Chapter 12

The "Quiet Revolution" in the Aquaculture Value Chain in Bangladesh[1]

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12.1 Introduction

There are two strands in the socioeconomic literature on aquaculture. The first, which we call "micro socioeconomics," is work centered on the role of farm households as fish producers, and the impacts of aquaculture on rural communities where aquaculture takes place. This strand can be divided into three themes: (i) farm technology diffusion and efficiency (e.g., Dey et al. 2005; Rauniyar 1998); (ii) farm interactions with the environment (e.g., Islam 2014; Primavera 2006); (iii) livelihoods. The latter can be divided further into studies linking aquaculture to poverty reduction and studies of impacts of aquaculture on communities. The "poverty" literature has focused on the role of small-scale and subsistence forms of aquaculture for household food security and incomes (e.g., Bondad-Reantaso and Subasinghe 2013). The "community" literature adopts a more critical approach to the distribution of benefits and losses from aquaculture among farm and non-farm households (e.g., Paprocki and Cons 2014; Toufique and Gregory 2008).

In focusing on the farm and its immediate environs, studies in the first strand tend to take the aquaculture value chains as given, paying little attention to chain transformation (change in structure and conduct) over time. The first strand is often based on surveys with small or unrepresentative samples, or on community case studies, and is "micro" in scope, largely neglecting the "meso" structural context in which farms and farm households are embedded.

The second strand, which we call "value chains," has been dominated by work on international fish and seafood value chains, particularly those to export markets in developed countries (e.g., Goss, Burch and Rickson

[1] An earlier version of the chapter was published in *Aquaculture,* 493: 456-468. This is reproduced with permission of the publisher.

2000), rather than domestic market value chains linking rural to urban areas. A corollary of this focus is a near exclusive attention to value chains supplying the few species (principally shrimp and salmon) demanded by developed country markets (Belton and Bush 2014).

The second strand also tends to focus on value chain governance and institutions (e.g., contracts, standards, and certification schemes). For example, it includes studies on the role of third-party standards and certification in governing value chains serving developed country export markets (Hatanaka, Maki, Carmen Bain, and Lawrence Busch 2005). This has highlighted challenges of compliance with such standards for small farmers (e.g., Marschke and Wilkings 2014).

By contrast, the second strand pays little attention to technological change among actors within chain segments. Moreover, even though the strand takes in a view not just of the aquaculture farm but also of midstream and downstream segments of the value chains, it tends to do so with small, non-representative sample surveys or case studies or key informant work (e.g., Macfadyen et al. 2012; Veliu, Gessese, Ragasa, and Okali 2009). As a result, there has been little detailed quantitative work on the dynamics of transformation of the structure (such as concentration over or within segments) and conduct (such as technologies used by the actors) of value chains overall and per segment.

The above synopsis of the literature leads to our making two critiques which we focus on the Asian context. On the one hand, contrary to the export focus of the existing aquaculture value chain literature, the great majority of fish farmed in Asia is sold and consumed in Asian domestic markets. For example, in Bangladesh, 94 percent of aquaculture production is destined for domestic consumption (calculated from FAO 2016). Furthermore, 42 percent of this fish is consumed in urban areas,[2] with urban dwellers having an average consumption per capita of 21.8 kg per capita, 31 percent greater than that of rural consumers (Toufique and Belton 2014). Rapid increases in urban consumption of farmed fish are consistent with changes taking place in food systems throughout Asia, as consumption has diversified from basic staples into higher value non-staple foods with rising real incomes. These developments are particularly significant for Bangladesh, where fish is the most important food after rice in terms of share of the food budget in value terms (Reardon et al. 2014).

On the other hand, both the "micro socioeconomics" and "value chain" literatures tend to have a static perspective. This approach is at odds with

[2] Compare that with the proportion of Bangladeshi population living in urban areas, which was 34 percent in 2015 http://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS

several trends. First, aquaculture is growing fast in Asia. Over 1984 to 2014, Bangladesh's farmed fish jumped from 124,000 tons to 1.96 million ton, increasing by 1,580 percent. As a result, aquaculture now accounts for 55 percent Bangladesh's fish supply, up from just 16 percent three decades ago (DOF 1994, 1997; 2006, 2015). Second, there has been a rapid shift from home-consumption (from one's own pond) to purchasing farmed fish from the market: consumers of farmed fish got 92 percent of it via purchase from the market in 2010, versus only 79 percent in 2000 (data extracted from BBS 2011).

Let us surmise that the share of purchases in farmed fish consumption grew by 10 percentage points in total consumption each decade, extrapolating from that change in the 2000s. That would mean that the purchase share was about 60 percent in the 1980s. Applying that assumption to the volume of farmed fish output in 1984 means there were roughly 75,000 tons in 1984. Applying the 92 percent to the output volume of 2 million tons in 2014 means there were roughly 1.84 million tons in 2010. That means the farmed fish market grew by a factor of 25 times in three decades. Note from above that in 2014 there were 1.96 million tons of farmed fish in 2014. Hence, 1.84/1.96 of the farmed fish output is marketed, or 94 percent is marketed, and only 6 percent is home-consumed.[3] This implies that "commercial aquaculture" (which we define simply as fish farming output that is sold, with no specification of the size of the farm) has moved to be far more important than subsistence fish farming. Yet subsistence aquaculture is the traditional focus of much of the literature on aquaculture in Asia.

Third, there has been rapid diversification of farmed fish composition. This involves a shift from traditional carps to introduced species (*tilapia* and *pangasius*) that lend themselves better than carp to intensification through higher stocking densities combined with use of manufactured feeds. This is an example of what economics terms the "product cycle", where in the evolution of a sector one observes a shift from traditional niche products to commoditized bulk products for a larger market, and finally to differentiated products either as varieties of the commoditized products or new niche products introduced. Typically, there is also technological change accompanying the increase in scale and, finally, in the creation or adaption for introduction of differentiated products. The product cycle in aquaculture has not been studied in Asia as an evolution in the market, although there has been extensive study of the technical issues in the farming of *tilapia* and *pangasius*.

[3] Note that the present fish farm survey results presented in this chapter show a sales share in total aquaculture output of 92 percent, so the macro and micro data track closely.

Fourth, far less studied is a rapid transformation of the structure of domestic aquaculture value chains in Asia, shown by the present survey results for Bangladesh. As the sector expanded, rapid commercialization and diversification of species occurred, and there was a proliferation of value chain actors, and in some cases concentration among them. This has been occurring both upstream from the farm, in feed milling and hatcheries, and downstream from the farm, in transport and wholesale.

The great majority of these changes have been driven by small and medium enterprises. These changes can be categorized as "immanent development" (Belton and Little 2011), that is, development unplanned and undirected by government or NGOs, arising mainly from private household, firm, and community choices, driven by changes in demand, technology, communications, and infrastructure, and abetted by propitious policies. This can be contrasted with "interventionist development" (NGO projects, centralized planning by governments). The "Quiet Revolution" in agro-food systems in Asia, observed by Reardon, Chen, Minten, and Adriano (2012) in rice and potatoes in Bangladesh, India, and China, is symptomatic of these broad processes of immanent development led by small farms and small off-farm enterprises. We argue that aquaculture in Bangladesh has experienced a similar quiet revolution.

Despite the rapid growth and restructuring of the upstream segments of inputs and services to aquaculture, and the downstream segments moving farmed fish to wholesale markets and retailers and consumers, these off-farm components have been little studied in Bangladesh—and certainly not yet using representative sample surveys of the actors in these chains. This omission is important because these structural changes in the supply chain have facilitated on-farm growth and technology change and commercialization.

In this chapter, we address the above four trends as a confluence, with an emphasis on the latter one, structure and conduct change in the aquaculture value chain in Bangladesh, with a focus on fish. We address two questions and thus important gaps in knowledge about value chain transformation. First, how is the domestic fish value chain restructuring? Second, how is the conduct of the segments changing in terms of product composition and technology? It is beyond the scope of this study to explore impacts on farmers or consumers of these value chain changes; that is an agenda for further research.

The chapter proceeds as follows. First, we describe the survey method. Second, we outline the characteristics of the main geographical "zones" or clusters included in the study, where high concentrations of farms and

other off-farm value chain actors occur. Third, we address the structure and conduct changes in the various segments of the aquaculture value chains in these zones serving rural and urban markets. Fourth, we conclude with policy implications.

12.2 Multi-layered Methodology in Comparative Perspective

We use a multi-layered methodology that is unique in several respects. First, we undertake a meso analysis (district by district, over a set of districts) focusing on growth and industrial organization, namely size distribution and thus concentration of actors per segment. This uses key informant focus groups at the district levels across four cluster areas (the main aquaculture areas in the country) to reconstruct inventories of numbers by size strata of actors in the main segments of the aquaculture value chain (hatcheries, feed mills, feed dealers, fish farms, and fish wholesalers).

Second, we undertake a micro analysis (in the same districts as the meso study) focusing on land and non-land productive assets and conduct (technology of production, procurement of inputs, and marketing of outputs) of a substantial sample of actors per segment of the value chain. These are formal structured surveys, not key informant studies. The questionnaires use the same logical structure but applied to their segment so they give comparable information over the segments about each segment and its relation to the other segments, such as traders' purchases from farmers and farmers' sales to traders, or whether farmers get value chain finance (advances) from traders. We call this micro survey approach "stacked value chain surveys" (after Reardon, Chen, Minten, and Adriano 2012) as full surveys are stacked one on top of the other from the upstream to the downstream segments. This differs sharply from the typical value chain study which uses very small samples and tends to rely on key informants, and does not use comparable questionnaires across segments or statistically robust samples. These kind of small sample studies thus cannot test hypotheses concerning determinants of behavior and variation over strata of actors in given segments, or determinants of linkages among the segments.

To the best of our knowledge, this multilayered approach has not been done in any other aquaculture value chain study. It is unique in several ways. First, no other study has done this meso analysis. Second, no other aquaculture study has done the stacked survey approach. Third, no other aquaculture value chain study has taken advantage of the cross perspective of meso and micro quantitative analysis.

We view our methodological approach as distinct from but complementary with two other multilayered approaches in recent research on value chains

and rural economic transformation in developing regions. First, Ponte and Sturgeon (2014) provide a conceptualization of value chain analysis that combines three levels (macro, or the whole value chain's governance, a micro level of determinants and dynamics of exchange at individual value chain nodes, and a meso level of the diffusion of the nodal level linkage mechanisms). Their approach emphasizes institutions and governance. Second, recent work in development geography on agrarian transitions in Asia (e.g., Rigg and Vandergeest 2012) combines two levels: community and household/individual livelihoods. Analysis of community takes place at a similar geographic scale to our meso level, but is more complex and focuses more on social outcomes of transformation. Similarly, analysis of livelihoods focuses on the micro level of determinants and consequences of a broader set of actions (e.g., migration and local nonfarm activity) than those pertaining to specific value chains, as well as on economic decisions that affect household interactions with the market. The work focuses on the rapid social and economic change occurring in rural Asia, including for example de-agrarianization.

Our study is complementary to Ponte and Sturgeon (2014) because our empirical approach allows cross-segment testing at the meso and micro level of the presence of "institutions" such as value chain finance. The study is also complementary to the approach of Rigg and Vandergeest (2012) to agrarian transitions. While our analysis does not offer (in the manifestation here) a fine-grained analysis of implications of change for individuals, households and communities, the "quiet revolution" provides an alternative framework for viewing processes of rural change related to agriculture. The study also provides an empirical example of rural transformation (with urban linkages) that does not necessarily entail de-agrarianization (delinking of livelihoods from agriculture)—quite the opposite, though our view of agriculture includes both farm and off-farm elements. Future research could combine a stacked survey approach with more fine-grained qualitative attention to the dynamics of livelihoods for those included or excluded from value chains and the communities of which they are part.

12.3 The Study Areas and Their Characteristics

To select our study zones, we undertook an extensive field-based "rapid reconnaissance" to identify the major clusters of (fish) aquaculture in the country. The importance of these areas was confirmed by crosschecks with official statistics and analysis of the 2008 Agricultural Census. On this basis, four production zones or clusters are identified in the Southwest, South-

center, North, and East. Each includes an array of most or all of the segments of the rural part of the farmed fish value chain.

The zones are listed in Table 12.1. The sample for the stacked survey has been drawn using purposive stratified random sampling because fish farming is concentrated in certain districts, and a nationally representative sample is neither necessary nor financially feasible. In each district, upazilas (sub-districts) with negligible fish production are eliminated from potential selection. This resulted in retention of 102 upazilas in 20 districts (Table 12.1). Within each zone, upazilas are randomly selected using proportional probability sampling (PPS), and 32 are selected out of the retained universe of 102. All *mouzas* (administrative sub-units) in each selected upazila are selected; those with fewer than 20 fish farmers are dropped. Once the list of *mouzas* was thus trimmed, two to three *mouzas* were randomly selected per selected upazila in each zone. These become the primary sampling units (PSU). Once PSUs are selected, a census of fish farmers is made in each, and 25 farmers are randomly selected per PSU (20 farmers, plus 5 replacements). The final farm household sample is distributed over 20 districts, 32 upazilas, and 77 *mouzas* (PSU).

Table 12.1: Zones and Sampled Districts

Zone	Districts
East	Chittagong, Noakhali, Comilla, Brahmanbaria, Sylhet, Cox's Bazar
North	Bogra, Dinajpur, Gazipur, Mymensigh, Natore, Narsingdi
Southwest	Khulna, Satkhira, Bagerhat
South-center	Barisal, Bhola, Chandpur, Jessore, Gopalgonj

Source: Study Survey 2014.

The selected *mouzas* are representative of 86 percent of the fish pond areas in the districts selected. In turn, the districts selected constitute 61 percent of all pond production in the country. (Bangladesh has 64 districts, and our 20 districts represent 61 percent of pond production of the country according to BBS numbers for 2014).

Survey questionnaires included four categories of questions: (a) demographic and business characteristics such as asset holdings; (b) intermediate input and factor procurement (land, labor, and capital, including variable and quasi-fixed inputs); (c) production technology and value addition; (d) marketing of outputs. In each upazila, a rapid enumeration of hatcheries, traders, and feed dealers was conducted. Hatcheries, traders, and feed dealers were randomly

selected for survey from these lists. The sample design for feed mills was based at the district level. Enumeration of feed mills was conducted in the sampled 20 districts, and mills were selected randomly.

Table 12.2: Definitions of Actor Size by Actor Type

Actor	Defining characteristic	Size category	Definition
Hatcheries	Total production area in decimals	Small	Less than 0.04 ha
		Medium	0.04-0.8 ha
		Large	>0.8 ha
Feed Mills	Total metric tons of feed produced per month	Small	Less than 50 MT
		Medium	50 to 300 MT
		Large	More than 300 MT
Input dealers	Total metric tons of feed sold per month	Small	Less than 10 MT
		Medium	10 to 100 MT
		Large	More than 100 MT
Farmers	Total pond area in decimals	Small	<0.2 ha
		Medium	0.2-0.8 ha
		Large	>0.8ha
Traders	Total metric tons of fish traded per week	Small	Less than 1 MT
		Medium	1 to 5 MT
		Large	More than 5 MT

Source: Study Survey 2014.

The sample design for the recent history, inventory of numbers and changes in value chain actors was based on *mouzas* selected for the household sample. In each *mouza*, two to five interviews were conducted with key stakeholders concerning the number and size distribution of value chain actors at the upazila and district level over 2004, 2009, and 2014. To obtain an indication of whether concentration of market share was taking place, information was collected for three "size of actor" categories (small, medium, and large). The definition of the size category varied by type of actor, but did not vary across zones.

Table 12.3 shows selected characteristics of the four zones or clusters. Several points stand out. First, there is a fairly homogenous picture across zones in terms of general characteristics. This may be because all the areas identified as containing high densities of ponds are located in major lowland rice growing areas with relatively easy access to the capital city, Dhaka. The study zones have broadly similar socio-economic conditions, as compared to more peripheral and remote areas with less conducive geographies and agro-ecologies for aquaculture.

Table 12.3: Zone Characteristics

Item	South-west	South-centre	North	East	All
Total area (km^2)	8,710	8,492	13,752	15,809	46,763
Population density (inhabitants/km^2)	757	1,354	1,388	1,445	1,302
Monthly per capita expenditure (BDT)	2,359	2,842	2,621	2,932	2,730
Road density (km of roads/km^2)					
2004	0.11	0.18	0.19	0.21	0.18
2009	0.12	0.19	0.21	0.20	0.19
2014	0.12	0.19	0.22	0.22	0.20
Share of paved roads in total roads					
2004	54%	60%	77%	55%	63%
2009	79%	84%	92%	78%	84%
2014	81%	82%	92%	82%	85%
Aquaculture area (ha)					
2004	168,493	38,614	39,795	113,994	360,896
2009	168,560	45,529	40,619	113,337	368,044
2014	220,223	116,809	126,667	111,794	575,493
Fish pond area (ha)					
2004	11,815	33,570	39,758	68,037	153,180
2009	16,630	46,368	60,071	48,901	171,970
2014	24,247	44,257	60,110	71,493	200,107
Change in pond area (%)	105.2	31.8	51.2	5.1	30.6
Aquaculture production (MT)					
2004	125,677	89,953	103,824	219,135	538,589
2009	140,289	114,416	121,491	231,098	607,294
2014	225,798	269,568	469,830	300,914	1,266,110
Fish production (MT)					
2004	37,264	87,852	101,110	177,415	403,641
2009	32,313	149,843	292,211	156,821	631,188
2014	56,107	182,123	398,979	240,468	877,677
Change in fish production (%)	50.6	107.3	294.6	35.5	117.4

[a] Aquaculture area is the total area of the two main culture systems: fish pond, shrimp/prawn farms, plus other minor production systems (pen and cage culture, and culture-based fisheries in oxbow lakes (*baor*), and seasonal floodplains).

Source: BBS Statistical Yearbook of Bangladesh, 2005, 2010, and 2015.

The study zones are of similar size. They have population densities of around 1,400 persons per square km, except for the Southwest (with 800 persons/km^2). The lower population density in the Southwest is a function of a large part of the land in its three districts being comprised of uninhabited mangrove forest. Income differences over zones are proxied by differences in total per capita expenditure per month. Again, the zones do not differ a great deal, with an expenditure of roughly $2,100 per year for a five-person household. Road density per square kilometer corresponds closely with differences in population density (lower in the Southwest, similar in other zones). The share of paved roads in total roads jumped dramatically over the 10 years from 2004 to 2014 in all zones, to more than 80 percent. The North, which had the highest share of paved roads in 2014, at 92 percent, also had the highest share in 2004, with 77 percent, indicating a historically well-developed transport infrastructure.

Second, as noted above, fish farming has developed rapidly in Bangladesh since the 1990s, accelerating during the 2000s. This is reflected in the table in the expansion of fish pond area which grew by 31 percent across the four zones (fastest in the Southwest and North, with increases of 105 percent and 51 percent respectively, and lowest in the East, which grew only 5 percent). Fish pond output increased more rapidly than pond area, indicating that intensification was taking place. Output rose 117 percent overall, with the greatest increase in the North (295 percent) and South-central region (107 percent), and lowest in the East (36 percent).

Third, yields (per hectare of pond surface) in the zones varied considerably, with 2.3 tons/hectare (ha) in the Southwest, to 3.4 in the East, 4 in the South-center, and 6.7 in the North. As a result of its high productivity, the North cluster (mainly Mymensingh) accounted for 45.5 percent of fish production in the four zones, from 30 percent of pond area. Large differences in land (pond) yields across zones reflect differences in the technologies deployed, with the North being the most "advanced" zone, and "cradle" of intensive aquaculture in Bangladesh. This status is partly path dependent, reflecting a number of initial conditions including: (i) superior road access to the capital city Dhaka (ADB 2005); (ii) a history of commercially oriented "green revolution" rice farming in districts such as Bogra (Crow 2001); (iii) the location of key institutions such as the Bangladesh Fisheries Research Institute (BFRI) in Mymensingh district which played an important role in the transfer of seed and production technologies for new species to well-connected farmers and hatcheries in the area (Belton and Little 2011).

12.4 Transformation of Structure and Conduct in the Value Chain

This section is organized into three sub-sections. The first focuses on "growth and concentration", essentially an industrial organization perspective, using the meso data. The second focuses on commercialization cum spatial elongation as they are closely linked. This draws especially on the micro data, and is a combination of structure and conduct analyses. The third subsection focuses on technological cum product composition/product cycle change and patterns, using primarily the micro data, but also linking back to the meso data to show that there is a mirror relation where input use changes on farms and input supply firms proliferate to meet that demand.

12.4.1 Growth and Concentration

There has been rapid development and proliferation of the off-farm components of the fish value chain in the study zones. The combination of this plus the rapid rise in aquaculture farms in these areas is creating dense clusters of value chain actors in these places. This has occurred "upstream" in the value chain, in hatcheries, feed milling, feed wholesale and retail, and farms, and "midstream and downstream" in transport, rural and urban wholesale markets (*arat*) and traders (*aratdar*), and retailing. In all segments, astounding development of these enterprises—and acceleration of that development in the past 5-10 years - has taken place. Tables 12.4 to 12.8 show structural change, proxied by numbers of different actors and shares of the size strata in the total number. We discuss this segment by segment, from upstream to midstream.

12.4.1.1 Hatchery Segment Restructuring

Over the four zones, the survey data show that there was a 207 percent increase in hatcheries over the ten years, with the rate of growth fastest in the Southwest (314 percent), and slowest in South-center (150 percent). This rate of expansion exceeded that of either fish farm numbers (up 63 percent), or farm output (up 117 percent), thus suggesting a shift to purchased seed. Big hatcheries (over 0.8 ha in size) accounted for 53 percent of hatchery area in 2014, a bit lower than 58 percent in 2004, showing slight de-concentration. The share of numbers of big hatcheries in all hatcheries over all zones together dropped a bit from 19 percent in 2004 to 15 percent in 2014. But still by 2014 the hatchery segment was concentrated: the big hatcheries had 19 percent of numbers but 53 percent of total hatchery area.

Table 12.4: Structural Change in Hatchery Clusters over 10 Years

Zone	Hatcheries											
	Total number			Share of small in total number			Share of medium in total number			Share of large in total number		
	2004	2009	2014	2004	2009	2014	2004	2009	2014	2004	2009	2014
Southwest	7	14	22	0%	0%	0%	88%	86%	91%	13%	14%	9%
South-center	80	102	120	7%	7%	5%	67%	65%	75%	25%	28%	20%
North	177	281	410	49%	50%	54%	33%	32%	31%	18%	18%	14%
East	104	142	209	37%	39%	39%	43%	43%	46%	20%	18%	15%
All	368	539	761	44%	46%	51%	37%	35%	35%	19%	18%	15%
				Share of small in total production area			Share of medium in total production area			Share of large in total production area		
				2004	2009	2014	2004	2009	2014	2004	2009	2014
Southwest				0%	0%	0%	71%	68%	79%	29%	32%	21%
South-center				0%	0%	0%	48%	45%	57%	52%	55%	43%
North				3%	3%	3%	38%	38%	42%	60%	59%	55%
East				2%	2%	2%	42%	45%	50%	57%	53%	48%
All				2%	2%	3%	40%	40%	44%	58%	58%	53%

Source: Fish Value Chain Meso Level Survey 2014.

The rapid increase in hatchery numbers, outstripping farm growth, and the tendency toward size de-concentration, may indicate the spread of new small and medium sized hatcheries beyond original "core" clusters. The preponderance of hatcheries in northern Bangladesh reflects the emergence of Bogra and Mymensingh as major producers of seed, for historical reasons described above. Bogra hatcheries export *pangasius* seed to India in addition to serving the domestic market (Ali, Haque, and Belton 2013).

Hatchery growth has been accompanied by rapid expansion of nurseries, particularly in nearby areas, which buy hatchlings or fry from hatcheries and raise them to fingerling size for sale to farms, directly, via small traders (*patil wallah*), or (over longer distances) by larger agents. Overall (from the survey but not shown in the tables), 53 percent of the seed produced by hatcheries is sold to fingerling traders, and 44 percent direct to farmers and nurseries.

12.4.1.2 Feed Mill Segment Restructuring

For feed mills (Table 12.5), as with hatcheries, there is a high degree of spatial concentration in the North, where 62 percent of the country's mills are located. These are located mostly in Gazipur, a highly industrialized peri-urban district bordering Dhaka to the South and Mymensingh to the North. Just under one-third of mills are located in the Southeast, around Chittagong, Bangladesh's second city and main seaport, and another major industrial center.

The number of feed mills jumped even faster than that of hatcheries, reflecting the later introduction and adoption of feeds as compared to hatchery seed. Interviews conducted during our rapid reconnaissance indicated that there were 7-8 feed mills (defined as formal firms, not backyard feed operations on farms) in Bangladesh in 2003. The number increased 15-fold to about 100 mills by 2014. Table 12.5 indicates the numbers of mills increasing by 268 percent over the period to 255, and rising fast in all zones. The difference between the 100 formal firms and the 255 total mills arises because the latter figure includes "semi-auto" feed mills—low-cost, locally manufactured machines used to produce small quantities of feed on-farm or by one local farm for several others around it.

The feed mill segment is even more concentrated than the hatchery segment for two reasons. First, many have developed from the addition of lines by existing large domestic poultry feed firms, with a "head start" in the industry, from major investments by foreign companies such as China's New Hope, Thailand's CP, and India's ACI Godrej. Second, there are economies of scale involved in sourcing raw materials, maintaining high utilization rates, and spreading fixed costs over a large volume. Big mills (with a capacity of 300 tons/month) accounted for 67 percent of total feed production volume in 2014, although the share of volume had barely changed from 2004 (66 percent).

Table 12.5: Structural Change in Feed Mill Clusters over 10 Years

Zone	Feed mills											
	Total number			Share of small in total number			Share of medium in total number			Share of large in total number		
	2004	2009	2014	2004	2009	2014	2004	2009	2014	2004	2009	2014
Southwest	4	5	7	68%	56%	49%	23%	37%	46%	9%	7%	5%
South-center	2	7	9	0%	29%	22%	50%	43%	56%	50%	29%	22%
North	62	100	154	30%	30%	27%	40%	37%	38%	30%	34%	35%
East	28	43	84	43%	30%	45%	26%	38%	27%	31%	32%	28%
All	95	155	255	35%	30%	33%	35%	37%	35%	30%	32%	32%
				Share of small in total volume			Share of medium in total volume			Share of large in total volume		
				2004	2009	2014	2004	2009	2014	2004	2009	2014
Southwest				17%	13%	11%	41%	59%	71%	42%	28%	18%
South-center				0%	3%	3%	28%	36%	48%	72%	61%	49%
North				4%	3%	3%	33%	29%	29%	64%	68%	69%
East				6%	3%	6%	23%	30%	26%	71%	66%	68%
All				4%	3%	4%	30%	30%	29%	66%	66%	67%

Source: Fish Value Chain Meso Level Survey 2014.

12.4.1.3 Feed Dealer Segment Restructuring

Input dealers (Table 12.6) are mainly feed dealers who distribute feed for mills. They are very numerous, totaling 15,000 over the four zones, up from 7,690 in 2004 (hence a two-fold growth, versus a 1.6-fold growth of farmers). Like hatcheries and mills, input dealers are concentrated in the North (which is home to 56 percent of dealers, but only 35 percent of farmers). But they are underrepresented relative to farmers in the Southwest and South-center, perhaps unsurprisingly given that fish yields (and thus by implication feed use), are lowest in these two zones. Some concentration in market share is present, with larger dealers (those selling more than 100 tons of feed per month) having 54 percent of the traded volume in 2004. Their share dropped to 48 percent in 2014 as many new small dealers entered the scene.

12.4.1.4 Fish Farm Segment Structure Restructuring

Fish farmers are more evenly distributed spatially than other value chain actors over the four clusters, with the North accounting for 36 percent and the Southwest and South-center 29 percent each, but the East only 9 percent. The total number of fish farmers across the four zones grew 63 percent, from 1.08 million in 2004 to 1.76 million in 2014, but the relative share of farm numbers across zones changed little over this period.

From the perspective of average household operated aquaculture land (pond surface), the average farm size in our study zones changed little over the decade, even as the total population of these nearly doubled. When the average area of aquaculture landholdings operated across zones between 2008 and 2013 is compared, the overall increase was moderate (7.2 percent). However, there is considerable variation between zones, with the North and South-center registering the largest increases, up 19 percent, up from (0.3 ha to 0.35 ha), and 17 percent from 0.24 ha to 0.28 ha, respectively, with other zones registering little change.

Fish farming households sampled in the stacked survey operated 0.29 ha of ponds in 2008 and 0.31 ha in 2013. Fish farmers in Bangladesh hold 0.86 ha of land (fish and non-fish land combined). Therefore, they are located in the second upper land quintile of farmers in the country, and they have approximately double the 0.45 ha average landholding of rice farmers (Ahmed et al. 2013). However, they are smaller than a typical fish farmer in other countries in the region, such as Myanmar and Thailand.

Table 12.6: Structural Change in Feed Dealer Clusters over 10 Years

Zone	Feed dealers											
	Total number			Share of small in total number			Share of medium in total number			Share of large in total number		
	2004	2009	2014	2004	2009	2014	2004	2009	2014	2004	2009	2014
Southwest	1,373	1,915	2,461	66%	69%	65%	31%	29%	31%	3%	3%	4%
South-center	1,428	2,109	3,111	50%	48%	43%	42%	45%	48%	8%	7%	9%
North	4,308	6,835	8,448	43%	41%	44%	32%	36%	36%	25%	23%	20%
East	581	907	1,464	69%	62%	60%	28%	32%	34%	3%	5%	7%
All	7,690	11,766	15,483	50%	49%	49%	34%	36%	37%	16%	15%	14%
				Share of small in total volume			Share of medium in total volume			Share of large in total volume		
				2004	2009	2014	2004	2009	2014	2004	2009	2014
Southwest				13%	15%	12%	68%	67%	64%	19%	19%	23%
South-center				7%	7%	5%	61%	67%	63%	32%	27%	31%
North				4%	4%	4%	31%	35%	38%	65%	61%	58%
East				15%	11%	9%	65%	61%	58%	20%	28%	32%
All				6%	5%	6%	41%	44%	46%	54%	51%	48%

Source: Fish Value Chain Meso Level Survey 2014.

Table 12.7: Structural Change in Fish Farmer Cluster over 10 Years

Zone	Fish farmers											
	Total number			Share of small in total number			Share of medium in total number			Share of large in total number		
	2004	2009	2014	2004	2009	2014	2004	2009	2014	2004	2009	2014
Southwest	335	417	494	15%	17%	17%	41%	41%	46%	44%	42%	37%
South-center	319	384	487	39%	35%	42%	39%	45%	34%	22%	20%	23%
North	343	474	634	43%	46%	45%	34%	33%	32%	23%	21%	23%
East	84	112	148	44%	43%	45%	34%	37%	32%	22%	20%	24%
All	1,081	1,388	1,763	33%	34%	36%	37%	39%	37%	29%	27%	27%
				Share of small in total pond area			Share of medium in total pond area			Share of large in total pond area		
				2004	2009	2014	2004	2009	2014	2004	2009	2014
Southwest				4%	4%	4%	30%	31%	36%	66%	65%	59%
South-center				14%	12%	15%	41%	47%	36%	46%	41%	49%
North				15%	17%	16%	36%	37%	34%	48%	46%	50%
East				16%	16%	16%	36%	41%	34%	48%	44%	50%
All				10%	11%	12%	35%	37%	35%	54%	52%	53%

Source: Fish Value Chain Meso Level Survey 2014.

Table 12.8: Landholdings and Tenancy by Year and Zone

Zone	Southwest		South-center		North		East		All	
	2008	2013	2008	2013	2008	2013	2008	2013	2008	2013
1. Total non-fish land overall (Ha/HH) (zeroes in average)	0.26	0.31	0.45	0.54	0.38	0.42	0.33	0.39	0.34	0.40
2. Total fish pond land, (Ha/HH) (zeroes in average)	0.59	0.64	0.24	0.28	0.30	0.35	0.49	0.48	0.43	0.46
2.1 Total operated land (used, including owned and rented-in lands)	0.51	0.52	0.18	0.21	0.17	0.22	0.20	0.20	0.29	0.31
2.1.1 Self-owned	0.36	0.33	0.12	0.12	0.10	0.11	0.05	0.05	0.18	0.17
2.1.2 Joint-owned with another HH	0.12	0.16	0.04	0.08	0.01	0.06	0.09	0.10	0.07	0.10
2.1.3 Rented in	0.04	0.03	0.02	0.01	0.06	0.05	0.06	0.05	0.04	0.04
2.2 Rented out	0.07	0.08	0.02	0.03	0.02	0.02	0.03	0.03	0.04	0.04
2.3 Jointly owned, used by other HH	0.01	0.03	0.04	0.04	0.10	0.11	0.25	0.24	0.10	0.10
3. TOTAL land	0.85	0.95	0.69	0.82	0.68	0.77	0.82	0.86	0.77	0.86

Note: HH = household

Source: Fish Value Chain Farm Household Survey 2014.

Further, the average 0.31 ha of pond area per fish farm in our sample is five times the average 0.06 ha area of "homestead ponds" reported by Belton and Azad (2012) in Bangladesh. This difference is explained above in the sample methods section where we note that districts with high concentrations of fish farming, which our household survey analysis shows, tends to be correlated with higher shares of commercial farms and lower shares of (subsistence) homestead fish ponds, were purposively selected.

Moreover, fish farming tends to be concentrated among the upper stratum of small farms. Figures extracted from Bangladesh Integrated Household Survey (BIHS) data—a nationally representative survey of rural households conducted by the International Food Policy Research Institute (IFPRI) in 2011-2012—show that 89 percent of the aquaculture households contributed just 25 percent of total production, while the top 2.4 percent of fish farming households accounted for 50 percent of total output.

Our meso survey data reflect this concentration. Larger farms (with 0.4 ha or more of pond area) constituted 27 percent of fish farms but had 53 percent of pond area in 2014, with little change in this share since 2004. The share of area among farmers of other size categories also remained stable over this period, at around 35 percent for medium and 11 percent for small farms (<0.2 ha), suggesting that while many new producers have entered farming, there has been little, if any, consolidation into larger farm units.

Table 12.9: Factor Productivity in 2013

Observations in 2013	South-west	South-center	North	East	All
	465	280	420	340	1505
1. Total fish output (kg) per:					
1.1 Labor day (own + hired)	9.0	7.2	32.7	20.8	18.9
1.2 Own labor day	10.3	10.5	42.5	23.8	23.9
1.3 Pond hectare	801	2,565	10,017	2,916	3,352
1.4 Capital (thousand BDT)[a]	5.3	9.8	25.2	10.2	13.0

[a] Capital is calculated as the total variable cost (labor, rent, purchased inputs, etc.), plus the annual amortization of quasi-fixed assets.

Source: IFPRI/MSU Fish Value Chain Farm Household Survey 2014.

Finally, Table 12.9 shows yields of 3.35 tons/ha on average in the sample in 2013. The North has far higher land-yields than the rest of the zones. This helps to explain why the concentration of farms in the North is low relative to the high concentration in the North of hatcheries, feed mills, and

input dealers. The North simply has a much more intensive production technology, heavy in external inputs supplied by these off-farm enterprises, and that intensification is reflected in its extraordinary yields relative to the rest of the fish farming clusters. Absolute yield growth was greatest in the North, up 96 percent, from 5 tons/ha to 9.8 tons/ha, while in relative terms the East grew faster from a lower base, up 113 percent from 1.3 to 2.7 tons/ha. South-center grew only 19 percent, from 2 to 2.4 tons/ha, while the Southwest remained stagnant at 0.7 tons/ha (see Table 12.13).

12.4.1.5 Fish Wholesale Segment Restructuring

The fish wholesale segment has been expanding rapidly. This occurred with a proliferation, especially during the 2000s, of rural fish wholesale markets, and an increase in fish wholesale markets in cities such as Dhaka. Fish trader numbers more than doubled across the four zones, from 14,800 in 2004 to 31,300 in 2014 (2.1 times, versus 1.6 times for farmers).

The largest share of traders was in the North (41 percent) in 2014, which had only 23 percent of the traders in 2004. Trader startups followed the concentration of fish production. Most village traders started about 10-15 years ago, over the same period as the beginning and development phase of the aquaculture boom.

12.4.2 Commercialization and Spatial Elongation

In Bangladesh mainly over the past 15 years, the value chain for farmed fish has commercialized, and it has "lengthened" geographically. This is a typical trend in transformation and modernization of food supply chains, with concomitant inter-district market integration and reduction of transaction costs. This happened for example in rice and potatoes in Asia over the past decade (Reardon, Chen, Minten, and Adriano 2012). The commercialization of fish farming is itself dependent on the proliferation of services we discussed above: the development of off-farm components of the value chain permits a division of labor wherein small farmers can specialize in pond operations, and enjoy cost saving via economies of scale, economies of scope, and economies of agglomeration by relying on the upstream feed and seed purveys and downstream wholesale and logistic services that themselves are specialized enterprises. Belton, Ahmed, and Jahan (2014) contend that the availability of these services facilitates the entry of smaller producers into commercial fish farming; Reardon, Chen, Minten, and Adriano (2012) contend similarly for rice and potato sectors. We discuss the trends of commercialization and chain lengthening below, from upstream to midstream.

Table 12.10: Structural Change by Rural Fish Traders Cluster over 10 Years

Zone	Rural fish traders											
	Total number (hundreds)			Share of small in total number			Share of medium in total number			Share of large in total number		
	2004	2009	2014	2004	2009	2014	2004	2009	2014	2004	2009	2014
Southwest	42	46	59	71%	74%	76%	26%	22%	20%	4%	4%	4%
South-center	24	33	38	61%	59%	45%	28%	26%	35%	11%	15%	20%
North	34	54	128	61%	58%	76%	22%	23%	14%	17%	19%	9%
East	48	74	88	68%	74%	71%	24%	21%	23%	8%	6%	6%
All	148	207	313	66%	67%	71%	24%	22%	20%	9%	10%	9%
				Share of small in total volume			Share of medium in total volume			Share of large in total volume		
				2004	2009	2014	2004	2009	2014	2004	2009	2014
Southwest				21%	23%	23%	45%	41%	37%	34%	36%	40%
South-center				11%	9%	5%	30%	24%	24%	59%	67%	71%
North				9%	7%	17%	19%	18%	19%	73%	75%	64%
East				15%	20%	18%	32%	33%	35%	53%	47%	48%
All				13%	13%	15%	30%	26%	26%	57%	61%	58%

Source: Fish Value Chain Meso Level Survey 2014.

12.4.2.1 Seed Commercialization

Farmers have shifted from trapping wild fish on their farms or buying locally available wild seed in the early 1990s (Ahmed, Rab, and Bimbao 1993) , to stocking hatchery-produced seed in the 2000s. By 2011, 98 percent of fish seed was produced by private hatcheries (Belton and Little 2011).

The shift to hatchery-produced seed resulted in a lengthening of the distances over which seed was traded. Private hatcheries developed first in Jessore where there were ideal iron-free water conditions and technical training was initially provided by a government hatchery in the 1970s. A vibrant long-distance trade in seed between Jessore and other areas, including the Northwest, developed rapidly. From the early 1990s, techniques first demonstrated in Jessore were established in other areas, such as Bogra in the North (also a location with iron-free groundwater), as a result of informal transfer of technical knowledge among seed producers (Lewis, Gregory, and Wood 1993). Many hatcheries were also established in Comilla (an area with a history of nursing wild seed captured, and the site of one of the earliest government hatcheries), and Mymensingh—a location with less ideal environmental conditions, but with technical support from government institutions, aquaculture development projects, and demand for seed from a rapidly growing farm sector. The geography of hatcheries reflects a mix of initial environmental and institutional conditions and the location sources of demand.

These trends have given rise to a situation in which there is a correlation of the level of activity of the broad cluster and the co-location of hatcheries. There is strong spatial concentration of hatcheries in the North, which has more than half of the hatcheries in the four zones. But our survey also finds that on average half of what hatcheries produce is sold to buyers outside of their own district (not shown in the tables). Hatcheries tend thus to be "shared" across districts and even zones.

12.4.2.2 Feed Commercialization

The commercialization of aquaculture feeds and the geographical lengthening of that segment have occurred in lockstep. There has been a long-term shift from little use of feed of any type (Ahmed, Rab, and Bimbao 1993), to use of feed available on-farm (e.g., cow manure, rice bran), to purchase of the latter, and increasingly, to purchase of formulated pelleted feeds. Ninety percent of the latter are made by medium and large-scale commercial mills in 2015 (Mamun-Ur-Rashid, , Belton, Phillips, and Rosentrater 2013).

Large feed mills in the peri-urban industrial zone north of Dhaka, where most feedlot poultry farming occurs, distribute feed throughout the country.

Mills are concentrated there for centralized acquisition of inputs, and because (similar to other countries) many fish feed manufacturers originally produced poultry feeds before diversifying into fish feed by adding additional lines. Eighteen of the 25 largest poultry feed mills in Bangladesh also produce fish feeds (Khaleduzzaman and Khandaker 2009).

The input acquisition supply chain for feed manufacture stretches over long distances. Most dried fish, one of the main ingredients in fish feed, is sourced from marine fisheries in coastal districts of Bangladesh but increasingly also imported from India and further afield, as is soy (another key ingredient). Meat and bone meals, important protein sources for feed, are sourced from the European Union (Mamun-Ur-Rashid, Belton, Phillips, and Rosentrater 2013). Much of the equipment utilized in the value chain (e.g., feed milling machines, vehicles, pumps, cold chain equipment) is imported, mainly from East and Southeast Asia, as are chemicals (Mamun-Ur-Rashid, Belton, Phillips, and Rosentrater 2013).

As elsewhere in Asia, foreign expertise has played an important role in the development of hatchery and feed operations (Belton 2012). For example, training received by Bangladeshi entrepreneurs (both at courses in Thailand and from foreign consultants working in Bangladesh) has been important in the establishment of monosex *tilapia* hatcheries. Over time, dependence on these sources of information has lessened as technical knowledge has become more widely available within Bangladesh.

12.4.2.3 Fish Farm Commercialization

The shift from subsistence to commercial production in the fish sector occurred as initially fish were only home-consumed from the household pond, then increasingly sold into nearby markets, and then marketed also to more distant urban markets. These sequential changes have occurred rapidly. As recently as the early 1990s, Ahmed, Rab, and Bimbao (1993) observed that only a small fraction of total harvested farmed fish entered the market outside the local village.

In contradiction to the traditional view of fish farming in Bangladesh as mainly subsistence-oriented, the value chain survey of the farm segment shows that 75 percent of households sell fish. Strikingly, the share of farms with a marketed surplus even in these dense aquaculture clusters was only 57 percent just five years prior to this, indicating that extremely rapid commercialization occurred. The Southwest has the highest share of fish farming households marketing fish (88 percent), in line with shrimp and prawn production in that zone (besides farmed fish); most of the shrimp are exported. Figures are around 70-75 percent for the South-center and North, and 60 percent for the less advanced (in terms of fish farming) East.

Table 12.11: Disposal of Fish Farm Harvest by Final User Type, 2013

Observations in 2013	South-west	South-center	North	East	All
	465	280	420	340	1505
1. Share of farmers selling fish	87.5	70.7	74.5	59.7	74.5
2. Farmer's own consumption	15.4	18.5	4.2	12.2	8.4
3. Sales through different value chains:					
a. Consumed by another farm household	0.3	0.0	0.0	0.0	0.0
b. Direct consumer	0.0	0.7	0.9	0.0	0.7
c. Retailer at traditional market	11.4	7.7	2.7	15.6	6.0
d. Assembler (collector)	5.6	2.8	8.1	14.7	8.4
e. Large wholesaler	49.2	54.5	68.1	56.4	62.8
f. Supplier (broker)	1.5	8.6	8.7	0.6	6.6
g. Supermarket	0.0	0.0	0.0	0.0	0.0
h. Auctioned	16.6	7.1	7.3	0.5	7.1
i. Others	0.1	0.0	0.0	0.0	0.0
j. Total	100.0	100.0	100.0	100.0	100.0

Source: IFPRI/MSU Fish Value Chain Farm Household Survey 2014.

Table 12.11 shows the disposal of fish output by aquaculture households in 2013 by final user type. Note that only 8 percent of the fish was home consumed; thus, the average household was highly commercialized. Interestingly, while yields differ a lot over zones, the marketed surplus rate does not: the home consumption share is 4 percent in the North zone and about 15 percent in the other zones.

Moreover, in contrast to the common image of the rural fish market being dominated by small rural brokers, the market has shifted to rural sourcing by large wholesalers based in towns and secondary cities. Tables 12.12 and 12.13 show that about two-thirds of the marketed volume goes to large wholesalers; again, that differs between the North with 68 percent and the average of the other zones at 54 percent. Three-quarters of the sales to large wholesalers are affected locally (in the village, union, or upazila). By contrast, local rural brokers have a mere 5 percent share of the market. Just over a decade earlier, fish farmers usually sold their fish to local traders or fish collectors (ADB 2005). Interestingly, this is the same market structure development that has occurred in rice and potatoes in Asia (Reardon et al. 2012).

Table 12.12: Disposal of Fish Farm Harvest by Final User Location, 2013

Observations in 2013	South-west	South-center	North	East	All
	465	280	420	340	1505
1. Farmer's own consumption	15.4	18.5	4.2	12.2	8.4
2. Sales through different value chains:					
2.1 Consumed by another farm household	0.3	0.0	0.0	0.0	0.0
2.2 Direct consumer	0.0	0.7	0.9	0.0	0.7
2.3 Retailer at local (village, union, upazila) traditional market	11.4	7.7	2.7	15.6	6.0
2.4 Assembler locally	5.6	2.6	5.5	14.7	6.7
2.5 Assembler in same district	0.0	0.2	2.5	0.0	1.7
2.6 Large wholesaler locally	46.3	46.7	64.4	31.8	55.5
2.7 Large wholesaler in same district	2.7	4.3	2.9	14.8	4.9
2.8 Large wholesaler in different district	0.1	3.5	0.8	9.7	2.3
2.9 Supplier (broker) locally	1.2	8.6	6.9	0.6	5.4
2.10 Supplier (broker) in same district	0.3	0.0	0.0	0.0	0.0
2.11 Supplier (broker) in different district	0.0	0.0	1.8	0.0	1.2
2.12 Supermarket	0.0	0.0	0.0	0.0	0.0
2.13 Auctioned locally	16.3	5.4	1.9	0.0	3.4
2.14 Auctioned in same district	0.1	1.1	5.3	0.0	3.6
2.15 Auctioned in different district	0.2	0.6	0.1	0.5	0.2
2.16 Others	0.1	0.0	0.0	0.0	0.0
2.17 Total	100	100	100	100	100

Source: IFPRI/MSU Fish Value Chain Farm Household Survey, 2014.

12.4.2.4 Rise of the Fish Trader Segment to Urban Areas

Growth in sales of farm output has been accompanied by a proliferation of traders in the midstream segment of the chain. As urban demand has grown and the road network has developed (Table 12.3), fish is increasingly sold by traders in the zones of production to Dhaka, and from one division to another. The national Household Income and Expenditure Survey, (BBS 2011) shows that from 2000 to 2005 the share of fish consumed in urban areas rose from 29 percent to 42 percent.

The conduct of the segment has also changed from the traditional image common in Asia that traders are advancing funds to farmers to "lock in" farmers in transactions. Our survey shows that none of the farmers received any cash advance from fish traders. That is confirmed by the present trader survey. But the trader survey shows that around 40 percent of traders, both

rural (operating from villages) and peri-urban (operating from secondary cities or towns), provide advances of working capital to other traders in order to secure supplies of fish, with an average loan duration of just under one month.

Among rural and peri-urban traders, our survey shows that the great majority have stalls in rural and peri-urban wholesale markets. Most rural fish traders (63 percent) and peri-urban traders (79 percent) take a commission on the transaction of fish (rather than through arbitrage where they buy and then sell). None of the rural traders and few of the peri-urban traders surveyed own trucks, and only 6 percent rent them, indicating their role as intermediaries who operate from a base and just link buyers and sellers, relying on hiring transporters (or having the farmer hire transporters to deliver). The average monthly working capital of rural traders is a little under half that of peri-urban traders as expected.

Few traders (<2 percent) own ice making plants, and almost none owns a cold storage. Only 31 percent of rural and 20 percent of peri-urban traders report icing the fish. This likely reflects their role as commission agents, who rapidly broker sales between buyers and sellers, without taking possession of the fish themselves, with buyers usually assuming responsibility for procuring ice from ice suppliers or manufacturers. The low ice use rate is not for lack of access to ice firms: 80-90 percent of the traders feel they have good access to ice firms. The domestic market demands whole fresh fish, with little, if any value addition occurring. It is thus not observed that wholesalers, feed companies, or hatcheries process their own fish.

12.4.3 Technological cum Product Composition/Product Cycle Change and Patterns

Important inter-linked changes have occurred in the technologies and the product composition of farm production concurrent with the above structural changes in the value chain. We discuss these below.

12.4.3.1 The Product Cycle

The "product cycle" is a widely observed feature of product development in many sectors of the economy, and can be observed for a range of agricultural sectors, including fish and fruit, in a number of other countries. Sequentially, the stages of the product cycle are: (i) local niche product stage; (ii) commodity stage, during which a local (or exotic) niche product is "commoditized" by production in large quantities, driving down costs, but with little product variety or quality differentiation; (iii) product differentiation stage: when

the commodity becomes differentiated along the lines of several possible tangible and intangible attributes (e.g. variety, quality, organic versus conventional, confined versus free range); (iv) commoditization stage, where the differentiated products are themselves produced on larger scale and commoditized, and; (v) introduction of new niche or differentiated products. The cycle can continue indefinitely depending on the capacity of innovation in the sector and the market.

We posit that the Bangladesh fish sector has followed a typical "product cycle" development path, facilitated by the linked technology changes along the value chain described above, although to date only the three stages can be discerned. The first (and ongoing) technology change linked to the first product cycle step (moving from niche to commodity) is the shift from capture of wild fish stocks from open waters, to their production in ponds under controlled conditions. This shift began in earnest during the 1980s, as ponds were increasingly utilized for aquaculture, primarily by stocking native carp species which were an important component of inland capture fisheries at that time (Ali 1997).

Carp cultivation expanded rapidly from the 1980s onwards, as hatcheries produced seed of both indigenous carps (e.g., *rohu*)—formerly a highly prized but infrequently accessible "local niche" product—and exotic carps (e.g., silver carp) became more widely available, leading to their commoditization.

In the mid-1990s, *pangasius*, an exotic (to Bangladesh) catfish, was introduced from southeast Asia (where it itself had originated as a local niche variety that had been commoditized). *Pangasius* was well suited to commoditization under intensive farming conditions due to its fast growth and hardy physiology (including the ability to breath atmospheric oxygen), which equate to good survival rates, and the ability to survive at high stocking densities. Production of *pangasius* grew rapidly in Bangladesh from the late 1990s onwards, with the product commoditizing as supply increased and real prices fell (Ali, Haque, and Belton 2013).

Widespread production of monosex Nile *tilapia* seed began in the early 2000s, facilitating its rapid uptake by farmers and commoditization.[4] *Tilapia*, which originates from Africa, has also shifted from being a local (African) niche product to a commodity with a pan-global distribution over the past 50 years. It was introduced into Bangladesh from its commoditized

[4] The introduction of hatchery technology needed to produce 'monosex' (all-male) tilapia seed was a necessary precursor to the commoditization of tilapia. All-male populations of tilapia do not breed, and grow quickly and to large sizes, whereas mixed-sex tilapia breed precociously, expending energy on reproduction rather than growth. This results in many stunted fish with low market value (Belton 2012).

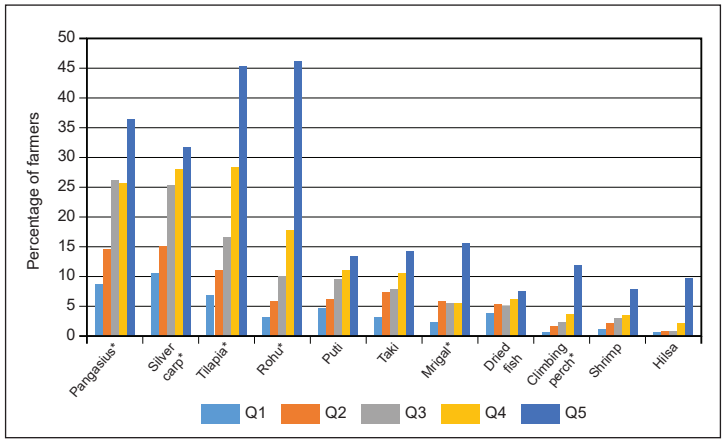
base in Southeast Asia (Belton and Little 2011). Although *tilapia* is not an air breather like *pangasius,* its fast growth, ability to tolerate high stocking densities and poor water quality, adaptability to a range of diets, and suitability for use in a wide range of food preparations, all make it an ideal candidate for intensification.

From the late 2000s there has been a further wave of farm production of native fish species such as climbing perch (*koi* in Bangla language), walking catfish (*magur*), stinging catfish (*shing*), feather back (*chitol*), and butterfish (*pabda*) which were formerly available only from domestic capture fisheries. Climbing perch farming in particular has already undergone rapid expansion of intensive production for the mass market, resulting in full commoditization. Climbing perch, a popular wild fish in Bangladesh, is, like *pangasius*, an air breather capable of surviving at high densities under conditions of poor water quality. The strains raised in Bangladesh at present were imported from Thailand and Vietnam and are faster growing and larger than the native wild strain. It is likely that one or two of the species in this niche group will also eventually become fully commoditized, and may subsequently spread to other countries as *pangasius*, *tilapia*, and improved climbing perch strains have to Bangladesh.

Data from BIHS depict on the consumption side the product cycle (Figure 12.1). After becoming commoditized during the 2000s, *pangasius* and *tilapia* are now the first and third most consumed fish in rural areas of Bangladesh. *Rohu*, an indigenous carp species that was among the first fish to be commoditized, and traditionally the most important farmed fish, is now ranked fourth in terms of consumption. The very recently commoditized climbing perch now ranks eighth. This change has occurred quickly. Comparison with similar household survey data collected in 2006-2007 shows *rohu* still the most consumed fish at that time, with *pangasius* third, *tilapia* ninth, and climbing perch not yet produced in sufficient quantities to feature (Belton, van Assledonk, and Thilsted 2014).

Our farm survey also shows evidence of product cycle changes in each zone in 2008 compared with 2013. There is a significant increase in production of *pangasius, tilapia*, and "niche" species in the North, and niche species in the East. Overall, carps are the dominant category of fish species produced in the study zones. However, the share of carps has decreased slightly (2 percent) while the share of *pangasius* has increased significantly (7 percent increase), as has *tilapia* to a lesser degree (3 percent increase). It is interesting that the production of niche species has increased slightly in the study zones, but in the North increased by 72 percent, and in the East increased 16 times, though from a low base.

Figure 12.1: Average Weekly Consumption Per Capita of Ten Most Consumed Fish Species in Rural Bangladesh



Note: Q1 = Expenditure quintile 1, etc.; Fish marked with an asterisk are produced predominantly from aquaculture. Source: Derived by authors from the BIHS data.

Table 12.13: Aquaculture Production by Fish Category, 2008 and 2013

Zone	Southwest		South-center		North		East		Total	
	2008	2013	2008	2013	2008	2013	2008	2013	2008	2013
Production (kg/year)										
Carps	173	175	235	325	521	928	233	369	291	445
Tilapia	58	71	60	99	182	503	169	309	116	244
Pangas	0	0	66	105	544	1,358	103	207	180	401
Shrimp	129	134	7	8	0	0	12	7	48	51
Niche	46	45	58	69	186	408	18	285	172	200
Others	42	46	60	70	92	216	94	137	70	117
Total	448	470	485	675	1,525	3,414	630	1,314	876	1,458
Share of production (%)										
Carps	39	37	49	48	34	27	37	28	33	31
Tilapia	13	15	12	15	12	15	27	24	13	17
Pangas	0	0	14	16	36	40	16	16	21	28
Shrimp	29	28	1	1	0	0	2	1	5	3
Niche	10	9	12	10	12	12	3	22	20	14
Others	9	10	12	10	6	6	15	10	8	8

Source: Fish Value Chain Farm Household Survey 2014.

12.4.3.2 Capital-led Intensification

The conventional image of the pond-fish sector was once millions of backyard "homestead ponds", utilized primarily for subsistence (home consumption). Dey, Bose, and Alam (2008, 13) refer to aquaculture in Bangladesh as a "low-input activity for household consumption".

However, the small and medium commercial farms that now dominate aquaculture output are making a transition from the traditional production technologies toward intensification—first by labor and then by productive capital (such as formulated feed and medicines and some equipment such as aeration). The main technology changes observed in the survey are as follows.

Rapid increase of purchased feed and seed. Use of wild fish seed has been replaced by use of hatchery produced fish seed. Jahan et al. (2015) report that less than 4 percent of farmers use fish seed from open-water sources. Seed stocking density has also increased. Our farm survey shows that nominal expenditure on fingerlings per hectare more than doubled between 2008 and 2013.

Moreover, there has been a transition in zones surveyed from no use of feed, to use of feed inputs available on farm, to use of hand-made feeds made with ingredients purchased off-farm, to use of purchased manufactured feeds, formulated to meet the complete nutritional requirements of the fish produced and, increasingly, from formulated sinking feed to floating formulated feed. The latter allows for greater production efficiencies via reduction of waste and higher digestibility.

Strikingly, our farm survey shows that 38 percent of farmers in 2013 used commercial pelleted feeds, up from 30 percent in 2008; both figures are surprisingly high, and run counter to the common image of fish farming in Bangladesh as mostly extensive or semi-intensive (ADB 2005). Use of commercially manufactured pelleted feeds is significant because their use can increase fish growth rates, facilitating higher yields, and is consistent with product cycle driven diversification into species of fish (e.g., *pangasius, tilapia*, and climbing perch) that require formulated diets to attain optimal growth.

Our survey results show that use of other supplementary feeds usually associated with semi-intensive farming (e.g., rice bran, mustard oilcake), was already widespread in 2008 (60 percent of farmers), but grew to 69 percent of farmers by 2013. This indicates a range of stages of intensification, with some farmers shifting from extensive to semi-intensive production and others "upgrading" to more intensive production with pelleted feeds.

Rapid increase in the use of chemicals. Use of medicines and other chemicals, including lime, antibiotics, salt, fungicides, insecticides, and feed additives such as vitamins have increased in line with higher stocking densities and feed use. This has occurred as the incidence of disease has increased and better management has been necessary to maintain water quality within the parameters required for fish survival and growth (Ali, Rico, Jahan, and Belton 2016).

Our farm survey shows that use of lime for pond preparation was already a widespread practice in 2008 (63 percent of farmers), and was adopted by 73 percent by 2013. Use of medicines and vitamins was less common (6 percent of farms each in 2013), increasingly slightly from 4 percent in 2008. Use of both these inputs was greatest in the North reflecting its intensified technology, and lowest in the least commercial zone, the East.

Increase of use of hired labor. Hired labor use has increased along with the overall need for labor. Whereas in the early 1990s aquaculture used little household labor as compared to crop or livestock cultivation (Ahmed, Rab, and Bimbao 1993), commercial forms of aquaculture in Bangladesh now generate higher average demand for hired labor per unit area of land than paddy cultivation, due in part to the long fish cropping cycles (Belton, Ahmed, and Jahan 2014) and more yield and input use to manage.

Our farm survey data show that both total labor inputs (measured in value terms, as the imputed value of the wage rate for family labor and the cost of outlays on hired labor), and inputs of hired labor have intensified per unit of (pond) land. The total outlay per hectare for labor (family plus hired) in 2013 was 1.6 times what it was in 2008. The share of hired (non-family) labor in total labor (hired plus own labor) doubled over the same period, from 11 percent to 21 percent.

Hiring labor was concentrated among a small subset of commercial farms. The share of farms hiring casual workers was 16 percent for pond preparation; 5 percent for stocking, 5 percent for the post-stocking/growing-out stage, and 6 percent for harvesting. The share of farms hiring salaried or permanent laborers is still much lower. Moreover, differences in total labor inputs and in hired labor vary markedly across zones, in line with patterns of intensification. Total labor use in 2008 was 50 percent higher in the South-center and North than in the Southwest and East. By 2013, these differences are even more extreme, with labor use per hectare in the South-center and North 100 percent higher than in the Southwest and East.

Rapid increase/investment in quasi-fixed capital (equipment). There has been substantial investment by fish farmers in productive capital. Investments

(at nominal terms) in assets used for fish farming[5] jumped by 235 percent over 2008-2013. The rate of investment is similar over all zones, with the exception of the South-center, which is somewhat slower. However, the rapid jump in productive fish-related capital holdings masks the fact that few fish farms had these. Pumps, owned by 14 percent of households, were by far the most frequently owned item. Investment growth is thus from a relatively concentrated base among the small/medium commercial farms. The money value of the stock of quasi-fixed capital inputs (rate of investment in capital) on fish farms rose faster than labor flow (total use of labor, measured in value terms) from 2008-2013.

Investment in agricultural equipment by fish farmers is reflected in productive capital stocks used for crop farming increasing by 185 percent. This too was similar across zones. Fish farmers also invested in livestock (increasing by 533 percent), while non-farm productive assets climbed 730 percent, and consumer durables by 240 percent. Even discounting these rates for inflation, these findings show that fish farmers are a vibrant capital accumulating segment.

Table 12.14: Fish Farm Capital to Labor Ratio by Zone, 2008 and 2013

Item	South-west	South-center	North	East	All
Capital/labor ratio, 2013	1.52	0.39	0.63	0.48	0.75
Capital/labor ratio, 2008	0.96	0.33	0.47	0.32	0.51
Change, 2008 to 2013 (%)	58	18	34	50	47

Source: Fish Value Chain Farm Household Survey 2014.

In sum, from 2008 to 2013 there has been a remarkable increase in use of external inputs by farms. Total outlay on external inputs (feed, fertilizer, chemicals and so on) tripled per hectare. The rate of external input use did not differ a great deal across three of the four zones. Average expenditure on inputs was much greater in the North however, reflecting the intensive technologies utilized there.

Despite the rapid increase in total outlay on external inputs, the composition of that outlay is very stable. Feed remains central, accounting for 78-79 percent of external input costs in both 2008 and 2013. Fertilizer[6]

[5] Assets used in fish farming are calculated by the summation of the value of the following assets: pumps, generators, aerators, nets, weighing scales, boats, bicycles, motorcycles, pickup trucks, trucks.

[6] Fertilizer is used to induce growth of phytoplankton in the pond, which provides a natural feed for fish.

stays at 5 percent; fuel 7-8 percent; and pesticide and lime 5-6 percent. Fifty percent of farmers (with a lower share in the East) use chemical fertilizer in the pre-stocking phase, up sharply from 39 percent in 2008. Use of other inputs also increased: 75 percent of farms use lime for pond preparation in 2013, up from 63 percent in 2008, and a third uses water pumps for filling the pond in 2013, up from one fifth in 2008, both indicating greater attention to maintenance of good water quality. In combination, these trends all point to a broad shift away from "traditional" low input forms of production, with capital intensification in the farm sector occurring in step with rapid growth, diversification and technological change in the feed and seed value chain segments.

12.4.4 Mirroring of Farm Capital-led Intensification: Growth and Technological Change in the Input Supply Segments

Capital intensification in the farm sector has occurred in steps with rapid growth and diversification in upstream value chain segments, most importantly feed and seed. As noted in Section 12.1, there has been a proliferation of feed mills, but overall a concentration of production in larger mills. Larger feed mills have multiple lines, and differentiate feed types for different fish species and age groups, by protein content, complementing the species differentiation taking place on farms and in hatcheries, in line with the product cycle. The most recent shift in feed mill technology has come about through the use of extrusion machinery to produce feeds that float instead of sink, providing further product differentiation, and offering efficiency gains to producers. Mamun-Ur-Rashid, Belton, Phillips, and Rosentrater (2013) find that from 2008 to 2012, production of formulated fish feeds almost trebled from 360,000 tons to an estimated one million tons. The share of floating feeds in total formulated feed production grew from less than 5 percent to close to 20 percent. The extrusion equipment used to manufacture floating feed represents a major investment. The size of mill and adoption of extrusion are closely correlated, and big mills dominate the floating feed supply. This factor may result in further concentration in the industry over time. The growing use of formulated feed has also seen rapid expansion in the number of fish feed dealers (both wholesalers and retailers) as noted in Section 12.4.1, and veterinary chemical/medicine input retailers.

Technological shifts have also occurred within the seed supply segment of the value chain. The product cycle is observed in hatcheries, mirroring farm production: The share of hatcheries reporting carps to be the most important species sold fell from 59 percent to 45 percent over 2008 to 2013, while the share of hatcheries reporting *pangasius* and *tilapia* (combined) as

their most important species rose from 15 percent to 20 percent, and the share of "niche" species jumped from 11 percent to 26 percent.

12.4.5 Reflections on the Policy Determinants of the Transformation

The government has played an important role in the early stages of some off-farm value chain segments. For instance, the first fish feed mill in Bangladesh was established in Mymensingh by SABINCO, a joint venture investment company owned by the Governments of Saudi Arabia and Bangladesh. This arguably provided proof of concept for private investors. The government has also played a role in the hatchery sector. For instance, Bangladesh Fisheries Research Institute (BFRI) in Mymensingh was central to the development of *pangasius* and *koi* farming by establishing and disseminating spawning protocols for both species, and importing *pangasius* brood from Thailand. Several universities and a large number of colleges offer fisheries and aquaculture degrees, providing graduates to the private and NGO sectors.

Other than these types of investments, sector specific policies and regulations have had little effect for the most part. There are laws intended to govern both the hatchery and animal feed sectors, but these are widely recognized to be poorly enforced. There has been, however, some continuity in the pro-business outlook of consecutive governments, despite frequent political instability. Policies friendly to foreign direct investment help to explain the high level of foreign ownership in the feed mill sector. However, the cost of doing business in Bangladesh is high, and this likely contributes to the high level of informality among small and medium-sized enterprises (SMEs). Similarly, legal recourse to contractual enforcement is poor, which again is likely to account for the predominance of informal trust-based coordination between value chain actors, in preference to formal contractual relations.

Despite Bangladesh's highly developed NGO sector, and large number of NGO-led aquaculture programs implemented over several decades, it is notable that NGOs have played a rather limited role in the development of the aquaculture value chain in Bangladesh, with the biggest impacts derived from the earliest projects, before "take-off" had occurred.

Nonetheless, successive governments have invested in infrastructure (rural roads, water management schemes, power generation). Telecommunications also grew following the sector's liberalization. These have likely been the most important non sector-specific policy changes. Agricultural land is privately owned and the government adopts a *laissez faire* approach to land use (e.g., there are no regulations in place on the type of crops that must be produced

on specific types of land). This in part accounts for the rapid growth of ponds, as fish farmers have been unencumbered by such restrictions. Microcredit provided mainly by the vibrant NGO sector is abundant, but is rarely invested in fish farming due to insufficient loan sizes and inconvenient loan repayment schedules. Growth of off-farm employment opportunities has likely fueled investments in fish farms through savings, but it is difficult to pinpoint a specific responsible policy, other than some of the general ones that similarly affect investments in fish farms.

12.5 Conclusions

The study has produced a single, powerful finding: the fish value chain in Bangladesh is growing and transforming very rapidly, in all segments. The quiet revolution in the fish value chain is a domestic market revolution. Dynamism of the aquaculture value chain in Bangladesh is shown in two inter-linked ways.

First, there has been a tripling of volumes and actors in all the segments of the value chain over the past decade. Second, there has been rapid capital deepening in the form of investments by hundreds of thousands of actors in the fish value chain; apparent in a great jump in feed use, investment in equipment and pond construction, and investments in mills, hatcheries and vehicles. These investments have been made by, and provided opportunities for, a multitude of smallholder farmers and small and medium enterprises throughout the chain.

Second, there has been diversification and specialization beyond carps into production of commercial species such as *tilapia* and *pangasius* catfish, which have raised yields and helped to move the fisheries sector along the "product cycle." One important positive externality of this process has been a reduction in the price of farmed fish over time, making an important contribution to food security.

This growth has been oriented towards the domestic market, as very little of Bangladesh's farmed fin-fish is exported. Unlike in the global value chain literature (which deals primarily with changes in value chain organization and conduct associated with adoption of standards and contracts driven by buyers and NGOs in developed country markets), we identify very little change having taken place as a result of the imposition of standards and contracts.

Policy has played some role in facilitating this growth, in particular through early investments in fish seed production, as well in electricity and road infrastructure in rural areas. A *laissez faire* policy in terms of crop choice has also been important. However, the direct influence of

government and NGOs in "causing" this quiet revolution has been relatively minor in comparison with the investments of millions of farm households and small and medium enterprises. Policies and investments that support a broad enabling environment for a wide variety of businesses (e.g., rural infrastructure development and minimization of regulatory constraints to enterprise start up and growth) will generally be of greater importance than those that aim to solve sector or segment specific problems. This can include things that government does not do, as much as those that it does (e.g., not restricting conversions of agricultural land to ponds).

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