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Shrimp aquaculture technology change in Indonesia: Are small farmers included?

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ABSTRACT

This study examines the adoption of (1) *P. vannamei* and (2) adoption of formulated shrimp feeds, both technologies critical to increasing productivity of shrimp farming in Indonesia. The primary objective was to identify if land-poor or capital-poor farm households were excluded in adopting *P. vannamei* and/or the adoption of feed. The study used primary data we collected in Indonesia to estimate adoption equations. We found: (1) There is no evidence for farm-scale barriers in the adoption of *P. vannamei*. (2) The lack of productive assets (pumps for example) is a significant constraint to adoption of *P. vannamei* and shrimp feed. This may constitute a "low-productivity trap" in aquaculture – with the asset-poor relegated to producing the unproductive *P. monodon* without external inputs. (3) In the adoption of feed, there is a strong threshold effect at half of a hectare. Micro-farms are a unique subset of the farming population that are oftentimes the most productive in farming a local species, like *P. monodon*, but are constrained in fully-intensive adoption of novel production systems. There are two implications for policy. First, policies that encourage the development of hatcheries and feed mills in small farmer areas will promote productivity and modernization of small shrimp farming. The second is that constraints to capital assets like pumps limit small farmer adoption of new technologies. Promotion of financial markets that help small farmers to invest in these productive assets will open doors to technological change in small farming areas.

Statement of relevance: This study focuses on adoption of a shrimp species new to small farmers in Indonesia, as well as adoption of feed. Contrary to conventional wisdom we found that small farmers adopted both, without land constraints affecting diffusion, but productive capital constraints hold back small farmers from adoption.

1. Introduction

Brackishwater aquaculture is believed to have started in Indonesia in the 1400s (Nash, 2011). It continued as an activity of coastal village households who produced mainly fish and some shrimp trapping wild shrimp larvae for grow-out in impounded water in mangroves. Eventually the farmers removed the mangroves and constructed dykes. They produced fish and shrimp without use of pelleted feed, just using the algae of the ponds. This "traditional, extensive technology" continued for centuries, present in the modern era among small farmers (Cremer and Duncan, 1979; Rimmer et al., 2013).

After a long gradual development of nearly seven centuries, in the 1960s–1980s shrimp aquaculture suddenly and steeply "took off" in Indonesia. This kind of abrupt economic transformation and technological change has been common in various sectors in the past century. The takeoff of aquaculture modernization was due to several reasons.

(1) In the 1960s and 1970s the traditional technology of shrimp farming started to change with the introduction of new technologies from Japan and Taiwan, for example the mass production in hatcheries of shrimp post-larvae to stock ponds and the use of formulated shrimp feeds.
(2) In the mid-1970s the government encouraged adoption of *P. monodon* shrimp (tiger shrimp) for aquaculture due to its high market value and demand in Japan (whose booming economy in the 1980s led to soaring imports of shrimp, Rimmer et al., 2013) and the US; *P. monodon* grew to be by far the leading species by the 1980s (Yusuf, 1995; Nash, 2011). A spur to aquaculture as compared to capture fisheries for shrimp was caused by overfishing leading to banning of coastal trawlers in 1980. Moreover, the government invested in water canals and *P. monodon* hatcheries in the 1980s (Wahyono, 1989).
(3) In the mid to late 1980s the government encouraged with regulations and land grants the emergence of the "nucleus-estate, small-scale out-growers scheme" (NESS) where shrimp companies entered into contract arrangements with small farmers, supplying them water, electricity, finance, and technical assistance. This led to 350 medium to large companies thus engaged by

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1990. In addition many other actors emerged along the shrimp value chain – large numbers of feed mills, hatcheries, and cold storages (Yusuf, 1995). The government also then liberalized foreign investment in shrimp farming, opening the door for example to Charoen Pokphand, one of the largest agribusinesses in Asia, to open the largest shrimp production scheme in the world (Central Proteina Prima in Indonesia, CP Prima, 2015). The upshot of 1–3 above was a huge growth of shrimp aquaculture, to 250,000 ha by 1988. (Compare that with 682 thousand in 2011 of brackishwater and 147,000 ha of freshwater ponds, KKP, 2011).

However, in the 1990s the intensification with densification of *P. monodon* farming led to an outbreak of the White Spot Syndrome Virus (WSSV) that severely depleted *P. monodon* aquaculture over the decade (Kusumastanto et al., 1998). To counter the trend, the government permitted the import of *P. vannamei* broodstock in 2000; in 2001 the government enacted a Ministerial Decree "Releasing *Vannamei* Shrimp as the Superior Variety of Shrimp," which decree controlled production and distribution of the species.

The government and the shrimp companies believed *Penaeus vannamei* to be resistant to WSSV, and to have other advantages over *P. monodon*, to wit, increased tolerance to high stocking densities, improved feed conversion rates, higher average daily growth rates, tolerance to a larger range of water salinity and temperature, and production of output with more consistent quality and size. Its success motivated rapid diffusion (Budhiman et al., 2005).

Fig. 1 shows the consequences of introduction of *P. vannamei* coupled with ongoing limitations of *P. monodon*. From about 50,000 tons of *P. vannamei* produced in 2004 output quintupled to 250 thousand in 2011; but *P. monodon* output stayed at roughly 130–140 thousand the whole period (FAO, 2014). The combined growth (doubling from nearly 200 to around 400 thousand, with the great majority exported) mirrors the rapid growth in aquaculture (shrimp plus fish plus seaweed), with aquaculture growing at 30% per year compared with capture fisheries at 2% per year (Rimmer et al., 2013).

This strong growth of brackishwater aquaculture is reflected in the growth in numbers of farmers, from about 482 thousand in 2006 to 553 thousand in 2010 (KKP, 2011). While output grew 30% per year, farmer numbers only grew 3% per year, indicating a gradual increase in average scale of shrimp farmer. However, the large number of farmers masks strong concentration over farms in terms of overall volume. Mudde (2009) for example posits that just three companies (with own and out-grower production) are responsible for 70 to 80% of shrimp output in Indonesia, while 15% come from medium scale enterprises (such as the 50–100 ha operations of the several hundred companies in the "Shrimp Club of Indonesia, SCI, 2009), and the rest,

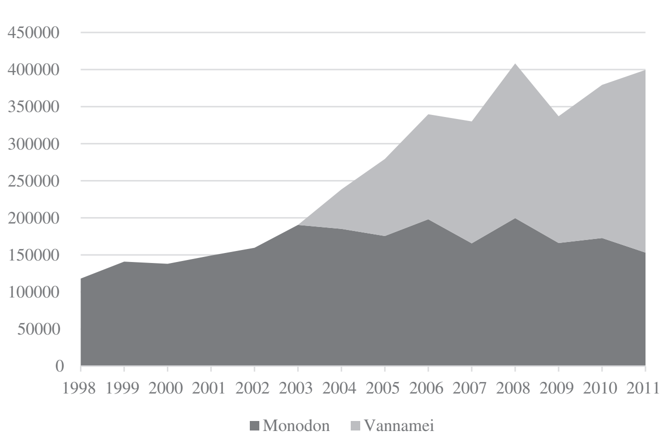

Fig. 1. Aggregate output in Indonesia overall and by species (MT).

only some 5–15%, is from small farmers that are considered to be traditional technology farmers (a key point discussed below).

Moreover, there is posited by the literature to be a fundamental "dualism" in the shrimp farming sector in Indonesia (Rimmer et al., 2013; Padiyar et al., 2012; Zainun et al., 2007; MMAF, 2006; Bosma et al., 2012; Hall, 2004; Muluk and Bailey, 1996; Chamberlain, 1991). This literature posits that there are two general categories of farmers:

(1) small "independent" farmers (not in contract grower schemes) that use "traditional" "extensive" technology (little or no feed from feed mills, *P. monodon* species, and little water control equipment like pumps and aerators), practice polyculture (milkfish with shrimp) or monoculture of shrimp, get post-larvae from the ocean and not from hatcheries, and have low stocking rates;
(2) medium or large farmers (or contract grower small farmers assisted by companies) that use semi-intensive or intensive technologies (with substantial feed from feed mills, *P. vannamei* species, water control with pumps and aerators, monoculture, high stocking rates, and purchase post-larvae (PL) from hatcheries).

The general tendency of the literature is summed up by Rimmer et al. (2013) and Mudde (2009) who hypothesize that there has been none or very little intensification by small farmers – hence little mixing between the two categories noted above – in terms of adoption of *P. vannamei* and use of feed from feed mills, the two "indicators" of taking the path toward modernization.

However, to our knowledge there has been no survey-based test of this hypothesis. While Briggs et al. (2004) documented the diffusion of *P. vannamei* shrimp at aggregate national levels, there is little known regarding the household decision to adopt *P. vannamei* or adopt shrimp feed. The existing studies in shrimp aquaculture have focused primarily technical aspects of production for the *P. monodon* shrimp species (Gunaratne and Leung, 1996; Sharma and Leung, 2003), and; *P. vannamei* as well (Yu and Leung, 2010).

This then forms the central questions of our paper: do small farmers intensify their farming systems, and what are the determinants of their so doing? We add depth to the question by decomposing "intensification" into its two main behavioral components: (1) intensification by shifting to the *P. vannamei* species, and; (2) intensification by adopting formulated shrimp feeds. Then proceed to test for farm-scale and non-land asset effects in the adoption of the more productive *Litopenaeus vannamei* shrimp post-larvae and the adoption of formulated shrimp feeds, the two critical inputs that are driving intensification of production systems and overall growth in the shrimp industry of Indonesia.

These question are of particular interest in terms of the modernization of smallholder aquaculture in LDCs. While *P. vannamei* is largely assumed to be only beneficial in intensive systems, this may not be the case in many LDC contexts where resource constrained farmers have been known to find creative and unexpected ways of using new varieties that fit their context and capabilities. For example, there are many cases of farmers in Asia increasing yields by using expensive hybrid seeds without applying the very fertilizers the variety was designed to respond to. We employ logic parallel to that latter point by examining if smallholders are able to adapt *P. vannamei* to fit their needs, potentially by using less feed or not using aerators; and, furthermore, to explore what factors are preventing household farms from adopting feed to unlock *P. vannamei*'s yield potential.

The research question is also of interest to the general literature on agriculture in economic development. It links to the emerging literature on aquaculture in poverty reduction and economic growth (Smith et al., 2010), with particular concern for smallholder farms (Belton et al., 2012). It also links to the longstanding literature on whether and to what extent and with what determinants small farmers can adopt modern technologies (Feder et al., 1985; Byerlee et al., 2009).

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