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Value chain development as public policy: Conceptualization and evidence from the agri-food sector in Bangladesh

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Value Chain Development as Public Policy: Conceptualization and Evidence from the Agri-Food Sector in Bangladesh

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Abstract

Value chain development (VCD) has become a popular policy instrument to help farmers in developing countries access markets. While VCD initiated by the private sector has received much attention in the literature, there is yet little research on public-led VCD. This paper provides a conceptualization of public-led VCD and discusses in what context it can be a relevant policy instrument. As an illustration, the paper then describes the project “SAFAL”, which directly intervenes in the aquaculture, horticulture, and dairy sector of South-West Bangladesh. Using a matched difference-in-difference methodology, it is estimated that SAFAL increased farmers’ output market participation, food production, and smallholder welfare, and reduced the number of days in which participating households were food insecure.

Key words: value chain development, market access, impact evaluation, aquaculture, smallholder, food security.

JEL classification: Q12, Q13, O13, O19, O22.

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1. Introduction

Market imperfections constrain the welfare and productivity of smallholders in developing countries. Smallholders incur high costs in acquiring improved plant and animal varieties, farm chemicals, equipment, financial services, and information services and face uncertainty regarding the quality of these inputs. (e.g., Bold et al. 2017; Croppenstedt, Demeke, and Meschi 2003; Shiferaw et al. 2015). High input costs and uncertainty result in low adoption and, consequently, low yields and low labor productivity. Smallholders also experience high costs and information asymmetries when selling their products on output markets, particularly if buyers require them to comply with stringent public or private standards regarding quality and food safety (e.g., Maertens, Minten, and Swinnen 2012; Pingali, Khwaja, and Meijer 2005; Reardon et al. 2009; Svensson and Yanagizawa 2009). In addition, these input and output market imperfections can be mutually reinforcing. Low access to output markets reduces the incentive and ability of farmers to adopt modern inputs (Swinnen and Kuijpers 2019b), while low access to inputs reduces access by farmers to output markets by constraining productivity and by hindering compliance with public and private standards (Barrett 2008; Kuijpers and Swinnen 2016).

Value chain development (VCD) is an increasingly popular policy instrument to assist farmers in overcoming these input and output market imperfections. No clear definition of VCD exists, but it is widely understood as a type of intervention that aims to establish or improve linkages between different actors in a value chain (Devaux et al. 2018). As such, the term is broadly used to describe initiatives both by the private sector (*private-led VCD*) and by the public sector (*public-led VCD*) (Stoian et al. 2012).

While private-led VCD is relatively well studied (see e.g., Bellemare and Bloem 2018; Swinnen and Kuijpers 2019a; Ton et al. 2018 for reviews), there is little research on public-led VCD. In particular, there is little consensus on what public-led VCD entails, in what context it is relevant, and how effective it is (Devaux et al. 2016). Meanwhile, governments, donors, and international organizations invest increasingly larger sums of public funds in VCD initiatives. For example, between 2012 and 2016 the Netherlands alone financed more than fifty public-led agri-food VCD programs in developing countries for a total value of EUR 417 million (IOB 2018).

This paper explores what “linking value chain actors” or “improving value chain linkages” means and it discusses in what context VCD can be relevant. As an illustration, the paper describes the public-led VCD project “SAFAL” that directly intervenes in the aquaculture, horticulture, and dairy sector of South-West Bangladesh. Using a matched double-difference methodology, this paper then estimates the effect of SAFAL on farmer market participation, farm production, farm revenue, net-farm income, and the length of the hungry season experienced by the farmer’s household.

To my knowledge, this is one of the first efforts to rigorously estimate the effectiveness of an integrated public VCD project. Others have investigated the effects of partial solutions, such as the use of farmer organizations for collective exchange (e.g., Verhofstadt and Maertens

2014), bringing value chain actors together in platforms (e.g., Cavatassi et al. 2011), and training farmers and certifying them (e.g., Ebata and Huettel 2017; Kersting and Wollni 2012; Ruben 2017; Carter, Tjernström, and Toledo 2019). The project studied in this paper, however, combines these and other activities into one intervention in an effort to identify and tackle all constraints in the value chain that are binding farmers in accessing technology and output markets.

The estimation of SAFAL's effectiveness is based on information obtained from households participating in the project and from a control group in 2014 and 2016. In an attempt to overcome project placement and self-selection bias, the estimation relies on a difference-in-difference methodology, whereby control farmers are matched with project farmers based on pre-project characteristics to ensure comparability over time.

Using this methodology, it is estimated that the project has, on average, increased the share of output sold by farmers in the market by 13 percentage points, total farm production value by USD 704, and farm revenue by USD 472. However, also farm expenditures increased by about USD 300 as a result of the project, resulting in an estimated increase in net-farm income of USD 404 and in farm profits of USD 172. Finally, it is estimated that the project has reduced the length of the hungry season experienced by participating households by about 12 days.

2. Value chain development in theory and practice

2.1. Agri-food value chains and market imperfections

A value chain describes how a production process is undertaken by different actors and at what stages the (intermediate) product is exchanged between actors. Products move from “upstream” to “downstream”—from input suppliers and farms to processors, traders, retailers, and, finally, consumers, while in the opposite direction there is a stream of finance and information.

With perfect markets, the coordination in the value chain happens through price changes. A change in demand at the consumer level affects prices throughout the value chain, such that the supply in each stage of the value chain is able to meet this demand. A higher consumer demand for safer food, for example, translates into higher prices and increases the demand by retailers for agricultural products that meet better food safety standards. This increases the price farmers can receive for these products and increases, in turn, their demand for knowledge and farm inputs necessary to meet these new standards. This gives farm input companies, service providers, and laborers, in turn, an incentive to provide these inputs.

Spot-markets for agri-food products and farm inputs and services might, however, not function perfectly and involve high transaction costs; possibly to such extent that some actors effectively have no access to these markets (e.g., Alene et al. 2008; De Janvry, Fafchamps, and Sadoulet 1991; Key, Sadoulet, and De Janvry 2000; Winter-Nelson and Temu 2005). Transaction costs can include costs incurred ex-ante, such as searching trade partners and obtaining information on prices, product attributes, and private standards; costs incurred during

the transaction, such as transportation and storage costs and tariffs; and costs incurred ex-post, such as monitoring and enforcement costs (Hobbs 1997; North 1990).

These transaction costs are expected to be higher for value chains that adhere to more stringent public or private standards, as these require more detailed and regular information transmission (Pingali, Khwaja, and Meijer 2005) and investments in specific technologies and practices to comply with these standards (Kuijpers and Swinnen 2016).¹ The necessity of relationship-specific investments by the farmer increases the contract enforcement costs as it introduces the risk of holdup by the buyer (Klein, Crawford, and Alchian 1978; Gow and Swinnen 2001). Buyers could, for example, renegotiate prices at product delivery, pay later, or renege in other ways on the contract after the farmer has made the relationship-specific investments. As a result, farmers may refrain from making these investments in the first place.

A market imperfection at one stage can affect the functioning of the entire value chain: the ability of the value chain to comply with public or private requirements, such as regarding product quality, food safety, or ethical and environmental standards (*value chain effectiveness*) and the costs incurred in the value chain to bring forward the final product (*value chain efficiency*). As such, it affects all actors involved in the chain. Not only the farmer is affected, for example, if he or she has inadequate access to input and output markets (Swinnen and Kuijpers 2019a). Also input and service companies are affected, because they cannot sell their farm inputs and services; traders, processors, and retailers are affected, because they cannot get the raw material that meets their requirements; and consumers are affected, because they cannot get the products they desire.

2.2 *Value chain development to overcome market imperfections*

Value chain development is a catch-all term for interventions that aim to improve value chain functioning. More specifically, it can be understood as an intervention that aims to increase the effectiveness or efficiency of a specific value chain by reducing the transaction costs between different stages and/or by supporting actors in the chain to enable them to provide intermediate products that meet the requirements of actors downstream. As mentioned in the introduction, value chain development can be initiated and financed by the private sector or by the public sector.

2.3 *Private-led value chain development*

VCD initiated by the private sector entails the introduction of new institutional arrangements, other than spot-markets, to coordinate transactions in the value chain. These include value chain innovations such as interlinked contracting (including contract farming and leasing), farmer cooperatives, triangular structures, special-purpose vehicles, and vertical integration (Swinnen and Kuijpers 2019a). These alternative institutional arrangements can lower transaction costs (Williamson 1979, 1991) and can enable specific value chain actors to adopt the technology necessary to meet the requirements of value chain actors downstream (Swinnen

¹ See Ruben, Boselie, and Lu (2007), for example, for a detailed account of the transaction costs incurred by supermarkets in Asia for the procurement of fresh vegetables.

and Kuijpers 2019). In this way, private-led VCD can improve both the efficiency and effectiveness of the value chain.

A better functioning value chain is potentially in the interest of all value chain actors. It is therefore not surprising that in practice VCD is observed to be initiated by traders, processors, and retailers (typically to secure a supply of raw materials that meet their quality and food safety standards); by farm input companies, such as equipment manufacturers, hatcheries, seed and chemical companies (typically to secure a demand for their intermediate products); and by farmer organizations (typically to secure access to high quality inputs and to remunerative output markets) (Swinnen and Kuijpers 2019).

A key issue with private-led VCD is that assisting farmers by providing inputs introduces the risk of holdup by these farmers (Swinnen and Vandeplas 2011; Kuijpers and Swinnen 2016). Examples of farmer holdup include side-selling of produce after application of the provided inputs, applying these inputs to non-contracted products, or selling the inputs. In the absence of public enforcement institutions, initiators of private-led VCD can try to cope with potential farmer holdup through private enforcement mechanisms: by ensuring enforcement by a third-party or by including safeguards in the contracts to make them self-enforcing. Safeguards can be formal, such as a re-alignment of incentives, for example, by paying a price premium (Swinnen and Vandeplas, 2011), or informal, such as through reputation or goodwill trust (Dyer and Singh, 1998).

2.4 Public-led value chain development

Public-led VCD, on the other hand, is initiated by (semi-) public actors, such as a government, international organization, or NGO, and typically motivated by specific social or environmental objectives. Common objectives include stimulating efficiency and growth in the agri-food sector, improving food safety, improving farmer market access and incomes, reducing the environmental impact of farm practices, or increasing consumer access to nutritious food. In this respect, interventions mainly aim to improve the effectiveness of value chains in achieving these outcomes.²

Broadly speaking, two approaches to public-led VCD are observed in practice: the direct and the indirect approach. The indirect approach entails enabling and incentivizing lead firms to develop the value chain(s) from which they source their produce; i.e., to enable private-led VCD. Private-led VCD requires access to finance by the company initiating the intervention, because setting up contracts and supporting value chain actors requires upfront investments (Dyer 1997; Ruben, Boselie, and Lu 2007). Moreover, VCD investments are risky, because they introduce the possibility of opportunistic behavior, such as side-selling or price re-

² Compliance with voluntary ethical and environmental standards is typically—but not necessarily—an objective for public-led VCD. Standards can define what “good” environmental or ethical practices entail (e.g., organic farming or paying a minimum “living” wage) or define the minimum or maximum social or environmental effects as a result of activities in the value chain (e.g., no deforestation). As such, standards also allow for monitoring and enforcement of compliance. In addition, standards can improve information transmission to the consumer and increase consumer demand for products meeting these standards.

negotiation at delivery (Swinnen and Vandeplas 2011). To overcome financial and risk constraints, (semi-) public actors can offer concessional loans for private-led VCD investments or engage in public-private partnerships (PPPs) in which both the costs and risks can be shared of a “project” that serves both public and private objectives.³

The direct approach to public-led VCD entails direct public support to key stages and linkages in the value chain. This can include financial and technical assistance to value chain actors (e.g., Carter, Tjernström, and Toledo 2019), capacity building of farmer associations (e.g., Donovan, Blare, and Poole 2017; Donovan and Poole 2014), bringing value chain actors together in platforms (e.g., Devaux et al. 2009), or an integrated project that uses a mix of these and other approaches.⁴ The logic of these interventions varies greatly, but they all have in common that they aim to improve value chain effectiveness or efficiency by reducing transaction costs and/or by supporting specific value chain actors.

3. Project context

Agriculture in (South-West) Bangladesh is characterized by large numbers of very small family farms that make intensive use of the scarce cultivable land available. Rice has always been the most dominant crop, covering about 80% of the cultivated area (Gumma et al. 2012). This means Bangladesh’s agricultural sector is one of the least diversified in the world (Headey and Hoddinott 2016).

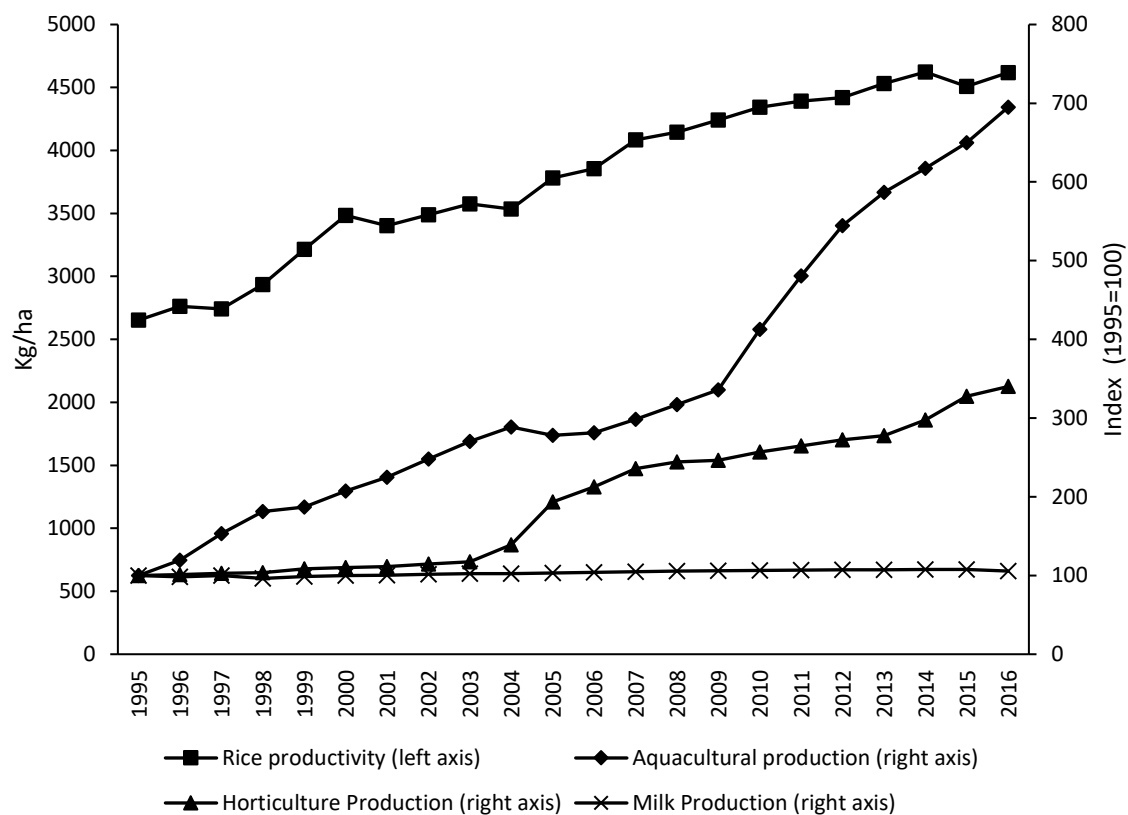
Bangladesh was at first slow to adopt high-yielding rice varieties, irrigation, and farm-chemicals (the so-called green revolution technologies), but since the 1990s adoption rates picked up (Headey and Hoddinott 2016; Hossain, Bose, and Mustafi 2006) and rice productivity rose from 2.5 tons per hectare in 1995 to more than 4.5 tons per hectare in 2016 (see Figure 1). This period of rapid rice intensification coincided with sustained economic growth, poverty reduction, and urbanization. This, in turn, increased consumer demand (and prices) for non-staple food products, such as fish, vegetables, fruits, dairy, and meat (Sur and Zaman 2008).

Higher rice productivity allowed farmers to reduce the land devoted to rice without compromising the caloric needs of their families, while the increase in demand for non-rice food products gave farmers an incentive to use this land for aquaculture and horticulture production. As such, Bangladesh is now moving away from rice monoculture and towards a more diversified agri-food sector.

³ See for example the Global Agriculture and Food Security program by IFC or the Facility for Sustainable Entrepreneurship and Food Security by the Netherlands Enterprise Agency (IOB 2018).

⁴ For examples of integrated projects using the direct public-led VCD approach see IOB (2018).

Figure 1: Rice productivity and production growth of aquaculture, horticulture, and dairy (tonnes).



Source: FAOstat and FAO - Fisheries and Aquaculture Information and Statistics Branch (accessed on 06/04/2018).

3.1 Aquaculture

The most spectacular shift has taken place towards aquaculture. Since 1995, aquaculture production increased by sevenfold: from 317,000 tons then to 2.2 million tons in 2016 (see Figure 1). This is explained both by increases in yields and by the expansion of fish pond area. In fact the land devoted to fish ponds in the South-West region has more than doubled between 2004 and 2014 (Hernandez et al. 2018). As a result, aquaculture is now the most important source of fish in Bangladesh, accounting for 56% of total fish production (Shamsuzzaman et al. 2017).

Hernandez et al. (2018) describe a number of trends that are closely interlinked with this growth in production. First, there was a strong increase not only in the land area devoted to aquaculture production but also in the number of aquaculture producers. Second, production systems shifted from a subsistence-orientation to a more commercial orientation with increased use of purchased inputs, such as fingerlings, manufactured feed, and chemicals. Third, the non-farm components of the fish value chain have experienced rapid transformation and growth. In particular, there has been strong growth in the number of hatcheries, nurseries, small- and medium-scaled feed mills, feed dealers, fish traders, and wholesale markets. Finally, these changes in aquaculture production are mirrored by growth in the domestic demand for

aquaculture products. Rashid et al. (2018) show that the increase in consumption took place across Bangladesh's population but that it was highest for the poorer households and the households in urban areas.

This growth in the aquaculture sector has important development implications. Rashid et al. (2018), for example, estimate that 10% of the poverty reduction in Bangladesh between 2000 and 2010 can be attributed to the growth in aquaculture. Others have linked the growth in aquaculture to the major improvements in food security and nutrition that Bangladesh has experienced (E-Jahan, Ahmed, and Belton 2010; Belton, van Asseldonk, and Thilsted 2014; Toufique and Belton 2014).

The described changes in the aquaculture sector of Bangladesh also apply to the South West. One way in which the aquaculture sector in the South-West is distinctly different, however, is that it is the main shrimp producing region. Although the region is still dominated by the production of white fish and tilapia in inland ponds like in the rest of the country, it also has a thriving shrimp sector, which needs saline coastal ponds or enclosures (Hernandez et al. 2018; Shamsuzzaman et al. 2017). This distinction is key, because unlike carp and tilapia, shrimp production is mainly targeted at the export market.

3.2 *Horticulture*

Although less rapidly than in aquaculture, there has also been growth in horticulture. In fact, between 1995 and 2016, the production of vegetables and fruits grew from about 2.9 million tons to about 9.8 million tons per year: a growth of 260% (see Figure 1). This is partially explained by a growth in yields, but primarily by an increase in land devoted to horticulture.⁵ Despite this rapid development, the diversification towards horticulture has received little attention in the literature. Perhaps this is due to the fact that this is a relatively recent phenomenon. In fact, growth in the horticulture sector took off as recently as 2003.

Although production growth in horticulture has been substantial, it has been unable to meet the growth in domestic demand. As a result, producer prices for important horticultural products have risen sharply in the past 15 years. For example, the annual producer prices (in USD) for onions, tomatoes, and mangoes grew, respectively, by a factor 1.66, 2.25, and 2.38 between 2003 and 2017. In reaction, the imports of fruits and vegetables has become much more important; growing from a mere USD 37 million in 1995 to almost USD 1 billion in 2015.⁶

3.3 *Dairy*

Unlike aquaculture and horticulture, the dairy sector in Bangladesh has been completely stagnant in the past two decades. Dairy output between 1995 and 2016 grew by just 6%. Milk yields are extremely low in international comparison and have not improved since 1995.⁷ The

⁵ While yields in horticulture have grown by about 35%, the land devoted to horticulture has grown by about 160% (author calculations based on data obtained from FAOstat on 25 april 2019).

⁶ The data on horticulture prices and import values are obtained from FAOstat.

⁷ Average yields have been at 205 liter milk per year per animal for the past twenty years. In comparison, average milk yield in Uganda, India, and the Netherlands is, respectively, a factor two, eight, and forty higher (FAOstat).

small growth in output is therefore entirely explained by a small expansion in the number of cattle. Meanwhile, there is a growing domestic demand for milk products and both milk prices and milk imports have risen sharply since 2005.⁸

There is little research on the underlying causes of low productivity in the sector. Some have suggested that an important explanation is the country's high population density, leading to severe land and hence feed constraints, particularly during the dry season (Choudhury and Headey 2018; Khan, Peters, and Uddin 2009). Other factors that have been suggested include low penetration of crossbreeds, high burden of animal disease, poor animal husbandry practices, low availability of vaccines, feed supplements, and artificial insemination services, and a low availability of collection points and processing facilities (Saadullah 2002; World Bank 2018).

4. Project description and intervention logic⁹

3.1 Project description

The Sustainable Agriculture, Food Security and Linkages (SAFAL) project directly intervenes in key stages and linkages in the aquaculture, horticulture, and dairy value chain. It is financed by the Netherlands Ministry of Foreign Affairs and implemented by the NGO Solidaridad.¹⁰ The goal of SAFAL is to improve the welfare and food security of about 58,000 smallholders in the districts of Khulna and Jessore in South-West Bangladesh. To achieve this, the project uses a flexible intervention logic to tackle all binding constraints faced by these farmers in accessing markets. In practice, the project activities can, however, be grouped in four components.¹¹

First, the project facilitated the formation of 1000 producer groups (500 in aquaculture, 300 in dairy, and 200 in horticulture) with about 45 to 60 members each. Every two producer groups is led by one “lead farmer” elected by the group members. These lead farmers are trained by the project in producer group management and are given intensive sub-sector specific training on production and marketing practices, such that they can act as service providers for their producer groups (e.g., testing of water quality, de-worming of cattle, advising on the use of organic pesticides etc.). Every lead farmer receives a fixed honorarium from the project of about 25 US dollar per month and are, in essence, an extension of the project staff. In addition, every producer group is governed by an executive committee consisting of seven famers. The committee is responsible for drafting a business plan, organizing member meetings, and engaging with providers of inputs and buyers of produce.

⁸ Producer prices for cow milk increased by 70% since 2004-2016, while imports of dried milk increased by 115% in the same period (author calculations based on data obtained from FAOstat).

⁹ Information in this section is obtained from official documentation such as project proposals, annual reports, newsletters, and the mid-term review and input from project staff in August 2013, January 2014, September 2016, and May 2019.

¹⁰ Financing was approved in November 2012. The first year and a half were primarily used to hire staff, fine tune the intervention strategy, signing MoU's with private companies, selecting project areas and program participants, and forming producer groups. Further implementation started in March 2014.

¹¹ This categorization is made by the author of this paper. On top of the four components described in the text the project also included a nutrition awareness and knowledge training.

The project uses an inclusive approach by allowing all households in the community that were active in a given sub-sector (either aquaculture, dairy, or horticulture) to participate in a producer group, regardless of their farm size or other characteristics. In addition, women were actively encouraged to participate as members of producer groups, in the executive committees, and as lead farmers.

The second component consists of farmer training and the promotion of new farming practices. The trainings are generally conducted by lead farmers together with field organizers, who are in turn trained by sub-sector experts. Trainings are planned throughout the year, following the production cycle. See Table 1 for a list of training topics by sub-sector. In addition, the project collaborated with farmers in setting up about 600 demonstration plots for displaying the benefits of existing technologies and about 120 pilot plots for the testing and promotion of novel technologies.

Within the third component, the project provides support to small-scale entrepreneurs in providing services to farmers in the community. This includes the lead farmers who provide fee-based services and farm inputs to farmers, agro-input shops, community livestock service providers, mobile agro-input sellers, cooled transport services, feed and organic fertilizer production, and collection centers. These entrepreneurs are supported financially (e.g., shop construction, stocking of products, provision of vans and rickshaws) and technically (i.e. training on the products and services they are providing) and are brought into contact with farm input companies with whom the project negotiated prices (see the fourth component below).

The fourth component consists of the representation of the producer groups and the micro- and small enterprises by the project (described under component 3) in coordination and negotiation activities with farm input companies and potential buyers, such as traders, processors, and retailers (see Table 1). This entails searching these companies, negotiation on contract terms, and engaging in agreements. With retail companies, processors, and traders the project entered into agreements about product and process requirements, payment-schemes, and potential (co-)investments in transport, collection, and packaging. Large scale buyers with whom the project entered agreements include dairy processor BRAC, supermarket AGORA, and shrimp processor and exporter MU SEAFOOD. With input companies the project entered into agreements regarding the distribution of quality inputs, discounts on agri-inputs, and (co-)investments in training and demonstration plots. Large agri-input companies (producing seeds, fertilizer, equipment, feed, and animal health products) with whom the project entered into agreements include R. Rahman Hatchery, Anik Hatchery, Winning Agro, ACI Agribusiness, Ispahani Agro, and Lalteer Seeds Limited.

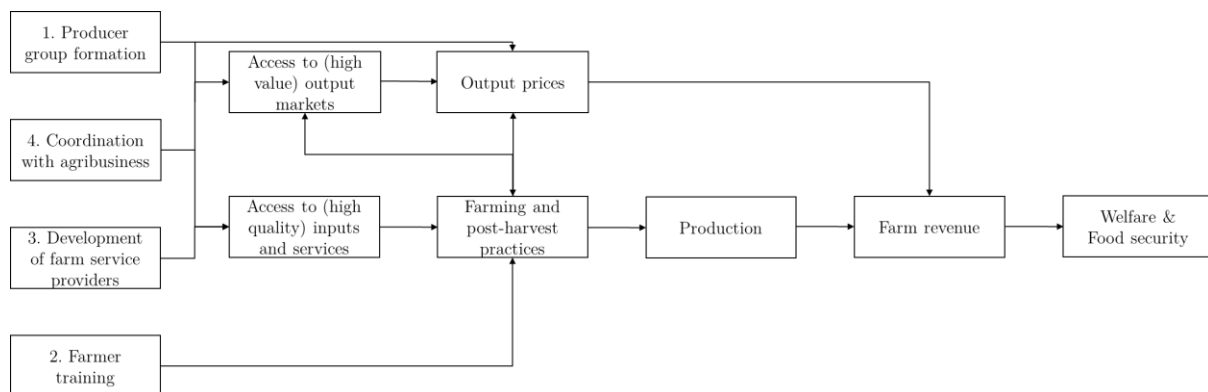
Table 1: Overview of project activities divided by component and sub-sector.

Component	Sub-sector		
	Aquaculture	Dairy	Horticulture
2. Farmer Training	<ul style="list-style-type: none"> - Pond preparation (e.g., regular draining and cleaning of ponds, applying lime and fertilizer, use of synthetic nets). - Stocking practices (e.g., nursing before stocking, determining optimal stocking density). - Water testing (pH-level, temperature, concentration of phyto and zoo plankton) and use of probiotics. - Feeding practices (precise dosage and timing, use of concentrated feeds, production of homemade feed). - Promotion and information on the importance of high quality (pathogen free) fingerlings. - Harvesting practices (frequent harvesting, selection based on size) . - Post-harvest handling (hygienic practices, use of trays). 	<ul style="list-style-type: none"> - Hygienic milking and handling (hand washing, cleaning udder, immediate transport to collection center). - Feed practices (e.g., use of concentrated feed and green grasses, production of homemade feed) - Improved shed management. - Promotion of deworming, vaccination, and medical check-ups. - Promotion of AI and cross-breeds. 	<ul style="list-style-type: none"> - Promotion of organic fertilizer (vermicompost, compost). - Promotion of safe and natural pest management technologies such as sex pheromone traps and bio pesticides. - Promotion of post-harvest practices (e.g., harvesting at maturity, protected storing, washing, grading, sorting, packaging (using paper), protected transport (using crates)).
3. Support to farm service providers	<ul style="list-style-type: none"> - Lead farmers (selling inputs, technical support) - Collection centers - Cooled transport services - Fish food producers 	<ul style="list-style-type: none"> - Lead farmer (selling inputs, technical support) - Collection centers - Local input shops (feed, medicine) - Community livestock Service providers (deworming, vaccination, medical check-ups, medicines) - Fodder and silage production - Milk transportation 	<ul style="list-style-type: none"> - Lead farmer(selling inputs, technical support) - Collection centers - Nurseries - Local input shops - Vegetable Collectors and sellers - Organic compost producers
4. Coordination activities with agribusiness	<ul style="list-style-type: none"> - With hatcheries ‘R. Rahman’ and ‘Anik Hatchery’ to supply farmers with high quality pathogen free post larvae (incl. discounts and credit facilities) - With processor/exporter M.U. Seafood (incl. establishment and support to collection center) 	<ul style="list-style-type: none"> - With dairy processor BRAC (establishment of five dairy collection centers, payment based on fat content, feed discount) - With Winning Agro, a company providing calf management solutions (financing pilots) - With DLS for artificial insemination services 	<ul style="list-style-type: none"> - With supermarket AGORA and other retailers and domestic traders (incl. transport support, provision of crates) - Several providers of seeds, chemicals, and equipment (discounts, cost-sharing of demo-plots, training support)

3.2 Intervention Logic

See Figure 3 for a schematic overview of the intervention logic of SAFAL. Central to the project is the immediate objective of improving farmer access to technology and to output markets by reducing transaction costs. The project is expected to reduce these transaction costs in at least three ways. First, the formation of producer groups (component 1) reduces the costs for dealing with a large number of farmers individually. In essence, it allows a portion of the transaction costs to be divided over a larger number of farmers. For example, it can reduce the per-farmer costs incurred for searching partners, obtaining information, negotiation, writing up contracts, transport, and contract enforcement. In addition, collective negotiation can lead to discounts on inputs, which essentially makes them better accessible. Secondly, by organizing farmers and by representing them in coordination activities with agribusinesses (component 4), the project incurs part of the one-time transaction costs of entering into agreements that would otherwise fall on the farmers themselves. And finally, by assisting farmer service providers the project reduces the distance farmers have to travel to purchase inputs or services or sell their produce to a certain market outlet (component 3).

Figure 2: Simplified intervention logic



Enhanced access to services and farm inputs, in combination with farmer training (component 2), is expected to enhance the ability of farmers to change their production and post-harvest practices. Besides increasing productivity and total production, the project intends to enable farmers such that they can meet buyer requirements (and access output markets). To this end, the project, for example, promoted practices such as the use of sex pheromone traps and organic pesticides, the use of pathogen-free post larvae, grading and sorting of vegetables, and protected and hygienic storage of produce.

Improved access to output markets is expected to be important for farmers to obtain better prices for their farm produce. Supermarket Agora, for example, is willing to pay a price premium for mangoes if farmers meet their requirements. However, not only larger companies are expected to pay better prices for better quality products. Some practices are expected to improve product quality and yield better prices, regardless of market outlet. These include protected storage, washing, and sorting of vegetables, improved cow feeding practices to increase fat-content in milk, and more regular and selective harvesting in aquaculture. In turn, access to output markets and the possibility of obtaining higher prices for produce also can provide an incentive to farmers to invest and change practices.

Finally, it is expected that higher prices in combination with higher total production will lead to higher farm revenue. Although it is expected that, as a result of better access to input markets, farm expenditures will increase as well, the net-effect on household income is expected to be positive. Finally, it is expected that higher income contributes to a reduction in food insecurity.

A second aspect that is central to the project is the simultaneous use of a push and pull strategy: value chain actors are both incentivized *and* enabled to invest and change their practices. This can be illustrated by Safal's activities in the Mango sector. The project first entered into an agreement with the domestic retailer Agora to introduce a high quality pesticide free mango variety on the shelves of the supermarkets of Dhaka. As the demand for pesticide-free mangoes is high and the supply low, Agora was willing to provide farmers with a price premium. The project supported their mango producer groups to meet Agora's requirements by promoting the adoption of organic pesticides, pheromone traps (to capture insects), and post-harvest practices (i.e. hygienic handling of produce, grading, sorting, and packaging). To achieve this, farmers were in need of services (e.g., collection centers and transport services) and farm inputs (e.g., pheromone traps and organic pesticides). This, in turn, provided an incentive for entrepreneurs to invest and provide these inputs. To ensure that they are able to do this the project supported these entrepreneurs financially and technically and negotiated discounts with the farm input companies.

The SAFAL program fits the conceptualization of a direct public-led value chain development program as discussed in Section 2. The program is initiated, financed, and implemented by (semi-) public actors: the Netherlands Ministry of Foreign Affairs and the NGO Solidaridad. It directly intervenes at key stages and linkages of the value chain by assisting farmers and farm input/service providers and by reducing the transaction costs between farmers, input companies, and buyers. Finally, the primary goal of the program is to improve the effectiveness of the value chains in creating better outcomes for farmers in terms of higher income and improved food security.

5. Identification Strategy

The goal is to estimate the average effect of the project on participating farmers. This effect is defined as the average difference in the observed outcome for farmers participating in the project and the outcome that would have been observed if these farmers would not have participated (i.e. the counterfactual). Using the potential outcome framework (Roy 1951; Rubin 1974; Splawa-Neyman, Dabrowska, and Speed 1990), this can be written more formally as

$$(1) \quad \gamma = E[Y(1)|D = 1] - E[Y(0)|D = 1],$$

with γ , the average effect on project participants, D the participation status (equal to one if the farmer is a participant and equal to zero otherwise), and $Y(D)$, the potential outcome as a function of participation. Because the counterfactual ($Y(0)|D = 1$) is unobserved (by definition), it must be estimated. This is done by using outcomes observed for farmers that did not participate in the project (a control group).

A random selection of control farmers is, however, expected to be different in observable and unobservable ways from project participants, making a simple comparison of outcomes biased. There are two reasons why this is the case. First, the NGO decided in which communities the project is implemented and which farmers are eligible for participation. It does this based on a number of criteria. The community, for example, should contain an adequate number of small farmers in a given sub-sector (aquaculture, dairy, or horticulture) willing to participate in a producer group, it should have sufficient potential for improving production and marketing practices, and it should be relatively food insecure. Farmers are only eligible for participation if they are active in either aquaculture, dairy, or horticulture and willing to form a group. Not taking this into account can lead to so called program placement bias at the village and farmer level. Secondly, as participation is voluntary, farmers “self-select” as participants in the project. It is likely that farmers who decide to participate are different from those farmers that decide not to participate in ways that are observable (e.g., age, land size, or productivity) and unobservable (e.g., entrepreneurial ability, risk preferences, and locus of control). In other words, participation is not random.

To overcome program placement and self-selection bias, this paper relies on a matched difference-in-differences (MDID) estimator (Heckman et al. 1998). Following Heckman et al. (1997) and Smith and Todd (2005), this estimator is given by:

$$(2) \quad MDID = \frac{1}{n_1} \sum_{p \in N_1} \{ (Y_{p,t=1} - Y_{p,t=0}) - \sum_{c \in N_0} W(p, c) (Y_{c,t=1} - Y_{c,t=0}) \}$$

where Y is the outcome of interest, p is an individual participant in the set of project participants N_1 that are included in the estimation, c is an individual control farmer in the set of control farmers N_0 , n_1 is the number of participants in the set N_1 , and t is the time with $t = 0$, the start of the project and $t = 1$, the end of the project. The weights $W(p, c)$ are obtained through a matching procedure (see below).

Like a normal difference-in-differences estimator (without matching) it compares the difference in outcome before and after the project between a group of participants and a control group. This allows for controlling for unobservable time-invariant farm characteristics that are related to both the participation-decision and the observed outcomes. The key assumption underlying a difference-in-difference estimator is that in absence of the project the average outcomes for the control and treatment group would have moved in parallel direction. This assumption is less likely to be valid if the participants and control farms have different pre-project characteristics, because this might cause different reactions to common trends and shocks, such as to weather shocks, infrastructural development, or the economic-boom in the aquaculture sector (Abadie 2005).

To improve the comparability through time, project participants are matched with control farmers based on observable pre-project characteristics.¹² This is done based on the pro-

¹² Both village and farmer level characteristics are used to match control and treatment farmers. Matching thus helps in reducing bias as a result of village and farmer program placement and self-selection. An additional way in which program placement bias is reduced is by selecting the sampling area for control farmers that match the

propensity score $e(X) = Pr(D = 1|X)$: the probability that a farm participates in the project conditional on observable farm characteristics X . Rubin and Rosenbaum (1983) showed that if potential outcomes are independent of participation conditional on covariates X , they are also independent of participation conditional on the propensity score $e(X)$.

To calculate the propensity scores I run a probit regression with participation (0 or 1) as dependent variable and a list of covariates (pre-project farm household characteristics) that are expected to influence both participation and the outcomes of interest. The propensity score for each household is then obtained by taking the predicted value of the estimated probit model.

The covariates included in the model cannot be affected by participation in the project. To ensure this, they should therefore either be constant over time or measured before the start of the project (Caliendo and Kopeinig 2008). In addition, it should be taken into account that omitting important covariates can increase bias in estimating the effectiveness, while including too many unimportant covariates can increase the variance of the propensity score (see Heckman et al. (1997), Dehejia and Wahba (1999), and Bryson et al. (2002) cited in Caliendo and Kopeinig (2008)). With this in mind, I included the pre-project age, gender, and education of the household head, the size of the household, the distance of the household to the main road, whether the farmer produced any dairy, horticulture, or aquaculture products in the year before participation, the size of the land owned by the household, the length of the hungry season, yearly wage income, yearly income from renting out land, the percentage of production sold, total production value, and farm expenditures.

Kernel matching is used to obtain the weights $W(p, c)$ in equation (2). This procedure matches each participant with a weighted average of *all* control observations (see Heckman et al. (1997) and Caliendo and Kopeinig (2008) for more details).¹³ It gives a higher weight to those control farmers that have a propensity score closer to the propensity score of the participant.

Only those observations are included that are within the common support. This means I drop the observations from the control group that have a propensity score lower than the minimum propensity score in the group of participants and those observations from the group of participants that have propensity score higher than the maximum propensity score in the control group.

Finally, I rely on the following weighted linear regression model to obtain the MDID estimator:

$$(3) \quad Y_{it} = \beta_0 + \beta_1 t + \beta_2 D_i + \beta_3 D_i * t + e_i$$

characteristics of project areas in terms location (i.e. by using neighboring regions), agricultural production structure, and geography. See Section 6 for more details.

¹³ More precisely, using an epanechnikov kernel function and a bandwidth of 0.05, the weight of a control household that is matched to one project participant is given by

$$W(p, c) = \frac{3}{4} \left(1 - \left(\frac{e(X^p) - e(X^c)}{0.05} \right)^2 \right) / \sum_{k \in N_0} \frac{3}{4} \left(1 - \left(\frac{e(X^p) - e(X^k)}{0.05} \right)^2 \right), \text{ with } \left| \frac{e(X^p) - e(X^c)}{0.05} \right| \leq 1.$$

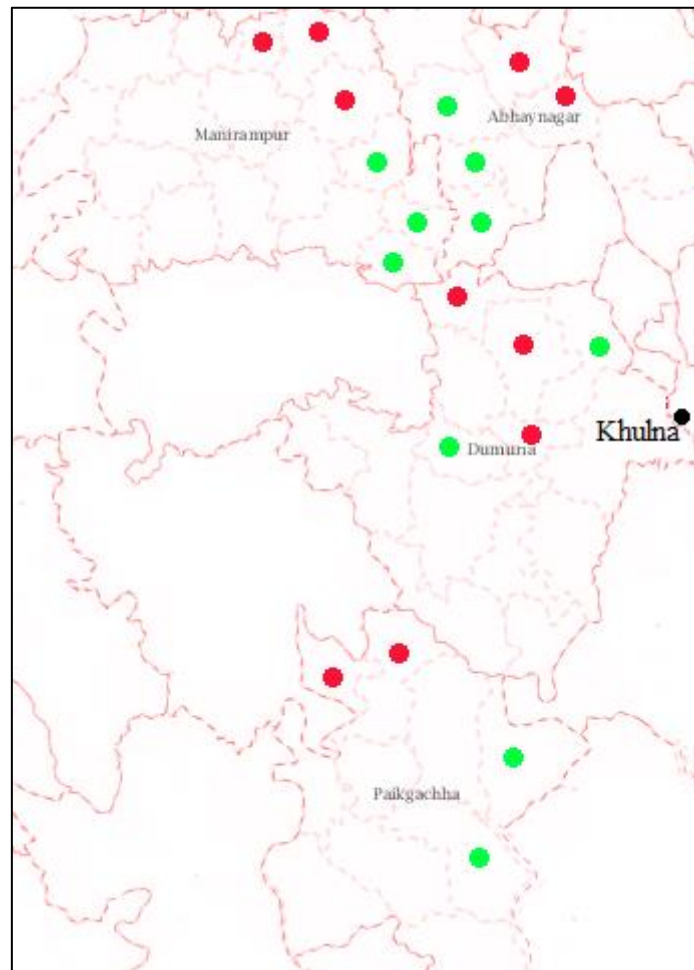
where β_3 is the MDID estimate of the project effect, obtained using weights equal to unity for participants and equal to $\sum_{p \in N_1} \sum_{c \in N_0} W(p, c)$ for the control households. Standard errors are obtained by bootstrapping (1000 repetitions). Each repetition includes the re-estimation of propensity scores, kernel matching, dropping of observations outside the common support, and a re-estimation of equation (3) using the newly obtained weights.¹⁴

6. Data

6.1. Survey

The data used in this paper were collected in the project upazilla's (sub-districts) of Manirampur, Abhaynagar, Dumuria, and Paikgachha in april-june 2014 and 2016. These upazilla's were selected because implementation in these upazilla's would start immediately after the baseline survey. The survey was commissioned and financed by the Policy and Operations Evaluation Department of the Netherlands Ministry of Foreign Affairs (as part of a review of the food security policy of the Netherlands) and implemented by a consortium of APE, AIDEnvironment, and BRAC University / Development Research Initiative (DRI).

Figure 3: Map of surveyed project (green) and control (red) unions.



¹⁴ The main estimation uses stata package “diff” (Villa 2016).

Within the project upazilla's, ten project unions were selected where SAFAL planned to start implementation immediately after the baseline survey: two in Dumuria, two in Paikgacha, three in Manirampur, and three in Abhaynagar. Then, to reduce the risk of spillovers but to ensure comparability over time, each project union was matched with a nearby control union in the same upazilla with similar characteristics (such as agricultural production structure, nearness to a regional town, and geography). See Figure 3 for a map with the resulting selection of project (green) and control unions (red). Although the control unions in the north are further from the district capital Khulna, they are in no sense more remote as they are close to the district capital of Jessore to the North (not on the map)

Households were selected using clustered random sampling at the village level. First, 27 project and 27 control villages were sampled randomly within the 10 project and control unions, respectively. Secondly, in each project village ten households were sampled randomly from a list of project participants. In the control village, ten households were sampled from a list of all households in the village that were active in either horticulture, aquaculture, or dairy.

6.2. Operationalization of outcome variables

Following the intervention logic (see Figure 3), I estimate the effect of the project on several indicators. First, output market participation is used as a proxy for output market access. Output market participation is defined as the gross value of farm sales divided by the gross value of all products produced by the farm (Govere, Jayne, and Nyoro 1999; Strasberg et al. 1999). Included are the production and sale of products from agriculture, aquaculture, and livestock rearing. Sales and production values are calculated based on product-specific median prices reported in the sample. The use of median prices is necessary to assign a value to products not sold. Median prices are kept constant over time to assure that any variation results from a change in proportion of produce sold.

The value of total production measured against medium prices in the pooled 2014 and 2016 sample is used as a proxy for farm production. Alternative indicators such as production in kilograms or agricultural yield are not viable, because project participants have highly mixed farming systems: they typically produce multiple agricultural crops in combination with multiple types of fish and livestock products.

Farm revenue is measured by the total earnings resulting from the sale of agriculture, aquaculture, and livestock products. In contrast to the value of total production, farm revenue uses the actual prices reported by the farmers (and not the median prices).

Two indicators are used to get some insight in the welfare effects of the project: farm profit and net farm income. Farm profit is defined as farm revenue minus farm expenditures. Net farm income is defined as the value of farm production minus farm expenditures. Farm expenditures include expenses on seed, fertilizer, pesticides, labor, irrigation, fish feed, fingerlings, veterinary products/advice, and livestock feed. The use of farm profit is more common, but this can only give a partial idea of the overall welfare effects in a context where farmers consume a large part of what they produce. In this case, looking at the total value of production minus costs would result in a more comprehensive assessment of the welfare effect.

Table 2: Descriptive Statistics for Control and Project group

Variables	Control	Project	Difference, p-value
Household head age (years)	49.211 (0.673)	48.783 (0.818)	0.670
Household head female (dummy)	0.034 (0.008)	0.024 (0.006)	0.289
Household head education:			
- Some primary (dummy)	0.196 (0.033)	0.138 (0.027)	0.189
- Finished primary (dummy)	0.121 (0.018)	0.083 (0.014)	0.092
- More than primary (dummy)	0.370/ (0.028)	0.549 (0.046)	0.002
Land size owned (hectare)	0.414 (0.086)	0.685 (0.058)	0.015
Household size (# of household members)	4.581 (0.074)	4.933 (0.117)	0.014
Wage income (USD/year)	372.405 (44.399)	293.726 (46.440)	0.227
Income from land rent (USD/year)	59.969 (26.541)	76.409 (21.715)	0.629
Milk Producer (dummy)	0.117 (0.034)	0.190 (0.040)	0.170
Aquaculture producer (dummy)	0.302 (0.068)	0.723 (0.043)	0.000
Horticulture producer (dummy)	0.170 (0.028)	0.154 (0.042)	0.751
Distance to main road (kilometer)	0.128 (0.031)	0.072 (0.016)	0.123
Output market participation (sold/produced)	0.308 (0.036)	0.516 (0.039)	0.001
Production value (USD)	614.454 (107.705)	1476.137 (230.100)	0.003
Farm Revenue (USD)	252.475 (59.216)	780.925 (156.906)	0.006
Farm expenditures (USD)	259.424 (48.150)	511.150 (84.282)	0.018
Farm profit (USD)	-6.949 (27.472)	269.775 (79.130)	0.005
Net farm income (USD)	355.030 (65.542)	964.986 (152.484)	0.002
Length hungry season (Months)	1.026 (0.143)	0.708 (0.125)	0.109
N	265	253	

Finally, the number of months in the past year in which households were worried about not having enough food (the length of the hungry season) is used as a proxy for food security (Bilinsky and Swindale 2010). This indicator measures the number of months in which the household did not have secure access to food.

6.3.Descriptive statistics

Table 2 presents the 2014 descriptive statistics for the project participants and control group and a balance test. Four project participants and four control households could not be re-interviewed 2016.¹⁵ In addition, fourteen observations are dropped because they contained outliers in terms of farm revenue.¹⁶ As a result, the total sample size used in the analysis contains 253 project participants and 265 control households.

Among the project participants, 175 households participated in a producer group around aquaculture, 54 in a producer group around dairy, and 42 in a producer group around horticulture.¹⁷ These households are spread out over 25 different aquaculture groups, 14 dairy groups, and 5 horticulture groups.

There are large differences between project participants and control households. In general, project participants tend to be better off as they have a higher farm revenue, a higher total production value, are better educated, own more land, and have higher output market participation. In addition, a (much) larger percentage of the project participants is a producer of aquaculture.

These differences in household characteristics are particularly important in light of our identification strategy. To reiterate Section 5, large pre-project differences make it less likely that the parallel trends assumption underlying the difference-in-difference estimation is valid. The fact that there are large difference in our case underlines the importance of matching the project participants with control farmers on pre-project characteristics.

In 2016, all farmers were asked whether they experienced an improvement in market access, access to technology, and prices. Project participants were more likely to report a positive change on all these aspects. About 92% of the project farmers reported to have experienced improvements in market access (vs. 64% in the control group), 66% experienced better access to technologies (vs. 35% in the control group), and 83% experienced better prices (vs. 62% in the control group). Although this subjective reporting is not sufficient to conclude that the project has been successful, it does warrant a further investigation.

¹⁵ This attrition may be a source of bias if it is associated with project outcomes. Since the rate of attrition in this case is very low (1.4%) and because it is present among both control and project households (and therefore less likely to be related to project outcomes), I do not correct for this in the estimation procedure.

¹⁶ The existence of outliers was determined using a histogram. All households that have a value beyond the 99-th percentile in terms of farm revenue in either 2014 or 2016 are dropped. The estimation results are, however, also robust to the use of the full sample (see discussion on the robustness of the results in Section 7.3).

¹⁷ Some households participate in multiple producer groups.

Table 3: Probit regression results for propensity score weighting procedure

Variables	Project participation
Household head age	-0.002 (0.005)
Household head female	0.024 (0.369)
Household head education:	
- Some primary	0.038 (0.192)
- Finished primary	-0.115 (0.230)
- More than primary	0.207 (0.167)
Land size owned	0.253** (0.117)
Household size	0.049 (0.039)
Wage income	0.000 (0.000)
Income from land rent	-0.000 (0.000)
Milk Producer	0.104 (0.176)
Aquaculture producer	0.878*** (0.149)
Horticulture producer	-0.374** (0.170)
Distance to main road	-0.340 (0.354)
Output market participation	0.223 (0.236)
Production value	0.000* (0.000)
Farm expenditures	-0.000 (0.000)
Length hungry season	0.057 (0.039)
Constant	-1.006*** (0.337)
N	518

Only the pre-project data captured in the 2014 survey is used.

7. Estimation Results

7.1. Project participation and matching

Table 3 displays the results of the probit regression of participation in the project on the pre-project farm household characteristics. These results suggest that project participation in our sample is positively associated with the size of land holdings, production value, and being an aquaculture producer, and negatively associated with being a horticulture producer.

Figure 4: Distribution of propensity scores of project participants (solid line) and control group (dashed line).

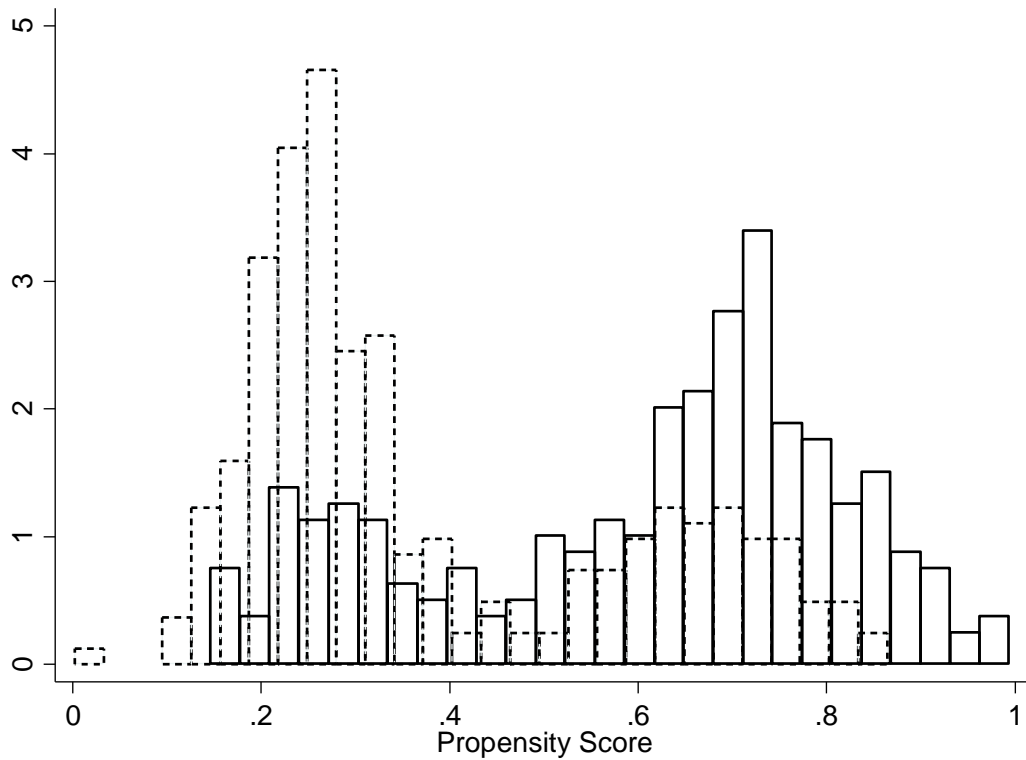


Figure 4 shows the distribution of the propensity scores of project participants and the control group. The two distributions are substantially different, with a much larger group of control farmers with low propensity scores. This further confirms the importance of matching prior to calculating the difference-in-difference estimator. Importantly, there is sufficient overlap of the distribution of the control group with the distribution of the project participants. This implies that there are project participants and control households with similar observable characteristics. However, eleven households from the control group (on the low end of the distribution) and eighteen households from the treatment group (on the high end) fall outside the common support area and are thus dropped from the sample. The remaining sample that falls within the common support thus includes 255 control households and 234 project participants.

See Table 4 for the descriptive statistics after the matching procedure. According to a two sample t-test, the two groups have become more similar in characteristics as result of the matching procedure. In fact, after applying the kernel weights, there are no statistically significant pre-project differences in average household characteristics remaining between the control and project group.

7.1. Main estimation

Using the kernel weights obtained through the matching procedure, Table 5 presents the 2014 and 2016 mean values for the four outcome indicators, the 2014 and 2016 differences between control and project group, and the double-difference estimate of the average project effect on the project participants. Before looking at the double-difference estimates, it is good to observe that the sample was balanced in 2014 in terms of pre-project outcomes: there are no statistical

significant differences between the project group and kernel weighted control group in any of the outcome indicators prior to the intervention.

Table 4: Two sample means, differences, and t-statistic after kernel weighting

Weighted Variable(s)	Mean Control	Mean Participants	Difference	t-statistic
Household head age	47.812	48.838	1.026	0.81
Household head female	0.020	0.026	0.006	0.45
Household head education:				
- Some primary	0.163	0.145	-0.018	0.54
- Finished primary	0.085	0.081	-0.004	0.15
- More than primary	0.544	0.543	-0.002	0.04
Land size owned	0.700	0.641	-0.060	0.85
Household size	4.741	4.850	0.109	0.77
Wage income	293.906	292.100	-1.807	0.04
Income from land rent	87.642	69.963	-17.679	0.73
Milk Producer	0.168	0.179	0.011	0.33
Aquaculture producer	0.701	0.705	0.004	0.11
Horticulture producer	0.192	0.167	-0.025	0.73
Distance to main road	0.081	0.076	-0.005	0.41
Output market participation	0.504	0.495	-0.008	0.27
Production value	1244.403	1184.508	-59.895	0.54
Farm expenditures	499.319	468.940	-30.379	0.66
Length hungry season	0.628	0.645	0.017	0.13

The double-difference estimates (last column of Table 5) suggest that there is a high likelihood that the project has had a positive effect on all our outcome indicators. According to our best estimation, project participation (on average) increased output market participation by 13% ($P = 0.009$), the value of farm production by USD 704 ($P = 0.011$), and farm revenue by USD 472 ($P = 0.017$). In other words, it is estimated that farmers, as a result of project participation, started to produce more (in monetary terms), sold a larger percentage of what they produced, and, as a result, increased their farm revenue.

For a better indication of the net-income effect of the project, we must take into account changes in farm expenditures. According to the results, farm expenditures went up with USD 300 ($P = 0.015$), on average, as a result of the project. A higher use of (purchased) farm inputs of higher quality was a project objective, so this was expected. In fact, it might be the case that production went up *because* of higher farm expenditures.

To assess the net income effect we subtract the value of production by these input expenditures to estimate the effect on net farm income. In addition, we look at farm profits, measured by subtracting farm expenditures from farm revenue. According to our point estimates,

net-farm income went up by USD 404 ($P = 0.037$) and farm profits increased by USD 172 ($P = 0.243$). The lower coefficient, in combination with a high standard deviation, means that there is quite some uncertainty regarding the estimated effect on farm profits. The statistically significant effect on net-farm income does suggest, however, that the overall welfare effect of the project has been positive.

Table 5: Double difference estimation (after kernel matching)

Outcome	Mean 2014 Control	Mean 2014 Project	Difference 2014	Mean 2016 Control	Mean 2016 Project	Difference 2016	Double Difference
(1) Output market participation	0.504	0.495	-0.009 (0.037)	0.437	0.560	0.123*** (0.037)	0.131** (0.051)
(2) Production value	1244	1185	-59.90 (161.2)	1232	1876	643.9*** (209.6)	703.8*** (261.2)
(3) Farm revenue	558.7	597.6	38.93 (103.4)	845.5	1356	510.7*** (166.6)	471.7** (198.0)
(4) Farm expenditures	499.3	468.9	-30.38 (62.1)	720.9	990.4	269.5** (106.9)	299.9** (121.4)
(5) Farm profit (3)-(4)	59.38	128.7	69.31 (82.6)	124.7	365.8	241.1** (107.7)	171.8 (132.3)
(6) Net farm income (2)-(4)	745.1	715.6	-29.52 (130.9)	511.5	885.9	374.4** (159.5)	403.9* (213.2)
(7) Length hungry season	0.628	0.645	0.0170 (0.126)	0.690	0.303	-0.386*** (0.131)	-0.403** (0.180)
N (on common support)	255	234		255	234		

Bootstrapped standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Finally, it is also estimated that the project led to a reduction in the length of the hungry season by about 0.4 months ($P = 0.023$). Assuming 30 days per month, this would imply an average reduction in the time in which households feel food insecure of about 12 days. This is a reduction of about 62% compared to 2014.

7.2. Robustness

The robustness of these findings is checked by estimating several alternative specifications (see Table 6 for a summary of the matched difference-in-difference estimates for the different specification and different outcome variables). First, I check whether the results are sensitive to the applied matching function by (a) increasing the kernel bandwidth to 0.1; (b) decreasing the bandwidth to 0.02; (c) applying three-to-one nearest neighbor matching with replacement as an alternative to kernel matching (see Caliendo and Kopeinig 2008); and (d) using weights equal to unity for the participating farmers and equal to $e(X)/(1 - e(X))$ for control farmers as suggested by Hirano and Imbens (2001) and Hirano et al. (2003).

Table 6: Summary of robustness checks: reporting the matched difference-in-difference estimates using different specifications

Model		Output market participation (1)	Production value (2)	Farm revenue (3)	Farm Expenditures (4)	Farm Profit (5)	Net farm Income (6)	Length hungry season (7)
(a)	Kernel bandwidth of 0.1	0.132** (0.051)	701.7*** (239.3)	491.6*** (176.9)	304.1*** (112.6)	187.6 (130.7)	397.6** (189.7)	-0.399** (0.180)
(b)	Kernel bandwidth of 0.02	0.135** (0.057)	729.6** (285.5)	476.4** (201.9)	314.0** (126.8)	162.4 (133.4)	415.6* (221.4)	-0.455** (0.196)
(c)	One-to-three nearest neighbors matching	0.120** (0.0458)	664.4*** (230.3)	465.8*** (157.3)	277.4*** (103.7)	188.4* (111.9)	387.0** (176.5)	-0.421** (0.185)
(d)	Hirano and Imbens (2001) matching	0.153*** (0.0422)	632.2*** (168.79)	460.3*** (146.2)	318.8*** (95.86)	141.4 (104.8)	490.2** (165.7)	-0.416** (0.166)
(e)	Matching variables excl. all pre-project outcomes	0.099** (0.047)	479.4** (239.4)	423.9*** (159.0)	346.9*** (103.5)	77.0 (117.6)	132.5 (190.2)	-0.539** (0.172)
(f)	Matching variables excl. all time variant variables	0.073 (0.051)	501.8** (229.7)	362.2** (167.0)	318.7*** (114.2)	43.5 (124.0)	183.1 (193.4)	-0.507*** (0.172)
(g)	Using IHS transformation	0.142*** (0.052)	0.692** (0.284)	0.701* (0.425)	0.559** (0.272)	0.915 (0.958)	1.766** (0.714)	-0.433** (0.187)
(h)	Keep observations with outliers farm revenue	0.128*** (0.050)	1095.0** (514.8)	763.5* (434.7)	288.0* (136.8)	475.5 (351.4)	807.05* (459.8)	-0.367** (0.180)

I also check whether the results are sensitive to the choice of matching variables by (e) excluding all outcome variables in the matching procedure following the critique by Chabé-Ferret (2017) and by (f) excluding all time-variant variables following the critique by Daw and Hatfield (2018).

Next, I use an inverse hyperbolic sine (IHS) transformation for farm revenue, production value, input expenditures, wage income, income from land rent, farm profit, and net farm income instead of the absolute values. The IHS transformation can be necessary because these variables have right-skewed distributions that can skew the estimates. In a way, the risk of skewed estimates is already reduced by trimming the data at the 99th percentile of farm revenue, but this might not be sufficient. Like the more conventional log-transformation, the IHS transformation returns a distribution closer to normal without the skewness but allows for retaining observations that have a value of zero (Burbidge, Magee, and Robb 1988). Finally, I also check whether *not* trimming the data at the 99th percentile of farm revenue changes the results (specification *h*).

All of the alternative specifications yield results similar to the main estimates presented in Table 5: none of alternative estimates is significantly different from the estimates using the main model. The point estimate for the net farm income effect using specification (e) and (f) is, however, quite a bit lower than the estimates using our main specification (i.e. to such that it is not statistically significant any more). One potential explanation is that using the alternative specifications resulted in statistically significant differences in pre-project characteristics between the control and project group after the matching procedure. In particular, the average pre-project farm revenue, production value, farm profit, and net farm income were significantly higher for the project participants than for the matched control group.

8. Conclusions and Implications

In this paper I have defined value chain development as an intervention that intends to increase the effectiveness and/or efficiency of a specific value chain by reducing the transaction costs between different stages and/or by supporting specific value chain actors. Value chain effectiveness in this context is understood as the ability of the value chain to comply with public or private requirements, such as regarding product quality, food safety, or ethical and environmental standards. Value chain efficiency, in turn, is understood as the costs incurred in the value chain to bring forward the final product that meets these requirements.

In a context characterized by imperfect markets, VCD can be a relevant intervention to be initiated not only by private actors but also by (semi-) public actors, such as governments, international organizations, and NGOs. From a public perspective, poorly functioning agri-food value chains can have negative consequences for economic growth, for the welfare of farmers and laborers in these value chains, for the environment, and for the quality and safety of consumer products. It is unclear, however, to what extent VCD is an effective policy instrument for improving value chain functioning and achieving better outcomes.

As an illustration of public-led VCD, this paper described the SAFAL project by the NGO Solidaridad that directly intervened in aquaculture, horticulture, and dairy value chains in South-West Bangladesh. By reducing the transaction costs between farmers on the one hand and buyers and providers of farm inputs on the other and by supporting key value chain actors, the project had the intention to improve the welfare and food security of about 58,000 smallholders. Central to the project was a push-and-pull strategy whereby value chain actors are both enabled and incentivized to invest and change their practices.

Using a matched difference-in-difference methodology, I estimate that SAFAL increased output market participation, total production, farm revenue, and net-farm income, and that it reduced the length of the hungry season experienced by farm households.

There are, however, a number of limitations to the applied estimation strategy. First, although the matched difference-in-difference estimator allows for controlling for a large number of household characteristics, it cannot completely exogenize project participation. Secondly, the outcome indicators are mere proxies for the actual project effects. It is yet unclear, for example, whether the project improved prices received by farmers and other aspects of food insecurity. In addition, the study has not captured the longer term effects of the project.¹⁸ It is yet unclear, for example, whether the newly established institutional structure will continue to exist also after the project ends. Lastly, and perhaps most importantly, there might be (unintentional) consequences that are not taken into account here. The project might, for example, have led to substitution of project farmers for non-project farmers in certain high-value value chains. Other stakeholders, which are not accounted for in the assessment include the supported micro-entrepreneurs, laborers in the value chains, and consumers.

This paper showed that public-led value chain development can be a relevant and potentially effective strategy to stimulate commercialization, increase food production, improve smallholder welfare, and reduce food insecurity. Obviously, this does not imply that value chain development will be effective as a policy instrument in any way it is implemented in any type of context. More research is needed to get a better grasp at what type of value chain intervention works best in what context. In addition, future research could use better identification strategies, such as randomized controlled trials, and could look beyond the immediate effects on farmers, to improve the assessment of its effectiveness.

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¹⁸ In fact, the project continued until one year after the follow up survey and was extended for a second phase (2017-2021).

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