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# Infrastructures as Catalysts: Precipitating Uneven Patterns of Development from Large-Scale Infrastructure Investments

Crelis Rammelt 

Institute for Interdisciplinary Studies, Faculty of Science, University of Amsterdam, Amsterdam 1090 GE, The Netherlands; c.f.rammelt@uva.nl; Tel.: +31-624621771

Received: 13 March 2018; Accepted: 20 April 2018; Published: 22 April 2018



**Abstract:** While infrastructure investments in developing regions may bring about aggregate benefits, the distribution of those benefits cannot be ignored. The present paper examines such distributional effects based on two illustrations: rural roads in Ethiopia and flood control systems in Bangladesh. In both cases, the infrastructures promote particular development patterns towards market-economic transformations and integration. We liken the introduction of these infrastructures to the addition of a catalyst in a chemical reaction. Rural roads, for example, catalyse existing flows of agricultural labour, while flood control catalyses agricultural productivity. Taking the analogy a step further, the effects of a catalyst are known to vary due to the presence of so-called inhibitors and promoters. Applying this to the two cases, the paper reveals that, among other factors, the ownership (or lack thereof) of modes of transportation in Ethiopia and land resources in Bangladesh represent significant promoters (or inhibitors) that can help to explain the unequal distribution of benefits. This question is by no means new; past technical assistance programmes were already fiercely criticized for exacerbating inequalities. Today, commercial and political interests are again intensifying infrastructural investments in developing regions with profound impacts on local economies and livelihoods. Revisiting the question of distribution is, therefore, as relevant as ever.

**Keywords:** infrastructure; investment; appropriate technology; inclusive development; catalyst; Bangladesh; Ethiopia

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## 1. Introduction

Large-scale infrastructure-led development is back on the agenda. The United Nations sets its 9th Sustainable Development Goal towards the mobilisation of finance flows and knowledge in order to build ‘resilient infrastructures’ [1]. In a similar vein, the World Bank reemphasises the importance of investments and public spending on infrastructures for fundamental transformations towards sustainable and resilient societies [2].

Infrastructure-led development is of course not a new phenomenon and has always been controversial. Modernisation efforts in the 1960s focused primarily on the physical structures, despite numerous examples showing that most problems revolved around their implementation. For example, insufficient attention was typically paid to the development of the necessary institutions to operate and maintain the infrastructures. This has been a common blind spot in “technical assistance” programmes and a source of recurring criticism [3–5]. Today, a re-examination of this criticism is warranted considering the strong financial and political resurgence of investments in large-scale infrastructures—especially in light of the proclaimed benefits for the poor under the popular banners of inclusive or resilient development.

Lessons from the appropriate technology movement of the 1970s are relevant in today’s context [6,7]. This movement blamed the transfer of inappropriate technology for sustaining and

promoting the interests of those that introduced it; for reinforcing existing power relations; for creating or maintaining conflicts between traditional and modern production sectors; for disturbing local markets; and for accentuating the contrast between rural and urban development [8–11]. In short, the critique focused on the inappropriateness of exogenous interventions.

In contrast to this focus on external factors, a more common modernisation perspective had been emphasising the problematic endogenous conditions that trap countries and groups in poverty [12–17]. The local social, political, economic, and cultural conditions in which the infrastructures are embedded are indeed decisive factors for understanding many failures. While it is, therefore, not sensible to attribute poverty solely to the unsoundness of external infrastructural interventions, the question remains whether local conditions can fully account for such a persistence (and worsening) of poverty (and inequality) over more than half a century of ‘well-intended’ efforts [18–20].

This paper contributes to assessments of the implications of infrastructure-led development for poor and marginalised social groups. Recognising the diverse local conditions in which a new infrastructure intervenes, the paper presents a novel framework based on a conceptual analogy of infrastructure as a ‘catalyst’ of development processes (as originally suggested by [21]). The aim of this paper is to illustrate this analogy with examples from the transport and water sectors in Ethiopia and Bangladesh, respectively. As we shall see, these infrastructures have catalysed the speed, range or magnitude of pre-existing flows of resources, people, information, and goods. In each illustration, we look at the role of so-called ‘inhibitors’ and ‘promoters’ in creating or exacerbating existing inequalities. The importance of understanding the context in which the infrastructures are implemented has long been recognised. What has been much more difficult to expose is the manner in which infrastructures that seem to bring benefits to all, such as rural mobility or protection against floods, can simultaneously widen the divide between social groups through subtle, concealed, or delayed effects. The infrastructures are not necessarily to blame; by acting as catalysts, they merely accelerate or expand ongoing and wider social, economic, or cultural transformations.

Before describing and discussing these examples, the paper starts with a review of the historical debate around infrastructure-led development. It is important to revisit these lessons and consider how they remain relevant in the context of today’s global market economic forces and associated flows of capital and resources.

In this paper, infrastructures are understood as the basic physical facilities and installations needed for the functioning of society, such as mines for resource extraction, landfills for waste disposal, grids for energy provision, roads for transportation, and embankments for flood protection. Technology is defined as the application of science to practical problems. The broader notion of technology, therefore, encompasses (but is not limited to) infrastructure.

## 2. Research Design

Drawing on field-based research and literature reviews, the paper presents two infrastructure-led developments in Ethiopia and Bangladesh.

The first example compiles findings from a larger study on the (in)direct effects of rural roads on productivity and employment in Tigray, Northern Ethiopia [22–24]. The study sites are in Kilde Awlalo and Raya Azebo, two of Tigray’s 35 districts, of woreda. Two rural communities, or tabias, were selected in each woreda. A tabia might in turn contain four to six villages called kushet. The data presented in this paper was collected through oral testimonies [25,26], which involved in-depth and unstructured interviews. They included general questions about the respondent, his or her occupation, mobility, and household composition. Other questions were directed towards the anticipated and observed effects of the roads in terms of costs/benefits or advantages/disadvantages. For the purpose of enhancing the diversity of responses, forty interviews were undertaken at various hours of the day, on market and non-market days, at different distances to the road, and selecting from different gender groups (16 female and 24 male), age groups (between 18 and 70 years), geographical areas (across

13 kushet), and occupational backgrounds (including traders, food producers, labourers, herders, students, kiosk owners, household heads, and dependents).

The second example compiles findings from a long-term study of a particular component of the 1990s Flood Action Plan (FAP) in Bangladesh. It included as one of its flagships the Compartmentalisation Pilot Project (CPP) in the district of Tangail. Between 1993 and 2006, six student research teams from Delft University of Technology studied CPP in collaboration with Unnayan Shahojogy Team, a non-governmental organisation operating in Tangail. The author was part of this study program and later joined as a student supervisor (for all references, see [27]). The paper draws from these sources and complements them with findings from several more recent field visits [28]. In 2013–2014, 20 semi-structured interviews were held in different localities in the CPP area. The sampling was accidental (not random). The variables were: time of the interview (various hours of the day), market and non-market days, different localities, different distances to the main regulator, and different gender and age groups. The interviews revolved around the following discussion points: the successes and failures of CPP; the manner in which it altered food production, irrigation practices, and flood protection; and its management structures and processes.

In both cases, the intention was not to make generalizations about the total population; rather, the aim was to compile a range of perspectives on the impacts of the infrastructures.

### 3. Infrastructure-Led Development in Retrospect

The widespread confidence in infrastructure-led development that arose during the industrial revolution was especially reinforced after World War II, following the successes of the Marshall plan in Europe. This confidence in ‘modern’ infrastructure, in combination with the political pressures for decolonisation and popular concerns for former colonies, led to a range of programmes of technology transfer—euphemistically labelled ‘technical assistance’ [29,30]. In the late 1940s, then US President Harry Truman spoke of “a bold new program for making the benefits of our scientific advances and industrial progress available for the improvement and growth of underdeveloped [sic] areas” [31].

This perspective offered two simple propositions: (1) there is a single development path with forerunners and latecomers, and (2) with technical assistance from the former, the latter can catch up. These assumptions justified the transfer of capital and technology to the stigmatised ‘underdeveloped’ areas because such investments were believed to be the universal key to economic growth, which was the assumed universal characteristic of development [32–35].

It was first assumed that rapid economic growth could take place if there was central planning and top-down control of the economy, with emphasis on industrialisation, modernisation, and urbanisation following the European pattern [36–38]. Gradually, however, the approach shifted towards deregulation and the expansion of market economic systems. This neoliberal orientation favoured policies that exposed local economies to global market forces. In this process, economic power largely shifted from locally rooted enterprises to multinational enterprises. Increasingly, local enterprises survived only by fulfilling specialised market niches or by servicing the needs of multinational enterprises on terms largely dictated by the latter [4,21].

This neoliberal shift has particularly intensified in the past decade. With it, global flows of investments in large-scale infrastructure are clearly back on the agenda. This agenda plainly reflects Truman’s original ideology. Jeffrey Sachs [39] (p. 41), for example, declared “that the single most important reason why prosperity spread, and why it continues to spread, is the transmission of technologies and the ideas underlying them”. Similarly, the World Bank [40] (p. 1) insists that “[t]he importance of international technology transfer (ITT) for economic development can hardly be overstated. Both the acquisition of technology and its diffusion foster productivity growth. As invention and creation processes remain overwhelmingly the province of the OECD, most developing countries must rely largely on imported technologies as sources of new productive knowledge”.

Despite the long-standing emphasis and belief in infrastructure-led development, the approach also brought about numerous failures characterised by negative social and environmental impacts.

Classically, infrastructure is known to have played a role in the creation of the so-called ‘dual society’—small islands of urban wealth where foreign industry (aligned with local elites) control production flows [8]. This is clearly visible today in the form of ‘enclaves’ of foreign investments and gated communities along so-called growth corridors in Africa, for example [41].

Historically, there have been noteworthy attempts to address and correct the evolution of such a dual society. For example, the appropriate technology movement of the 1970s–1980s considered technology as a ‘Trojan Machine’ [42] (quoted in [29]), or as a cultural and political artefact carrying the genetic code of its country of origin [6,9]. This movement clarified how specific features in the design of technological systems often provided a convenient means to establish patterns of authority in a given setting [11,43,44]. It also aimed to address this problem by promoting alternative technologies and infrastructures—usually small scale, labour intensive, and rooted in local resources and knowledge [6,7].

The same period also witnessed the emergence and popularisation of so-called ‘bottom-up’, ‘grassroots’, and ‘participatory’ approaches [30,45]. These approaches called for the development of local institutions, not just for the operation and maintenance of the infrastructures, but also for their design and development. However, in general, poverty and inequality persisted despite the efforts. An explanation for this failure was then sought in the ineffectiveness of participatory development programmes. As world-system analysts had long argued, the potential benefits of such programmes might have been overshadowed or negated by wider national or global market economic influences and interests [46–51]. At the same time, local elites who benefited from top-down interventions were often working against genuine participatory efforts [6,45].

In the recent decade, the call for participation has been reformulated under the banner of inclusive development [52,53]. However, the focus of those defining the development agenda in the peripheries has hardly changed; it remains squarely on economic growth, on integration into global markets, and on stimulating the export sectors [23]. As in the past, when infrastructures are introduced, pre-existing social structures and survival strategies tend to be displaced and replaced by specialisation and competition. Exclusion may sometimes lead to self-organisation at the margins, but in most cases, marginalised people have been unable to respond and find themselves both “shunned by the ‘advanced’ sector and cut off from the old ways” [54] (p. 3). Evidence for this wider trend is best revealed by the persistence of extreme poverty [18] and the worsening of income inequality over several decades of development efforts [19,20].

#### 4. Infrastructure as a Catalyst

In general, infrastructure investments in the global South have effectively boosted economic growth, but they have certainly not managed to reduce inequality. In this paper, we explore the possibility that infrastructures accelerate or expand unequal patterns of growth by acting as so-called ‘catalysts’ in a context of ‘inhibitors’ and ‘promoters’.

In chemistry, a reaction can be enhanced with the addition of a substance called a catalyst. The catalyst reduces the activation energy that is needed for the reaction, which can then occur faster. In this paper, the addition of a catalyst to a chemical reaction is seen as analogous to the introduction of infrastructures or technologies in the context of particular socio-economic conditions and dynamics. For example, Mark Kurlansky [55] presents an account of the events that led to the depletion of the North Atlantic codfish: catches that were already declining kept on being pulled in with new and more efficient fishing techniques. Eventually the schools did not return. Globally, the decline of fisheries has been accelerating with each new innovation, such as bottom trawls, harvesting machines, or sonars. In this case, the technologies act as ‘catalysts’ that have precipitated pre-existing processes of growth of fishing industries and depletion of fish resources, i.e., the normal ‘chemical reactions’ of the wider economic system in which the technological innovations take place. This paper emphasises infrastructures as specific artefacts that exhibit these catalytic properties.

The analogy can be taken one step further. A reaction inhibitor is a substance that hinders the working of a catalyst. An inhibitor, therefore, decreases the rate or effectiveness of the chemical reaction, or even prevents it altogether. In contrast, a reaction promoter is sometimes added to a reaction to increase the performance of the catalyst. Neither inhibitors nor promoters change the nature of the reaction; they simply (counter)act the effect of the catalyst.

An age-old question regarding the introduction of infrastructures is about the distribution of costs and benefits. As a result of social, economic, demographic, physical, or cultural barriers—or ‘inhibitors’—some social groups will not be able to take advantage of the new infrastructures. Other groups, however, will be much more predisposed to benefit from the new infrastructures by virtue of their capacities—or ‘promoters’. The distribution of these inhibitors and promoters creates a gap in access to, use of, or benefit from the new infrastructure, which might further increase existing inequalities. Coming back to the example of fisheries, an innovation such as the bottom trawl will only benefit fishermen who already own larger seaworthy ships—at the expense of artisanal fisheries who might share the same waters and gradually lose their livelihoods.

## 5. Illustrations: Rural Roads in Ethiopia and Flood Control in Bangladesh

The paper now presents two examples where the introduction of infrastructures has had a catalytic effect on flows of resources, people, information, and goods: rural roads in Ethiopia and flood control in Bangladesh. The examples have been selected for their diversity, so as to show the wider relevance of the notion of infrastructure as catalyst. We start with a brief context.

Heavily dependent on rain-fed agriculture, Ethiopian farmers are regularly plagued by droughts [56]. However, even in times of stable rainfall and food production, high levels of income inequality and malnutrition persist [57]. An explanation for this lies in the capacity to produce food from one’s own land. Landownership is vested in the state and farmers hold usufruct rights that are inheritable and can be temporarily rented out to others [58]. The capacity to cultivate the land is nevertheless skewed due to the unequal distribution of non-land assets such as draft animals, ploughs, and irrigation pumps [59]. A large and poor section of the population has no choice but to rent out their land and to look for work in oversaturated and underpaid labour markets [60]. As will be illustrated, the recent rise in (foreign) direct investment in the transport sector adds additional complexity to the matter, as it leads to enhanced but differing economic opportunities for different social groups.

Unlike Ethiopia, Bangladesh has a long history of agricultural modernization [61]. With the transition to new high-yielding farming practices that began in the 1960s, agricultural productivity has surpassed even the population growth rate [62]. However, Bangladesh still suffers from one of the highest levels of under- and mal-nutrition in the world [61,62]. An explanation for this can be found in the steadily rising concentration of land ownership (as opposed to concentration resulting from rental agreements in Ethiopia). A small and relatively wealthier rural class progressively accumulated most available private land [61,63]. The result was, as in Ethiopia, an increase in employment-seeking labour. In this case, infrastructural developments in the water sector have led to enhanced but differing economic opportunities for different social groups.

In both cases, the infrastructures succeed in stimulating economic growth through increased productivity. This is essentially their catalytic property. However, their implementation also brings about unequal distributional effects. In each case, we will look at the role of inhibitors and promoters that either undermine or foster the catalytic effect for different socio-economic groups. Again, this is not argument against infrastructures; it is a plea to recognise their role in wider socio-economic developments and the propensity for unequal distribution of their benefits.

### 5.1. Rural Roads in Ethiopia

African roads and tracks historically evolved from the everyday flows of people and animals rather than from controlled design. These pathways gradually began to support long distance trade



and to facilitate the imposition of law and order in peripheral regions [64,65]. In time, the contribution of roads shifted to developmental objectives.

At first, a dominant current in modernisation theory argued that improved and extended transportation was a pre-requisite for integrating isolated regions into the national economy. Transportation infrastructure was perceived as being conducive—or catalytic—to economic growth [66,67]. The catalytic effect was expected to occur because the infrastructure would ease, cheapen, and speed up flows of goods, services, and labour. In the 1960s, this perspective was widely endorsed by investors and development banks [64,68]. However, with increasing evidence of the persistence of poverty and inequity, the 1970s marked a shift in ideological and political focus from economic growth alone towards self-reliance and basic needs [69]. Road investments retained their status as important instruments, but with a marked shift in attitude: investments in rural roads were no longer reserved for centralised transport networks only, but also for where traffic levels were low or negligible [64,67,70].

By the end of the 1970s, the contribution of rural roads to self-reliance and basic needs also began to be questioned. A range of field studies had suggested that roads benefited only the needs and requirements of larger farms [64,66,70]. The rural poor mostly travelled for water and firewood collection, which generally involved walking on off-road paths [67]. So, while highways failed to induce economic growth, rural roads failed to create development opportunities for the poor, which suggests that this socioeconomic category was hampered by particular ‘inhibitors’, such as access to vehicles and transportation services.

Since the 1990s, earlier hesitations about the capacity of (rural) roads to induce economic growth and reduce inequalities have been brushed aside by mainstream development thinking and practice. The World Bank, for example, has returned to an argument for a big push in promoting road infrastructure in Africa, which is “necessary not only to break out of underdevelopment but, more importantly to be on the path to sustained growth” [71] (p. 212). Similarly, the Ethiopian Road Authority recently stated that “road infrastructure supports and catalyses the achievement of social and economic growth and the meeting of poverty reduction objectives” [72] (p. 7), quoted in [68] (p. 19).

Today, investments in roads, including decentralised rural networks, are some of the largest donor-funded projects in Africa [65]. Questions about the relationship between transport infrastructure and regional economic disparities are being asked in the regional economic literature (see, for example, [73,74]). However, there is surprisingly little research dealing with the multiple (in)direct effects of roads and the local distribution of these effects [64,65,68], which was a key focus in our research in Tigray [22–24]. In the name of inclusive growth, a recent government programme successfully established dry-weather unpaved gravel roads in all *tabias* (rural communities) in Tigray [75]. These so-called feeder roads serve as traffic feeders from *tabia* centres and facilities of socio economic importance to *woreda* (sub-regional or district) centres or to the nearest all-weather road.

On the surface, the construction of feeder roads inspires euphoric reactions from local populations [22]: “The road is our bloodline!” (personal communication, Adi Kisandid, 19 February 2015). Through enhanced mobility and accessibility, the benefits include procuring inputs, selling food, purchasing food, and seeking of employment opportunities. Beyond these initial praises, however, one can expect the benefits to be distinctly distributed among a heterogeneous local population, which will have long-term consequences for poverty and inequality [22,24,64,65,68].

A survey in Tigray revealed that 24.3% of rural households rent out part of their land, 43.3% are pure owner-operators, and 32.4% are tenant-cum-owner households [76]. A household may, therefore, simultaneously generate profits from agricultural production as well as wages from selling its labour. The relative share of these returns (profits and wages) in total household income tells us something about how members of the household depend on and exploit the benefits from feeder roads. Households with relatively higher income shares from profits rely on the road to procure inputs and sell food. On the other hand, households with relatively higher income shares from wages rely on the road to seek employment and purchase food [23]. Now, we briefly explore the distribution of road impacts for both economic groups (households that are predominantly producers or labourers).

Poor road systems and remote market channels in Tigray are said to limit the availability and/or the procurement of agricultural inputs [77]. In line with official policy, formal seed provision was decentralised to the tabia offices of the bureau of agriculture [78]. However, input adoption still relies on a certain level of mobility, depending on the vicinity of the farm relative to the feeder road and the office. A study in north-western Ethiopia indeed revealed that 94% of all farming households in the least remote quintile use inorganic fertiliser compared to 70% in the most remote quintile [79]. Meanwhile, mobility-enhancements remain decisive for procuring other inputs that are not available through extension services within the tabia, such as fuel for irrigation and vegetable seeds [22]. Respondents explained: “I get fuel from Wukro [the district town]. If I buy 20 litres I can irrigate my farm five times” (personal communication, Adi Kisandid, 19 February 2015); “Vegetable seeds are mostly brought from the district town; they are not available at the local markets” (personal communication, May Quiha, 23 February 2015).

Feeder roads are also associated with the transportation of the output of production. Roads create mobility-enhancements for food producers by opening the way to distant markets. In the opposite direction, the feeder road also brings customers closer to the farms. Faster transportation both ways is also linked to an increase in crop diversity, as food producing households are able to produce and sell more perishable crops [22]. These opportunities arose in conjunction with developments in engine-powered groundwater irrigation.

Feeder roads, therefore, speed up, i.e., catalyse, the adoption of inputs and selling of outputs. The question is: how are these benefits distributed? Farmers that follow a path of agricultural modernisation are able to derive a richer advantage from the roads. For example, bulk transportation of crops is obviously going to be relatively cheaper for farmers with greater production output. This will raise their profit margin allowing them to build capital and raise their local competitiveness. “Those with access to irrigation obtain a lot of extra income on top of their rain-fed agricultural profits. As a result, some of them are able to buy a Bajaj [a local three-wheeler taxi scooter]” (personal communication, Hade Alga, 27 March 2015). This remains a very skewed development with vehicle ownership only a little over 2 vehicles per 1000 population [67].

An important promotor or inhibitor in this case seems to be the level and nature of agricultural productivity. In other words, households with already higher profits (relative to wages) enjoy a competitive advantage at the time a feeder road is established over households with lower profits [22]. Competition creates winners and losers. With limits to arable land, participation as producers in the local economy will eventually become a zero-sum game, and competition will lead to accumulation by dispossession.

A question to ask is whether the aggregate growth of benefits for the group of producers is coupled to a decline in benefits for households who rely more on wages for their income.

It has been suggested that better access to roads in Tigray will improve labour force mobility and thereby increase access to job opportunities [80]. Indeed, according to one respondent: “we have farm activities, but we also have those who are in need of jobs. They need to travel to Wukro [the district town] and other areas, so the road is important” (personal communication, May Quiha, 24 February 2015). Rural roads, therefore, catalyse the flows of employment-seeking labour. Whether or not a road will contribute to an increase in wages, however, will depend on the size of the total labour force. Surplus labour exists in crop production in Tigray as a whole [81]. Rising productivity may, therefore, not raise local wages if new roads increase labour supplies into those localities [65]. A respondent explains how “sometimes, when there is a lot of labour available in this area, some of them may not get jobs. Also, when there are a lot of labourers, the employers decrease the wage rate” (personal communication, Were Abaye, 28 February 2015).

Potentially counteracting the increased demand for labour resulting from a rise in agricultural productivity, surplus food producers might increasingly invest in labour-saving technologies. In north-western Ethiopia, for example, sorghum producers that were well connected to extension services and markets (through roads) adopted more modern inputs compared to less-connected

producers. The more connected farms also required fewer labour inputs [79]. This could happen, for example, during the weeding season: “if farmers use herbicide, they do not need to recruit labourers” (personal communication, Abraha Watsbaha, 17 March 2016). This observation places a question mark behind the assumption that by boosting productivity, feeder roads also boost labour demand and wages. Indeed, roads also facilitate the adoption of labour-saving technologies [22].

By enhancing mobility and accessibility, roads are expected to catalyse not only the flows of food production in a region, but also the flows of food purchases and consumption. First, by contributing to aforementioned developments in productivity, the roads are expected to help reduce prices to consumers [80,82]. Second, roads also facilitate the movement of consumers to those markets. Moreover, roads catalyse the establishment of local outlets and shops. So far, however, food prices have continued to rise in Tigray [83]. Infrastructural developments must, therefore, be understood as part of a broader socio-economic context. It is possible, for example, that wholesalers regulate their stores to keep prices high or that wider national or international market forces draw food out of the region.

Finally, those who benefit less from the increased mobility and connectivity and who might eventually lose, may seek to engage in local activities that reduce their reliance on markets for labour and for food. However, their capacity to do so seems undermined on a more systemic level. Several respondents mentioned that mutual support systems have withered, that there is less trading and labour-sharing directly between households, that production is transported to more profitable outlets, and that local waged-employment has become more competitive. “If I have money, I would prefer to recruit so as to speed up the work. If we share labour among each other, a task that might have been completed in one month would take two months” (personal communication, Tsaeda Naele, 17 March 2016). These changes are in many ways linked to inclusive growth policies (e.g., those aimed at incorporating local (surplus) producers in cash crop value chains and local labour in formal employment structures) and their infrastructures [22].

Everyone seems to have benefited from the associated mobility and accessibility enhancements, be it for procuring inputs, investing in household assets, selling food, purchasing food, or seeking employment opportunities. It has already been suggested that roads in Ethiopia have a ‘catalyst’ function [64]: they do not change the nature of existing economic flows, but merely speed up these flows. As Howe and Richards [66] (p. 2) put it: “personal mobility and goods transport have always existed; thus expanding a road program is not adding a new dimension to development”. However, for flows to be catalysed, they must first be produced. As the capacity to produce is unequally distributed, so too will be the catalytic benefits of roads.

### 5.2. Irrigation Schemes in Bangladesh

Traditional water management in Bangladesh was characterised by decentralised and non-structural infrastructures for irrigation and flood protection, such as overflow canals and temporary dams. Starting in the 1950s, these systems disappeared almost entirely with the push for Flood Control, Drainage, and Irrigation (FCD/I) infrastructures, which included networks of permanent embankments and canals with centrally regulated water in- and outlets.

These infrastructural changes coincided with the so-called Green Revolution—a major program intended to boost productivity in the agrarian sector. International and national initiatives promoted the adoption of High-Yielding Varieties (HYV) of rice that grow faster than traditional species when combined with inorganic fertiliser and intensified irrigation. From the 1960s to the 1990s, fertiliser use increased more than tenfold [61] and farmers doubled or even tripled their harvests [84]. The seeds, chemicals, and other inputs were no small investment and, therefore, required protection against floods, which FCD/I infrastructures would provide by reducing the depth of flooding and keeping out untimely floods. In this way, the infrastructures catalysed a significant boost in agricultural productivity.

Despite the obvious success of the Green Revolution and its infrastructures, Bangladesh still suffers from high levels of under- and mal-nutrition [61,62]. It is clear that hunger cannot be attributed



to a lack of food availability. In the last three decades, increasing output even surpassed population growth rates [62]. Other factors must, therefore, be involved. Contrary to the expectations, a large section of the population did not benefit from the rising productivity. For many, the catalytic effect of the infrastructures was hindered by several inhibitors. This will be illustrated with a prominent FCD/I case in the district of Tangail. In the 1990s, the Compartmentalisation Pilot Project (CPP) was designed as a new form of FCD/I that would pay much more attention to social and ecological concerns. During its implementation (1991–2000), however, CPP became highly controversial on both accounts. Eventually, it was phased out and not replicated elsewhere.

CPP included the construction and upgrading of a horseshoe shaped embankment that enclosed a 130 km<sup>2</sup> area engineered into a network of canals and embankments. Regulated inlets and outlets were constructed to enable the controlled flooding and drainage of agricultural plots in compartments. As explained, this type of infrastructure protected the farmers' investments in HYV seeds and inorganic fertiliser. Their use in the CPP area indeed increased by 50% in the 1989–1998 period [85]. However, the reliance on agrochemicals also grew through force of circumstance. By averting major floods, FCD/I infrastructures, including CPP, were also barring beneficial annual floods that maintained natural soil fertility 'for free' [86,87].

At the same time, the use of groundwater irrigation also increased with the expansion of intensive agriculture into the dry season. While FCD/I infrastructures provided protection against floods, their contribution to irrigation remained relatively low [88]. By the late 1990s, surface water irrigation covered 30% of the total irrigated area. The remaining 70% was covered by groundwater irrigation through tube-wells [89], which implied rising investment and operational costs for farmers. As with agrochemicals, the reliance on groundwater also grew through force of circumstance. Accounts from local people in Tangail over several years suggest that water flows were slowing down and silt sank to the bottom of the rivers leading to a gradual rise of the riverbeds. Many of the smaller canals were said to have silted up entirely as a result of the permanent embankments [85,90–92]. A villager in Shadullapur explained: "The main problem is that flood water isn't coming anymore since the construction works. As a consequence, mud from the floods isn't covering the land inside the embankment and more chemical fertilisers are needed. Also, tube-wells are now active all year long to irrigate the fields" (cited in [91]).

Historically, not all farmers had the capacity to cope with the rising costs (seeds, fertiliser, fuel, and so on). This catalysed yet another process: increasing landlessness. Census data reveal an astonishing tenfold increase in the number of landless households in the 1977–1996 period [63]. More recently, the combined groups of functionally landless (owning less than 0.2 ha) and marginal farmers (owning 0.2 to 0.6 ha) account for 86% of the agricultural population (65 and 21%, respectively) [61]. A small and relatively wealthier rural class has progressively accumulated the available land. Some of the causes for landlessness were the loss of farmland to urban expansion and to riverbank erosion, as well as the fragmentation of agricultural plots as children each inherit a portion of their parent's land.

However, the unequal patterns of landlessness are intricately linked to the Green Revolution and its infrastructures for two reasons. First, schemes were introduced to support farmers with the initial investments in pumps, high-yielding seeds, and other inputs through credits and technical assistance. Only a very small proportion of the landowners—typically those with larger properties—had sufficient political power to draw on the support [93,94]. Second, many of the smaller farms that still managed to make the switch to the new farming techniques on their own found it increasingly difficult to keep up. In order to maintain productivity, increasing amounts of inorganic fertiliser were needed as the soil was slowly depleted of its richness in natural nutrients [95]. These nutrients were no longer naturally replenished as a result of FCD/I developments. As subsidies on the inputs were gradually dropped, many could not cope and were forced to sell their holdings and join the growing landless population [93].

What can we conclude from the case so far? While CPP catalysed a highly productive form of agriculture, its infrastructures also contributed to a process that created winners and losers.

The embankments secured high-yielding and groundwater-irrigated agriculture at the expense of 'free' access to fertile surface water on which subsistence farming relied. In this process, the technological and institutional structures were inextricably linked. With severe inequalities in land ownership, decision-making power and participation in local water management institutions became severely one-sided [91]. Subsistence farmers had little control over the operation of sluice gates and lost access to water resources. Moreover, the local institutions in Tangail managed the water system for the benefit of (surplus) farmers, not for landless fishermen, boatmen, and other marginalised groups. According to a former fisherman, "due to this project there is hardly any water inside the embankments so we cannot catch fish as we did earlier" (personal communications, Jugini village, 17 November 2013). Many were forced to look for work as agricultural day-labourers or rickshaw drivers.

The impacts of CPP are still felt long after the project was phased out. Based on recent observations and interviews in the project area, several canals have indeed silted up and sluice gates have long been abandoned. According to one respondent: "What would the sluice gate do? There is no water to flow through it" (personal communication, Bhatchanda village, 25 October 2013). Others explain: "Due to using embankments the silt cannot enter through the gates, which hampers the improvement of the fertility of the land". "They are of no use; these sluice gates have not been used for years" (personal communications, Shadullapur village, 25 October 2013). Even the main water regulator for the entire compartmentalised area was found in disrepair. Soil and plant growth had accumulated inside the water inlets and the chain for operating one of the three sluice gates was broken (field observations, 25 October 2013). A respondent mentioned that "there is hardly enough water to use the sluice gate and control the water flow" (personal communications, Jugini village, 25 October 2013). This evidence is anecdotal, but it confirms the earlier studies and warrants further investigations.

Revisiting this particular project is as relevant as ever, as the threats of climate change will either reinforce once more the top-down command and control approach to water management or provide an avenue to explore the more adaptive non-structural solutions. This tension has remained strong in subsequent water-sector projects, for example, the current Dutch-Bangladeshi Blue Gold program, and continues to have implications for the distribution of costs and benefits from FCD/I infrastructures [28,96–99].

## 6. Conclusions

Table 1 below summarises the key findings from the illustrations in this paper. The aim was not to develop a comparative analysis of the two situations. Rather, the aim was to illustrate how infrastructures can catalyse uneven patterns of development in very diverse contexts. In both cases, the infrastructures produce aggregate benefits. However, pre-existing conditions enable or prevent different groups from benefiting, in varying degrees, from the infrastructures. Certain groups are even worse off as a result of the infrastructure.

In Ethiopia, improved mobility is useful for the employment-seeking household, insofar as this occurs in a situation where there is regional labour shortage, which is not the case for Tigray. Increased competition among a more mobile labour force has been shown to lead to a drop in wages. This improved mobility is useful for the individual food-producing household. However, with varying levels of productivity at the time of construction of a rural road, different food-producing households are more or less able to harness its benefits, such as access to markets for seeds, fuel, and other inputs and access to outlets for their crops. These differences raise the following questions: What will happen to the gap between surplus and subsistence producers? Will more and more subsistence producers be forced to join an already large and competitive labour force?

Compared to Ethiopian rural roads, flood control infrastructures in Bangladesh are much less subtle in their effects. In the case of CPP, the environmental changes they brought about led to severe livelihood losses for fishermen and boatmen. The conditions were also changed for subsistence farmers. By keeping out disastrous floods, the embankments also blocked beneficial annual floods that maintained soil fertility. This was not a problem for better-off farmers with access to seeds, fertilizer,

pesticide, fuel, irrigation pumps, etc. Contrary to the Ethiopian example, the gap between surplus and subsistence producers has clearly widened. Together with disenfranchised fishermen and boatmen, many subsistence farmers became more dependent on wage labour, which had a depressing effect on wage rates.

**Table 1.** Summarizing the catalytic effects, promoters, and inhibitors.

Infrastructure	Catalytic Effect	Promoters	Inhibitors
Rural roads in Ethiopia	The expansion of the rural road network catalyses aggregate productivity and economic growth by facilitating and accelerating the flows of employment-seeking labour, the access to agricultural inputs, and the selling of output on distant markets.	The catalytic effect is most effective for those who control a disproportionate amount of productive land, who produce higher levels of surplus, and who are able to reinvest profits in other assets, e.g., means of transportation and production.	Limited land resources and productivity restrict the benefits of enhanced access to inputs and market outlets. Improved mobility benefits labour, but also increases competition among a growing labour force.
Flood control in Bangladesh	Flood control systems catalyse aggregate productivity and economic growth by securing investments in intensive agriculture, but also by pushing for groundwater irrigation and fertiliser adoption after barring the flows of nutrient-rich flood waters.	The catalytic effect is most effective for those who own more land, who can afford capital, inputs, and means of production, and who hold more decision-making power in local water management institutions.	Open access fishermen and boatmen are displaced. Subsistence farmers are harmed by the changing environmental conditions imposed by the infrastructures and lack the capacity to cope with the rising costs of intensive agriculture.

In both cases, the infrastructures were conducive to productivity growth. Ethiopian roads catalysed production by facilitating the flows of inputs and outputs. Flood control structures in Bangladesh catalysed production by protecting investments in intensive agriculture. However, the illustrations have also clarified how the presence of inhibitors and promoters leads to unequal distributional effects. Infrastructure is, thus, not the silver bullet for inclusive development. The unequal effects will be overlooked as long as aggregate indicators, for example, total production output or average income, prevail as measures of success. It is possible that overall productivity gains from a region will increase at the expense of equality of access to and productive use of land and water resources.

Infrastructures in general, whether exogenous or endogenous, create new physical environments that nurture or hinder different social groups and their room for further actions. Infrastructure can thus bolster growth, while the costs and benefits of this growth are unequally distributed. By the very nature of their position, different socio-economic groups can benefit or suffer from the new infrastructure, or simply be bypassed. The last sixty years have indeed witnessed the simultaneous rise of infrastructure investments and economic inequality. The infrastructures have mostly served to nurture a development process in favour of global market integration to the benefit of particular socio-economic groups. Apparently, the poor have generally not been in a position to control the rise of economic-infrastructure systems that are not meeting their particular needs. A simple labelling of these processes as ‘participative’ or ‘inclusive’ is in many cases misleading. By perceiving infrastructures as potentially having unequally distributed catalytic effects, we should be able to better grasp their role in upholding—and perhaps in addressing—poverty and inequality.

**Acknowledgments:** The Ethiopian case study was part of the research agenda of the Knowledge Platform Inclusive Development Policies and funded by the Ministry of Foreign Affairs of the Netherlands through NWO-WOTRO (Netherlands Organisation for Scientific Research-Science for Global Development). Fieldwork for the Bangladeshi case was made possible through support from the International Research Collaboration Scheme (2012-2013) of the University of New South Wales (UNSW). The author is also grateful for the insightful and constructive comments by four anonymous reviewers and by Prof. Dr. A. Zoomers.

**Author Contributions:** Rammelt conceived and designed the research; analysed the data; and wrote the paper.

**Conflicts of Interest:** The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; and in the decision to publish the results.

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