = n - \left(\frac{w}{\gamma\theta}\right)^{\frac{1}{\gamma-1}} \left[n + x + \left(\frac{w}{\alpha}\right)^{-\epsilon}\right]^{\gamma_2} \tag{16}$$

Using those we can show that:

$$\frac{\partial f}{\partial \theta} = -\frac{G_\theta}{G_f} = \frac{\frac{1}{\gamma-1}\left(\frac{w}{\gamma}\right)^{\frac{1}{\gamma-1}} (1-f)^{\gamma_2}\, \theta^{\frac{\gamma}{1-\gamma}}}{1 - \gamma_2 \left(\frac{w}{\theta\gamma}\right)^{\frac{1}{\gamma-1}} (1-f)^{\gamma_2-1}} < 0 \tag{17}$$

$$\frac{\partial f}{\partial w} = \frac{\frac{1}{1-\gamma}\left(\frac{1}{\theta\gamma}\right)^{\frac{1}{\gamma-1}} (1-f)^{\gamma_2}\, w^{\frac{2-\gamma}{\gamma-1}} + \epsilon\alpha^{\epsilon} w^{-1-\epsilon}}{1 - \gamma_2 \left(\frac{w}{\theta\gamma}\right)^{\frac{1}{\gamma-1}} (1-f)^{\gamma_2-1}} > 0 \tag{18}$$

$$\frac{\partial f}{\partial x} = \frac{-1}{1 - \gamma_2 \left(\frac{w}{\theta\gamma}\right)^{\frac{1}{\gamma-1}} (1-f)^{\gamma_2-1}} < 0 \tag{19}$$

$$\frac{\partial n}{\partial \theta} = -\frac{K_\theta}{K_n} = \frac{\frac{1}{1-\gamma}\left(\frac{w}{\gamma}\right)^{\frac{1}{\gamma-1}} \theta^{\frac{\gamma}{1-\gamma}} \left[n + x + \left(\frac{w}{\alpha}\right)^{-\epsilon}\right]^{\gamma_2}}{1 - \gamma_2 \left(\frac{w}{\theta\gamma}\right)^{\frac{1}{\gamma-1}} \left[n + x + \left(\frac{w}{\alpha}\right)^{-\epsilon}\right]^{\gamma_2-1}} > 0 \tag{20}$$

$$\frac{\partial n}{\partial w} = \frac{(\theta\gamma)^{\frac{1}{1-\gamma}} \left\{ \underbrace{\frac{1}{\gamma-1} w^{\frac{2-\gamma}{\gamma-1}} \left[n + x + \left(\frac{w}{\alpha}\right)^{-\epsilon}\right]^{\gamma_2}}_{<0} - \underbrace{\frac{\epsilon}{\alpha}\gamma_2 w^{\frac{1}{\gamma-1}} \left[n + x + \left(\frac{w}{\alpha}\right)^{-\epsilon}\right]^{\gamma_2-1} \left(\frac{w}{\alpha}\right)^{-1-\epsilon}}_{>0} \right\}}{1 - \gamma_2 \left(\frac{w}{\theta\gamma}\right)^{\frac{1}{\gamma-1}} \left[n + x + \left(\frac{w}{\alpha}\right)^{-\epsilon}\right]^{\gamma_2-1}} < 0 \tag{21}$$

$$\frac{\partial n}{\partial x} = \frac{\gamma_2 \left(\frac{w}{\theta\gamma}\right)^{\frac{1}{1-\gamma}} \left[n + x + \left(\frac{w}{\alpha}\right)^{-\epsilon}\right]^{\gamma_2-1}}{1 - \gamma_2 \left(\frac{w}{\theta\gamma}\right)^{\frac{1}{\gamma-1}} \left[n + x + \left(\frac{w}{\alpha}\right)^{-\epsilon}\right]^{\gamma_2-1}} \geq 0 \tag{22}$$

□

Proposition 3. *Under Assumption 1, there exists a productivity threshold value $\bar{\theta} \leq \theta^c$ such that for $\theta^d \geq \bar{\theta}$, decentralization reduces conflict, and increases output and welfare. In the economy with externalities this threshold satisfies $\bar{\theta} < \theta^c$, and in the economy without externalities this threshold satisfies $\bar{\theta} = \theta^c$.*

Proof. Our general strategy is to first compute the changes in conflict, output and welfare generated by moving from the centralized to the decentralized case. Then, we show that these changes are monotone in productivity level θ^d. This first allows us to find points at which the outcomes of decentralized and centralized management coincide, and thereby to establish the relevant thresholds.

We start with proving the proposition for the model with externalities. The optimal solutions in eq. (11) and (12) lead to:

$$y^{d*} = \theta^d \cdot (1 - f^*)^{1-\gamma} \cdot (n^*)^{\gamma} \tag{23}$$

$$= \theta^d \cdot \left[\frac{x + \left(\frac{w}{\alpha}\right)^{-\epsilon}}{1 - \left(\frac{w}{\theta^d \gamma}\right)^{\frac{1}{\gamma-1}}} \right]^{1-\gamma} \cdot \left[\left(\frac{w}{\theta\gamma}\right)^{\frac{1}{\gamma-1}} \cdot \frac{x + \left(\frac{w}{\alpha}\right)^{-\epsilon}}{1 - \left(\frac{w}{\theta^d \gamma}\right)^{\frac{1}{\gamma-1}}} \right]^{\gamma} \tag{24}$$

$$= \theta^d \left[\frac{x + \left(\frac{w}{\alpha}\right)^{-\epsilon}}{1 - \left(\frac{w}{\theta^d \gamma}\right)^{\frac{1}{\gamma-1}}} \right] \left(\frac{w}{\theta^d \gamma}\right)^{\frac{\gamma}{\gamma-1}} \tag{25}$$

and

$$y^{c*} = \theta^c \left[\frac{x + \left(\frac{w}{\alpha}\right)^{-\epsilon}}{1 - \left(\frac{w}{\theta^c \gamma}\right)^{\frac{1}{\gamma-1}}} \right] \left(\frac{w}{\theta^c \gamma}\right)^{\frac{\gamma}{\gamma-1}} \tag{26}$$

Thus, the change in output is given by:

$$\Delta y = y^{d*} - y^{c*} = \theta^d \left[\frac{x + \left(\frac{w}{\alpha}\right)^{-\epsilon}}{1 - \left(\frac{w}{\theta^d \gamma}\right)^{\frac{1}{\gamma-1}}} \right] \left(\frac{w}{\theta^d \gamma}\right)^{\frac{\gamma}{\gamma-1}} - \theta^c \left[\frac{x + \left(\frac{w}{\alpha}\right)^{-\epsilon}}{1 - \left(\frac{w}{\theta^c \gamma}\right)^{\frac{1}{\gamma-1}}} \right] \left(\frac{w}{\theta^c \gamma}\right)^{\frac{\gamma}{\gamma-1}} \tag{27}$$

$$= \frac{\left(\theta^d\right)^{\frac{1}{1-\gamma}} \left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}} \left\{ x \left[1 - \left(\frac{w}{\theta^c \gamma}\right)^{\frac{1}{\gamma-1}} \right] + \left(\frac{w}{\alpha}\right)^{-\epsilon} \right\} - \left(\theta^c\right)^{\frac{1}{1-\gamma}} \left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}} \left(\frac{w}{\alpha}\right)^{-\epsilon}}{\left[1 - \left(\frac{w}{\theta^c \gamma}\right)^{\frac{1}{\gamma-1}} \right] \cdot \left[1 - \left(\frac{w}{\theta^d \gamma}\right)^{\frac{1}{\gamma-1}} \right]} \tag{28}$$

Because $\frac{\left(\theta^d\right)^{\frac{1}{1-\gamma}}}{1-\left(\frac{w}{\theta^d \gamma}\right)^{\frac{1}{\gamma-1}}}$ is increasing in θ^d, it follows that Δy is strictly increasing in θ^d. Now, we find the threshold $\overline{\theta^d_{output}}$ at which $\Delta y = 0$:

$$0 < \left(\overline{\theta^d_{output}}\right)^{\frac{1}{1-\gamma}} = \frac{\left(\theta^c\right)^{\frac{1}{1-\gamma}} \left(\frac{w}{\alpha}\right)^{-\epsilon}}{x\left[1 - \left(\frac{w}{\theta^c\gamma}\right)^{\frac{1}{\gamma-1}}\right] + \left(\frac{w}{\alpha}\right)^{-\epsilon}} < \left(\theta^c\right)^{\frac{1}{1-\gamma}} \tag{29}$$

The last inequality follows as Assumption 1 implies that $1 - \left(\frac{w}{\theta^c\gamma}\right)^{\frac{1}{\gamma-1}} > 0$. This proves that there exists $\overline{\theta^d_{output}}$ such that decentralization increases output if $\theta^d \in \left(\overline{\theta^d_{output}}, \theta^c\right)$.

Next, we compute the change in welfare from the centralized case to the decentralized case. By eq. 11 and 12, consumption is given by:

$$c^{j*} = \theta\left(1 - f^{j*}\right)^{1-\gamma}\left(n^{j*}\right)^{\gamma} + w \tag{30}$$

$$= \theta\left[\frac{x \cdot 1_{j=d} + \left(\frac{w}{\alpha}\right)^{-\epsilon}}{1 - \left(\frac{w}{\theta\gamma}\right)^{\frac{1}{\gamma-1}}}\right]^{1-\gamma} \cdot \left[\left(\frac{w}{\theta\gamma}\right)^{\frac{1}{\gamma-1}} \cdot \frac{x \cdot 1_{j=d} + \left(\frac{w}{\alpha}\right)^{-\epsilon}}{1 - \left(\frac{w}{\theta\gamma}\right)^{\frac{1}{\gamma-1}}}\right]^{\gamma} + w \tag{31}$$

$$= \theta\left[\frac{x \cdot 1_{j=d} + \left(\frac{w}{\alpha}\right)^{-\epsilon}}{1 - \left(\frac{w}{\theta\gamma}\right)^{\frac{1}{\gamma-1}}}\right] \cdot \left(\frac{w}{\theta\gamma}\right)^{\frac{\gamma}{\gamma-1}} + w \tag{32}$$

Therefore, utility is given by:

$$u^{j*} = c^{j*} + \alpha\frac{\left(1 - f^{j*} - n^{j*} - x \cdot 1_{j=d}\right)^{1-\frac{1}{\epsilon}}}{1 - \frac{1}{\epsilon}} \tag{33}$$

$$= \theta\left[\frac{x \cdot 1_{j=d} + \left(\frac{w}{\alpha}\right)^{-\epsilon}}{1 - \left(\frac{w}{\theta\gamma}\right)^{\frac{1}{\gamma-1}}}\right] \cdot \left(\frac{w}{\theta\gamma}\right)^{\frac{\gamma}{\gamma-1}} + w + \alpha\frac{\left[\left(\frac{w}{\alpha}\right)^{-\epsilon}\right]^{1-\frac{1}{\epsilon}}}{1 - \frac{1}{\epsilon}} \tag{34}$$

Thus, the welfare change induced by moving from centralized to decentralized management is given by:

$$\Delta u = u^{d*} - u^{c*} = \Delta y \tag{35}$$

As such, Δu is also increasing in θ^d and the threshold satisfies $\overline{\theta^d_{output}} = \overline{\theta^d_{welfare}}$.

We now proceed to the analysis of decentralization's impact on conflict. By eq. 11,

the change in conflicts reads:

$$\Delta f = f^{c*} - f^{d*} = \frac{x + \left(\frac{w}{\alpha}\right)^{-\epsilon}}{1 - \left(\frac{w}{\theta^d \gamma}\right)^{\frac{1}{\gamma-1}}} - \frac{\left(\frac{w}{\alpha}\right)^{-\epsilon}}{1 - \left(\frac{w}{\theta^c \gamma}\right)^{\frac{1}{\gamma-1}}} \tag{36}$$

$$= \frac{\left(\frac{w}{\alpha}\right)^{-\epsilon} \cdot \left(\frac{w}{\gamma}\right)^{\frac{1}{\gamma-1}} \left[\left(\theta^d\right)^{\frac{1}{1-\gamma}} - \left(\theta^c\right)^{\frac{1}{1-\gamma}}\right] + x \cdot \left[1 - \left(\frac{w}{\theta^c \gamma}\right)^{\frac{1}{\gamma-1}}\right]}{\left[1 - \left(\frac{w}{\theta^d \gamma}\right)^{\frac{1}{\gamma-1}}\right] \cdot \left[1 - \left(\frac{w}{\theta^c \gamma}\right)^{\frac{1}{\gamma-1}}\right]} \tag{37}$$

Since $\frac{\left(\theta^d\right)^{\frac{1}{1-\gamma}}}{1-\left(\frac{w}{\theta^d \gamma}\right)^{\frac{1}{\gamma-1}}}$ is increasing in θ^d, this establishes that Δf is increasing in θ^d. By setting $\Delta f = 0$, we can obtain the relevant threshold:

$$\left(\overline{\theta^d_{conflict}}\right)^{\frac{1}{1-\gamma}} = \frac{\left[\left(\frac{w}{\alpha}\right)^{-\epsilon} + x\right] \left(\frac{w}{\gamma}\right)^{\frac{1}{\gamma-1}} \left(\theta^c\right)^{\frac{1}{1-\gamma}} - x}{\left(\frac{w}{\gamma}\right)^{\frac{1}{\gamma-1}} \left(\frac{w}{\alpha}\right)^{-\epsilon}} < \left(\theta^c\right)^{\frac{1}{1-\gamma}} \tag{38}$$

where the inequality follows by Assumption 1.

For compactness of notation, let $A = \left(\frac{w}{\gamma}\right)^{\frac{1}{\gamma-1}}$, $B = \left(\frac{w}{\alpha}\right)^{-\epsilon}$, $C = \left(\theta^c\right)^{\frac{1}{1-\gamma}}$. Then:

$$\left(\overline{\theta^d_{conflict}}\right)^{\frac{1}{1-\gamma}} - \left(\overline{\theta^d_{welfare}}\right)^{\frac{1}{1-\gamma}} = \frac{Bx\left[2AC - (AC)^2 - 1\right] + x^2\left[2AC - (AC)^2 - 1\right]}{AB\left\{B + x\left[1 - AC\right]\right\}} \tag{39}$$

$$= \frac{-x\left(1 - AC\right)^2\left(B + x\right)}{AB\left\{B + x\left[1 - AC\right]\right\}} < 0 \tag{40}$$

The last inequality exploits that $A > 0$, $B > 0$, $AC \in (0, 1)$, $x > 0$. This establishes that $\overline{\theta^d_{conflict}} < \overline{\theta^d_{welfare}}$. Thus, the latter threshold is relevant for our proposition and concludes the proof for the case with externalities.

Proceeding to the model without externalities, by eq. (13) and (14), we know that

$$y^* = \theta^{\frac{1}{1-\gamma}} \cdot \left(\frac{w}{\gamma}\right)^{\frac{1}{\gamma-1}} \tag{41}$$

$$u^* = \theta^{\frac{1}{1-\gamma}} \cdot \left(\frac{w}{\gamma}\right)^{\frac{1}{\gamma-1}} + w + \alpha \frac{\left[\left(\frac{w}{\alpha}\right)^{-\epsilon}\right]^{1-\frac{1}{\epsilon}}}{1 - \frac{1}{\epsilon}} \tag{42}$$

So the changes in conflict, output and welfare read:

$$\Delta f = f^{c*} - f^{d*} = x + \left[\left(\theta^d\right)^{\frac{1}{1-\gamma}} - \left(\theta^c\right)^{\frac{1}{1-\gamma}}\right] \cdot \left(\frac{w}{\gamma}\right)^{\frac{1}{\gamma-1}} \tag{43}$$

$$\Delta y = y^{d*} - y^{c*} = \left[\left(\theta^d\right)^{\frac{1}{1-\gamma}} - \left(\theta^c\right)^{\frac{1}{1-\gamma}} \right] \cdot \left(\frac{w}{\gamma}\right)^{\frac{1}{\gamma-1}} \tag{44}$$

$$\Delta u = u^{d*} - u^{c*} = \left[\left(\theta^d\right)^{\frac{1}{1-\gamma}} - \left(\theta^c\right)^{\frac{1}{1-\gamma}} \right] \cdot \left(\frac{w}{\gamma}\right)^{\frac{1}{\gamma-1}} \tag{45}$$

It follows that although in the no-externality case there exists a threshold $\overline{\theta^d_{conflict}} < \theta^c$, it is also the case that $\overline{\theta^d_{output}} = \overline{\theta^d_{welfare}} = \theta^c$, which concludes the proof. □

Corollary 1. *Under (i) Assumption 1, and (ii) $\theta^d \geq \bar{\theta}$ established in Proposition 3, conflict reduction triggered by decentralization is larger in places with a higher productivity θ^d and a higher time cost of irrigation maintenance x.*

Proof. The result follows immediately from Proposition 3 as a consequence of Proposition 1 showing that $\frac{\partial f}{\partial \theta} < 0$ and $\frac{\partial f}{\partial x} < 0$. □

Proposition 4. *Under Assumptions 1 and 2 in the model with externalities ($\zeta = 1$), there exists a region of the initial level of conflict $(\bar{f}_0, 1)$ and the slope of the cost of high cooperation $(\underline{\chi}^H, \bar{\chi}^H)$ s.t. the level of cooperation in period 1 is low (L) and in period 2 is high (H). The level of conflict in period 1 is higher than that in period 2.*

Proof. Our general strategy is to consider all combinations of low and high co-operation in periods 1 and 2, derive the associated utility levels, and to derive conditions under which agents prefer profile (L,H), i.e. low co-operation in period 1 and high in period 2, to any other alternative.

In period 1, the household i can choose H or L, and the optimal level of conflict and labor supply are given by eq.(11) and (12), respectively. Notice that $\alpha = 1$. For compactness of notation, we will omit i and denote $v_{i,t}$ as v_t where v stands for endogenous or exogenous variables.

If it chooses L, the period-1 utility is given by:

$$u_1^L = c_1^L + \frac{\left(l_1^L\right)^{1-\frac{1}{\epsilon}}}{1-\frac{1}{\epsilon}} \tag{46}$$

$$= \theta^L \left(1 - f^*\right)^{1-\gamma} n^{\gamma} + w \tag{47}$$

$$= \left(\theta^L\right)^{\frac{1}{1-\gamma}} \left[\frac{x + w^{-\epsilon}}{1 - \left(\frac{w}{\theta^L \gamma}\right)^{\frac{1}{\gamma-1}}} \right] \left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}} + u_0 \tag{48}$$

where

$$u_0 = w + \frac{\left(w^{-\epsilon}\right)^{1-\frac{1}{\epsilon}}}{1-\frac{1}{\epsilon}} \tag{49}$$

If it chooses H, the optimal f and n is still the same as before; however, there will be cost of high cooperation that leads to decrease in utility. Therefore, the utility is

given by:

$$u_1^H = c_1^H + \frac{\left(l_1^H\right)^{1-\frac{1}{\epsilon}}}{1-\frac{1}{\epsilon}} - 2\chi^H f_0 \tag{50}$$

$$= \left(\theta^H\right)^{\frac{1}{1-\gamma}} \left[\frac{x+w^{-\epsilon}}{1-\left(\frac{w}{\theta^H\gamma}\right)^{\frac{1}{\gamma-1}}}\right] \left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}} + u_0 - 2\chi^H f_0 \tag{51}$$

where f_0 is the initial level of conflict.

In period 2, the household faces the same static problem as period 1.

If it chooses L, the period-2 utility is given by:

$$u_2^L = c_2^L + \frac{\left(l_2^L\right)^{1-\frac{1}{\epsilon}}}{1-\frac{1}{\epsilon}} = \left(\theta^L\right)^{\frac{1}{1-\gamma}} \left[\frac{x+w^{-\epsilon}}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}}\right] \left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}} + u_0 \tag{52}$$

If it chooses H, there will be the cost of high cooperation that leads to decrease in utility. So the period-2 utility is given by:

$$u_2^H = \begin{cases} u_2^H\left(f_1^H\right), \text{ if } d = H \text{ at } t = 1 \\ u_2^H\left(f_1^L\right), \text{ if } d = L \text{ at } t = 1 \end{cases} \tag{53}$$

where

$$u_2^H\left(f_1^H\right) = c_2^H + \frac{\left(l_2^H\right)^{1-\frac{1}{\epsilon}}}{1-\frac{1}{\epsilon}} - 2\chi^H f_1^H \tag{54}$$

$$= \left(\theta^H\right)^{\frac{1}{1-\gamma}} \left[\frac{x+w^{-\epsilon}}{1-\left(\frac{w}{\theta^H\gamma}\right)^{\frac{1}{\gamma-1}}}\right] \left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}} + u_0 - 2\chi^H \left[1 - \frac{x+w^{-\epsilon}}{1-\left(\frac{w}{\theta^H\gamma}\right)^{\frac{1}{\gamma-1}}}\right] \tag{55}$$

$$= \left[\left(\theta^H\right)^{\frac{1}{1-\gamma}} \left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}} + 2\chi^H\right] \left[\frac{x+w^{-\epsilon}}{1-\left(\frac{w}{\theta^H\gamma}\right)^{\frac{1}{\gamma-1}}}\right] + u_0 - 2\chi^H \tag{56}$$

and:

$$u_2^H\left(f_1^L\right) = c_2^H + \frac{\left(l_2^H\right)^{1-\frac{1}{\epsilon}}}{1-\frac{1}{\epsilon}} - 2\chi^H f_1^L \tag{57}$$

$$= \left(\theta^H\right)^{\frac{1}{1-\gamma}} \left[\frac{x+w^{-\epsilon}}{1-\left(\frac{w}{\theta^H\gamma}\right)^{\frac{1}{\gamma-1}}}\right] \left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}} + u_0 - 2\chi^H \left[1 - \frac{x+w^{-\epsilon}}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}}\right] \tag{58}$$

The household then solves:

$$u = \max\left\{u_1^L, u_1^H\right\} + \beta \max\left\{u_2^L, u_2^H\right\} \tag{59}$$
$$= \max\left\{u\left(L,H\right), u\left(L,L\right), u\left(H,L\right), u\left(H,H\right)\right\} \tag{60}$$
$$= \max_{k,j}\left\{u\left(k,j\right)\right\} \tag{61}$$

where $u\left(k,j\right)$ stands for the overall welfare induced by the cooperation level k in period 1 and cooperation level j in period 2. Specifically,

$$u\left(L,H\right) = u_1^L + \beta u_2^H\left(f_1^L\right) \tag{62}$$
$$= \left(\theta^L\right)^{\frac{1}{1-\gamma}}\left[\frac{x+w^{-\epsilon}}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}}\right]\left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}} + u_0 \tag{63}$$
$$+\beta\left\{\left(\theta^H\right)^{\frac{1}{1-\gamma}}\left[\frac{x+w^{-\epsilon}}{1-\left(\frac{w}{\theta^H\gamma}\right)^{\frac{1}{\gamma-1}}}\right]\left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}} + u_0 - 2\chi^H\left[1-\frac{x+w^{-\epsilon}}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}}\right]\right\} \tag{64}$$
$$= \left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}}\left(x+w^{-\epsilon}\right)\left[\frac{\left(\theta^L\right)^{\frac{1}{1-\gamma}}}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}} + \beta\frac{\left(\theta^H\right)^{\frac{1}{1-\gamma}}}{1-\left(\frac{w}{\theta^H\gamma}\right)^{\frac{1}{\gamma-1}}}\right] + \left(1+\beta\right)u_0 - 2\beta\chi^H \tag{65}$$
$$+ 2\beta\chi^H\left[\frac{x+w^{-\epsilon}}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}}\right] \tag{66}$$

$$u\left(L,L\right) = u_1^L + \beta u_2^L \tag{67}$$
$$= \left(\theta^L\right)^{\frac{1}{1-\gamma}}\left[\frac{x+w^{-\epsilon}}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}}\right]\left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}} + u_0 + \beta\left\{\left(\theta^L\right)^{\frac{1}{1-\gamma}}\left[\frac{x+w^{-\epsilon}}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}}\right]\left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}} + u_0\right\} \tag{68}$$
$$= \left(1+\beta\right)\left(\theta^L\right)^{\frac{1}{1-\gamma}}\left[\frac{x+w^{-\epsilon}}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}}\right]\left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}} + \left(1+\beta\right)u_0 \tag{69}$$

$$u\left(H,L\right)=u_1^H+\beta u_2^L \tag{70}$$

$$=\left(\theta^H\right)^{\frac{1}{1-\gamma}}\left[\frac{x+w^{-\epsilon}}{1-\left(\frac{w}{\theta^H\gamma}\right)^{\frac{1}{\gamma-1}}}\right]\left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}}+u_0-2\chi^H f_0 \tag{71}$$

$$+\beta\left\{\left(\theta^L\right)^{\frac{1}{1-\gamma}}\left[\frac{x+w^{-\epsilon}}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}}\right]\left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}}+u_0\right\} \tag{72}$$

$$=\left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}}\left(x+w^{-\epsilon}\right)\left[\frac{\left(\theta^L\right)^{\frac{1}{1-\gamma}}}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}}+\beta\frac{\left(\theta^H\right)^{\frac{1}{1-\gamma}}}{1-\left(\frac{w}{\theta^H\gamma}\right)^{\frac{1}{\gamma-1}}}\right]+\left(1+\beta\right)u_0-2\chi^H f_0 \tag{73}$$

$$u\left(H,H\right)=u_1^H+\beta u_2^H\left(f_1^H\right) \tag{74}$$

$$=\left(\theta^H\right)^{\frac{1}{1-\gamma}}\left[\frac{x+w^{-\epsilon}}{1-\left(\frac{w}{\theta^H\gamma}\right)^{\frac{1}{\gamma-1}}}\right]\left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}}+u_0-2\chi^H f_0 \tag{75}$$

$$+\beta\left\{\left[\left(\theta^H\right)^{\frac{1}{1-\gamma}}\left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}}+2\chi^H\right]\left[\frac{x+w^{-\epsilon}}{1-\left(\frac{w}{\theta^H\gamma}\right)^{\frac{1}{\gamma-1}}}\right]+u_0-2\chi^H\right\} \tag{76}$$

$$=\frac{x+w^{-\epsilon}}{1-\left(\frac{w}{\theta^H\gamma}\right)^{\frac{1}{\gamma-1}}}\left\{\left(1+\beta\right)\left(\theta^H\right)^{\frac{1}{1-\gamma}}\left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}}+2\beta\chi^H\right\}+\left(1+\beta\right)u_0-2\chi^H f_0-2\beta\chi^H \tag{77}$$

Therefore, we can compute:

$$\Delta u_A=u\left(L,H\right)-u\left(L,L\right) \tag{78}$$

$$=\beta\left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}}\left(x+w^{-\epsilon}\right)\underbrace{\left[\frac{\left(\theta^H\right)^{\frac{1}{1-\gamma}}}{1-\left(\frac{w}{\theta^H\gamma}\right)^{\frac{1}{\gamma-1}}}-\frac{\left(\theta^L\right)^{\frac{1}{1-\gamma}}}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}}\right]}_{>0}+2\beta\chi^H\left[\frac{x+w^{-\epsilon}}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}}-1\right] \tag{79}$$

First, $\frac{\partial\Delta u_A}{\partial\chi^H}<0$ because $f^*>0$ implies that $\frac{x+w^{-\epsilon}}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}}-1<0$. Hence, χ^H should not be too large so that $\Delta u_A>0$.

Set $\Delta u_A = 0$ and solve for the upper bound threshold $\bar{\chi}^H$, we have:

$$\bar{\chi}^H = \frac{\left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}} \left(x + w^{-\epsilon}\right) \left[\frac{\left(\theta^H\right)^{\frac{1}{1-\gamma}}}{1-\left(\frac{w}{\theta^H\gamma}\right)^{\frac{1}{\gamma-1}}} - \frac{\left(\theta^L\right)^{\frac{1}{1-\gamma}}}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}}\right]}{2\left[1 - \frac{x+w^{-\epsilon}}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}}\right]} > 0 \tag{80}$$

When $\chi^H \in \left(0, \bar{\chi}^H\right)$, $\Delta u_A > 0$.

Second,

$$\frac{\partial \Delta u_A}{\partial \beta} = \left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}} \left(x + w^{-\epsilon}\right) \left[\frac{\left(\theta^H\right)^{\frac{1}{1-\gamma}}}{1-\left(\frac{w}{\theta^H\gamma}\right)^{\frac{1}{\gamma-1}}} - \frac{\left(\theta^L\right)^{\frac{1}{1-\gamma}}}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}}\right] + 2\chi^H \left[\frac{x + w^{-\epsilon}}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}} - 1\right] \tag{81}$$

If $\chi^H \in \left(0, \bar{\chi}^H\right)$, then $\frac{\partial \Delta u_A}{\partial \beta} > 0$.

Third,

$$\frac{\partial \Delta u_A}{\partial f_0} = 0. \tag{82}$$

$$\Delta u_B = u\left(L, H\right) - u\left(H, L\right) = 2\beta\chi^H \underbrace{\left[\frac{x + w^{-\epsilon}}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}} - 1\right]}_{<0} + 2\chi^H f_0 \tag{83}$$

First, $\frac{\partial \Delta u_B}{\partial f_0} = 2\chi^H > 0$. Hence, f_0 should not be too small so that $\Delta u_B > 0$. Set $\Delta u_B = 0$ and solve for the lower bound threshold $\bar{f}_0$, we have:

$$\bar{f}_0 = \beta \left[1 - \frac{x + w^{-\epsilon}}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}}\right] > 0 \tag{84}$$

When $f_0 > \bar{f}_0$, $\Delta u_B > 0$.

Second, $\frac{\partial \Delta u_B}{\partial \beta} < 0$. Therefore, we can solve for the threshold $\bar{\beta}$ by setting $\Delta u_B = 0$.

$$\beta < \bar{\beta} = \frac{f_0}{1 - \frac{x+w^{-\epsilon}}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}}} \tag{85}$$

When $\beta < \bar{\beta}$, $\Delta u_B > 0$.

Third, if we set $\Delta u_B = 0$, χ^H drops out. Hence, only f_0 and β matter for case B. At the end of this proof we show that our parametric assumptions deliver $\Delta u_B > 0$

$$\Delta u_C = u\left(L,H\right) - u\left(H,H\right) \tag{86}$$

$$= \left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}} \left(x + w^{-\epsilon}\right) \underbrace{\left[\frac{\left(\theta^L\right)^{\frac{1}{1-\gamma}}}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}} - \frac{\left(\theta^H\right)^{\frac{1}{1-\gamma}}}{1-\left(\frac{w}{\theta^H\gamma}\right)^{\frac{1}{\gamma-1}}}\right]}_{<0} \tag{87}$$

$$- 2\beta\chi^H \left(x + w^{-\epsilon}\right) \underbrace{\left[\frac{1}{1-\left(\frac{w}{\theta^H\gamma}\right)^{\frac{1}{\gamma-1}}} - \frac{1}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}}\right]}_{>0} + 2\chi^H f_0 \tag{88}$$

First, notice that

$$\frac{\partial \Delta u_C}{\partial \beta} = -2\chi^H \left(x + w^{-\epsilon}\right) \underbrace{\left[\frac{1}{1-\left(\frac{w}{\theta^H\gamma}\right)^{\frac{1}{\gamma-1}}} - \frac{1}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}}\right]}_{>0} < 0 \tag{89}$$

Therefore, β should not be too large so that $\Delta u_C > 0$. We solve for the threshold β by setting $\Delta u_C = 0$.

$$\bar{\beta} = \frac{K}{2\chi^H} + \frac{f_0}{Q} \tag{90}$$

where

$$K = \frac{\left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}} \left[\frac{\left(\theta^L\right)^{\frac{1}{1-\gamma}}}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}} - \frac{\left(\theta^H\right)^{\frac{1}{1-\gamma}}}{1-\left(\frac{w}{\theta^H\gamma}\right)^{\frac{1}{\gamma-1}}}\right]}{\frac{1}{1-\left(\frac{w}{\theta^H\gamma}\right)^{\frac{1}{\gamma-1}}} - \frac{1}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}}} < 0 \tag{91}$$

and

$$Q = \left(x + w^{-\epsilon}\right) \left[\frac{1}{1-\left(\frac{w}{\theta^H\gamma}\right)^{\frac{1}{\gamma-1}}} - \frac{1}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}}\right] > 0 \tag{92}$$

Second,

$$\frac{\partial \Delta u_C}{\partial \chi^H} = -2\beta \left(x + w^{-\epsilon}\right) \underbrace{\left[\frac{1}{1-\left(\frac{w}{\theta^H\gamma}\right)^{\frac{1}{\gamma-1}}} - \frac{1}{1-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}}\right]}_{>0} + 2f_0 \tag{93}$$

The sign of $\frac{\partial \Delta u_C}{\partial \chi^H}$ is uncertain. It depends on the value of β and f_0.

Third, $\frac{\partial \Delta u_C}{\partial f_0} = 2\chi^H > 0$. Hence, f_0 should not be too small so that $\Delta u_C > 0$. Set $\Delta u_C = 0$ and solve for the lower bound threshold $\bar{f}_0$, we have:

$$\bar{f}_0 = \beta Q - \frac{KQ}{2\chi^H} \tag{94}$$

Table below presents summary of the intermediate conclusions on threshold conditions (final ones are summarized at the end of this proof):

Table A1: Summary of threshold conditions

	initial level of conflict	cost of high cooperation	discount parameter
$u(L,H) - u(L,L)$	$\frac{\partial \Delta u_A}{\partial f_0} = 0$	$\frac{\partial \Delta u_A}{\partial \chi^H} < 0$	$\frac{\partial \Delta u_A}{\partial \beta}$ uncertain
$u(L,H) - u(H,L)$	$\frac{\partial \Delta u_B}{\partial f_0} > 0$	$\frac{\partial \Delta u_B}{\partial \chi^H}$ uncertain	$\frac{\partial \Delta u_B}{\partial \beta} < 0$
$u(L,H) - u(H,H)$	$\frac{\partial \Delta u_C}{\partial f_0} > 0$	$\frac{\partial \Delta u_C}{\partial \chi^H}$ uncertain	$\frac{\partial \Delta u_C}{\partial \beta} < 0$
Conclusion	$f_0 > \bar{f}_0$	$\chi^H < \bar{\chi}^H$	$\beta < \bar{\beta}$

Finally, we solve for these thresholds:

$$\bar{\chi}^H = \frac{-KQ}{2P} > 0 \tag{95}$$

$$\bar{f}_0 = \frac{\beta Q}{2} \tag{96}$$

$$\bar{\beta} = \frac{2f_0}{Q} \tag{97}$$

$$\bar{\beta} = \frac{K}{2\chi^H} + \frac{f_0}{Q} \tag{98}$$

$$\bar{f}_0 = \beta Q - \frac{KQ}{2\chi^H} \tag{99}$$

where

$$P = 1 - \frac{x + w^{-\epsilon}}{1 - \left(\frac{w}{\theta^L \gamma}\right)^{\frac{1}{\gamma - 1}}} > 0 \tag{100}$$

Let $\chi^H = \bar{\chi}^H$ and we have four unknowns $\beta, \bar{\beta}, f_0, \bar{f}_0$.

$$\begin{pmatrix} -P & 0 & 1 & 0 \\ 0 & P & -1 & 0 \\ 0 & Q & -1 & 0 \\ Q & 0 & 0 & -1 \end{pmatrix} \begin{pmatrix} \beta \\ \bar{\beta} \\ f_0 \\ \bar{f}_0 \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ -P \\ -P \end{pmatrix} \tag{101}$$

$$\begin{pmatrix} \beta \\ \bar{\beta} \\ f_0 \\ \bar{f}_0 \end{pmatrix} = \begin{pmatrix} \frac{P}{P-Q} \\ \frac{P}{P-Q} \\ \frac{P^2}{P-Q} \\ \frac{P^2}{P-Q} \end{pmatrix} \tag{102}$$

The solution is invalid because $\beta > 1$.[28]

So we decrease $\beta = 1$ and substitute the new solution

$$\begin{cases} \bar{\beta} = 1 \\ \bar{f}_0 = P + Q \\ \bar{\chi}^H = \frac{-KQ}{2P} \end{cases} \tag{103}$$

into equations (78),(83), and (86). We can verify that :

$$\Delta u_A = \beta \left(-KQ - 2\chi^H P\right) = 0 \tag{104}$$

$$\Delta u_B = 2\chi^H \left(-\beta P + f_0\right) > 0 \tag{105}$$

$$\Delta u_C = KQ - 2\chi^H \left(\beta Q - f_0\right) = 0 \tag{106}$$

$P + Q < 1 - x$ requires that

$$\frac{1}{1 - \left(\frac{w}{\theta^H \gamma}\right)^{\frac{1}{\gamma-1}}} < \frac{2}{1 - \left(\frac{w}{\theta^L \gamma}\right)^{\frac{1}{\gamma-1}}} - \frac{x}{x + w^{-\epsilon}} \tag{107}$$

From equation (94), we know that $\Delta u_c > 0$ as long as $f_0 > \bar{f}_0$, holding other parameters fixed. Then we look at equation (93). Note that the sign of $\frac{\partial \Delta u_C}{\partial \chi^H}$ is uncertain. If we set equation (93)=0, then we can get $f_0 = \beta Q$. When $f_0 > \beta Q$, $\frac{\partial \Delta u_C}{\partial \chi^H} > 0$. When $f_0 < \beta Q$, $\frac{\partial \Delta u_C}{\partial \chi^H} < 0$. But we have the condition $f_0 > P + Q > \beta Q$. So $\frac{\partial \Delta u_C}{\partial \chi^H} > 0$.

Therefore, $f_0 > \bar{f}_0$ implies that $\frac{\partial \Delta u_C}{\partial \chi^H} > 0$, which means χ^H cannot be too small.

We now want to find conditions ensuring that $\Delta u_c > 0$ when:

$$\begin{cases} 0 < \beta < \bar{\beta} = 1 \\ 1 > f_0 > \bar{f}_0 \\ \underline{\chi}^H < \chi^H < \bar{\chi}^H \end{cases} \tag{108}$$

[28] Notice that $Q - P = (x + w^{-\epsilon}) \left[\frac{1}{1-\left(\frac{w}{\theta^H \gamma}\right)^{\frac{1}{\gamma-1}}} - \frac{1}{1-\left(\frac{w}{\theta^L \gamma}\right)^{\frac{1}{\gamma-1}}}\right] - 1 + \frac{x + w^{-\epsilon}}{1-\left(\frac{w}{\theta^L \gamma}\right)^{\frac{1}{\gamma-1}}} = \left[\frac{\left(x + w^{-\epsilon}\right)}{1-\left(\frac{w}{\theta^H \gamma}\right)^{\frac{1}{\gamma-1}}}\right] - 1 < 0$. So $0 < Q < P < 1$.

By equation (106), the underbar of χ^H is $\underline{\chi}^H = \frac{KQ}{2(\beta Q - f_0)}$. Since $KQ < 0$ and $f_0 > P + Q > \beta Q$, and from equation (95) $\bar{\chi}^H = \frac{-KQ}{2P} > 0$, so $\beta Q - f_0 < -P$ (we need $\underline{\chi}^H < \bar{\chi}^H$). This also holds because $f_0 > \bar{f}_0 > P + Q > P + \beta Q$.
Therefore, given f_0 and β,

$$\frac{-KQ}{2\left(f_0 - \beta Q\right)} < \chi^H < \frac{-KQ}{2P}. \tag{109}$$

We can verify that $\frac{\partial \Delta u_B}{\partial \chi^H} > 0$ under these threshold conditions.

By equation (105) and the threshold solutions, we know that $\left(\Delta u_B\right)_{\min} = 2\chi^H\left(\bar{f}_0 - \bar{\beta}P\right) = 2\chi^H\left[(P+Q) - P\right] = 2\chi^H Q > 0$. So Δu_B is always > 0 as we increase f_0 and decrease β.

Since $\frac{\partial \Delta u_B}{\partial \chi^H} = 2\left(f_0 - \beta P\right)$ and $f_0 > \bar{f}_0 = P + Q > \beta P$, $\frac{\partial \Delta u_B}{\partial \chi^H} > 0$.

Finally, from equation (104) and equation (106), we can verify that under these threshold conditions $\Delta u_A > 0$ and $\Delta u_C > 0$.

Table below provides the final summary of threshold conditions derived.

The level of conflict in period 1 is higher than that in period 2 because at the optimal level the household chooses (L,H) and we have shown in Proposition 1(a) that $\frac{\partial f}{\partial \theta} < 0$. □

In order to prove the version of above proposition in the model without externalities, we need the following assumption:

Assumption 3. *The productivity parameters θ^L and θ^H satisfy:*

$$\begin{cases} 0 < 1 - \left(\frac{w}{\gamma}\right)^{\frac{1}{\gamma-1}}\left[\left(\theta^H\right)^{\frac{1}{1-\gamma}} - \left(\theta^L\right)^{\frac{1}{1-\gamma}}\right] < \frac{\gamma}{w} f^*\left(\theta^L\right) \\ 0 < \left(\frac{w}{\gamma}\right)^{\frac{1}{\gamma-1}}\left[\left(\theta^H\right)^{\frac{1}{1-\gamma}} - \left(\theta^L\right)^{\frac{1}{1-\gamma}}\right] < f^*\left(\theta^L\right) < 1 \end{cases} \tag{110}$$

where $f^*\left(\theta^L\right)$ is the optimal level of conflict with low cooperation level in equation (13).

This assumption ensures that $\bar{\beta} < 1$ and $\bar{f}_0 < 1$ (See the proof below for details).

Proposition 5. *(no-externality case) Under Assumptions 1 and 3, there exists a region of the initial level of conflict $(\bar{f}_0, 1)$, the slope of the cost of high cooperation $[\underline{\chi}^H, \bar{\chi}^H]$, and the discounter parameter $(0, \bar{\beta})$ s.t. the level of cooperation in period 1 is low (L) and in period 2 is high (H). The level of conflict in period 1 is higher than that in period 2.*

Proof. In the no-externality case, the optimal level of conflict and labor supply are given by eq.(13) and eq.(14), respectively. Thus, we can compute the welfare with low

or high cooperation level in the two periods, which are:

$$u_1^L = c_1^L + \frac{\left(l_1^L\right)^{1-\frac{1}{\epsilon}}}{1-\frac{1}{\epsilon}} \tag{111}$$

$$= \theta^L n^\gamma + \frac{\left(w^{-\epsilon}\right)^{1-\frac{1}{\epsilon}}}{1-\frac{1}{\epsilon}} \tag{112}$$

$$= \left(\theta^L\right)^{\frac{1}{1-\gamma}} \left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}} + u_{00} \tag{113}$$

where

$$u_{00} = \frac{\left(w^{-\epsilon}\right)^{1-\frac{1}{\epsilon}}}{1-\frac{1}{\epsilon}}. \tag{114}$$

$$u_1^H = c_1^H + \frac{\left(l_1^H\right)^{1-\frac{1}{\epsilon}}}{1-\frac{1}{\epsilon}} - 2\chi^H f_0 \tag{115}$$

$$= \left(\theta^H\right)^{\frac{1}{1-\gamma}} \left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}} + u_{00} - 2\chi^H f_0 \tag{116}$$

$$u_2^L = c_2^L + \frac{\left(l_2^L\right)^{1-\frac{1}{\epsilon}}}{1-\frac{1}{\epsilon}} = \left(\theta^L\right)^{\frac{1}{1-\gamma}} \left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}} + u_{00} \tag{117}$$

$$u_2^H = \begin{cases} u_2^H\left(f_1^H\right), \text{ if } d = H \text{ at } t = 1 \\ u_2^H\left(f_1^L\right), \text{ if } d = L \text{ at } t = 1 \end{cases} \tag{118}$$

where

$$u_2^H\left(f_1^H\right) = c_2^H + \frac{\left(l_2^H\right)^{1-\frac{1}{\epsilon}}}{1-\frac{1}{\epsilon}} - 2\chi^H f_1^H \tag{119}$$

$$= \left(\theta^H\right)^{\frac{1}{1-\gamma}} \left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}} + u_{00} - 2\chi^H \left[1 - w^{-\epsilon} - x - \left(\frac{w}{\theta^H\gamma}\right)^{\frac{1}{\gamma-1}}\right] \tag{120}$$

and

$$u_2^H\left(f_1^L\right) = c_2^H + \frac{\left(l_2^H\right)^{1-\frac{1}{\epsilon}}}{1-\frac{1}{\epsilon}} - 2\chi^H f_1^L \tag{121}$$

$$= \left(\theta^H\right)^{\frac{1}{1-\gamma}} \left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}} + u_{00} - 2\chi^H \left[1 - w^{-\epsilon} - x - \left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}\right] \tag{122}$$

Therefore, we can compute the overall welfare:

$$u\left(L,H\right)=u_1^L+\beta u_2^H\left(f_1^L\right) \tag{123}$$

$$=\left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}}\left[\left(\theta^L\right)^{\frac{1}{1-\gamma}}+\beta\left(\theta^H\right)^{\frac{1}{1-\gamma}}\right]+\left(1+\beta\right)u_{00}-2\beta\chi^H\left[1-w^{-\epsilon}-x-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}\right] \tag{124}$$

$$u\left(L,L\right)=u_1^L+\beta u_2^L \tag{125}$$

$$=\left(1+\beta\right)\left(\theta^L\right)^{\frac{1}{1-\gamma}}\left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}}+\left(1+\beta\right)u_{00} \tag{126}$$

$$u\left(H,L\right)=u_1^H+\beta u_2^L \tag{127}$$

$$=\left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}}\left[\left(\theta^H\right)^{\frac{1}{1-\gamma}}+\beta\left(\theta^L\right)^{\frac{1}{1-\gamma}}\right]+\left(1+\beta\right)u_{00}-2\chi^H f_0 \tag{128}$$

$$u\left(H,H\right)=u_1^H+\beta u_2^H\left(f_1^H\right) \tag{129}$$

$$=\left(1+\beta\right)\left(\theta^H\right)^{\frac{1}{1-\gamma}}\left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}}+\left(1+\beta\right)u_{00}-2\chi^H f_0-2\beta\chi^H\left[1-w^{-\epsilon}-x-\left(\frac{w}{\theta^H\gamma}\right)^{\frac{1}{\gamma-1}}\right] \tag{130}$$

Therefore, we can compute:

$$\Delta u_A=u\left(L,H\right)-u\left(L,L\right) \tag{131}$$

$$=\beta\left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}}\left[\underbrace{\left(\theta^H\right)^{\frac{1}{1-\gamma}}-\left(\theta^L\right)^{\frac{1}{1-\gamma}}}_{>0}\right]-2\beta\chi^H\left[1-w^{-\epsilon}-x-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}\right] \tag{132}$$

$$\Delta u_B=u\left(L,H\right)-u\left(H,L\right) \tag{133}$$

$$=\left(1-\beta\right)\left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}}\left[\underbrace{\left(\theta^L\right)^{\frac{1}{1-\gamma}}-\left(\theta^H\right)^{\frac{1}{1-\gamma}}}_{<0}\right]-2\beta\chi^H\left[1-w^{-\epsilon}-x-\left(\frac{w}{\theta^L\gamma}\right)^{\frac{1}{\gamma-1}}\right]+2\chi^H f_0 \tag{134}$$

$$\Delta u_C=u\left(L,H\right)-u\left(H,H\right) \tag{135}$$

$$=\left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}}\left[\underbrace{\left(\theta^L\right)^{\frac{1}{1-\gamma}}-\left(\theta^H\right)^{\frac{1}{1-\gamma}}}_{<0}\right]-2\beta\chi^H\left[\left(\frac{w}{\gamma}\right)^{\frac{1}{\gamma-1}}\left[\left(\theta^H\right)^{\frac{1}{1-\gamma}}-\left(\theta^L\right)^{\frac{1}{1-\gamma}}\right]\right]+2\chi^H f_0 \tag{136}$$

We can further simplify them into:

$$\Delta u_A = \beta M - 2\beta \chi^H N \tag{137}$$

$$\Delta u_B = -\left(1-\beta\right) M + 2\chi^H \left(f_0 - \beta N\right) \tag{138}$$

$$\Delta u_C = -M + 2\chi^H \left(f_0 - \beta S\right) \tag{139}$$

where

$$M = \left(\frac{w}{\gamma}\right)^{\frac{\gamma}{\gamma-1}} \left[\left(\theta^H\right)^{\frac{1}{1-\gamma}} - \left(\theta^L\right)^{\frac{1}{1-\gamma}}\right] \tag{140}$$

$$N = 1 - w^{-\epsilon} - x - \left(\frac{w}{\theta^L \gamma}\right)^{\frac{1}{\gamma-1}} \tag{141}$$

,and

$$S = M \cdot \frac{\gamma}{w}. \tag{142}$$

Therefore, we have the following: To solve for the threshold χ^H, we set $\Delta u_A = 0$ and obtain:

$$\bar{\chi}^H = \frac{M}{2N} \tag{143}$$

To solve for the threshold β, we set $\Delta u_C = 0$ and obtain:

$$\bar{\beta} = \frac{f_0}{S} - \frac{1}{2\chi^H} \tag{144}$$

To solve for the threshold f_0, we set $\Delta u_B = 0$ and obtain:

$$\bar{f_0} = \beta N + \frac{\left(1-\beta\right) M}{2\chi^H} \tag{145}$$

Let $\bar{\chi^H} = \chi^H$ and we have:

$$\begin{cases} \bar{\chi}^H = \frac{M}{2N} \\ \bar{\beta} = \frac{\frac{w}{\gamma} f_0 - N}{M} \\ \bar{f_0} = N \end{cases} \tag{146}$$

Note that Assumption 3 is equivalent to the following:

$$\begin{cases} 0 < \left(1-S\right)\frac{w}{\gamma} < N \\ 0 < S < N < 1 \end{cases} \Rightarrow \begin{cases} 0 < \frac{w}{\gamma} < M + N \\ 0 < S < N < 1 \end{cases} \Rightarrow \begin{cases} \left(\bar{\beta}\right)_{\max} = \frac{\frac{w}{\gamma} \cdot 1 - N}{M} < 1 \\ 0 < S < N < 1 \end{cases} \tag{147}$$

Given the solution above in expression (146), we can establish that:

$$\frac{\partial \Delta u_A}{\partial \beta} = M - 2\chi^H N > M - M = 0 \tag{148}$$

$$\frac{\partial \Delta u_B}{\partial \beta} = M - 2\chi^H N > M - M = 0 \tag{149}$$

$$\frac{\partial \Delta u_B}{\partial \chi^H} = 2\left(f_0 - \beta N\right) > 2\left(1-\beta\right) N > 0 \tag{150}$$

We can verify that $\Delta u_A > 0$ when $\chi^H < \frac{M}{2N}$.

We also want:

$$\Delta u_B = -(1-\beta)M + 2\chi^H (f_0 - \beta N) > 0 \tag{151}$$

and

$$\Delta u_C = -M + 2\chi^H (f_0 - \beta S) > 0 \tag{152}$$

Now we impose $\Delta u_C > \Delta u_B > 0$.

$\Delta u_C > \Delta u_B$ gives us

$$\chi^H > \frac{M}{2(N-S)} \tag{153}$$

$\Delta u_B > 0$ and $\beta = 0$ give us

$$\chi^H > \frac{M}{2f_0} \tag{154}$$

Note that $f_0 > N > N - S > 0$, so the under bar of χ^H is:

$$\underline{\chi}^H = \frac{M}{2(N-S)} \tag{155}$$

So finally we have: The level of conflict in period 1 is higher than that in period 2 because at the optimal level the household chooses (L,H) and we have shown in Question 1(a) that $\frac{\partial f}{\partial \theta} < 0$. □

Table A2: Summary of threshold conditions

	initial level of conflict	cost of high cooperation	discount parameter
$u(L,H)-u(L,L)$	$\frac{\partial \Delta u_A}{\partial f_0}=0$	$\frac{\partial \Delta u_A}{\partial \chi^H}<0$	$\frac{\partial \Delta u_A}{\partial \beta}>0$ if $\underline{\chi}^H<\chi^H<\bar{\chi}^H$
$u(L,H)-u(H,L)$	$\frac{\partial \Delta u_B}{\partial f_0}>0$	$\frac{\partial \Delta u_B}{\partial \chi^H}>0$	$\frac{\partial \Delta u_B}{\partial \beta}<0$
$u(L,H)-u(H,H)$	$\frac{\partial \Delta u_C}{\partial f_0}>0$	$\frac{\partial \Delta u_C}{\partial \chi^H}>0$	$\frac{\partial \Delta u_C}{\partial \beta}<0$
Conclusion	$1>f_0>\bar{f}_0$	$\underline{\chi}^H<\chi^H<\bar{\chi}^H$	$0<\beta<\bar{\beta}=1$

Table A3: Summary of threshold conditions

	initial level of conflict	cost of high cooperation	discount parameter
$u(L,H)-u(L,L)$	$\frac{\partial \Delta u_A}{\partial f_0}=0$	$\frac{\partial \Delta u_A}{\partial \chi^H}<0$	$\frac{\partial \Delta u_A}{\partial \beta}$ uncertain
$u(L,H)-u(H,L)$	$\frac{\partial \Delta u_B}{\partial f_0}>0$	$\frac{\partial \Delta u_B}{\partial \chi^H}$ uncertain	$\frac{\partial \Delta u_B}{\partial \beta}$ uncertain
$u(L,H)-u(H,H)$	$\frac{\partial \Delta u_C}{\partial f_0}>0$	$\frac{\partial \Delta u_C}{\partial \chi^H}$ uncertain	$\frac{\partial \Delta u_C}{\partial \beta}<0$
Conclusion	$f_0>\bar{f}_0$	$\chi^H<\bar{\chi}^H$	$\beta<\bar{\beta}$

Table A4: Summary of threshold conditions (no-externality)

	initial level of conflict	cost of high cooperation	discount parameter
$u(L,H)-u(L,L)$	$\frac{\partial \Delta u_A}{\partial f_0}=0$	$\frac{\partial \Delta u_A}{\partial \chi^H}<0$	$\frac{\partial \Delta u_A}{\partial \beta}>0$
$u(L,H)-u(H,L)$	$\frac{\partial \Delta u_B}{\partial f_0}>0$	$\frac{\partial \Delta u_B}{\partial \chi^H}>0$	$\frac{\partial \Delta u_B}{\partial \beta}>0$
$u(L,H)-u(H,H)$	$\frac{\partial \Delta u_C}{\partial f_0}>0$	$\frac{\partial \Delta u_C}{\partial \chi^H}>0$	$\frac{\partial \Delta u_C}{\partial \beta}<0$
Conclusion	$1>f_0>\bar{f}_0$	$\underline{\chi}^H<\chi^H<\bar{\chi}^H$	$0<\beta<\bar{\beta}$

A.2 IV assumptions

We invoke four key assumptions to use the decentralization reform as an instrumental variable in our upcoming analyses:

1. **First-Stage Relevance**: This assumption requires that the instrumental variable (the decentralization reform) is strongly correlated with the endogenous explanatory variable. The strength of this relationship is confirmed in Table A5, which shows a statistically significant association between the decentralization reform and the variable of interest. This indicates that the reform effectively influences the endogenous variable, fulfilling the first-stage requirement.

2. **Monotonicity and Stable Unit Treatment Value Assumption (SUTVA)**: Monotonicity assumes that the effect of the instrument moves in a consistent direction for all subjects, while SUTVA presumes that there are no interference effects between units. Although there is a possibility of these assumptions being violated, such as through non-compliance with treatment assignment or spillovers, any violations are likely to bias our estimates downward. This is because non-compliance would dilute the treatment effect, and positive spillovers could lead to contamination of the control group, both of which would result in conservative estimates rather than inflating our findings.

3. **Ignorability (Exogeneity)**: The ignorability assumption posits that the instrument (the timing of WUA reform introduction) is not correlated with any unobservables that affect our outcome variable (riots). The absence of pre-existing trends prior to the reform, illustrated in the left panel of Figure 1 in the main text suggests that this assumption is plausible. The lack of such trends suggests that factors other than the reform itself did not systematically influence the outcome variable, thereby supporting the ignorability condition.

4. **Exclusion Restriction**: This assumption asserts that (conditional on the share of villages experiencing droughts or not) the instrument (the timing of WUA reform introduction) affects our key outcome variable (riots) only through the endogenous variable (share of decentralized irrigation units) and not through any other pathways. An obvious concern are changes in the amount of state subsidies for irrigation that could constitute part of the decentralization reform, and so affecting the conflict directly through the income effect. We assess the plausibility of this assumption by conducting a falsification test documenting that state subsidies are not influenced by the reform (see Section 6.4 in the main text). This suggests that the decentralization reform does not reduce communal violence through the most plausible alternative channel, supporting the idea that the instrument operates through the designated endogenous variable, and thereby making the exclusion restriction plausible.

Table A5: First stage in IV regressions

	(1) Priv. Share Irrig.
Privatiz. Reform	0.052***
	(0.010)
Model	OLS
Unit of analysis	District
Unit + Time FE	Yes
Mean of Dep. Var.	0.820
SD of Dep. Var.	0.245
R-squared	0.856
Sample	'93/'00/'06/'13
N	1829

Standard errors clustered at the district level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

A.3 Heterogeneous treatment effects

To further understand the impact of decentralization reforms, we investigate whether the effects are moderated by social structure and the incidence of weather shocks. In socially stratified areas or during periods of acute resource scarcity, the potential for conflict may be heightened if reforms are perceived as unfair or if they disproportionately benefit already privileged groups. Therefore, it is essential to consider these moderating factors when assessing the overall effectiveness and equity of decentralization reforms in reducing conflict.

Decentralization works irrespective of caste structure The social fabric of a region, particularly the concentration of underprivileged castes, can significantly influence how reforms are received and their subsequent outcomes. In areas with a higher caste diversity, decentralization reforms may exacerbate existing inequalities if these groups lack the resources or access to participate fully in the newly privatized systems. For example, if underprivileged castes are systematically excluded from accessing privatized services or resources, the reforms could unintentionally reinforce social hierarchies, leading to increased tension and conflict rather than reducing it (see Bros and Couttenier 2015).

We investigate this heterogeneity by interacting the decentralization reform dummy with caste fractionalization index (Herfindahl-Hirschmann Index, later HHI). The higher values of the HHI index indicate greater caste homogeneity, while the lower values indicate greater fractionalization. Columns 1—3 of Table A6 show the results of these interactions. Against the exlusion hypothesis (Bros and Couttenier 2015), in column 1, we find a positive interaction between the caste HHI index and the reform, significant at the 10% level. This result indicates that the reform has stronger effects in reducing conflict in areas hosting more heterogeneous populations with respect to the caste divides. This pattern could be explained by the fact that the decentralization reduces institutional discrimination of these groups, an interpretation that is consistent with the pattern documented in column 4, where we show that the reform decreases irrigation premium for non-scheduled castes. The variable is operationalized as the difference in the share of irrigated land among land owners from non-scheduled (privileged) castes and the share of irrigated land among schedules castes and tribes, divided by the share of irrigated land by schedules castes and tribes. It captures the relative gains coming from the decentralization reform between scheduled and non-scheduled castes. Negative coefficient on the reform variable indicates that decentralization narrows the gap between scheduled and non-scheduled castes' access to irrigation, thus benefiting the former more strongly.

Interestingly, the productivity gains from privatized irrigation vary with the local caste composition in the *opposite* direction. In villages with greater caste homogeneity, the reform has a stronger impact on agricultural productivity, as measured by yields (column 3). This pattern may arise because scheduled groups tend to have less advanced production technology or lower agricultural skills, leading to a smaller increase in yields in more heterogeneous areas. Consistent with this interpretation, Rao (2017) finds that scheduled castes and tribes achieve lower yields than other Indian castes (see Table 3 in the cited study). However, in these cases, peace improves more significantly,

likely because privatization reduces disparities in irrigation access.

We do not find significant heterogeneities in the reform's effects on irrigated area (column 2).

Table A6: Decentralization, conflict, and cooperation: Interactions with Caste Status

	(1) Riots (per 100k)	(2) Irrig. Ha (log)	(3) Yields (log)	(4) Non-SC/ST Irrig. Premium
Decentralization Reform	-13.272**	0.243**	0.102	-0.215**
	(5.973)	(0.120)	(0.118)	(0.107)
Reform x HHI Scheduled	14.289*	0.112	0.265**	
	(8.388)	(0.138)	(0.117)	
Model	OLS	OLS	OLS	OLS
Unit of analysis	District	Village	Village	District
Unit + Time FE	Yes	Yes	Yes	Yes
Drought control	No	No	No	No
Mean of Dep. Var.	7.743	4.213	-2.600	0.433
SD of Dep. Var.	11.045	1.682	0.854	1.547
R-squared	0.532	0.862	0.558	0.545
Sample	'90-'16	'01/'11	'01/'11	'93/'00/'06/'13
N	13035	964833	909564	1745

Standard errors clustered at the district level in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Decentralization works irrespective of weather shocks Furthermore, the effects of decentralization reforms may vary considerably in the context of weather shocks, such as droughts. During times of drought, access to water becomes a critical issue, and competition for this scarce resource intensifies. In such periods, the equitable distribution of water resources and the efficiency of water management systems become crucial. Decentralization reforms that improve irrigation infrastructure and governance could potentially alleviate some of these pressures by ensuring a more reliable water supply. However, if the reforms fail to address the needs of all communities equitably, they might instead intensify conflicts over water access.

To investigate this heterogeneity, we interact the decentralization reform dummy with indicators of weather shock status. For analyses conducted at the district level, we use the share of villages with drought in a given year; for the analyses at the household level, we use the indicator of whether the village experienced drought in a given year. Table A7 shows that the reform has comparable effects on conflict and productivity in environments that experience droughts (columns 1 and 3). However, in column 2, we find that the incidence of drought in the village may be associated with larger gains in the access to irrigation following the decentralization reform. Similarly to the above analyses of heterogeneous treatment effects with respect to caste structure, we do not find consistent evidence that weather shock moderate the effect of the reform. Decentralization seems to work irrespective of the challenging environmental factors.

Table A7: Decentralization, conflict, and cooperation: Interactions with Weather Shocks

	(1) Riots (per 100k)	(2) Irrig. Ha (log)	(3) Yields (log)
Decentralization Reform	-4.107***	0.291***	0.212***
	(0.703)	(0.045)	(0.079)
Share Villages wt Drought	-0.103		
	(0.313)		
Reform x Share Drought	0.868		
	(0.543)		
Village wt Drought		0.012	-0.033
		(0.022)	(0.035)
Reform x Drought		0.096*	-0.012
		(0.051)	(0.054)
Model	OLS	OLS	OLS
Unit of analysis	District	Village	Village
Unit + Time FE	Yes	Yes	Yes
Mean of Dep. Var.	7.743	4.213	-2.558
SD of Dep. Var.	11.045	1.682	0.837
R-squared	0.544	0.862	0.576
Sample	'90-'16	'91/'01/'11	'01/'11
N	10082	959182	648618

Standard errors clustered at the district level in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

A.4 IV: Robustness tests

Below, we present the results of our IV regression models adding potentially time-varying controls. The controls include population size (log), the share of the population in rural areas, the share of the literate population, primary school penetration, the share of the agriculture sector of the economy, luminosity (a measure of wealth), average rainfall, as well as the Herfindahl index measuring caste fractionalization and the share of scheduled (inferior) castes and tribes. Table A8 shows that the results remain unchanged.

Table A8: Decentralization and conflict: IV with controls

	(1) Riots (per 100k)	(2) Riots (per 100k)	(3) Riots (per 100k)
Share Dec. Irrig.	-4.051**	-20.215*	
	(1.713)	(11.314)	
Decentralization Reform			-1.123*
			(0.584)
Controls	Yes	Yes	Yes
Model	OLS	IV-2SLS	IV-Reduced
Unit of analysis	District	District	District
District + Time FE	Yes	Yes	Yes
Mean of Dep. Var.	7.510	7.510	7.510
SD of Dep. Var.	9.948	9.948	9.948
R-squared	0.646	-0.025	0.646
Sample	'93/'00/'06/'13	'93/'00/'06/'13	'93/'00/'06/'13
N	1327	1327	1327

Standard errors clustered at the district level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

A.5 Main results without controlling for drought

Table A9: Decentralization and conflict

	(1) Riots	(2) Riots (per 100k)	(3) Riots (per 100k)	(4) Riots (per 100k)	(5) Riots (per 100k)
Decentralization Reform	-39.943***	-4.258***			-1.327***
	(9.206)	(0.633)			(0.496)
Share Dec. Irrig.			-4.153**	-25.613**	
			(1.617)	(10.493)	
Model	OLS	OLS	OLS	IV-2SLS	IV-Reduced
Unit of analysis	District	District	District	District	District
Unit + Time FE	Yes	Yes	Yes	Yes	Yes
Share drought control	No	No	No	No	No
Mean of Dep. Var.	123.908	8.052	7.510	7.510	7.510
SD of Dep. Var.	213.228	10.924	9.948	9.948	9.948
R-squared	0.517	0.607	0.613	-0.100	0.613
Sample	'90-'16	'91-'11	'93/'00/'06/'13	'93/'00/'06/'13	'93/'00/'06/'13
N	13799	10061	1829	1829	1829

Standard errors clustered at the district level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table A10: Decentralization and local cooperation, public goods provision, and yields

	(1) Land with Irrigation (log)	(2) Yields (log)
Decentralization Reform	0.323***	0.069***
	(0.051)	(0.023)
Model	OLS	OLS
Unit of analysis	Village	Village
Unit + Time FE	Yes	Yes
Drought control	No	No
Mean of Dep. Var.	4.213	-2.547
SD of Dep. Var.	1.682	0.844
R-squared	0.862	0.448
Sample	'91/'01/'11	'00-'16
N	965414	8177917

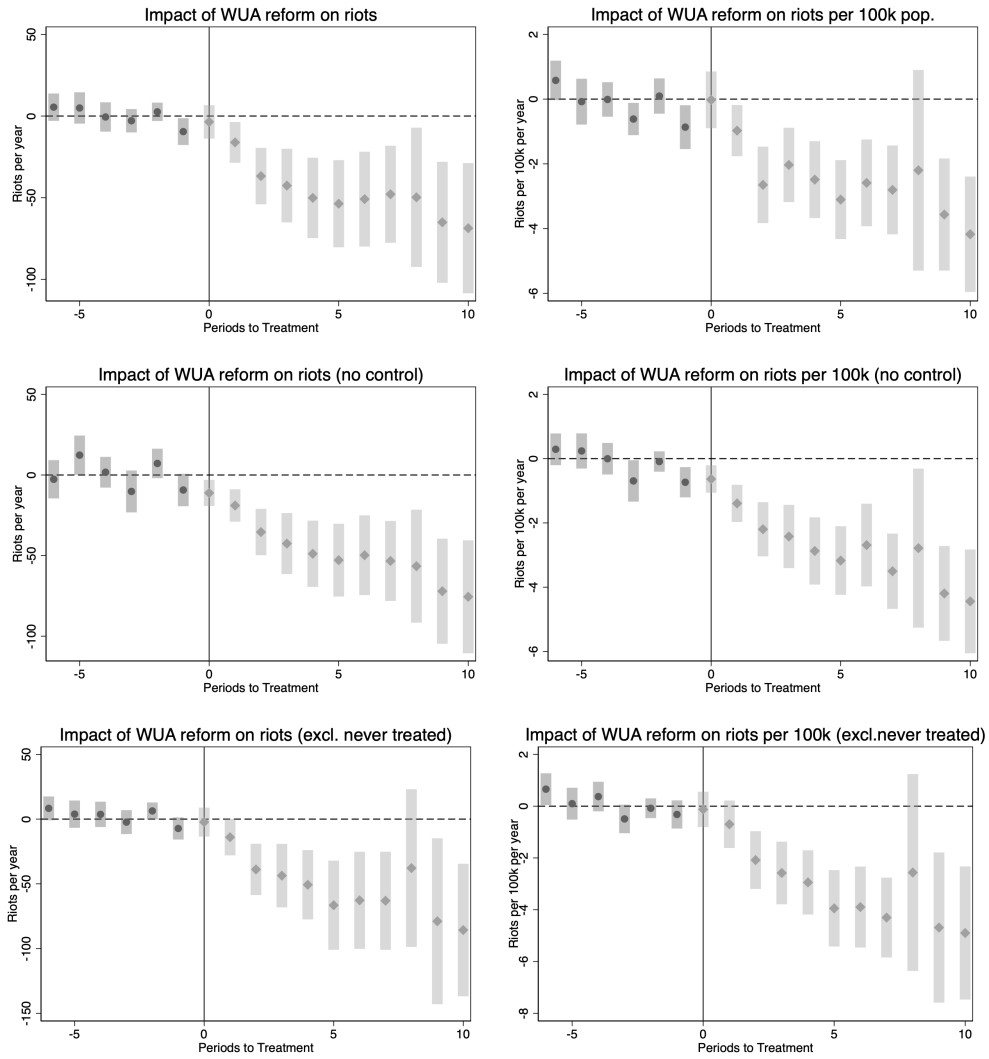
Standard errors clustered at the district level in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

A.6 Additional tables and figures

Table A11: Heterogeneous Introduction Timing of Water User Association Laws in India

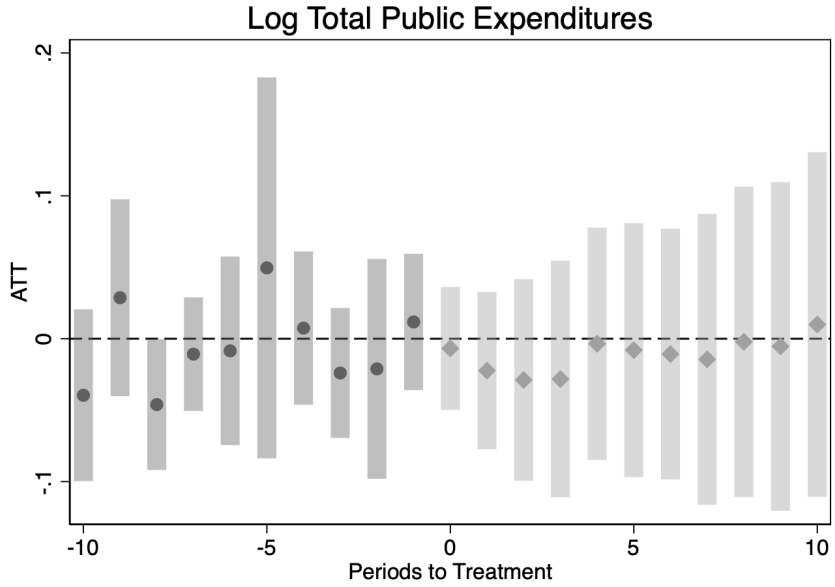
State	Act name	Year
Andhra Pradesh	Andhra Pradesh Farmers Management of Irrigation Systems Act	1997
Assam	The Assam Irrigation Water Users Act	2004
Bihar	The Bihar Irrigation, Flood Management and Drainage Rules	2003
Chhattisgarh	Chhattisgarh Sinchai Prabandhan Me Krishkon Ki Bhagidari Adhiniyam	2006
Goa	Goa Command Area Development Act	1997
Gujarat	Gujarat Water Users' Participatory Irrigation Management Act	2007
Karnataka	Karnataka Irrigation (Levy of Betterment Contribution and Water Rate) Act	2000
Kerala	Kerala Irrigation and Water Conservation Act	2003
Madhya Pradesh	Madhya Pradesh Sinchai Prabandhan Me KrishkonKi Bhagidari Adhiniyam	1999
Maharashtra	Maharashtra Management of Irrigation Systems by Farmers Act	2005
Nagaland	Nagaland Farmers Participation in Management of Irrigation System Act	2014
Orissa	Orissa Pani Panchayat Act	2002
Rajasthan	Rajasthan Sinchai Pranali Ke Prabandh MeKrishkon Ki Sahabhagita Adhiniyam	2000
Sikkim	Sikkim Irrigation Water Tax Act (PIM Ammendment)	2008
Tamil Nadu	Tamil Nadu Farmers Management of Irrigation Systems Act	2000
Uttar Pradesh	Uttar Pradesh Participatory Irrigation Management Act	2009

Figure A1: Event study evidence: reforms lower incidence of riots (different specifications)



Notes: The figure shows Callaway and Sant'Anna (2021) event-study estimates with 95% confidence intervals from regressing annual number of riots on WUA reform implementation years and the control variable of the share of villages experiencing droughts (except for plots in the middle panel, as indicated). The assumed control group is states not yet (or never) treated by the reform, as indicated. The left panel shows plots using the raw riots count, while the right panel shows plots using the riots variable normalized by 100,000 population. Plots including the drought control use doubly robust DiD estimator based on stabilized inverse probability weighting and ordinary least squares (Sant'Anna and Zhao 2020). Plots without this control use outcome regression DiD estimator based on ordinary least squares.

Figure A2: Decentralization reform and total public expenditures



Notes: The plot shows event-time coefficients and 95% confidence intervals constructed using the estimator by Callaway and Sant'Anna (2021).

Table A12 regresses the effective uptake of decentralization policy at the district level on a wide range of covariates, capturing economic development and wealth, type of economy, education, group fractionalization, and groundwater depth (relevant for irrigation via wells that accounts for over 80% of minor irrigation infrastructure). We find that the only significant predictor of the effective uptake of decentralization is population size, with smaller population district decentralizing more. We account for this pattern by normalizing our key outcome variables by population size.

Table A12: Predictors of Effective Decentralization

	(1) Share Dec. Irrig.
Share Literate	0.044
	(0.166)
Share Primary Educ.	9.892
	(47.551)
Av. Nighttime Luminosity	-0.003
	(0.003)
Share Scheduled Caste/Tribe	-0.514
	(0.491)
Share Drought Villages	0.003
	(0.008)
Population (log)	-0.121*
	(0.070)
HHI (castes)	-0.214
	(0.432)
HHI (religious groups)	0.179
	(0.206)
Groundwater Depth	0.005
	(0.012)
Share Agriculture	-0.021
	(0.203)
Power Access	-0.007
	(0.006)
Model	OLS
Unit of analysis	District
Unit + Time FE	Yes
Control	N/A
Mean of Dep. Var.	0.812
SD of Dep. Var.	0.246
R-squared	0.822
Sample	'93/'00/'06/'13
N	1517

Standard errors clustered at the district level in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table A13 shows the effect of the decentralization reform on a series of supplementary economic outcomes, capturing the key implications of our model. In column 1, we show the effect of reform on the number of household members who worked in agriculture in a given wave. Only those household members who had worked at least 240 hours in agriculture in the previous year are included in the measure (as per IHDS coding rule). We find that the reform increases the amount of agricultural labor by affected households, in line with our conceptual model. This pattern in confirmed in columns 3 and 4, where we use the household-member-level data and document that the reform is associated with more hours of work dedicated to agriculture per household member. The effect is sizable: the reform generates 240 hours of work per household member in a given wave, translating in about six additional weeks of agricultural work. Note that the estimated increase corresponds to IHDS minimum requirement to consider a household member as working in agriculture. The result hold for the raw hours and the logged variable. In column 2, we find that it increases income from agriculture, consistent with the documented productivity gains.

Table A13: Decentralization and Work in Agriculture

	(1) # HH Workers in Agric.	(2) Agric. Income (log)	(3) Work Hours in Agric.	(4) Work Hours in Agric. (log)
Decentralization Reform	0.186***	0.116*	240.106***	0.320***
	(0.052)	(0.060)	(31.415)	(0.063)
Model	OLS	OLS	OLS	OLS
Unit of analysis	Household	Household	HH-member	HH-member
Unit + Time FE	Yes	Yes	Yes	Yes
Drought control	No	No	No	No
Mean of Dep. Var.	1.131	9.732	660.504	5.953
SD of Dep. Var.	1.409	1.590	652.427	1.170
R-squared	0.742	0.733	0.523	0.524
Sample	'05/'14	'05/'14	'05/'14	'05/'14
N	39900	18726	62640	62640

Standard errors clustered at the district level in parentheses.
*** p<0.01, ** p<0.05, * p<0.1