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Overcoming barriers to climate smart agriculture in India

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Abstract

Purpose – This paper aims to report on a case in which encouraging climate-smart agriculture in the form of better irrigation techniques in India can contribute to both climate change mitigation and adaptation goals by improving resource-use efficiency. It provides grounded institutional analysis on how these transformations can occur.

Design/methodology/approach – The authors based their research on three complementary approaches: institutional, sociological and technical. The institutional approach analyzed actors and interests in the water-energy nexus in India via over 25 semi-structured key informant interviews. The sociological approach surveyed over 50 farmers and equipment suppliers for insight into technology adoption. The technical component analyzed water and energy consumption data to calculate potential benefits from transitioning to more efficient techniques.

Findings – Because policymakers have a preference for voluntary policy instruments over coercive reforms, distortions in policy and market arenas can provide opportunities for embedded actors to leverage technology and craft policy bargains which facilitate Pareto superior reforms and, thereby, avoid stalemates in addressing climate change. Enlarging the solution space to include more actors and interests can facilitate such bargains more than traditional bilateral exchanges.

Practical implications – The analysis provides insights into crafting successful climate action policies in an inhospitable institutional terrain.

Originality/value – Studies about climate change politics generally focus on stalemates and portray the private sector as resistant and a barrier to climate action. This paper analyzes a contrary phenomenon, showing how reforms can be packaged in Pareto superior formats to overcome policy stalemates and generate technology-based climate and environmental co-benefits in even unpromising terrain such as technologically laggard and economically constrained populations.

Keywords India, Energy, Politics, Sector, Irrigation, Climate smart agriculture

Paper type Research paper

1. Introduction

Agricultural production is particularly relevant to climate change management strategies from both mitigation and adaptation perspectives. Agricultural and livestock production contributes almost one-quarter of global human-induced greenhouse gas (GHG) emissions according to the Food and Agriculture Organization (FAO, 2009), but discussions about

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mitigation tend to focus overwhelmingly on the energy and transport sectors. Consequently, climate-related research about food production in developing countries is mostly centered on adaptation, notwithstanding that decarbonization – addressing both long- and short-lived GHG – can be both immediate and cost-effective, have a large impact on emissions and simultaneously contribute to making these systems more resilient (Fay *et al.*, 2015).

With regard to adaptation, models of potential changes in water availability and the impacts of temperature increases on irrigation requirements and crop productivity raise several and severe concerns about the impact of climate change on food security, especially given the fact that the global population is expected to increase by 25 per cent to almost ten billion by 2050 and, again, according to FAO estimates, crop production would need to increase by up to 70 per cent to feed this population (FAO, 2009). If current trends are not addressed, within just a few decades, the majority of the world's population could face food and water shortages.

The good news is that technologies and practices for better water management and climate-smart agriculture (CSA) in general do exist, but the bad news is that their diffusion is slow and limited. For example, in India, a technology – drip irrigation (DI) – which can address water and electricity wastage exists and is already known to policymakers, administrators and farmers in the region. However, DI (where water is delivered directly to the roots of the plant as opposed to flooding the fields) has not spread enough to fulfill its potential, and flood irrigation remains more prevalent (Grant Thornton, 2016).

While CSA in the tropics has been recognized to have the potential to provide adaptation and mitigation benefits, what is less known are the kinds of transformations in policies, institutions and funding, which are required to facilitate their adoption (Harvey *et al.*, 2014). Understanding the dynamics which underlie the diffusion of an innovation in this context, therefore, remains an important piece of the puzzle that determines which climate action initiatives can take hold and the processes by which they do so.

In this paper, the authors seek to provide some grounded analysis on how transformations in technology use and practice can occur and to show how it is possible to take advantage of the presence of substantial distortions in many policy and market arenas to leverage technology and craft policy bargains which facilitate Pareto superior reforms, i.e. reforms in which no party is worse off and at least one party is better off (Mornati, 2013). Merely identifying where such distortions exist, however, is insufficient to actually realizing such putative gains. Winners from policy changes do not automatically or often compensate the losers and, thus, reforms which are Pareto superior in theory are not so in practice. As a result, the key participants need to craft bargains for using the resources "wasted" through policy distortions to compensate those stakeholders who incur costs in making climate-positive changes in technology use and behavior. This requires an intensive political mobilization. What forms do these bargains take, who are the principal actors in these processes and what are the politics behind the crafting of these bargains are some of the questions which are key to unlocking the potential for more climate-positive initiatives.

The need for research that is aimed at overcoming policy stalemates and facilitating changes in technology and practice is important in India where distortions in irrigation-related policies and practices cause widespread water and electricity wastage. The largest direct contributor to agricultural emissions in India is livestock, but as approximately two-third of India's emissions come from energy production, and agriculture consumes about a quarter of this production, addressing wastage in this sector could reduce a substantial portion of food-system related emissions in India (USAID, 2014). Addressing this would not only help India reduce its carbon footprint, it would, at the same time, help Indian agriculture prepare for the water stress that climate change models predict.

The paper is organized as follows: in the following section, the research is contextualized to the current academic discussions over climate change inaction and the role possibilism in conceptualizing escape paths from low-level stalemates is presented. Section 3 presents the case and methodology of the paper. In Section 4, the causes of previous policy reform inaction are analyzed, while in Section 5, the authors show how the main actors were able to construct superior bargains for overcoming institutional stalemates over CSA. Section 6 concludes with some policy and practice-relevant discussions.

2. The politics of climate change management

2.1 The politics of inaction

The research on the politics of climate change adaptation and mitigation, especially in developing countries, is often pessimistic. While technologies which would reduce the carbon footprint of many economic activities do exist, these are usually viewed as expensive and a competitive drag (Helm *et al.*, 2012). The ability to free-ride on climate action by others is also tempting (Gollier and Tirole, 2015). Moreover, developing countries, who feel the industrialized nations owe a carbon debt (Martinez-Alier, 2002), do not want to sacrifice potential economic growth to address emissions and often view demands to do so as neocolonial (Agarwal and Narain, 1991). For these countries, climate change adaptation is a more pressing concern, though even these are spottily addressed and often waiting for donor funding (Betzold, 2015). Donors, on the other hand, even when they have the funds to contribute to adaptation measures, lack the political will or the administrative capacity to support massive and sustained action in this arena, and when they do, it is often with attached conditionalities which seek to impinge on basic governance processes in the receiving country (Molenaers *et al.*, 2015). This blunts their focus and effectiveness. For these reasons, even though it is becoming increasingly clear that avoiding climate action is a false economy, knowledge about climate change is not translating into sufficient action.

In the case of India, a large emitter though not in per capita terms, climate research shows the country is increasingly vulnerable to recurrent natural disasters, primarily droughts and floods (Brenkert and Malone, 2005). The human and financial costs of these disasters take a steady toll on the country's social and economic fabric. Conservative estimates of India's average annual losses from natural disasters are US$10bn (UNISDR, 2015) or about 0.5 per cent of its gross domestic product (GDP). Even though fewer lives are lost nowadays because of better disaster preparation protocols, the emotional and economic costs borne by the population, especially the poor, are huge. Between 2009 and 2014, the Government of India spent about US$7.5bn on disaster response and relief, which means only a small proportion of the actual losses of over US$50bn were covered. These conditions are not new – India has always been subject to droughts and floods – but the scientific consensus is that these events are becoming more intense and frequent because of climate change (Diffenbaugh *et al.*, 2017; Kumar *et al.*, 2006). Yet, the politics of climate change in India are dominated by an unwillingness to take substantial and immediate action to address even adaptation needs let alone to engage in climate change mitigation where the domestic politics – focused on development, resistant to pressures which can be perceived to impinge on national sovereignty and convinced of the ethical foundations of the common-but-differentiated responsibility (CBDR) principles for climate action – permit little scope for combating emissions at the expense of economic growth (Tankha and Rauken, 2015).

2.2 The politics of possibilism

While the macro-politics of climate change with its diversity of actors and interests and array of veto points have long been in focus, an interesting new literature on the regional and local is emerging and highlighting how international and national action is often outshined by sub-national initiatives, for example, in cities, which are replacing or circumventing (in)action at higher levels of government (Jordan *et al.*, 2015; Betsill and Bulkeley, 2006; Barber, 2013). While much of this literature focuses on outcomes, equally important are the processes and politics by which these outcomes are obtained. Indeed, in its latest assessment, the Intergovernmental Panel on Climate Change (IPCC), recognizing that transformation in climate actions depends in substantial measure on both the available technologies and the social processes or politics which govern their deployment and adoption, has begun to emphasize the study of the processes of decision-making to address mitigation and adaptation, especially in its political dimensions (IPCC, 2014).

Other researchers have noted how politics plays a critical role in opening (or closing) spaces for action (Eriksen *et al.*, 2015), though much of the critical literature in this sphere as it relates to developing countries relies on tropes of elite control to explain dysfunction rather than progress. Less common are nuanced approaches to the study of power relations within society which focus on embedded politics, such as by Migdal (2001) and Evans (1995), to understand how superficially powerful elites, individuals as well as organizations and institutions, still have to game, negotiate and compromise with a multiplicity of subaltern actors to maintain their position. While these approaches are also often used to explain dysfunction in reform endeavors, they can be more useful in explaining the kinds of possibilism to which Hirschman (1971) once alluded. In geography, possibilism refers to the ability of human agency to surpass the limits set by the environment, while in politics, the term has a more conservative orientation and represents a belief in attempting only the realistically achievable. In development studies, Hirschman (1971) inverted the approach, arguing that possible avenues of escape from (the more-easily modeled) low-level equilibrium are unique, unexpected, possible rather than probable. In doing so, he argued for creative human agency to overcome deterministic pessimism and a reliance on fixed sequences.

Compromises, negotiations and shared understandings, thus, provide a critical window to observe how actors and interests at multiple levels can be reconciled to stitch together climate-positive alliances. In this vein of studying local, nuanced and negotiated political processes to understand how knowledge and innovation transpire into planning processes for adaptation and mitigation, which overcome veto points, the role of interstitial actors who mediate needs and resources among different groups in society is only infrequently addressed. In the academic literature, the interstitial actors which are investigated are usually the non-governmental and civil society organizations which mediate flows among governments, donors and communities, but their reach and effectiveness is by the nature of the organizations and their funding necessarily limited and rarely have they had transformational and large-scale impacts (Banks *et al.*, 2015; Bebbington and Farrington, 1993). Considerably less prominent is the literature on the political roles of the private corporate sector (Tienhaara, 2014), which is usually characterized or caricaturized as a veto point in the politics to address climate change rather than viewed as a contributor to climate-positive action. Here, the mainstream literature has theorized on how corporations wield power in their various dimensions – structural, instrumental and discursive – in the environmental arena (Fuchs, 2007), and complementary empirical research has illustrated how corporations generally force or reinforce the hard negotiation positions of governments through lobbying and by diffusing an economic impacts discourse (Newell and Paterson, 1998). How and which types of corporations may contribute positively to sustainability transitions is rarely addressed, and the few studies which have investigated the role of corporations in these processes have done so almost exclusively within the thematic categories of corporate social responsibility and green marketing, the latter frequently criticized as merely greenwashing (Walker and Wan, 2012; Laufer, 2003).

The lack of positive corporate contributions to climate change mitigation and adaptation is a surprising gap in the research agenda. For example, if we look closely at the politics of climate change negotiations in India, which is known for adhering strictly to the CBDR principles in climate change mitigation negotiations, we find that their preoccupation with the development imperative also means that if engaging with climate change can create economic opportunity, the political and bureaucratic apparatus will have incentive to mobilize in favor of actions which directly or indirectly address mitigation. Indeed, one of the few commitments India has made has been to reducing the carbon intensity of its production, thereby seeking improvements in the production processes, but not limiting their growth options. In the course of this research, in fact, the authors came across senior administrators who spoke about making several trips to various European capitals in connection with climate change negotiations, always inquiring about the possibilities for accessing climate-friendly technologies (though these were invariably politely rebuffed on grounds of intellectual property and appropriateness)[1]. Yet, the assumption that investments in technology will enable societies to maintain and improve living standards while maintaining the viability of ecosystems is implicit in many parts of the commitments regime being negotiated. Such technological possibilism, which forms the basis of the United Nation's Sustainable Development Goals, such as Goal 12 on Sustainable Consumption and Production (Gasper *et al.*, 2019), requires not just appropriate policies from the state, but also and especially of the private corporate sector which now plays critical roles in technical innovation and its deployment into the market, particularly in terms of scalability (Arora *et al.*, 2004). Here, the gap in the literature is considerable, especially in its empirical dimensions, and a case-based approach such as the one presented in this paper has the potential to elucidate the practices embedded in policy spaces in a manner which can contribute to both theoretical development and strategy replication.

3. Case details and methodology

The research presented in this paper is framed around the case of sugarcane cultivation in the western Indian state of Maharashtra. This is one of the most important crops in India, generating US$16bn in annual sales and employing over 50 million farmers in its cultivation, not to mention millions of others in associated activities such as sugar refining and marketing (Solomon, 2011). Sugarcane cultivation is, therefore, very political.

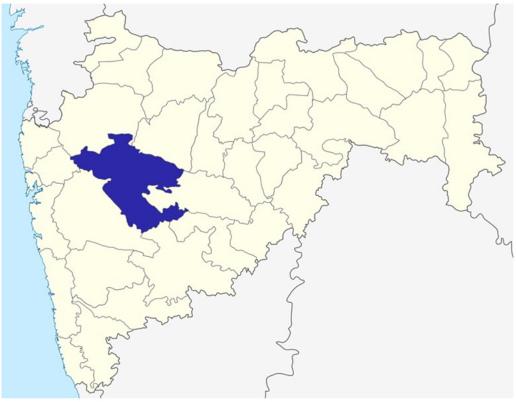
Sugarcane is also a very thirsty crop – to irrigate 1 ha. of sugarcane requires around 20,000 l of water in Maharashtra (GoI, 2012; Shrivastava *et al.*, 2011). On the one hand, this leaves it vulnerable to climate change, as droughts of increasing frequency will take a toll on production. On the other hand, given the state of irrigation management in India, a considerable amount of water needed in the production of sugarcane and other crops comes from groundwater extracted by electric pumps, which results in a substantial amount of emissions. Improving the efficiency of irrigation systems, thus, can serve both mitigation and adaptation needs. This issue is also becoming urgent, as conflicts over the increasingly scarce water resources in the region are becoming ever more frequent. This is particularly relevant to sugarcane as it is reported that the crop is planted on only about 4 per cent of Maharashtra's land, but consumes over 70 per cent of its irrigation supplies (Mohan, 2015).

3.1 Location

Maharashtra has a population of 114 million spread over an area similar to that of Germany. Within Maharashtra, the authors studied sugarcane cultivation in Ahmednagar district (see Figure 1). Located about 250 km east of Mumbai, this district is Maharashtra's largest as well as one of its poorest. It lies in the rain shadow of the Western Ghats, receiving an average monsoon rain of 497 mm (but, since 2014, rainfall has been less than 400 mm)[2]. Despite being a "thirsty crop," almost 80 per cent of Maharashtra's sugarcane is actually cultivated in drought-prone districts such as Ahmednagar, which means reliance on irrigation, particularly groundwater irrigation, is significant. Within Ahmednagar district, the authors based their study in two of its 14 talukas (a sub-district administrative unit), Rahuri and Shirampur (Table I). Both talukas fall in the water-scarce part of the district, receiving 478 and 470 mm of the annual rainfall, respectively (see Note 2).

3.2 Data collection

The research for this paper was based on three complementary approaches: institutional, sociological and technical. The institutional approach consisted of organizational research on electricity and irrigation management in India (for which the authors also leveraged their experience with previous empirical research in these arenas). This included an analysis of the key actors in the water-energy nexus in India to determine the distribution of interests and institutional capacities. As part of this analysis, dozens of semi-structured key informant interviews were conducted with:



Source: Own elaboration

Figure 1. Case study area – Ahmednagar district, Maharashtra, India

Table I. Shrirampur and Rahuri

No.	Features	Shrirampur	Rahuri
1	Area of taluka	1,307 ha	1,554 ha
2	Total population	5,883	9,089
3	Number of households	1,188	1,807
4	Literacy levels	78% male 59% female	74% male 56% female
5	Number of government canals	700 ha	787 ha
6	Land use of wells (with electricity)	597 ha	661 ha
7	Total irrigated area	1,297 ha	1,487 ha
8	Un-irrigated area	10 ha	7 ha

Source: Census of India (2011)

- public officials in electricity, irrigation, agriculture and general administration in Maharashtra;
- representatives of the cooperative sugar factories (which is the main organizational form of sugarcane production and processing in Maharashtra); and
- private sector agents who are engaged with irrigation systems manufacture and distribution.

The sociological approach consisted of field research among farmers and equipment suppliers. For this, the authors surveyed sugarcane farmers about irrigation practices and experiences with DI in the two talukas mentioned above. Prior to conducting this survey, the authors trialed it on a smaller scale in another district in the state. The technical research consisted of gathering and analyzing data on irrigation requirements and energy production and emissions to calculate the potential benefits from transitioning to more efficient irrigation techniques. These data were obtained from various national and state government agencies and cross-checked against estimates obtained from the survey of farmers in Ahmednagar. The authors combined these three research strands to analyze the roles played by different actors in generating climate co-benefits.

4. The politics of inaction in irrigation reform

The broad contours of the problem of irrigation and electricity management in India are well-known (Tankha *et al.*, 2010; Singh, 2006) and will only be briefly sketched here. At one end, canal irrigation infrastructure, which traps and distributes surface water, e.g. from rivers, is poorly constructed and badly maintained by the agricultural departments in most parts of the country. This has led farmers to rely on groundwater using electric pumps. At the other end, the state electricity companies have been running perennially colossal deficits and are unable to keep up with the growing demand for electricity because state governments have responded to the problems in surface irrigation infrastructure by providing massive energy subsidies for farmers in the form of cheap or even free electricity as well as subsidies to purchase pumps.

A third dimension to this problem is that groundwater irrigation has now become the primary source of irrigation in India, rather than being a safety net to be deployed when there is drought. It is estimated that 40 million ha are irrigated by borewells and 80 per cent of irrigation requirements are met through groundwater (Shrivastava *et al.*, 2011). This accounts for over 75 per cent of groundwater extraction, the rest being used by households and industry. With the progressive depletion of aquifers, watertables have collapsed and borewells now have to go down as far as 300 m, a depth at which aquifers can recharge only very slowly. In Maharashtra, as in much of the rest of India, most watersheds are now classified as over-exploited, and the problem is worse in the drought-prone districts[3].

At the same time agriculture soaks up US$1bn in electricity subsidies annually, 63 per cent of which is cross subsidized by industry. The debt incurred by the various state electricity companies is now around US$80bn or about 5 per cent of India's GDP, this in spite of multi-billion-dollar bailouts in 2001 and 2011 (Pargal and Banerjee, 2014). Perennially running huge financial deficits, which impede their ability to invest in infrastructure and proper maintenance, power companies also have high levels of transmission and distribution losses. This wasted generation leads to increased emissions intensity of production, a problem which is compounded by the fact that coal-burning thermal plants are the mainstay of Indian power generation. In addition, in dealing with power shortages, many consumers are forced to self-supply with generators, which is economically and environmentally even more inefficient.

In the case of Maharashtra, a quarter of the power supplied by its electricity distribution company (MSEDCL) goes to agriculture, but this generates only 12 per cent of the company's revenue. Even these figures do not state the true extent of the subsidies received by farmers because the state government provides MSEDCL US$0.03 per kWh of subsidy reimbursement. In fact, of the US$0.09 per kWh average cost of supply, farmers are billed only US$0.02 per kWh, but with the collection efficiency at only 37 per cent, MSEDCL collects less than one cent per kWh supplied to farmers[4].

Reforming these sectors has been difficult. It is not that the problem is not recognized or researched. The Government of India has itself constituted several committees (Vadnere, Mendigiri, Kulkarni, and Upage Commissions) to study the problem and issue recommendations (which have mostly not been implemented) and power sector reform in India is a perennial favorite of the World Bank. However, none of the scores of studies on irrigation and electricity management and reform in India have managed to chart a feasible reform trajectory because the reforms invariably proposed variations on themes of rational pricing of water and electricity (Ray, 2007).

The arguments for treating irrigation water or electricity as scarce economic resources to be priced accordingly are as intellectually attractive as they are politically and administratively infeasible. In spite of the trend toward increasing urbanization (often encouraged or facilitated by government), among all the large developing countries, India remains, by far, the most dependent on agriculture, which contributes 15 per cent to the country's GDP (World Bank, 2019). Comparably, in Brazil, agriculture contributes only 5 per cent to GDP, while in China, agriculture's contribution is 8 per cent (World Bank, 2019). India's population is also more rural, about 66 per cent, than the other two countries which have rural populations of 14 and 42 per cent, respectively (World Bank, 2015). The numbers of people involved in agriculture are thus a potent political force. Proposals for significantly higher water and electricity rates are viewed almost universally among the political class as an easy issue around which to mobilize opposition and agitation. In addition, many administrators believe that farmers have genuine claims on assistentialist programs. Several public sector officials the authors interviewed mentioned how overcoming food crises in the 1970s and the green revolution were built upon policies of rapid and subsidized infrastructure expansion, indicating a strong socialization of this narrative among the civil servants. One power sector veteran also mentioned that before flat-rates were introduced for agricultural power, electricity inspectors would often harass poor farmers, leading politicians to promise reprieves as a potent vote attractor[5]. Consequently, government departments are not energetic in collecting even the mostly symbolic and relatively nominal electricity and irrigation water charges, and currently, there are around US$200m of arrears in irrigation water tariff collection in Maharashtra[6].

A related complication which is almost never discussed in the context of agricultural reform is that the elimination of various supports and subsidies would lead to increasing and more volatile food prices which would have severe repercussions – economic as well as political – in urban India as well, especially among those who spend a substantial part of their income on food. Thus, to move to more market-rational agricultural and power sectors, the government would have to implement a series of complex and politically challenging reforms more or less simultaneously to dampen the propagation of negative resonance throughout the system. In a highly competitive political system such as India's, such several, contentious and simultaneous reforms are unlikely, because a separately organized and multi-participant political opposition would have to be tackled and overcome for each particular reform. These kinds of wicked problems – as such systemically complex situations are referred to – thus require a very different kind of policy approach than market rationality. Not surprisingly then, one of the senior bureaucrats the authors spoke with commented that "agriculture is like religion, you can't touch it[7]".

As a result, though subsidized power to farmers costs the Indian state billions every year and additional billions are spent on the increasingly more frequent drought-relief programs, successive governments have not invested more attention and funds in water management institutions, organizations and infrastructures. Even if they were unable to increase spending, the government could have redistributed funds among different departments to improve overall efficiency and productivity, such as by shifting some funds from electricity departments to fund irrigation improvements which reduce demands for subsidized power. However, interviews with public officials at all levels revealed that there is little to no coordination among various government departments. The electricity, irrigation and agricultural departments simply do not speak to each other beyond the most routine field-level meetings, and there is no joint strategizing at higher levels[8]. To some extent this is surprising, given that:

- the political leadership exercises close control over administrative departments and, hence is able, if it so chooses, to overcome and over-rule organizational silos; and
- The senior leadership of all the departments comes from the same pool of IAS officers who in their careers constantly move across departments and so should not be beholden to narrow organizational interests[9].

Deterministic pessimism about the potential for reform is, thus, understandable in our case.

5. The politics of possibilism in drip irrigation

5.1 Drip irrigation: Great promise, slow progress

Motivations to adopt an innovation obviously depend on the quantum of benefits that it provides. Several technical studies have enumerated the potential benefits of DI. These can be classified under seven categories (Table II), but the main benefits are obviously water and energy savings. Given that there are approximately one million ha under sugarcane

Table II.
Putative benefits of DI

No.	Benefits	Remarks
1.	Water use	Plot studies indicate sugarcane cultivation under DI uses 44 to 55 per cent less water than under flood irrigation
2.	Electricity use	Water-use efficiency translates directly into reduced electricity use in fields which are irrigated by groundwater pumping. Electricity savings can be between 25 and 50 per cent
3.	Fertilizer use	DI requires less fertilizer because flood irrigation washes away a substantial amount of the fertilizer that is applied to the crop
4.	Crop yield	In experimental plots, it has been found that a 23 per cent productivity increase can be obtained by DI in sugarcane cultivation in Maharashtra
5.	Drought resilience	As drip-irrigated sugarcane requires less water, the crop can be more effectively watered under drought conditions
6.	Soil maintenance	Flood irrigation results in increasing soil salinity, and this has been verified in several sugarcane cultivation areas of Maharashtra
7.	Labor use	DI requires less labor and, moreover, this can be planned in more convenient ways. For example, during field research, farmers indicated that flood irrigation sometimes has to be done at night when there is a heightened danger of animal attacks.

Sources: Postel *et al.* (2001), Narayanamoorthy (2004), Surendran *et al.* (2016), World Bank (2006), own research cultivation in Maharashtra, the potential energy savings translate into approximately one million metric tons of reduced emissions per crop cycle, while water savings potentially amount to 160 million m^3 for the current levels of production (Table III).

The figures recorded in the tables are indicative, as agricultural innovations are imperfectly fungible and not without associated collateral problems such as, in this case, groundwater depletion. Nevertheless, the experience with DI reported by our respondents is positive. Both talukas recorded increasing profitability deriving from a combination of higher yields and a reduction in labor and fertilizer costs. In the case of fertilizers, for example, farmers observed that US$300 is required for three acres under flood irrigation, whereas the corresponding expense is US$40 for fields under DI. They also reported savings in electricity use, though given that they use standard pumps and pay the standard subsidized electricity charge levied on all farmers, they often have not derived much financial benefit from switching to DI.

While the Indian Government began to promote DI in 1980s, beginning with the establishment of a National Committee on the Use of Plastics in Agriculture, and has steadily increased the budgets and the land brought under DI (the 2015 Union Budget allocated over US$1.5bn for micro-irrigation schemes), progress has been slow: despite delivering tangible benefits to farmers and receiving policy attention, DI is still practiced in only 1 per cent of the groundwater irrigated area.

Our field research pointed toward a combination of two inter-related factors which determine why DI uptake has been slow:

- what March and Olsen (2009) called the *logic of appropriateness* (decisions made on the basis of considerations of tradition rather than potential benefits); and
- the limited resources available to the state to introduce and promote DI.

Given the role education is supposed to play in the diffusion of innovations (Rogers, 1962) and the fact that younger farmers are more educated, the authors were initially surprised to find in their field surveys that younger farmers were less likely to have installed DI. It was only after further investigation that the authors were able to discover that in the case of the younger farmers, it was their fathers who still took the major decisions on farming matters and, in this case, prevented their sons from adopting DI systems. This observation was later confirmed by both administrators and the DI suppliers, who concurred on the role of intergenerational dynamics. "Although I have a PhD in agricultural science," explained one agricultural research scientist, "my father does not believe he needs to go against what has

No.	Energy requirements and emissions	Results
1	MW required to irrigate 1 ha of sugarcane under flood/furrow irrigation with groundwater (per crop cycle)	3,000-4,000 kWh per ha
2	MW required to irrigate 1 ha of sugarcane with micro/DI (per crop cycle)	1,700-3,000 kWh per ha
3	Energy savings per ha per crop cycle	Approximately 1 MWh of energy saved per ha per crop cycle by DI
4	Average emissions per MW coal-fired electricity plants in Western India	1,000 kg
5	Avoided emissions per crop cycle in Maharashtra	1,000kg CO_2 × 1,000,000 ha = 1 million metric tons

Sources: Narayanamoorthy (2004), Surendran *et al.* (2016), own calculations

Table III. Energy and emissions data of DI and flood irrigation systems worked well so far, and so he won't allow us to install a DI system in our fields"[10]. In interviews with senior management of India's largest DI supplier, another important theme emerged – averseness to taking on debt. "If a farmer has debt," the authors were told, "no one would like to marry into that family." The existence of such strong social pressures helps explain the extent of farmer suicides when monsoons and crops fail. Both these observations indicate that what farmers consider appropriate may not be based on straightforward calculations of costs and benefits.

Upgrading farming systems with technologies which require capital infusion, therefore, face considerable hurdles. To overcome traditionalist hesitancy, a new logic of what is appropriate must be developed, and this requires intensive work with farmers to convince them to make the switch. The manpower resources required are concomitantly high. Moreover, in precarious socio-economic environments, where targeted means-based support and emergency programs are inexistent, market-based solutions such as credit extension are more problematic for the vulnerable, for they may end up being more exposed to the effects of crop failure.

Meanwhile, the role of the state in diffusing innovations can be divided into two major spheres (Moon and Bretschneider, 1997). First, the state can provide the information which potential adopters need to make informed decisions, thus reducing information asymmetries. Second, the state can influence the economics of the decision-making process by offering subsidies for the adoption of technologies (or penalize undesirable practices through regulation or charges), in a sense internalizing the positive socioeconomic externalities generated by the innovation and sustaining the innovation until it is able to make for itself a compelling economic case for rapid and widespread diffusion. In both of these tasks, the authors found problematic tendencies, though also partial successes in the case of DI diffusion.

When the authors began their research, they were expecting to analyze a rather traditional and straightforward institutional environment in which the main actors were the elected politicians, bureaucrats, agricultural extension officers (AOs) and farmers. Instead, the authors found that the role of DI equipment manufacturers was much broader and more critical than that of being mere product suppliers. The authors were expecting to find that AOs were playing the central role in demonstrating and proselytizing DI to sugarcane farmers. However, farmers indicated to them that they had minimal contact with the AOs. At most, the AOs dropped by once a month on a perfunctory visit. Unless there is a government scheme, the farmers informed us, the AO has no business to conduct, and because government schemes are mostly for dryland agriculture, AOs do not interact much with sugarcane cultivators. Even the cooperative sugar factories, around which sugarcane cultivation is organized in Maharashtra, were doing little to promote DI in spite of the fact that DI was a stated government priority[11]. Notably, not one of the farmers the authors interviewed indicated any influence of government officials in promoting DI. Indeed, one informant reported that the Gram Panchayat (elected village-level governing council) in Rahuri had recently organized a micro-irrigation program in collaboration with the agriculture department, but the farmers did not find the presentations credible or persuasive. Instead, the farmers reported that the main credible activities of demonstrating DI are being done by the suppliers of these systems. The largest DI supplier, in fact, has a small army of agricultural graduates penetrating into each village to demonstrate the benefits of micro-irritation systems[12]. As this supplier has grown over the past 25 years, it now employs close to as many agricultural graduates as the government itself. Interviews with these graduates revealed that quite a few of them had indeed left government to work for the supplier, and those that had done so reported that they were able to reach more farmers and provide more concrete help through the company than in their previous employment with the government.

Thus, in terms of the first responsibility – reducing information asymmetries – diffusion activities, although originally developed by the government, are now being expanded more by the DI suppliers. In a sense, this could even be seen as a successful incubation by the state[13] wherein an initial phase of incentives has led to a sustainable commercially viable activity run autonomously of the state, though this may have been more the result of neglect than a purposive strategy.

With regard to subsidies, the other major component of state intervention in the promotion of DI, the authors found descriptions and responses of farmers' experience to be fairly consistent. The average time reported for receiving the subsidy was 1.5 years, and the average amount received was 40 per cent to 50 per cent of total costs, though, in Shrirampur, some farmers reported that in the early years of DI it could take more than five years to get the subsidy. In the case of subsidies too, the DI supplier, realizing that sales would suffer because farmers were unsure about how long it would take to get the subsidies, assumed a central role as it would provide the system at the subsidized price, apply for the subsidy on behalf of the farmers and receive the money directly from the government, in effect extending free credit to the farmers. On the one hand, it could be argued that concerns about falsification in the submission of bills and other forms of corruption force the government to take a cautious approach to approving subsidy applications, which is compounded by the shortage of personnel to process the applications. On the other hand, it could also be argued that those responsible for approving payments purposely delay approvals to obtain rents. The CEO of the largest DI supplier in India says his firm is increasingly shifting strategies to market the systems on the basis that just the increased production of crop from DI will be enough to pay for the system in about three years, and to facilitate this, it has set up an agricultural non-banking finance company with anchor financing from the International Finance Corporation to provide loans for the purchase of the systems. Nevertheless, weaning the system away from subsidies is difficult. Field-level sales agents interviewed still emphasized the importance of the subsidies in clinching sales, and the farmers themselves noted that they would find it hard to switch irrigation systems without subsidies.

5.2 The Pareto superior bargain

The low-level equilibrium trap in the irrigation water-electricity nexus in India is easily modeled here (Kimmich, 2016), but to understand how these equilibria are overcome, we must look closely at how actors maneuver around limiting conditions. Within this environment of coordination failure, the Maharashtra Government recently announced plans to promote the use of solar-powered agricultural pumps[14]. According to this program, in its first phase, the state government aims to distribute 500,000 solar pumps to farmers. By leveraging financing available from the Ministry of New and Renewable Energy, the program aims to subsidize more than 80 per cent of the cost of the pumps. These solar pumps are designated as replacements for conventional electric powered pumps, which should in effect reduce electricity demands on the state power grid (thereby freeing up power availability for other consumers) as well as reduce the financial burden on state electricity companies by taking subsidized farmers off-grid. Such a program could encourage even more intense groundwater extraction, but the pumps come with associated DI systems which would increase water use efficiency. While the program is expensive – at the rate of US$6,000 per pump, the program would cost US$3bn – it should be viewed in the context of the fact that the Maharashtra Government already spends about US$1.7bn annually on power subsidies.

The key feature of this initiative is that for the principal stakeholders the program is substantially Pareto superior. Farmers are not threatened by losing access to cheap power, power subsidies can be reduced over the long term, helping the ongoing reform efforts in the electricity sector, and much of the cost to the exchequer will be balanced by savings in subsidies. The associated environmental benefits derive from both reduced emissions as solar power replaces coal-based generation and micro-irrigation increases water-use efficiency. Meanwhile, other growing sectors of the economy will be able to receive more reliable, cheaper and less carbon-intensive electricity.

5.3 Crafting the bargain

As Tables II and III show, DI by itself would have created similar Pareto superior benefits, but the market uptake for DI sets has been slow because of low levels of finance and prioritization. Coupling micro-irrigation with solar pumps enlarged the potential support coalition and also accessed new channels of finance by enlarging the solution space to incorporate not just the economically struggling agriculture sector, but also the more powerful industrial interests around energy.

It may appear that the appearance of significant and urgent needs had finally convinced the government to overcome previous barriers to coordination and devise a coordinated response across sectors, but during the course of field investigations, the authors discovered that the plan for introducing solar pumps had been devised by the same firm which produces micro-irrigation systems and, then, intensively marketed to the state government[15].

What explains why such a program was devised by a private sector corporate actor rather than the administration itself? The organization theory on innovation activities provides some clues on where to look. It has long been theorized that capacity constraints in organizations limit their innovativeness, and that slack resources are necessary for organizations to make investments in innovation (Bourgeois, 1981). Even though resource-constrained organizations may be even more in need of innovation to overcome their limitations, too little slack discourages experimentation, which by definition begins with uncertain possibilities of success (Nohria and Gulati, 1997) and is, therefore, considered an unaffordable luxury. Moreover, tightly wound organizations experience higher levels of internal conflict, which is also unfavorable to innovation (March and Olsen, 1983).

These hypotheses fit in well with our case findings. The Indian state, in contrast to its commonly conceptualized image as a bloated one, is in reality over-extended. After decades of employment freezes, the staffing levels with respect to the population that needs to be served are quite low and falling[16]. This was alluded to by several informants throughout the government who said that there has been a *de facto* hiring freeze in many departments, and that agricultural departments especially are being increasingly de-emphasized[17]. Moreover, with weak agency controls and high levels of both public choice and rent-seeking, the fact is that even if staffing levels had been nominally adequate many personnel do not exert themselves. This means that the ones who do are even more over-extended. Because organizational budgets and other resources are severely constrained in comparison to the task environment which they face, administrative departments do not proactively engage in cooperative behavior or coordinated strategies. Indeed, they are more likely to engage in turf and budget-protective behavior and, more importantly, to demonstrate reluctance in taking on new responsibilities[18]. Rather than institutional rules and culture, therefore, it is the limited capacities of the state in combination with the large amounts of claims it must process which create the conditions wherein the state is no longer the *locus* for policy innovation.

With governments constrained in their strategic planning, spaces become available for other actors to offer solutions, though how these spaces are opened and constructed is difficult to model. The concept of possiblism, focusing on how solutions are innovated and stitched together, is useful in analyzing such situations. As noted previously, in our case, the equipment supplier emerged as a key supplementary actor to state structures for DI in terms of both technical outreach and subsidy delivery. In the case of the solar pumps, the supplier again replicated these functions and, in addition, extended the solution space to involve other government agencies and interests to attract new resource flows, including the attention of administrators and policymakers, the last actually being an important and scarce resource. Acting at the boundaries between different segments of government and citizens (farmers) and between different administrative organizations (irrigation, agriculture and electricity), the equipment supplier became an interstitial node which is supplying the connective tissue at programmatic and project levels to bring together different interests that are represented in the broadly defined categories of state and society. This interstitial role consisted of more than merely facilitating a pass-through of resources. While the DI supplier began several decades ago as an equipment supplier responding to modest government-induced demand, it has since progressively added to its original function as it has grown commercially. It has assumed the major responsibility for demonstrating the equipment, which incorporates not just a marketing function but also an educational or knowledge dissemination one. Further, it assumed an administrative function when it began to simplify and centralize the subsidy distribution process. Finally, the supplier has now also assumed a policy innovation function by managing local-level claims and privileges in the process of providing a packaged solution, thereby combining the functions of policy as well as commercial entrepreneurship.

An enabling condition can be recognized in the embeddedness of the DI supplier in local networks which allows it to pick up on quiet signals and work incrementally in developing a series of sequential solutions which are optimized to the prevailing demands and resource distributions of the principal stakeholders. As a long-term actor in the agricultural sector, the DI supplier has access to the research regarding both DI and solar-power agricultural pumps, intimate knowledge of farmers' attitudes and needs and resources they have available and ongoing contact with government personnel at all levels. The idea of using solar-powered agricultural pumps combined with DI systems did not originate with the DI supplier. Several studies investigating the technical and economic feasibilities of such systems have been conducted all over the world, including in South Asia and India (KPMG, 2014; Hossain *et al.*, 2015; Shouman *et al.*, 2016). This enables it to perform a bridging function that builds on accurately perceiving needs and resources to package a bundle of solutions. Its key contribution as an interstitial actor here is not the execution of a demonstration project to establish the viability of a technological approach (through a demonstration project, properly controlled or otherwise), but instead it is the execution of the more difficult task of deploying an innovation at a large and sustained scale. In highlighting this embeddedness, the authors note that this case also inverts the logic generally followed in what Boehmer–Christiansen (2002) noted as the intellectual efforts of the World Bank and Global Environment Facility to facilitate investments in sustainable development based on the "search for markets by Northern money and expertise." This might also explain why, for example, donor-based initiatives to introduce new technologies to less industrialized developing countries may never move beyond the confines of the projects which finance them.

6. Discussion and conclusions

Framing policy initiatives using the concept of possibilism, this paper contributes to the ongoing development of this literature by demonstrating how reforms can be packaged in

Pareto superior formats to overcome policy stalemates and generate technology-based climate and environmental co-benefits in even unpromising terrain characterized by large technologically laggard and economically constrained populations. In our case, it facilitates CSA practices which have large payoffs in both adaptation and mitigation.

The authors have also identified certain enabling conditions: the first, of course, was the technology itself which had gone beyond the proof-of-concept. Here, the state played a critical role in the early stages of technology introduction to the country in the absence of which a DI industry would probably not have emerged to the extent that it has. The second was an enlargement of the solution space to interests and funds in associated sectors which helped overcome lethargy in the principal arena of action. The third was the opening up of the policy innovation space to the actors beyond the state. To some extent, this depended on the presence of an established and embedded local entity, which in turn depended on the existence of a potential and long-term market for the innovation, the latter, in fact, having been created by the state. Thus, one of the main and stable roles of the state has been to provide open-ended market assurances to convince the relevant actors to make the necessary investments in production capabilities and facilities. Meanwhile, the role of the private actors evolved to include the labor-intensive functions of awareness raising and demonstration, a role in which it has displaced the state. In addition, the private actors have also evolved to assume the policy development role from the state and to facilitate the creation of multi-stakeholder platforms for innovation diffusion.

In addition, the authors have shown the preference policymakers have for voluntary policy instruments over coercive reforms and how the private sector has responded to this challenge. The case of DI is not unique in terms of realizing potential Pareto optimal bargains. Take, for example, the case of the smog which now regularly paralyzes New Delhi in November. Here, the *New York Times* reported that the smog is caused to a large extent by farmers burning rice fields in the neighboring states, and that in this case too, a technological solution is was available – a seeder which can plant wheat without needing to dispose the straw left over after the rice harvest – but farmers said they could not afford it (Anand, 2016). Here too, it turns out that the government is offering a 50 per cent subsidy, but the availability of funds and uptake remain low.

In investigating this case, the authors also find an interesting example of the emergence of more complex networks of polycentric governance linking private sector and governments in which the former plays a more clearly defined interstitial role in mediating claims and solutions between citizens and the state, developing policy solutions for the state and even executing the program[19]. While some scholars have investigated the role of corporations in addressing environmental problems (Levy and Newell, 2005), they have focused mostly on the global scale. This paper has extended the research to more micro-level interventions, though of course, astute readers would have noticed that the motivations of the various actors in our case did not stem primarily from environmental concerns. Very often, climate and environmental action will emerge from or be based on initiatives that are not at all climate-centric in their intent and, indeed, given that climate change is not often high on the agenda of the political and administrative structures of developing countries, a "climate first" approach to tacking climate change may be self-limiting because of the political noise it generates. Yet, this paper shows how economic and environmental and climate co-benefits may still be realized through the exercise of judicious self-interest and by broadening the potential problem and solution spaces to bring in to bear extra resources and coalitional interests.

Notes

1. Interview with former delegate of India's climate change negotiating team, currently Divisional Commissioner in Maharashtra (November 2015) and with former member (from the Indian Administrative Service – IAS) of committee which drafted India's National Action Plan on Climate Change (October 2014).
2. http://ahmednagar.gov.in/html_docs/rainfall_information_of_district.htm, (accessed 1 November 2016).
3. Interviews with former Additional Commissioner, Maharashtra Groundwater Surveys and Development Agency (November 2015), and Chief Engineer, Vidarbha Irrigation Development Program (December 2015).
4. This information was provided by Maharashtra Electricity Regulatory Commission via personal communication.
5. Interview with former Chairman, Central Electricity Regulatory Commission, November 2015.
6. Comptroller and Auditor General of India report, 2014. www.saiindia.gov.in/sites/default/files/audit_report_files/Maharashtra_Report_3_2014_chap_6.pdf, (accessed 1 October 2016).
7. Interview with Secretary Irrigation, Maharashtra Water Resources Department, November 2015. Similar ideas were communicated in interviews with the Divisional Joint Director (Agriculture), Additional Chief Secretary (Agriculture) and Commissioner, (Agriculture), Government of Maharashtra (December 2015).
8. Interview with Senior Engineer, Maharashtra Water Resources Department, Commissioner (Agriculture), and Additional Chief Secretary (Agriculture), Government of Maharashtra (December 2015).
9. All the IAS officers the authors interviewed confirmed that they invariably represent the interests and viewpoints of the organizations to which they are posted, and that these change as often as their postings. Given that their average tenure in any given department never exceeds three years, it is not that they develop an affinity for any given departmental viewpoint. Although they recognize the need for and lack of coordination, they were unable to articulate why they did not do so. While exploring this theme is beyond the scope of this research, the authors flag it as an important and interesting item for future research.
10. Interview with agricultural scientist, Jain Irrigation, December 2015.
11. From interviews at a sugar cooperative factory in Baramati district, and with the Director General of the Vasantdada Sugar Institute (the government's premier sugar research institute), Pune, India.
12. In our research, the authors had interactions with the largest DI supplier in India, Jain Irrigation, which has over 10,000 employees and an annual turnover of around US$1bn. The next largest DI supplier in India, Netafim, has a little less than half that many employees and annual revenues of around US$100m.
13. Indeed, DI in India probably would have been much more marginal had it not been for central government support to import the technology from Israel in the 1980s.
14. www.livemint.com/Industry/DUaYl2Icsqjgqp0PWGkBGL/Maharashtra-to-invite-tenders-to-supply-solar-pumps-to-farme.html. Accessed January 14, 2015.
15. While the authors were shown several of the technical reports and documents submitted by the supplier to the state government, they were asked not to cite the documents and maintain to some confidentiality about the contents.
16. Based on Reserve Bank of India statistics. See www.rbi.org.in/scripts/PublicationsView.aspx?id=15804. Accessed 15 November, 2016.

17. Interviews with Additional Chief Secretary (Agriculture), Government of Maharashtra (November 2015).
18. Similar ideas were stated in three Interviews with different senior administrative officials, from the Maharashtra Water Resources Department, Department of Agriculture and Divisional Commissioner, Nagpur, 2014-2015.
19. This experience is not unique, but part of an emerging trend. For example, the second largest DI supplier in India also has a multi-million-dollar contract with a neighboring state to expand irrigation networks. www.bloomberg.com/news/articles/2014-01-23/netafim-to-build-largest-india-s-drip-irrigation-project, Accessed 1 November 2016.

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