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EXPLAINING TRUST IN LARGE BIOMETRIC INFRASTRUCTURES: A CRITICAL REALIST CASE STUDY OF INDIA'S AADHAAR PROJECT

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Abstract
The need for formulation of solid explanatory theories is heightened in information and communication technologies for development (ICT4D) by the high incidence of failure, which involves substantial costs for the countries affected. A core argument of this paper is that a critical realist ontology offers intellectual tools that can ground the formulation of causal theory in ICT4D. The paper illustrates such potential through the case study of India's Unique Identity Project (Aadhaar), which Indian states are increasingly using within their anti-poverty programmes. Following a critical realist retroductive methodology, the paper seeks to explain the incorporation of Aadhaar into India's main food security system, the Public Distribution System; an incorporation somewhat paradoxical given the mistrust often associated with biometric infrastructures in social protection. Critical realism allows construction of a theory of trust-building in Aadhaar, based on mechanisms of *institutionalisation* (state governments framing Aadhaar as a core institutional means to receive benefits) and *image formation* (authorities systemically associating Aadhaar with an image of effective pro-poor reform). Based on primary and secondary data collected over the course of six years, this paper contributes a theoretical explanation of an important phenomenon in Indian development, and illustrates how a critical realist philosophy is instrumental in building the type of causal theory that is needed in ICT4D.

Keywords: ICT4D, critical realism, food security, anti-poverty policy, Aadhaar, India

1. INTRODUCTION

Despite the importance of producing solid explanations of phenomena, focus on explanatory theories has been relatively limited in the information systems (IS) field (Avgerou, 2013a). In particular, interpretive IS researchers seem to be especially cautious about expressing the intention 'to explain', which is viewed as inextricably linked to theories of causation (Gregor, 2006; McGrath, 2013: 2). Explanatory theory however addresses the root causes behind observed phenomena, and is hence instrumental in leading to a better understanding of the world (Avgerou, 2013a: 400).

The need for solid causal theories is particularly strong in the study of information and communication technologies for development (ICT4D). The reason for this is twofold, and is most commonly ascribed to the lack of explanatory theories that systematically link ICT to particular development outcomes (Walsham & Sahay, 2006; Avgerou, 2010; Walsham, 2012). A second reason, less frequently explored, lies in a more practical problem: ICT-based projects in developing countries present high rates of failure, largely due to limited ability of designs to incorporate the reality of beneficiaries (Heeks, 2002). High incidence of failure, resulting in

high human and economic costs, generates the need to produce explanatory theory that illuminates the causes of such negative outcomes.

Rooted in the work of Bhaskar (1978, 1979), critical realism aims to construct solid causal explanations of phenomena, seeking to reconcile the dichotomy between the main tenets of positivism and interpretivism (Smith, 2006; McGrath, 2013). The ontology of critical realism admits the existence of an objective reality, but its epistemological relativism (Heeks & Wall, 2017) implies that our knowledge of it can only be partial and subjective (Sayer, 2000; Easton, 2010). With its sharp focus on causality, critical realism has strong potential to generate the type of explanatory theory that is needed in ICT4D.

This paper illustrates such potential through the case study of a large biometric infrastructure initiative, India's Unique Identity Project (Aadhaar), which constitutes the biggest project of biometric identification in the world. In particular, we seek to explain Aadhaar's apparently successful incorporation into India's main food security system, known as the Public Distribution System (PDS), a unique phenomenon given extant weaknesses in India's public service infrastructure (Corbridge, Srivastava, Williams & Véron, 2005) and the mistrust generally associated with biometrics in social protection programmes (Gelb & Clark, 2013; McGrath, 2016). The object of the study is important to Indian development because Aadhaar's uptake may result in transition of the current subsidy system to cash transfers, which is radically changing the nation's logics of delivery of anti-poverty programmes.

In response to an explanatory question, our analysis follows a critical realist retroductive process (Mingers, 2004; Wynn & Williams, 2012). Retroduction is the process through which "we take some unexplained phenomenon and propose hypothetical mechanisms that, *if they existed*, would generate or cause that which is to be explained" (Mingers, 2004: 94-95). Our choice of retroduction stems from the need to explain a puzzling phenomenon, which calls for the construction of middle-range theory to identify the mechanisms at its origin. The puzzle of Aadhaar's incorporation into India's food security system, a type of social protection structure in which biometrics are generally seen with suspicion, is the starting point of our analysis.

Our retroductive reasoning results in a theory of trust-building in Aadhaar, based on the intertwined mechanisms of *institutionalisation* (state governments framing Aadhaar as a core gateway to benefits) and *image formation* (national authorities entrenching Aadhaar in an image of effective pro-poor reform). Such mechanisms are then validated through data triangulation (Wynn & Williams, 2012), to prove their plausibility in explaining the phenomenon of interest. Data triangulation is made possible by our use of three related datasets, resulting from two field studies and a review of state-level cases of Aadhaar-based PDS.

The intended contribution of this paper is twofold. First, it offers a theoretical explanation of an important phenomenon in Indian development, which affects the nature of the nation's anti-poverty system. Second, it illustrates how a critical realist philosophy is instrumental in building the type of causal theory that is needed in ICT4D. Such theory, as illustrated here, belongs to the domain of middle-range theories (Avgerou, 2017), as explanations needed to avoid failure in ICT4D concern phenomena that, while circumscribed in time and space, are of crucial importance for people's lives and livelihoods in developing country contexts.

The paper is structured as follows. We first focus on the nature of explanatory theory, and detail the reasons for its relevance to ICT4D. We then state the core principles of critical realism, focusing on their relation with generation of causal theory. We then introduce the case of Aadhaar and its progressive incorporation into India's main food security programme, which we seek to explain through the means of a retroductive process. Finally we detail the

implications of our study, both for Indian development and for the value of critical realism for theory-building in ICT4D.

2. ICT4D AND THEORY FOR EXPLAINING

Gregor (2006) identifies theory for explaining as one of the fundamental types of theory in IS. Such theory offers a lens for seeking the causes of phenomena, and more specifically to explain "how" and "why" some given phenomena occur. In Gregor's taxonomy of IS theory types, this can also be called a class of "theories for understanding", as "they often have an emphasis on showing others how the world may be viewed in a certain way, with the aim of bringing about an altered understanding of how things are or why they are as they are" (Gregor, 2006: 624). The importance of this theory lies in illustrating the internal workings of phenomena, leading to solid explanations of real world problems (McGrath, 2013).

In Gregor's (2006) classification, "theory for explaining" (type 2) is distinguished from "theory for predicting" (type 3), and "theory for explaining and predicting" constitutes a separate type altogether (type 4). As such, theory for predicting may be avulsed from explanation, and lead to prediction of outcomes without explaining the causal connections behind them. According to this logic, "theories aiming at prediction say what will be but not why", and will leave parts of the system as a "black box" (Gregor, 2006: 625). Conflation of explanatory and predictive theory is an extant problem (Avgerou, 2013a: 400), which confuses the search for causal processes with the intention to make predictions.

Avgerou (2013a) identifies extant discussions of causality in the IS literature, pointing at Markus and Robey's (1988) distinction between *variance* and *process* causal models. While variance models of causation are empirically validated through statistical techniques, process models seek to answer the question of "how" causation occurs, seeking to trace the mechanisms that connect factors to outcomes. A similar distinction is traced by Orlikowski and Baroudi (1991, cited in Avgerou 2013a: 401) among positivist and interpretivist approaches. In this respect, positivism seeks causal relations that can be empirically identified and tested, whereas interpretive approaches aim at "understanding actors' views of their social world and their role in it" (Orlikowski & Baroudi, 1991: 9).

These perspectives reveal the importance of explanatory theory, and the presence in the IS field of conceptual instruments for building it. Nevertheless, scholars have argued that limited attention has been devoted to causal theory in IS, and this has constrained the field's ability to produce solid means to understand reality. The problem, illustrated in Avgerou (2013a, 2013b), is further conceptualised by McGrath (2013: 2), who notes that the main goal of interpretive research has been largely framed as "insight" and "analysis" rather than explanation. In particular, lack of theories for explaining weakens the field's ability to draw plausible inferences, and to move the level of generalisation beyond the immediate object of research (Avgerou, 2013b).

An important premise of this paper is that the need for theories for explaining, underlined by extant research in IS, is particularly strong in the discipline of ICT4D. The first reason for this is theoretical, and lies in the field historically suffering from a lack of theories linking technology to development (Akpan, 2003; Walsham & Sahay, 2006; Avgerou, 2010). Despite some 30 years of ICT4D history (Walsham, 2017), such theory still needs systematic strengthening to generate valid propositions on the ICT-development link and on its practical enactments (Njihia & Merali, 2013). In particular, as observed by Avgerou (2010), limited focus on explanatory theory systematically affects the field's ability to make strong arguments on IT-enabled socio-economic development.

But another reason, less intensively explored, heightens the importance of causal theory for ICT4D. This lies in the argument, first presented in Heeks (2002), that failure is frequent in

projects involving ICT in developing countries, and is largely due to discrepancies between designers' mindsets and the reality lived by users. Failure in ICT4D poses theoretical problems, with which recent research in the field has engaged (Dada, 2006; Dodson, Sterling & Bennett, 2012; Masiero, 2016). But it deals, at the same time, with more practical issues: if we take Walsham's (2012) invitation to commit to "making a better world" with ICTs, it is then important to study the root causes of failure, and to develop viable strategies to combat them.

Over the last decade, ICT has become more pervasive in development projects worldwide. First linked to the Millennium Development Goals (Heeks, 2005), ICT is of crucial importance to strategies for reaching the Sustainable Development Goals, formulated within the post-2015 global development agenda (Heeks, 2014). Within this framework, ICT has become an integral part of schemes related to vital sectors such as healthcare, emergency management, food and water security in developing countries. Failure of ICT projects in such sectors has a direct impact on human lives, making the need to understand and minimise failure an even more urgent one.

This practical motivation, adding to the theoretical gap highlighted above, makes it important to engage in generating solid causal theory in ICT4D. Researchers need to seek philosophies aimed at producing such theory, which has recently brought critical realism to the field's attention.

3. CRITICAL REALISM AND CAUSAL THEORIES

Explicitly stated interest of ICT4D research in critical realism is a relatively new phenomenon, rooted in the conformity of this paradigm to core theoretical and thematic aspects of the field. As discussed by Heeks and Wall (2017), in a discipline whose attention to paradigms is generally limited, such interest is functional to strengthening processes of theory-building, and the critical component of the paradigm mirrors the field's recent turn towards issues of ethics, power and justice (e.g. Dearden, 2013; Taylor, 2017; Heeks & Renken, 2018). All these factors argue in favour of greater engagement of ICT4D with the ontology, epistemology and methodology of critical realism.

Numerous papers have reviewed the key aspects of critical realism, framing them in the landscape of IS research (e.g. Mingers, 2004; Smith, 2006; Wynn & Williams, 2012; Henfridsson & Bygstad, 2013; Zachariadis, Scott & Barrett, 2013) and more recently of ICT4D (Heeks & Wall, 2017; Heeks & Ospina, 2018). Here we provide a synopsis of the most important aspects of critical realism, conceptualising their connection with the generation of causal theory. In line with previous literature, we focus on three fundamental aspects: a stratified ontology, epistemological relativism, and methodological aspects based on retroduction and triangulation of data sources. These aspects are illustrated below.

From an ontological perspective, critical realism postulates that the world exists independently from our knowledge, and reality is referred to as *intransitive*, being independent of human cognition (Bhaskar, 1978). Our knowledge of reality is instead part of a *transitive* domain dependent on contingent factors. Reality is articulated in three nested domains, summarised by Wynn and Williams (2012: 790):

> The domain of the real includes the entities and structures of reality and the causal powers inherent to them as they independently exist. The next domain, the actual, is a subset of the real that includes the events that occur when the causal powers of structures and entities are enacted, regardless of whether or not these are observed by humans. The final domain, the empirical, is a subset of the actual and consists of those events which we are able to experience via perception or measurement.

The nested domains are connected in such a way that only the empirical is directly experienced by human beings, so that our knowledge of the world is inevitably partial and fallible (Aaltonen & Tempini, 2014). In reconciling aspects of positivist and interpretive paradigms, critical realism espouses the positivist belief in an objective reality, and the interpretivist stance that knowledge of that reality is subjective and depending on context (Mingers, 2004; Easton, 2010; Bygstad & Munkvold, 2011).

Epistemologically, the critical realist view of a dichotomy between transitive and intransitive reality implies that knowledge is not only subjective, but mediated by the *social structures* to which we belong, such as other researchers or discipline groups (Wynn & Williams, 2012: 793). Such structures are hence important for the purpose of explanation. Furthermore, referring to Gregor's (2006) distinction of explanatory and predictive approaches, the focus of critical realism is placed squarely on explanations, seeking to reach the domain of the real based on indications acquired in the empirical space (Mingers, 2004). To do so the researcher needs to arrive at the identification of *mechanisms*, conceived as the causal powers that operate behind reality (Henfridsson & Bygstad, 2013). The critical realist views a mechanism as a means of access to the domain of the real, and uncovering them is hence a core part of the construction of explanations (Sayer, 1992; Mingers, 2004; Bygstad, 2010).

The methodology of critical realism flows directly from the aspects reviewed above. A key aspect is the need for a process that allows us to navigate the world's stratified ontology, moving from the domain of the empirical to the causes and structures that characterise the real. This is why the main process of critical realist analysis is identified with *retroduction*, through which "we take some unexplained phenomenon and propose hypothetical mechanisms that, if they existed, would generate or cause that which is to be explained" (Mingers 2004: 94). Retroduction is the core means to construction of causal explanations in critical realism, and it is articulated by McGrath (2013: 9-10) in four stages:

1. *Description of the phenomenon of interest*, in terms that make it relevant to the concepts of some particular theories. The retroductive process starts from a precise description of the phenomenon, or the aspect(s) of it for which explanation is sought. This is accompanied by justifications of the relevance of the phenomenon, and of the factors that make it important to study and explain.

2. *Hypothesising mechanisms* whose existence would generate the observed phenomenon. Once the phenomenon has been described in its real-life setting (Yin 2003), possible explanations have to be produced, in the form of mechanisms that may constitute their causal origin. Mechanisms, as pointed out by McGrath (2013: 5), are generally unobservable except in their effects (Bhaskar 1978), and hence need to be imagined on the basis of the empirical layer of reality.

3. *Elimination of competing explanations* and attempts to demonstrate mechanisms through further empirical research. Once competing explanations have been devised, they need to be tested against what is reflected in the data, typically leading to elimination of some possible explanations and reinforcement of other ones. Once some explanations come across as potentially viable, further empirical research is required to check their correspondence to the world.

4. *Identification of the generative mechanism that provides the best approximation* and appropriate theory development. Grounded in triangulation of data sources, one or more

mechanisms are finally identified as most plausible, and development of causal theory is conducted on their basis.

Important for the functioning of a retroductive process are principles devised by Wynn and Williams (2012) for the choice of a research question. This should be constructed to mirror the explanatory nature of the paradigm, and hence be of the type: "what caused the events associated with the phenomenon to occur?" (Easton, 2010). As in Wynn and Williams (2012: 800),

> (…) the researcher conducts what Weick (1989) described as *thought trials* to identify and describe the elements of the causal mechanism and the contextual influences responsible for its activation. Given that mechanisms are rarely, if ever, experienced directly, the retroduced mechanism presents a logical argument explaining how the phenomenon of interest came to be through the emergent properties of the structure interacting within the study context.

The retroductive process, illustrated above, can hence be conceived as a set of thought experiments with the objective of imagining *how the world should be like* for a given phenomenon to occur (Mingers, 2004). As such, the phase of hypothesising mechanisms is largely creative and emergent (Wynn & Williams, 2012: 800), and empirical rigour is heightened when possible explanations are tested through the data. It is through data that some possible explanations are eliminated, while some are preserved and demonstrated through existing sources.

Triangulation is an integral part of the process, which allows validation of the most plausible mechanisms found in the analysis. Data triangulation involves collecting data from a multiplicity of sources, to achieve a clearer understanding of the causal factors and relationships at work in the case in point (Wynn & Williams, 2012: 802). For example, in a study of adoption of ICTs in a social protection net, data can be triangulated across multiple stakeholders such as software developers, policymakers, intermediaries, and the beneficiaries of the anti-poverty programme that is being computerised. The relevance of triangulation, in the context of critical realism, is due to the importance of obtaining the best possible set of sources to confirm emergent explanations.

For the purposes of this paper, it is important to focus on the relevance of critical realism for building the type of causal theory that is needed in ICT4D. A retroductive process, starting from description of phenomena and proceeding through the selection and refinement of explanations, hence needs to be conducted for research questions in our field.

4. RESEARCH SETTING

Consensus exists among critical realist researchers around the idea that the case study constitutes "the best approach to explore the interaction of structure, events, actions, and context to identify and explicate causal mechanisms" (Wynn & Williams, 2012: 795). The single intensive case study, centred on a phenomenon within its real-life context (Yin, 2003), is hence recognised as a first-best method for conducting critical realist research. Arguably, if a critical realist case study is conducted in ICT4D, the phenomenon also needs to illuminate a key aspect of the relation between ICT and development.

This has inspired us to conduct a case study of India's Aadhaar, which constitutes the largest project of biometric identification worldwide (Dass, 2011). Based on free and voluntary enrolment of Indian residents, the Aadhaar project endows each enrolee with a 12-digit number and capture of biometric details, meaning fingerprints and an iris scan. A recent Economic Survey (Government of India, 2015) openly recommended incorporating Aadhaar into the

main social safety schemes in the country, making the system directly entrenched within the nation's anti-poverty policy. Launched in 2009, the Aadhaar project is managed by the Unique Identification Authority of India (UIDAI), an agency that, since its establishment also in 2009, is seen as an integral part of the Indian government.[1]

Two orders of reasons make it generally difficult for governments to incorporate biometric infrastructures into social protection systems. First, as noted by McGrath (2016), citizens are often suspicious of interventions based on biometric data capture, which makes it hard to obtain popular support for this type of measure. Second, transition of social schemes to biometric authentication involves high levels of technical complexity, potentially resulting in *exclusion errors* out of which genuine recipients are denied their entitlements (Gelb & Decker, 2011; Gelb & Clark, 2013). As a result uptake of biometrics in global schemes of social assistance is at best cautious, and often bypassed in order to avoid costs that would exceed the benefits (Devereux & Vincent, 2010).

Nevertheless, India has been thoroughly introducing Aadhaar in its social security system. In spite of the multiple fragilities that characterise the nation's public service infrastructure, Aadhaar has reached massive enrolment rates throughout the country, and since the launch of the project it has been quickly incorporated into the national system of anti-poverty schemes. The oldest and most pervasive of these schemes is the PDS, the food security system that since 1965 provides subsidised rations of primary necessity items to the Indian poor. The uniqueness and importance of this experience lead us to ask, what explains the incorporation of Aadhaar into India's main food security system?

To produce solid explanations, critical realism requires a plurality of data sources (Heeks & Wall, 2017), hence three related data sets have been used to answer our question. The first has been collected in 2011-2012, during an eight-month period of fieldwork on the computerisation of the PDS in the state of Kerala. At that time, while Aadhaar was not yet formally part of India's anti-poverty agenda, states were in the process of conducting intensive enrolment campaigns, and pilot projects of Aadhaar-based PDS were being started. Data collected in Kerala consisted of 126 interviews (Table 1) with actors revolving around the PDS, observation in PDS outlets undergoing computerisation, and system demonstrations by the software designers engaged in digitalisation of the programme.

Table 1: Field Study of Computerisation of PDS in Kerala, 2011-2012

Interviewees	**Main topics discussed**	**No.**
Officers at Food and Civil Supplies Department (Government of Kerala)	PDS supply chain, fit of the Kerala PDS with the national anti-poverty strategy, nature and extent of leakage of PDS goods to the non-poor, potential of biometric infrastructures to solve the problem	7
District and sub-district level Food and Civil Supplies officers (Government of Kerala)	PDS supply chain, ground-level perceptions of leakage, computerisation of the PDS, potential of biometric infrastructures to solve the problem	17

[1] Under the provisions of the Targeted Delivery of Financial and Other Subsidies Benefits and Services Act (2016), most commonly known as Aadhaar Bill, UIDAI is an authority established by the Government of India under the Ministry of Electronics and Information Technology.

PDS ration dealers	Role of ration dealers in the PDS supply chain, issues experienced after national shift to a targeted PDS, their perception of feasibility and usefulness of a national switch to a biometric PDS	15
National Informatics Centre (NIC) software developers	Computerisation of the different phases of the PDS, how software developers liaise with state-level government officers, the ways in which digitalisation can combat leakage of the PDS, hurdles encountered in the process, scope of biometric infrastructures to reduce leakage	9
Staff at Kerala State Information Technology Mission (KSITM)	Relevance of ICT to the national and state development strategy, use of ICT within anti-poverty programmes, likelihood of a shift from subsidies to cash transfers in the national system of social protection, expected effects of such shift on ration shops and beneficiaries	8
Staff at Akshaya telecentre project (management, telecentre entrepreneurs)	Role of telecentres as Aadhaar enrolment centres, diffusion of Aadhaar in Kerala and India at large, causes and expected trends of such diffusion, role of telecentre staff in facilitating online applications for ration cards	24
PDS beneficiaries	Perceptions of the PDS, its advantages and disadvantages, perceived extent, nature and geographies of leakage, perceptions of the potential of biometric infrastructures to improve the food security system	36
Civic and political activists	Perceptions of national and state systems of social protection, advantages and disadvantages of computerisation, perceived ability of biometric infrastructures to improve the food security system, experiences of access to the PDS by citizens living below the poverty line	10
Total		126

The second data set has been collected in 2014-2015 in the state of Karnataka, whose level of transition to a biometric PDS was significantly more advanced than that of Kerala. In this state, at the time of fieldwork, 6 out of 28 districts had adopted biometric identification of PDS users in the ration shops where subsidised commodities are bought, which digitised the transactions between PDS providers and beneficiaries. Data collected in Karnataka included 62 interviews (Table 2) with actors revolving around the PDS, observation in newly computerised ration shops, and demonstrations of the functioning of biometric point-of-sale machines recognising users biometrically.

Table 2: Field Study of Biometric PDS in Karnataka, 2014-2015

Interviewees	**Main topics discussed**	**No.**
Staff at Food, Civil Supplies, and Consumer Affairs Department (Government of Karnataka)	PDS supply chain and its problems, nature and extent of leakage, reasons for developing biometric access to the PDS, expected effects on effectiveness and accountability of the programme, diffusion of Aadhaar in the state	5
Staff at PDS godowns (warehouses where PDS foodgrains are stored)	Role of Authorised Wholesale Dealers in the PDS supply chain, frequency and nature of controls by food inspectors, computerisation of the PDS, perception of its user-friendliness and usefulness to tackle leakage	9
PDS ration dealers	Role of ration dealers in the PDS supply chain, issues experienced after national shift to a targeted PDS, their perception of the switch from manual to biometric transactions with beneficiaries	12
National Informatics Centre (NIC) software developers	Computerisation of the different phases of the PDS, how software developers liaise with state-level government officers, scope of biometric infrastructures to improve the programme, expected advantages and disadvantages of the switch to an Aadhaar-based PDS	5
Technology implementers working on Aadhaar-based applications	Technical aspects of the infrastructure behind Aadhaar, its suitability for the national food security system, use of Aadhaar within the national anti-poverty agenda, expected advantages and disadvantages of such a move, drivers of the diffusion of Aadhaar in Karnataka and across India	6
PDS beneficiaries	Perceptions of the PDS, its advantages and disadvantages, perceived extent, nature and geographies of leakage, their experience with a biometric PDS, advantages and disadvantages encountered with the new system, perceptions of its ability to improve the PDS	18
Civic and political activists	India's anti-poverty policy, the national strategy for social protection, the role of Aadhaar within it, its expected advantages and disadvantages for the poor, expected effects of a shift from subsidies to cash transfers to citizens below the poverty line	7
Total		62

The third data set, obtained through secondary sources, consists of a systematic review of the cases of Aadhaar-based PDS in India so far. By March 2017, ten states had completed their transition to such a system, and others were in the process of adopting it (Saini, Gulati, Sharma & Von Braun, 2017). Events related to Aadhaar and the PDS (chiefly the passing of the Aadhaar Bill in 2016, and legislation aimed at enabling direct cash transfers to the poor) have produced vivid debates on traditional and social media, providing more material for data collection. While based on publicly available secondary sources, this data set has been integrated with four field visits to India for different research projects in 2016-2017, which led us to periodically discuss our findings on Aadhaar with fellow academics, members of civil society, social activists and volunteers at pro-poor organisations.

5. CASE STUDY: BIOMETRIC INFRASTRUCTURES AND FOOD SECURITY IN INDIA

5.1. Background: The Indian Public Distribution System

The concept of rationing was introduced in pre-independent India by the British government in 1939, as an emergency measure against hunger and malnutrition. This system however lacked a regional food policy, a situation that became unsustainable in 1943, when a food crisis caused between 1.5 and 3 million casualties in Bengal (Sen, 1981). In the aftermath of the Bengali famine a Food Department was created, to buy foodgrains from private producers in surplus provinces and sell them at a fair price in deficit ones. The same redistributive structure was maintained in independent India, albeit inconsistently throughout the first decades (Mooij, 1998: 81).

In 1965 the food security system became known as the PDS, with the establishment of a dedicated government agency, the Food Corporation of India (FCI), for its management. Similarly to the pre-independence Food Department, the FCI purchases primary necessity goods from private producers in surplus areas, and distributes them at subsidised prices through a network of fair-price shops, known as *ration shops*, throughout the nation. Goods subsidised under the PDS are both food items (rice, wheat, sugar, oils and pulses), and non-food items (oil, kerosene and cloth), with each state then able to subsidise more commodities at its own government's discretion. The difference between PDS and market prices is intended to allow poorer households to afford their basic needs.

The PDS supply chain is articulated into three phases. First, goods procured from private producers through the FCI are distributed at the district level through Authorised Wholesale Dealers (AWDs), who store them in dedicated warehouses known as *godowns*. Goods are then taken from the local AWD by ration shop owners, who collect them on a monthly basis for redistribution to beneficiaries. Finally, beneficiaries buy goods from ration shops at subsidised rates, within the quota established by their monthly entitlement. The phases of the PDS supply chain are illustrated in figure 1.

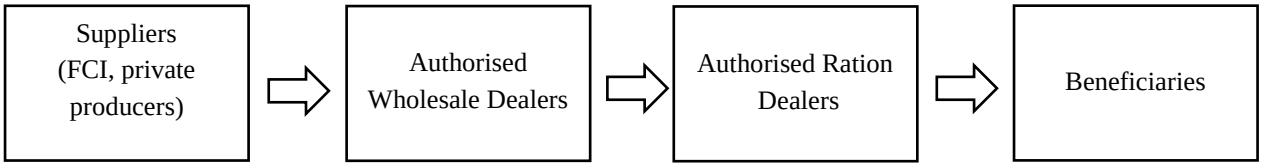

Figure 1: The national PDS supply chain

In its original formulation the PDS was universal, meaning that subsidy was equal for all citizens. In the early 1990s however, a fiscal crisis led the central government to reconsider the design of the system, in the light of its high burden on national expenditure. As the central government's reliance on the PDS as a food security system increased, the size of subsidy went up from 0.04% of the national GDP in 1970-1971 to 0.5% in 1990-1991 (Ahluwalia, 1993). So designed, the system achieved limited transfer to the poor at very high costs (Radakrishna & Subbarao, 1997), a problem that was taken into account by the Structural Adjustment Programme started in 1991.

This led to the design and launch, in June 1997, of the targeted PDS, in which subsidies are targeted to households recognised as below-poverty-line (BPL). Poverty incidence is estimated at the state level by the Indian Planning Commission, and goods are allocated across the nation on the basis of the relative poverty of each state. In 2000 an additional scheme, known as Antyodaya Anna Yojana (AAY), was designed to reserve additional quotas of foodgrains to households recognised as the poorest of the poor. The amount of subsidy for each good is decided by Food and Civil Supplies ministries at the state level, as well as the quota of items reserved to BPL and AAY households.[2]

The move to a targeted system reduced the fiscal burden of the PDS, increasing its financial viability (Umali-Deininger & Deininger, 2001). However the programme still suffers from systemic failure, due to leakage of commodities to non-entitled recipients. Illicit diversion of goods is determined by two related sources: first, the price difference between market and PDS goods, which creates an incentive for PDS actors to divert commodities on the market (Khera, 2011). Second, ration shop owners – known as *ration dealers* – were put in a dire financial situation by the move to a targeted system, which significantly reduced the number of their customers. This resulted in debt-induced ration dealer suicides (Suchitra, 2004) and in engagement of ration shops in illicit networks, which became known as *rice mafia* (Justice Wadhwa Committee on Public Distribution System, 2010).

The most recent estimates of PDS leakage reveal that 53% of commodities, on a national basis, still do not reach their intended beneficiaries (Saini et al., 2017). The National Food Security Act (NFSA), approved by the Indian parliament in 2013, expands the coverage of the PDS to two thirds of the population, reducing the exclusion errors that prevent genuinely poor households from receiving their entitlement (Sen & Himanshu, 2011). On the leakage front, parallel reform has been undertaken, to identify sources of diversion and disable its key mechanisms. Aadhaar's biometric infrastructure has been gradually inscribed into such anti-leakage reform.

5.2. Description of the Phenomenon of Interest: Aadhaar and the PDS

On January 28, 2009, the Government of India set up UIDAI with a gazette notification. The agency was established to collect the biometric and demographic data of all residents, store them in a central database, and release a unique 12-digit number to each enrolee. In June 2009, co-founder of Infosys, Nandan Nilekani, was appointed as the first head of UIDAI, which was established as an office of the Planning Commission of the central government. The first Aadhaar number was issued in September 2010, and since then more than 1.2 billion Aadhaar

[2] States can, at their discretion, maintain a quota of subsidy for households recognised as above-poverty-line (APL). Our two fieldwork states adopt such policy but keep subsidies for the APL at levels that approach market prices for the same goods.

numbers have been issued to the residents of India, making this the biggest biometric identification scheme worldwide.[3]

Identity verification schemes are set up to facilitate access to government services, establish people's right of residence in a region, and help combat crime and illegal immigration (McGrath, 2016). In the case of India, the choice of adopting a unique identification scheme based on biometric authentication had two main sources, the first one being the "identity gap" (Gelb & Clark, 2013) due to which only 40% Indians had their birth registered (UNICEF 2013, cited in Bhatia & Bhabha, 2017: 65). Such a gap resulted in easy duplication of extant identification documents, made possible by the lack of robust recognition infrastructures such as biometrics (Gelb & Decker, 2011). A second reason was the importance of guaranteeing national security, perceived as high by the United Progressive Alliance (UPA) government under which UIDAI was founded.

In August 2017, 86.7% of the population had an Aadhaar number assigned, and high enrolment rates were also achieved in India's poorest states.[4] Enrolment centres were set up all over the nation, and state governments led proactive campaigns to increase their residents' adherence to the scheme. The current National Democratic Alliance government has supported continuation of the scheme, as well as its inscription into the social protection system designed to serve the nation's poor (Bhatia & Bhabha, 2017). This makes Aadhaar an integral part of India's social policy, and the government's strategy openly incorporates it into the fight against leakage that affects the PDS (Government of India, 2015).

Incorporation of Aadhaar into the PDS started in 2011-2012, with state-level projects undertaken across the country (Saini et al., 2017). In such projects, Aadhaar-based PDS consisted of automation of the last-mile phase of the supply chain, in which beneficiaries obtain their monthly entitlement of subsidised commodities from the ration shop. Under this scheme, PDS beneficiaries are required to register with Aadhaar, and their unique identification number is then linked with the extant state database – called a *ration card* database – in which their households' poverty status is listed.[5] Ration shops are, at the same time, endowed with biometric point-of-sale machines, set to recognise the beneficiary through their fingerprint and determine their monthly allotment.

So designed, state-level pilot projects of Aadhaar-based PDS enabled a twofold accountability mechanism, aimed at guaranteeing the entitlement of beneficiaries on the one hand, and on the other preventing ration dealers from engaging in illegal sales. These schemes were initially confined to the stage of pilot projects given the voluntary nature of enrolment in Aadhaar, which was restated by a Supreme Court order in 2013. Vivid debate has occurred in the public sphere on the extent to which enrolment was effectively involuntary, given the increasing entrenchment of Aadhaar authentication in most other parts of the Indian public sphere. In August 2015, a new Supreme Court order allowed states to use Aadhaar in their PDS, hence providing legal backing to its incorporation.

Legal backing was finally sanctioned with the Targeted Delivery of Financial and Other Subsidies Benefits and Services Act, most commonly known as the Aadhaar Bill, passed in the Indian Parliament in March 2016. Criticism emerged around the governing coalition's choice to pass the act as a Money Bill, a type of legislative act which does not require a vote in the upper house of parliament, but is directly enforced once passed in the lower house.[6] Based on

[3] https://uidai.gov.in/about-uidai.html

[4] https://uidai.gov.in/enrolment-update/ecosystem-partners/state-wise-aadhaar-saturation.html

[5] A *ration card* is the paper-based document traditionally assigned to PDS beneficiaries, listing the details of all household members, the households' poverty status and the corresponding monthly entitlement.

[6] One of the main critiques to the Bill is that it is viewed as purposefully designed to evade the Supreme Court Order of 2013, which restricted the use of Aadhaar for social protection.

the National Identification Authority of India Bill, passed in 2010, the Aadhaar Bill established the possibility for states to include Aadhaar identification in their social protection systems, hence enabling state-level PDS to become officially Aadhaar-based. Implying a formal shift to biometrics in core programmes, the Bill is seen as the final act in the process of incorporation of Aadhaar into the national social protection system.

There are at least two reasons why India's experience of UIDAI is unique on a global scale. First, the enrolment rates reached by Aadhaar (above 90% in 14 states out of 29) defy the expectations of mistrust that often surround systems of biometric identification. Second, in a nation characterised by severe pitfalls in public service provision, a biometric infrastructure has been swiftly incorporated into the social protection system, setting out to transform its supply chain and effectively combat diversion of subsidised goods. This outcome is both puzzling and important for Indian development, and mechanisms underpinning its achievement should be identified.

5.3. Explaining the Phenomenon: Emerging Mechanisms

What explains the apparent success of Aadhaar? We first sought to grasp the design of the biometric technology, and how this was meant to change the functioning of the food security system. This has brought us to interviews with government officials, as well as software developers in charge of different stages of state-level computerisation of the PDS. This served the purpose of understanding the intentionality behind the transition to a biometric system.

Integration of Aadhaar, as depicted in governmental narratives, was conceived in close continuity with the creation of a better PDS. The primary objective was that of effectively combating leakage, tackling the black markets through which subsidised goods were being diverted away from beneficiaries. This meant, in the case of the PDS, combating the illegal transactions that ration dealers systematically indulged in to raise their profits. Since our first interviews, three reasons were raised by respondents, for which Aadhaar was associated with a more effective and accountable system.

First, Aadhaar enables the secure identification of programme beneficiaries. This allows it to tackle the phenomenon of bogus ration cards, meaning fake documents mimicking a proper ration card and hence enabling access to rations from non-entitled individuals. With its biometric nature, Aadhaar is designed to securely recognise beneficiaries, preventing impersonation of entitled individuals and making it difficult to bypass access requirements. This makes it an optimal technology to ensure that only entitled households access the system, so that leakage to the non-poor is minimised.

Second, a biometric system allows monitoring of the quantity of commodities taken at every transaction made in the ration shops. As a result, it provides a total sum of the goods sold on a monthly basis to entitled beneficiaries. As it emerged from our interviews, this is a particularly important feature, as ration dealers collect foodgrains from the local AWD every month, and they can only obtain goods on the basis of the amount sold to beneficiaries in the previous month. Biometric tracking prevents them from indulging in a previously common practice, based on selling on the private market and then claiming to have sold to entitled users.

Third, the new system can exempt households from the need to buy rations exclusively from their local ration shop. In the original formulation of the PDS, all households are registered with only one ration shop, which prevents opting out from ration dealers who are suspected to engage in corrupt practices. Due to its portable nature, linked to the capture of biometric details, Aadhaar enables recognition of users in *all* ration shops, enabling a system in which sale of subsidised commodities can occur from everywhere. While this has remained, at the time of writing, a theoretical implication of an Aadhaar-based PDS, portability is an important feature that the new system can in principle lead to.

All these explanations have emerged in the early stages of our research. Raised from different actors, they supported a common point: Aadhaar's success may be linked to the perception of trustworthiness of the system from citizens and state governments, meaning their trust in its ability to improve the programmes for which it was designed. Secure identification of users, ability to monitor commodity quantities taken, and portability of access all made the system appealing, and increased its reliability from a citizens' perspective. For state governments, these were all good reasons to accept the transformation of the old system into a biometric one.

Based on our data, these emerged as possible explanations to trust a complex new technology as a means of change. These have contributed to legitimating Aadhaar's entrenchment in the ongoing social protection reform, depicting it as a means of minimising leakage of subsidy to the non-poor. If a biometric infrastructure results in a more effective PDS, state governments have a strong reason to adopt it, and citizens enrol with the trust that this will enable secure access to their entitlements.

5.4. Hypothesising Mechanisms: Eliminating Competing Explanations

The explanations above emerged from our first interactions with government officials and software designers. As the research progressed, however, a more complex picture unfolded. This led us to problematise the initial picture of effectiveness, and incorporate the technical and political issues brought by the transition to a biometric system.

To start with, the view of Aadhaar-based systems as trustworthy is problematised by our field data. At the time of our early fieldwork in Kerala, the intention of moving to a biometric PDS was met with suspicion by most respondents, who saw their ration dealers' misbehaviour – often reporting "running out" of subsidised goods for the poor – but often did not see biometrics as a solution to the problem. Interviews with beneficiaries revealed that theft of PDS commodities happens along the supply chain as a whole, and its major share is in the phases that precede the last mile, hence happening *before* commodities are obtained by ration dealers (Khera, 2011). This problem, emerging from both citizens and policymakers, substantially reduces the payoff of digitally enabled control of ration dealers.

Furthermore, computerisation does not tackle the root cause of the problem, leading ration dealers to join black markets in the first place. In particular, ration dealers report engaging in sales outside the PDS for business survival, imposed by the substantial loss of customers caused by the move to a targeted PDS. Biometric monitoring is designed to prevent them from selling to such markets, as monthly allotment of foodgrains is based on the sales reported by the Aadhaar-based point-of-sale (POS) machine. Such a system should control their ability to deviate, but does nothing to remove their incentive to diversion, which remains high if their profit margins are kept low by a narrowly targeted system.

From the Karnataka study on a pilot project of biometric PDS, several technical issues have emerged. The shops we have visited have been transformed by weighing-cum-POS machines, enabled to recognise users' fingerprints and provide their monthly entitlement through an incorporated scale. But several users, on paper entitled to PDS goods, were not recognised by the new system, due to mismatch of their fingerprints or absence of updating of the machine's software. This has resulted in exacerbation of exclusion errors, which already affect the PDS (Swaminathan 2008; Khera 2011). Based on these technical problems, some ration dealers had to resort to paper-based records of their transactions, which exposes users to the same risk of diversion that the original PDS entailed.

The problem of technical fragility emerges with particular visibility in states that have adopted an Aadhaar-based PDS. In Rajasthan, whose transition was completed in 2016, there have been cases of violent demonstration and smashing of POS machines in ration shops, due

to people's frustration with inability of the new system to function properly. The problem implicit in the transition to Aadhaar is summarised by the economist Jean Drèze:

> This system requires multiple fragile technologies to work at the same time: the PoS machine, the biometrics, the internet connection, remote servers and often other elements such as the local mobile network. Further, it requires at least some household members to have an Aadhaar number, correctly seeded in the PDS database. (cited in Shagun & Aditi, 2016)

Based on existing reports and field data, the issue is not with Aadhaar registration, which is made simple by its free nature and the many enrolment centres across the nation. The problem occurs when, at the moment of performing transactions in the ration shop, the system fails to work, depriving beneficiaries of their entitlements. Rates of non-recognition have not yet been estimated, but the frequency of malfunctioning entailed by technical issues casts some doubt on the effectiveness of the move. Shagun & Aditi (2016) show that outcomes of the switch to Aadhaar in terms of reduction of leakage appear to be at best uncertain in the long run.

Given these fragilities, Aadhaar's trustworthiness *per se* does not explain success. To understand its striking outcomes on acceptance and pervasiveness, other explanations need to be devised.

5.4.1. Institutionalisation

Since its creation, the nature of Aadhaar enrolment has been framed as voluntary. Non-coercion was one of the properties set by founder Nilekani, and characterised the establishment and continuation of the scheme (Nilekani & Shah, 2016). A citizen who wants to enrol can do so freely and easily, but no person should be forced into enrolment or be suffering from lack of it. Formally, the principle of voluntary adherence has been preserved by the Aadhaar Bill too.

However, this did not prevent central and state governments from framing Aadhaar as the most convenient channel for social protection, and for access to public services at large. Focus has been primarily on the undocumented poor, whose inability to prove their identity would prevent them from accessing basic social services (UIDAI, 2010). In all phases of its development Aadhaar enrolment was not mandatory, but it has been so deeply linked to national public services that Indian residents started seeing it as such. There are three main components to this process.

First, India's "identity gap" results in numerous undocumented residents across the country (Gelb & Clark, 2013). At the time of our fieldwork in Kerala, the main constraint for citizens to accessing the PDS (or to being recognised as BPL) was that of obtaining documents of entitlement, available only through complex paper-based procedures at village and district offices. In UIDAI's strategy documents, Aadhaar appears to be designed specifically for the undocumented poor, since enrolment is free and based on a simple identification document, or on recognition of the person by two witnesses (UIDAI, 2010). This has meant new entitlements for undocumented people, determining a strong incentive for them to join the project.

Second, Aadhaar has been framed as capable of simplifying access to social assistance even for those who already accessed anti-poverty programmes. In response to our questions on the schemes for which Aadhaar was required, beneficiaries have pointed to the main components of national social assistance, citing food security schemes as well as programmes of health insurance and rural development. The most important of the latter is the Mahatma Gandhi National Rural Employment Guarantee Act (NREGA), a scheme that confers to rural households the right to 100 days of employment per year at the minimum wage, and has significantly contributed to income generation in rural India (Ravi & Engler, 2015). Schemes

such as the NREGA have massive importance for the rural poor, and their connection with Aadhaar has pushed further masses of citizens into enrolment.

Third, Aadhaar has not been ingrained just in the social protection structure, even if its anti-poverty purpose is strongly advocated by UIDAI and the government. It has been entrenched, more at large, in the national system of public services, attempting to "escape the limits of the old paper state" which affected it (Bhatia & Bhabha, 2017). The old structure, making India famous for a heavy bureaucracy and ineffective procedures, is replaced, in the intentions of the government, by a system in which biometric authentication guarantees real-time access to all services. This change affects the public sphere as a whole, and is meant to maximise effectiveness and accountability of the state.

Importantly, the process of Aadhaar's entrenchment in the national public sphere has not been without critiques. A substantial stream of commentators accuse the system, and the legal backings behind it, to have coerced residents into enrolment, leaving them with no option but applying (e.g. Ramakumar, 2010; Ramanathan, 2014). In this view the system, constructed as a means to help the undocumented poor, has become a sanctioned infrastructure for surveillance, violating people's rights to refuse biometric profiling. This strand of critique is synthesised by Usha Ramanathan (2014):

> The idea of parting with fingerprints and iris impressions has been marketed as a means to more efficiently and surely deliver services to the poor. This, and threat of exclusion from a range of services if a person is not biometrically enrolled, has placed the weight of such projects on the shoulders of the poor.

Debate on the legality and fairness of UIDAI is vivid in traditional and social media. The common denominator, across proponents and critics of the project, is the view of the system as the main route to access services, especially pro-poor programmes for fulfilment of basic needs. This recalls a process of *institutionalisation* (Madon, Reinhardt, Roode & Walsham, 2009) in which an infrastructure, initially framed as optional or incidental, is over time reframed and reconstructed as the primary means of access to a given service. If this process has happened, institutionalisation of Aadhaar as the main gateway to social protection is one explanation for its massive uptake.

5.4.2. Image formation

As illustrated above, the process of Aadhaar's institutionalisation as the main means of access to social protection has not happened without critique. If an infrastructure as pervasive as biometric recognition is allowed into the lives of residents, it requires some form of legitimation, challenging the mistrust associated with biometrics and people's reluctance to give up their personal data (Whitley & Hosein, 2010). In our search for explanations, there hence is a need to grasp the processes that brought the public legitimation of Aadhaar.

According to Kuriyan and Ray (2009), states use ICTs in government services not just to improve provision, but to *represent themselves in a new way* to citizens. The argument holds for transition from paper-based to digital service provision, and relates to a process of image formation in which technology is implicated. In substance, ICTs are not only implied in the search for better service provision, but are at the same time instrumental in improving the public image of the government. If a government is renowned for unresponsiveness to citizens' needs, the uptake of service technologies contributes to evolution of that image into one of effectiveness.

Since the beginning of our research, data revealed that Aadhaar has been inscribed into a strong public image, which has been preserved with the change in government in 2014. The fact that the programme is an integral part of anti-leakage reform, and not an incidental

component of it, concurs in constructing this image of it with citizens. From analysis of UIDAI strategy documents, the project comes across as centred exactly on the pro-poor benefits that it entails:

> The speed of UID adoption in India depends on whether the [*unique ID*] number can help in eliminating poverty and marginalization, and in enabling greater transparency and efficiency in service delivery. If it succeeds in these goals, the number will become indispensible for residents in accessing services. (UIDAI, 2010)

Crucially, the reform intention into which Aadhaar is inscribed is deeper than a fix to extant anti-poverty programmes. This emerges from further analysis of UIDAI's strategy, which since 2014-2015 presents Aadhaar in conjunction with two more programmes, namely a financial inclusion system (known as the *Pradhan Mantri Jan Dhan Yojana*) and mobile payments. The former, usually referred to simply as Jan Dhan Yojana, is a government scheme aimed at providing low-income households with a bank account, hence sensibly reducing the unbanked population of India. Mobile payments aim at delinking pro-poor finance from banks and post offices, absent in many rural and tribal parts of the nation.

The system consisting of Jan Dhan Yojana, Aadhaar and mobile payments has been popularised as "JAM Trinity" by the current government (Government of India, 2015). Its purpose in the longer run is not that of improving the PDS but that of doing away with it, substituting extant subsidy schemes with direct cash transfers to the bank accounts of entitled poor households. The rationale behind this is that a cash transfer system would bring significant advantages compared to subsidies:

> [With cash transfers], by reducing the number of government departments involved in the distribution process, opportunities for leakage are curtailed (…) In addition to net fiscal savings, income transfers can compensate consumers and producers for exactly the welfare benefits they derive from price subsidies without distorting their incentives. (Government of India, 2015)

As this reveals, the idea behind Aadhaar is much more profound than a superficial fix to the PDS. It is an idea of radical reform, which substitutes an ineffective system with one that is described as more effective and accountable. Such an argument is highly contested, for reasons of technical feasibility and because by converting rations into cash, it determines a shift from state to market in the management of anti-poverty systems (Khera, 2014). Notwithstanding vehement contestation, the purpose of rebuilding the social safety system on the basis of direct cash transfers is the core idea in which Aadhaar is embedded, and it is put forward to motivate collection of biometric data for all residents.

An image of substantial pro-poor reform, centred on the JAM Trinity and aimed at guaranteeing a radically better system of entitlements, is the image that the government seems to be building through biometrics. More specifically, it is this image of the state as effective problem solver that India seeks to build with Aadhaar, and that legitimates its institutionalisation as a main gateway to services. If it is so, a mechanism of image formation based on biometrics corroborates the previous explanation, revealing how the system, in spite of technical fragilities, is accepted and adhered to by millions of residents, and hence enabled to become an integral part of the nation's anti-poverty infrastructure.

5.5. Data Triangulation: A Theory of Trust-Building in Aadhaar

We can now return to our research question, on what explains Aadhaar's apparently successful incorporation into the food security system of a big developing country. We have rejected the explanation based on sheer technical trustworthiness, given the multiple fragilities encountered in its implementation. Data analysis has brought us to eliciting two related mechanisms as

summarised in figure 2: institutionalisation, meaning that governments frame Aadhaar as the main way to access services, and image formation, meaning that Aadhaar is associated with an image of effective pro-poor reform. The two mechanisms, which are mutually reinforcing, are set to explain an important development experience, which is among the most debated and transformative governmental programmes of the present time.

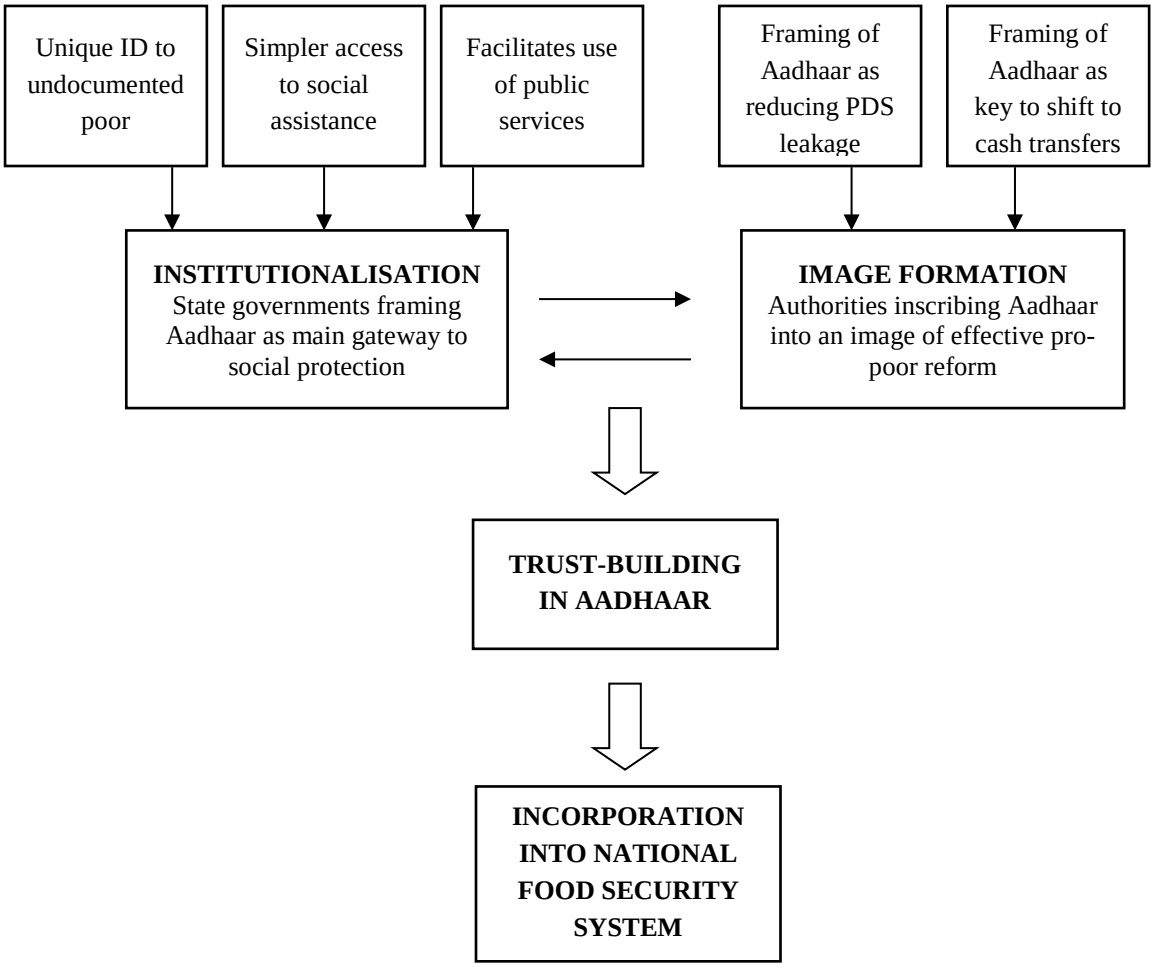

Figure 2: Emerging explanations of Aadhaar's incorporation into national food security

How can we assert that these mechanisms provide the best approximation of the structures behind the phenomenon of interest? As in Weick (1989), researchers have to engage in thought trials to produce explanations. Mechanisms are not observable in nature (Mingers, 2004), and can only be accessed through the empirical layer of reality, using retroduction to attain the domain of the real. While the phase of finding mechanisms is creative and emergent (Wynn & Williams 2012), elimination of possible explanations is a rigorous process that is firmly rooted into the data. In our case, the most obvious explanation of Aadhaar's success – technical trustworthiness – has been first questioned on the basis of field data, and then finally refused when triangulated with secondary sources.

Explanations based on institutionalisation and image formation were developed during the research, and refined over time through further data collection and interpretation. These reveal the causal powers (Henfridsson & Bygstad, 2013) behind the fact that in a developing country, with poor records in terms of public sector effectiveness, a large biometric

infrastructure was not only established, but ingrained into the social protection system to transform it at its very roots. As in Gregor (2006), mechanisms respond to both "why" and "how" questions on the phenomenon of interest, describing the way Aadhaar became embedded in social protection and tracing the causes of this. So formulated the two mechanisms are confirmed by data triangulation, since secondary data confirm the framing of Aadhaar as the main means to access social schemes and its association with an image of effective reform.

A potential limitation of our triangulation process is that it was conducted across diverse data sources, but not across quantitative and qualitative methods, as other critical realist studies do (e.g. Henfridsson & Bygstad, 2013; Zachariadis et al., 2013). Given the nature of our research question, descriptive statistics on Aadhaar's uptake detail the size of national diffusion, but it is hard to inscribe quantitative elements in other parts of the research design. Our data triangulation, however, draws its strength from the longitudinal nature of the study, conducted over a six-year time interval and hence able to account for the phenomenon's evolution. Reinforcing our conclusions is also the availability of data from different Indian states, which despite multiple differences display similar processes leading to Aadhaar's acceptance.

Bygstad and Munkvold (2011) argue that an approach based on mechanisms can improve research by providing "ontological depth, creative thinking and more precise explanations". With this research we have experienced both the emerging phase, based on thought trials aimed at finding explanations, and the structured one, in which we have eliminated some explanations and refined other ones based on the data. This has enabled us to engage in theory-building on trust in a large biometric infrastructure, whose implications for the delivery of social programmes to the poor are massive. While knowledge, in a critical realist view, is always partial and subjective, this approach has led us to engage in a structured process of construction of explanatory theory.

6. DISCUSSION

Our study has sought to explain incorporation of Aadhaar into India's food security system, using a retroductive process to identify mechanisms behind it. The study contributes to extant literature on Indian development, as it explains the establishment of a technology that has deep consequences for the country's social security system. It contributes, at the same time, to theory-building in ICT4D, illustrating how critical realism offers the intellectual tools to produce the type of causal theory that is needed in the field.

6.1. Aadhaar's Infrastructure and Indian Development

There has been a major expansion of social security schemes in India over the last few years. There is growing evidence of their contribution to human and economic development (Drèze & Khera, 2017), and transformation of such programmes directly affects the lives of millions of recipients. Explaining the incorporation of Aadhaar into India's system of social protection, our study illustrates how the project is set to modify the nature of such schemes, constituting an innovation that is deeply ingrained in the reform of the national social protection system.

It should be remarked that the image of effective pro-poor reform, to which Aadhaar is systematically associated, is contested from multiple sides in Indian social policy. A first strand of critique observes that inscribing Aadhaar into social protection means subordinating the rights of the poor to enrolment, eluding the Supreme Court orders that previously sanctioned its voluntary nature. As observed above, this is seen by several commentators as a means to coerce residents into a system of surveillance, to which social protection, that should be guaranteed by law, is conditional (Ramanathan, 2014, Drèze & Khera, 2015). This strand

of critique hence addresses the nature of the new system, seen as making social assistance predicated on the poor's willingness to enrol.

Secondly, doubt has been raised on the adequacy of biometric infrastructures to improve pro-poor social security schemes. The issue of exclusion errors, substantiated by narrow criteria for recognition of below-poverty-line status, still results in exclusion of genuinely entitled households from the social protection system (Swaminathan, 2008; Drèze & Khera, 2015). By expanding the national coverage of the PDS, the NFSA legislation has contributed to reducing such errors, allowing inclusions that would have not been possible before promulgation of the Act. In this context, Aadhaar-enabled systems are seen by some as determining a move in the opposite direction, by restricting access to the enrolled and potentially incurring the risk of further exclusions (Khera, 2014).

Thirdly, the move from subsidies to a cash transfer system has itself been the object of diverse critiques, based both on technical feasibility and on implications for national social security. Lack of familiarity of vulnerable groups with banking systems is one of the main concerns around such move, and is combined with limited infrastructural readiness especially in rural and tribal zones. These fears need to be added to political understandings of the proposed shift, based on involvement of cash transfers in a system which the PDS had configured as firmly state-based. PDS user surveys reveal strong preference for PDS to cash transfers (Aggarwal, 2011; Puri, 2012; Khera, 2014), making it important to consider the advantages and disadvantages that such move would entail.

Viewing our findings in the Indian national context, we hence need to problematise the developmental effects that Aadhaar's incorporation would have on the programme. The points made here are to be compared with the government's argument for cash transfers, which are set to reduce distortions induced by subsidies and combat the extant problem of leakage at its very roots. While assessing the robustness of each argument needs economic analyses that transcend our research, our study has revealed the mechanisms underpinning the transformation of the nation's anti-poverty system, which the adoption of a large biometric infrastructure is set to determine. This will substantially affect the delivery of basic entitlements to the nation's poor.

6.2. Critical Realism and Theory-Building in ICT4D

As argued earlier, strong causal theories are particularly needed in ICT4D, to fill the gap in existing knowledge of processes linking ICTs to development and to help avoid failure. We have observed that critical realism, which is specifically oriented to the construction of such theories, is hence particularly relevant for ICT4D. In our study we have elicited the core mechanisms underpinning a phenomenon of interest, which a retroductive process has enabled us to illuminate. Our ability to explain Aadhaar's incorporation into India's food security system has been firmly predicated on the choice of a critical realist ontology.

Knowledge in ICT4D is enriched, according to Avgerou (2017), by middle-range theories which focus on specific phenomena related to ICTs in developing country contexts. Their specific focus makes theories at the middle-range level different from grand theories, which make broad arguments on how ICT adoption and usage are related to development at large. Avgerou's (2017) argument for the need of middle-range theories is based on the fact that these illustrate the genesis of important phenomena of development, highlighting exactly how ICTs are implicated in their emergence. This strengthens the field's abiliy to theorise socio-economic development, filling the gap that Walsham and Sahay (2006) and Avgerou (2010) identified earlier in the field's history.

The theory of trust-building emerging from this study is at the middle-range level. It is predicated on specific aspects of context, aims to build explanations for a phenomenon of

interest and refrains from undertaking a predictive intent. Knowing that governmental action – through the mechanisms of institutionalisation and image formation – influences trust-building in Aadhaar does not imply that a similar intervention would be successful in another country or region, or that such actions necessarily lead to greater effectiveness of anti-poverty schemes. But it creates explanations of an important phenomenon, which influences the management of food security in a country whose rates of hunger and malnutrition have remained high despite economic growth (Sen & Himanshu, 2011), further increasing the importance of effective social protection strategies.

Critical realism is particularly oriented to the creation of middle-range theory (Smith, 2006; McGrath, 2013), and this contributes to making it suitable for studies in ICT4D. As noted above, failure of ICT projects in developing countries may lead to particularly severe outcomes, especially if it occurs in a type of systems – social assistance, emergency management – on which many human lives depend. As in Heeks (2002), building causal theory does not only mean discovering the roots of failure, but also becoming able to imagine and devise systems to prevent it in a given context. This increases the practical relevance of middle-range theories, and contributes to the argument for which these are particularly important for ICT4D specifically.

Furthermore, as noted by Heeks and Wall (2017), studies in ICT4D have recently turned to issues of power and justice, and to questions on how ICT is implicated in such problems. Our study has shown the emerging links between adoption of a biometric infrastructure and exclusion errors, illuminating how technology is entrenched in the ability of an anti-poverty programme to reach its beneficiaries. Decisions related to technical aspects of ICT directly affect the entitlements of the poor, especially if an Aadhaar-based transition from subsidies to cash transfers is envisaged. Through retroduction, we have illuminated aspects of power distribution in the case, observing how a technology-based reform is perceived as more or less right and equitable by different interest groups.

The critical realist concept of social structures hence acquires a particular value in ICT4D, indicating structures that "underpin rights, ethics and justice" (Heeks & Wall 2017: 9). Technology is deeply entrenched in such structures, and its adoption may result in changes to people's entitlements. As our study seeks to illustrate, critical realism is particularly functional in bringing to light such structural problems, which form an important object of research in our field. This is a further reason why such philosophy, aimed at discovering the causal powers behind the empirical world, is particularly useful for enriching knowledge in ICT4D.

7. CONCLUSION

Our study builds a theory of trust in Aadhaar's biometric infrastructure, based on mechanisms that explain its incorporation into India's largest food security programme. Two contributions have been made, respectively to development policy in India and to ICT4D at large. With respect to India we have problematised the developmental effects brought by Aadhaar's apparent success, illustrating the mixed outcomes on pro-poor reform that are emerging from its uptake. For ICT4D we have shown the importance of critical realism in building the middle-range theories of causation that the field needs, and in illuminating the implications of ICT adoption on issues of power and entitlement.

In terms of directions for further research, the current historical moment requires particular attention to the study of technology adoption in anti-poverty programmes. Eradication of poverty and hunger are on top of the SDG list as they were for the MDGs, and significant emphasis remains on the role that ICT may play in achieving them. But over time, awareness has increased on how ICT uptake may result in unintended or even negative

outcomes, such as those for beneficiaries excluded from the Aadhaar-based PDS and hence prevented from receiving food rations. Given the rapidly increasing incorporation of ICTs into anti-poverty schemes worldwide, further research is needed to shed light on the specific intertwining between technology and social protection strategies.

Another open question pertains to whether critical realism, beyond middle-range theory, may also contribute to the grand theories which the field of ICT4D still needs (Heeks & Wall, 2017; Walsham, 2017). The study of mechanisms is predicated on a specifically described phenomenon, hence middle-range theory seems to constitute the best fit for the approach (McGrath, 2013). Yet several IS scholars have engaged with formulation of more general theory through critical realism: for example, Henfridsson & Bygstad (2013) explain how and why digital infrastructures evolve over time, hence generating theory above the middle-range. Similarly Zachariadis et al. (2013) observe the effect of ICT adoption on firm performance, building grand theory on an important IS topic.

These are examples of greater levels of abstraction, which use critical realist insights to contribute to broader theories of the world. Based on how mechanisms are constructed, critical realism could in principle contribute to generation of grand theories, and there seems to be no apparent reason why this should not hold in ICT4D. Further research is needed on whether and how broader theories on ICT and development may be built through critical realism, theorising the link at levels of abstraction that transcend contextually specified phenomena. If this is found to be the case, this will further enhance the contribution of the critical realist paradigm to ICT4D.

This reinforces the argument that views critical realism as a means to building solid explanations, in social sciences at large and particularly for our discipline. A retroductive approach brings to light specific entanglements of ICT and development, and helps elicit the issues of power and entitlement on which the field is currently focusing. This is needed in an era of pervasive diffusion of ICTs in development projects, and it ultimately supports the engagement of ICT4D with the established paradigm of critical realism.

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