Vertical Coordination and Aquaculture Farm Performance: The Case of Catfish Sector in Vietnam

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Using an original dataset from the Vietnamese catfish sector, I analyze the impact of vertical coordination options, namely contract farming and vertical integration on farm performance. Farm performance is measured in terms of yield and revenue per hectare. The effects of vertical coordination are estimated using a maximum simulated likelihood estimator and a two-stage least square regression with instrumental variables to account for exogenous farm and household characteristics and the sample selection bias. The results show that vertically integrated farms have substantially higher yields and revenue per hectare than non-integrated farms. The levels of gains, which can be attributed to integration, are large and consistent under different estimation procedures. There is no difference between non-integrated and contract farms in terms of farm performance.

1. Introduction

Global agri-food sectors typically rely on international standards and vertical coordination in governing transactions from production of raw commodities through processing, transport and storage to the sales of finalized products. Several mechanisms of vertical coordination, such as: spot market transactions, contracts or full vertical integration have received sizeable attention in recent years as they affect the ability of farmers from developing countries to benefit from participation in high-value sectors. It is argued that too costly and complicated conditions of participation marginalize smallholders (Reardon, Barrett, Berdfpegué, & Swinnen, 2009). At the same time, contract and integrated farms enjoy higher welfare than non-integrated farmers who sell in the spot market (Barrett et al., 2012; Dries & Swinnen, 2004; Miyata, Minot, & Hu, 2009; Warning & Key, 2002). Little has been said so far on the relationship between the forms of vertical coordination and farm performance. Given that different forms of vertical coordination affect the conditions of farmer participation in high-value export sectors, understanding the effect of vertical coordination on productivity is crucial for improving the smallholder welfare in developing countries.

Allen and Lueck (1998) argue that the nature of the production system determines which form of organization in a specific sector will be more efficient. Vertically integrated farms will be more efficient in sectors where it is easier to mitigate seasonality and random shocks to output, while independent, family farms have advantage in riskier sectors and in sectors where monitoring labor effort is easier. The former case is found in capital intensive, less seasonal sectors, such as poultry and livestock production and the latter in crop production. The empirical evidence shows that family farms were significantly more productive than corporate farms (Mathijs & Swinnen, 2001). Also, contract farms can be more productive than independent farms if the contracts improve managerial efforts, increase knowledge and technology transfer or provide resources that directly increase output. For example, contract farms who receive fertilizer and compost will have better soil fertility and thus productivity than independent farms, as in the case of rice sector in Madagascar (Minten, Randrianarison, & Swinnen, 2009). To my knowledge, there are no studies that explore the link between the form of sector organization and farm performance in aquaculture.

I analyze the impact of different forms of vertical coordination on farm performance using the case of a large aquaculture sector, that of the striped catfish sector in Vietnam. In particular, I compare the yield and revenue outcomes on non-integrated, contract and vertically integrated catfish farms. Catfish is a farmed freshwater fish that can be found under several other names: pangasius, swai, basa, river cobbler or iridescent shark. This sector is relevant for the study of vertical coordination outcomes for several reasons. First, this fish is sold in more than 100 countries, yielding over 1 million metric tons of output and around USD 1 billion in revenue (Phuong & Oanh, 2010). Second, the sector has received a modest research attention. Recent studies have primarily focused on characterizing the sector and analyzing the political-economic factors that shape the industry (Belton, Little, & Sinh, 2011; Loc, Bush, Sinh, & Khiem, 2010; Ponte, Kelling, Jespersen, & Kruijssen, 2014). Third, the organization of the sector has changed dramatically in the past five years. Bosma et al. (2011) report a large increase in the number of vertically integrated farms, that is, farms who are established or owned by processing companies. These changes may have significant social welfare costs or benefits depending on how integration affects farm performance.

The paper contributes to the literature on participation in modern agri-food sectors with contract farming and vertical integration in three more ways. First, I simultaneously assess the effect of two vertical coordination forms on productivity. Previous studies have investigated these effects separately for contract and vertically integrated farms. For example, Minten et al. (2007) have found higher productivity on farm plots with a contract compared to those plots without a contract, while Dries and Swinnen (2004) attribute significant improvements in productivity to vertical integration in the Polish dairy sector. Key and McBride (2003) measure the impact of contracts on partial and total factor productivity of the U.S. hog farms. They find that production contracts lead to significant increase in factor productivity compared to independent production. Second, unlike the studies that compare producers in the export sector with producers that only sell in the domestic market (for example, Maertens & Swinnen, 2009), I estimate the outcomes for three groups of farmers that all participate in the catfish export sector and only differ by the vertical coordination status. This enables overcoming the challenges of confounding the effect of vertical coordination with the effect of export market access. Finally, I control for the unobservable farm and household characteristics using the maximum simulated likelihood estimator with instrumental variables developed by Deb and Trivedi (2006).

The results show that farm performance depends on the organizational structure in the catfish sector in Vietnam. Vertically integrated farms have higher yields and revenue per hectare than non-integrated farms. Conversely, there is no difference in performance between contract and non-integrated farms. These results highlight the advantage of large scale aquaculture and the need for improving capabilities of smallholders if they are to remain participating in the sector.

2. Vertical coordination and farm performance

Linkages between transacting parties can range from spot markets to hierarchies, also called full vertical integration, with a range of vertical coordination arrangements, such as: contracts, strategic alliances, partnerships, joint ventures and non-profit organizations. These different types of arrangements set up as a response to uncertainty and information asymmetries between market actors. Coase's (1937) concept of transaction costs is used to explain the decision of organizing transactions within the firm (vertical integration) as opposed to open market. Transacting in open market includes costs, such as discovering prices or enforcing contracts that would be reduced if undertaken within the firm, which then assumes integration of adjoining market functions. As the internal organization may induce problems of information flows, incentives and monitoring, the nature of the firm is determined by the relative cost of organizing transactions under alternative institutional arrangements (Klein, 1998). Transacting parties will choose vertical integration if the costs of organizing transactions within a firm are lower than the costs of organizing transactions through market relations (Joskow, 1988; Klein, 2008; Masten et al., 1991; Williamson, 1975).

Downstream customer demands for maintaining strict quality and quantity schedules can additionally incentivize vertical integration (Maertens and Swinnen, 2009). Facing strict food regulation in destination markets and domestic credit market imperfections, farmers from developing countries often receive support from downstream buyers in the form of training, trade credit, input supply or technical advice. Vertical coordination can thus be seen as a means to guarantee loyalty of suppliers or as a tool for maintaining the necessary product quality and quantity. From these rationales for vertical coordination, it follows that the choice of arrangements under which a farmer participates in global markets can affect farm performance, measured as either productivity or revenue.

Several channels have been identified through which integration enhances productivity, among which improved logistics coordination, technological synergies and efficiencies in asset use are commonly cited (Alfaro et al., 2010; Hortacsu and Syverson, 2007). In addition, higher productivity can be attributed to vertical integration in sectors in which seasons are not highly important and sectors which demand high levels of capital (Allen and Lueck, 1998). The analysis of restructured former state enterprises in Germany, however, shows that family farms are significantly more productive than corporate farms (Mathijs and Swinnen, 2001). This implies that the expected effect of vertical integration on productivity is ambiguous.

Having a contract with a processing company can also change farm performance. Supplying inputs to farmers relieves them to a certain extent from credit constraints, potentially leading to higher investments and more efficient use of inputs (Key and McBride, 2003; Minten et al., 2007). Sensitivity of a sector to requirements about product quality and safety also matters. If after the implementation of quality standards, downstream companies face shortages of sufficient quantities of high-quality inputs, which may lead to under-utilization of their processing capacity, they are likely to initiate a range of activities for upgrading and increasing production on farms (Fałkowski, 2012). However, aquaculture requires sizeable investments in specific assets, which increases vulnerability of farmers with respect to downstream processing companies and buyers in case of market and corresponding contract terms changes. Large investments in assets made because of a contract may decrease the bargaining power of contractees with respect to contractors, leading to less than optimal investment levels and lower productivity (Shelanski and Klein, 1995). Weak legal institutions can also undermine farm performance. As described for several transition and developing economies, late payments by processing companies are a well-known problem claimed to have a negative impact on farm investments as the appropriate sanctions for contract violations cannot be implemented (Bigsten et al., 2000; Gow and Swinnen, 2001; Herck et al., 2012). Thus, whether one can predict the effects of different forms of vertical coordination on farm performance in the context of an emerging economy is an open empirical question.

3. Data and descriptive statistics

The analysis is based on the data obtained through farmer survey and qualitative interviews. The data collection took place from April through June 2011 in Mekong River Delta, Vietnam. Qualitative interviews included 52 interviewees with specialized knowledge about the sector, while the survey comprised 276 catfish farmers. The total number of catfish farmers in Vietnam – and thus the sampling frame – was not known at the time of the survey. However, the communes where catfish production takes place could be identified from the 2005 Agricultural Census. Using this information to locate catfish farmers, 47 communes were randomly selected in three provinces: Can Tho, Dong Thap and An Giang. After the communes had been identified, the commune staff or the officers of the Department of Agriculture and Rural Development have lead the research team to individual farms. The goal was to interview all catfish farmers in a given locality, but this was not achieved, leaving the non-response rate of 22 percent. The questions in the questionnaire referred to the respondents' situation in 2010. Apart from basic household and demographic information, the survey data contains information on production characteristics, asset ownership, marketing choices, infrastructure, expenditure and consumption. Among the surveyed farmers, 66 reported that they did not produce market-sized catfish in the previous year, but larvae or fingerlings, which are sold to other farmers for grow-out. Further, 26 farmers have not responded to questions about output quantity and 16 have not responded to questions necessary to calculate the revenue from catfish farming. These farms were excluded from the dataset, leaving thus 168 farms for the analysis.

Table 1 shows the key indicators of farm performance, namely yield and revenue per hectare of the production surface, as well as the key household and farm information separated by three forms of vertical coordination. The sample comprises 56 non-integrated, 57 vertically integrated and 53 contract farms. These farm categories are mutually exclusive, meaning that farmers cannot belong to more than one out of three groups in total, reflecting an impartial commitment to contracting or working on a processor-owned farm. Earlier studies show evidence that farmers can allocate one part of their land and labor to contract crops while working independently on non-contract crops (see, e.g., Maertens and Swinnen, 2009). The catfish sector in Vietnam differs because farmers dedicate the whole production area either to contract farming or full-time employment on processor-owned farms. This arises because almost 95% of catfish is exported, the main marketing channel being through processing companies, with almost non-existing opportunities to sell locally (Belton et al., 2011).

[Table 1 around here]

Comparing the three farm types, it is visible that vertically integrated and contract farms have higher yields and revenue per hectare than non-integrated farms, as indicated by the *t*-test. [1]Vertically integrated farms are the largest (measured by the pond surface) and they are run by the youngest farm operators. All farm types use similar amount of labor. Both contract and vertically integrated farms spend more on feed than non-integrated farms. The cost of feed on vertically integrated farms is the highest, which could be due the sole reliance on industrial feed or different growing methods. Contract farmers have the highest rate of completing formal education and they are the most active in attending village meetings. Vertically integrated farmers have the lowest share of off-farm employment in the household. Farms do not differ significantly in terms of the proximity to the nearest road.

[1] Note that the non-integrated farms are the base category and that vertically integrated and contract farms are compared to non-integrated farms.

4. Estimation Strategy

The objective of the paper is to estimate the impact of vertical coordination, I_i, on farm performance, Y_i. Obtaining the causal impact is made difficult by the fact that the vertical coordination outcomes are not independent of household and farm characteristics, so the endogeneity problems need to be accounted for. The estimation has two parts. First, I identify farm and household characteristics that determine different vertical coordination options. Then, I compare the farm performance outcomes for different vertical coordination options. The observed alternatives are non-integration ($j = 0$), whereby farmers sell on the spot market; vertical integration ($j = 1$), whereby processing companies establish their own farms and contract farming ($j = 2$), whereby farmers sign either production (resource providing) or marketing contracts with processing companies.

The production contracts specify which inputs (fry, fingerlings, feed and medicines) processing companies supply to the farmer and which quantity of fish farmers need to deliver to the processing company. These contracts also describe the production process, which should follow the prescribed hygiene and management rules. Marketing contracts are more frequent (83 percent of contracts in the sample). They only specify quantities and price, with the price depending on the results of the quality test performed right before the purchase. Farms are classified as vertically integrated for the purpose of this paper if the ownership share of processing companies exceeds 50 percent. These farms can be run by catfish farmers who decided to forego farming on their own or they can be run by managers and employees appointed by processing companies. Processing companies started establishing their own farms faced with the insufficient capabilities of independent farmers for assuring quality and complying with regulation in export markets. The trend for integrated, company-owned farms has also kept high due to the need to assure stability in fish supply, which was made difficult by low contract enforcement capabilities.

That these three groups of farms are comparable is assured by the fact that almost total catfish production is exported, so all three groups of farmers sell in the same marketing channel. Of course, conditions under which the participation in the sector takes place are different. This allows me to minimize the problem of confounding the effect of vertical coordination with the effect of participation in two different marketing channels: selling in domestic or export markets.

The choice about contracting or vertical integration and the resulting outcomes for farmers depend on transaction costs, perceptions of the alternatives and, perpetuated by the weak contract enforcement, social norms, trustworthiness, reliability or reputation. These are unknown to the researcher, but processors can find ways of obtaining such information, or some specific indicators that reveal such information. To account for the unobservable factors that are important in decision-making and behavior and thus establish causality, I use the maximum simulated likelihood (MSL) estimator proposed by Deb and Trivedi (2006).

To estimate the outcome for contract and vertically integrated farms with the outcome for non-integrated farms, I use the following model:

$$Y_i = \boldsymbol{\beta x}_i + \rho_1 I_{i1} + \rho_2 I_{i2} + \lambda_1 t_{i1} + \lambda_2 t_{i2} + \varepsilon_i \qquad (1)$$

where Y_i is yield from farm i in the year 2010 in the first specification and revenue from catfish farming in 2010 in the second specification, $\boldsymbol{x_i}$ are the observable household and farm characteristics and the coefficients ρ_1 and ρ_2 are the average effects of vertical coordination on yield and revenue. As the decision about vertical coordination is made with future output and revenue in mind, the vertical coordination status is most likely not exogenous. If I_1 and I_2 are not exogenous, the result would show inconsistent estimates of ρ_1 and ρ_2. In equation (1), I denote as t_{ij} the unobservable characteristics that influence at the same time coordination decision and farm performance. Likewise, I denote the coefficients associated with unobservable characteristics as λ_j. Thus, the estimated effect of vertical coordination can be considered as the causal effect conditional on the control characteristics in $\boldsymbol{x_i}$ and t_{ij}. Finally, ε_i stands for the independently distributed random error.

The first dependent variable used in the estimation is the yield of catfish, calculated as yearly output per total pond surface area in hectares. The second dependent variable used in the estimation is the revenue from catfish per hectare measured in local currency, Vietnamese Dong (VND). The yearly measures of both variables were used as the harvest takes place two times per year over a couple of days, making it likely for the farmers to be able to recall this information with acceptable reliability. Moreover, 83% of the surveyed farmers keep production records, which further supports the choice of aggregate measures.

The controls, $\boldsymbol{x_i}$, include a range of observable household and farm characteristics, which are described in Table 2. Farm resource endowments are potentially positively related with productivity and vertical coordination. Larger farms are probably more attractive to processors as they enable benefiting from economies of scale (Maertens and Swinnen, 2009). However, in developing countries, farm size is found to be negatively correlated with yields due to factor market imperfections or omitted variable estimation bias (Barrett et al., 2010; Benjamin, 1992). This means that it is not known in advance what direction the relationship between farm size and productivity will take. The farm size enters the estimation function in the form of the surface of the aquaculture area. The estimation also controls for the use of two most important production inputs, labor and feed. The feed is measured as the cost of feed used per hectare of pond surface.[2] The expected relationship between the labor endowment, measured as a sum of household and hired labor, and productivity is positive.

Individual farmer and household characteristics (for example age and education) may also affect the probability of vertical coordination and farm productivity. In the context of this study, it is expected that younger and better-educated farmers have greater chances of benefiting from contracts and employment on the estate farms, as found in previous studies (Barrett et al., 2012). To capture the potential exposure to information about specific interventions that would favor different vertical coordination options and productivity, I use the variable for off-farm employment and the variable for attendance of village meetings. It is expected that farmers who are better connected experience higher productivity gains, as shown in the case of the new agricultural technology adoption (Conley and Udry, 2010).

As processing companies may have specific preferences for contracting or establishing farms in convenient locations, it is important to account for the possibility of a location bias. To control for the influence of location, I use the distance to the nearest road in kilometers, which enters the estimation exogenously as it primarily captures the potential exposure to information about different vertical coordination options. While living in a specific location may determine farmer's exposure to the information about vertical coordination, it may not affect how much the farmer will profit from it as fish is exclusively transported by water. I expect to find a negative relationship between farm performance and distance from the nearest road, which indicates overall remoteness from major markets, services and sources of information.

[2] The cost of fry and fingerlings does not enter the estimation as the overall contribution to the total production costs seems negligible according to previous studies (Bui et al., 2010). Around 5% of farms produce fingerlings on their own and 13% have not responded to the question about these inputs, so including this variable would further decrease the sample size.

The estimation of the impact of both forms of vertical coordination (contracts and vertical integration) on farm performance is done jointly, as in Deb and Trivedi (2006). When $\rho_1 > 0$, vertically integrated farms perform better in terms of yields and revenue than non-integrated farms, on average, and when $\rho_2 > 0$, contract farms perform better on average than non-integrated farms. This approach allows for comparing the effects of two forms of vertical coordination and directly interpreting the selection effects through factor loadings λ_1 and λ_2. If $\lambda_1 > 0$, the unobserved characteristics that incentivize vertical integration are associated with better on-farm performance. If, for example, integrated farms are managed better, $\lambda_1 > 0$ shows the indication of positive selection. Conversely, $\lambda_1 < 0$ points to adverse selection. Analogous interpretations apply to λ_2 with respect to vertically integrated farms.

The endogenous decision about vertical coordination, namely contracting or vertical integration, needs to be instrumented to correct for selection bias. I use two instrumental variables to account for two forms of coordination. Based on the evidence of the strong influence of social collateral and information on vertical coordination outcomes (Reardon et al., 2009), the right instruments should account for network and information effects. The underlying assumption is that the costs of search, selection, information, procurement and investment decrease with the knowledge about primary production and the proximity between farmers and processors. Therefore, the tendency to contract or vertically integrate is expected to increase when farmers and processors are closely located and when it is easier to obtain information about each other. Also, in previous studies on contract farming, the instruments were, in one way or another, indicators of social capital, information or transaction costs. For example, Bellemare (2012) uses a randomly assigned hypothetical measure of farmers' willingness to pay for participation in contract farming, Rao and Qaim (2011) use the membership in a farmer group, Miyata et al. (2009a) use the distance between respondent's farm and the farm of the village leader, Roy and Thorat (2008) use a direct measure of transaction costs related to the purchase of inputs and Warning and Key (2002) use measures of respondent's trustworthiness.

I use two location-specific variables as instruments, because the occurrence of vertical coordination in a certain area might imply lower costs and more knowledge for both processors and farmers. First, I expect a higher likelihood of new vertically integrated farms in locations where processors have already established farms, assuming that processors will face lower cost of establishing new farms and links with farmers in familiar localities. I use the number of processing companies in a specific district as the second instrumental variable. Second, I expect a positive relationship between the history of contracts in a certain village and subsequent occurrence of contracts, so the first instrument I use is the number of years since the first contract was signed in a specific village. Both of these instruments enable decreasing the estimation bias that may come from unobserved characteristics that simultaneously affect farm performance and a decision about which vertical coordination option to pursue. The incidence of different forms of vertical coordination in a particular area in previous years can be considered exogenous with respect to individual-specific unobservable factors and farm performance, thus enabling to minimize the endogeneity bias.

5. Results

5.1. Determinants of Vertical Coordination

In this section, I show which variables determine the vertical coordination status of the farm. As Table 2 shows, the vertical coordination depends on several household and farm characteristics. Columns (1) and (2) show results from the multinomial logistic regression; columns (3) and (4) show the first stage results from the MSL model, while columns (5) and (6) show the equivalent for the two-stage least squares (2SLS) estimation with instrumental variables. The results of three models are fairly consistent in terms of signs and significance of control variables.

All three model specifications show that the aquaculture area size is positively correlated with vertically integrated farms, but negatively correlated with contract farming. This is consistent with the analysis of mean differences in Section 2 that has shown that contract farms have the smallest ponds. Vertical integration is more likely for younger farmers, while contracts seems appealing to better educated farmers. The higher catfish price observed at the village level increases the likelihood of contract farming.

[Table 2 around here]

The instruments significantly predict the vertical coordination outcomes. The first instrument, the share of vertically integrated farms in a specific village, positively predicts vertical integration in all estimations, as shown in columns (1), (3) and (5). At the same time, the presence of contract farms in a specific village negatively predicts vertical integration, most likely pointing to high competition among processing companies when establishing farms in specific locations. The second instrument, the number of years since the first contract has been signed in a village, significantly predicts contract farming in all specifications, as shown in columns (2), (4) and (6). This may arise because early adoption of contract farming in a specific village can increase the probability of contracting more farmers in the future. At the same time, longer experience with contracts in a specific location can decrease the probability of establishing estate farms, as shown in columns (1), (3) and (5). The *F*-statistic for a test of joint significance of the two used instruments is 7.40, indicating no concerns over the weak instruments (Stock and Yogo, 2005).[3]

5.2. Farm Performance and Vertical Coordination

Table 3 shows that the performance of catfish farms depends on the farm type and the relationship is observed in OLS, treatment MSL and 2SLS regressions. Using different estimators, I show in panel (a) that vertically integrated catfish farms have significantly higher yields than non-integrated farms. The OLS regression estimate is 0.48, indicating 62% higher yields on vertically integrated farms. Controlling for the unobserved heterogeneity with the MSL estimator, I obtain almost identical coefficient, while the coefficient obtained in the 2SLS regression in column (3) is 0.535, indicating somewhat higher effect of 71%. In contrast, the yield on contract farms is not statistically different from the yield on non-integrated farms in any specification.

Panel (b) in Table 3 shows that vertically integrated farms have significantly higher revenue per hectare than non-integrated farms. The OLS and the MSL estimations show 74% higher revenue on vertically integrated farms in in columns (4) and (5), while the 2SLS regression in column (6) shows 101% higher revenue on vertically integrated farms. These results affirm earlier findings of higher returns on integrated fish farms, such as in the case of hybrid striped bass in Gempesaw II et al. (1992). Just as in the case of yields in panel (a), contract farms do not show significant advantage over non-integrated farms in terms of revenue.

[Table 3 around here]

Earlier studies have attempted to measure the impact of contract farming and vertical integration on household welfare (Bellemare, 2012; Maertens and Swinnen, 2009; Miyata et al., 2009b; Warning and Key, 2002). They have thus far established that contract farming and employment on industrial farms lead to significant income gains for farmers from developing countries. In addition,

[3] At 7.40, the F value is higher than critical values proposed by Stock and Yogo (2005), indicating consistent instrumental variables. Stock-Yogo weak identification test critical values are: 7.03 at 10% maximal IV size; 4.58 at 15% maximal IV size; 3.95 at 20% maximal IV size and 3.63 at 25% maximal IV size.

significant gains in productivity have been attributed to contract farms (Key and McBride, 2003; Minten et al., 2007) and integrated farms (Dries and Swinnen, 2004). This paper supplements the earlier literature by finding gains in yields and revenue for vertically integrated farms.

Looking at the control variables, Table 3 shows a negative relationship between the yield and the size of aquaculture production area in panel (a) and a negative relationship between the revenue per hectare and the production area in panel (b). However, as the dependent variable in panel (a) is yield, calculated as output per hectare (aquaculture area size) and revenue per hectare in panel (b), the true coefficient size is obtained by adding one to the coefficient estimate, showing that larger farms are more productive.[4] Next, Table 3 shows, as expected, a positive relationship between labor endowment and yields in panel (a) and a positive relationship between labor and revenue in panel (b). This relationship holds in all specifications. Table 3 further shows that farmers operated by younger farmers are likely to achieve higher revenue.

In the absence of perfect instruments, the results with the presented instruments could still contain some endogeneity bias. This is likely to be small, first, because the chosen instruments performed well in the *F*-test and second, because the coefficient sizes between different estimation methods do not differ a lot, being within 10% of each other in the yields estimation and within 20% in the revenue estimation.[5] The OLS and MSL estimations returned almost identical coefficients, while the 2SLS estimation returned slightly higher coefficients in all estimations. This could indicate a potential downward bias in the OLS estimation, which could come from the unobservable farm and household characteristics. The lower section of Table 3 shows the MSL estimates of the unobserved heterogeneity bias. Selection on unobservable characteristics seems important for both vertically integrated and contract farms. The effect of the unobservable characteristics, λ_1, in case of the vertically integrated farms is negative and significant in panels (a) and (b), indicating a negative selection into vertical integration both in the estimation of yield and revenue. This indicates that the unobservable characteristics, which increase the probability of vertical integration also lead to lower farm performance. It could be that working on company-owned farms is more appealing to somewhat less capable farmers who at the time being would not be successful in farming independently. The sign of the latent factor λ_2 is positive and significant, suggesting that unobserved

[4] I thank the anonymous referee for pointing this out.

[5] Instruments at the farm level would perhaps have been more appropriate, but none of the potential farm-level instrumental variables in the dataset could meet all the criteria of instrument validity. In particular, the distance between the farm and the processing company as an instrument for vertical integration and the membership in a farmer union as an instrument for contract farming were tried, as they were used in previous studies (see, e.g., Miyata et al., 2009b; Rao and Qaim, 2011), but were found not to be correlated with vertical integration and contract farming.

characteristics, which increase the probability of belonging to the contract farming group also lead to better farm performance. This implies that contracts are appealing to more capable farmers.

6. Conclusion

The results show that vertically integrated farms have substantially higher yields and revenue per hectare than non-integrated farms in the Vietnamese catfish sector. It follows that with the same resources as non-integrated farms, vertically integrated farms can achieve higher yields and revenue. The levels of gains, which can be attributed to integration, are large and consistent under various estimation procedures. The results account for exogenous farm and household characteristics, self-selection bias and compared to previous studies, avoid confounding the effect of selling in two different marketing channels – domestic and export, as almost entire production is exported.

Better farm performance on integrated farms can be attributable to the ability of processing companies to manage the production process more successfully than independent farmers. Processing companies prefer growing catfish on their own farms over purchasing from independent farmers because in that way they can assure the right quality, decrease the risk of product failure and secure sufficient product quantities. This is achieved by better knowledge of the production process, the quality of credit and key inputs (such as feed), the access to right services on time (such as veterinary care to manage disease outbreaks) and the access to better infrastructure (such as dams that prevent overflow of ponds during the rainy season). The same results in terms of product quality and reliability of supply could be achieved with contracts, but the enforcement is problematic in Vietnam. These motives were also voiced strongly during qualitative interviews with processing companies.

The fact that contract farms are not more successful than non-integrated farms could be because true production contracts that entail not only the input provision, but also a guidance during the production process, are still not common in the catfish sector. The majority of contracts are pure marketing contracts that are signed just before the trade and do not include any components of knowledge transfer. Thus, to improve the farm performance, contracts should include the learning component.

The magnitude of the estimated gains in yields and revenue on integrated farms suggests that this was the likely cause of the increase in integration that was observed in recent years in the catfish sector in Vietnam. Because integrated farms are large, it follows from the results that their competitive position will continue to improve over the small producers. Indeed, some types of production have better efficiency if conducted on large scale. For example, Jaforullah and Whitman (1999) find that productivity of the use of inputs (technical efficiency) on dairy farms in New Zealand could be improved by increasing farm size. Based on the results presented here, it may appear that local policies should favor integration, as integrated farms can provide employment (see, Maertens & Swinnen, 2009). However, it is unsure whether all independent farmers can find satisfactory employment alternatives for catfish farming. So it would be premature to make recommendations in favor of greater integration based on this study alone because it does not contain information about the costs of a wider organizational reform in the sector. In spite of better performance of integrated farms, not all farms in the catfish sector should become industrial due to potentially negative welfare effects for the local economy. It seems equally appealing to let the non-integrated farmers catch up in terms of capabilities and technology.

The results come with some caveats. First, I classified the farms with either marketing or production contracts as contract farms, which could decrease the precision of the result. Second, the cross-section nature of the data does not permit the analysis of the effects over time. Instead of using the instrumental variables to account for unobservable characteristics and endogeneity, the analysis could be based on a panel dataset and obtain results with better efficiency and consistency. However, such a panel could not be found at the moment. Finally, due to the missing observations on several variables, the sample size included in the analysis is modest, but hopefully illustrative of the important changes in high-value aquaculture sectors in developing countries.

Tables

Table 1. Differences in farm characteristics for different vertical coordination options

Variables	Unit	All farms	Non-integrated farms	Vertically integrated farms	Contract farms
Yield (output per hectare)	ton/ha	354.79	312.18	368.58	384.98*
		(256.05)	(254.67)	(250.29)	(262.46)
Revenue per hectare	VND billion/ha	6.89	5.58	7.34**	7.79**
		(5.30)	(4.67)	(5.07)	(5.97)
Aquaculture area size	Hectare	2.56	2.06	4.27***	1.24**
		(4.25)	(2.52)	(6.17)	(2.12)
Labor	Number	12.91	11.30	13.67	13.81
		(28.08)	(17.02)	(41.74)	(17.72)
Cost of feed per hectare	VND billion/ha	2,019	1,361	2,702**	1,991*
		(3,285)	(2,247)	(4,373)	(2,729)
Age of the farm operator	Years	42.60	46.61	35.61***	45.96
		(13.27)	(14.98)	(11.61)	(9.76)
Education (any formal schooling, 1/0)	Share	60.24	51.79	52.63	77.36***
		(49.09)	(50.42)	(50.37)	(42.25)
Off-farm employment (1/0)	Share	27.71	33.92	12.28***	37.78
		(44.89)	(47.78)	(3.11)	(48.94)
Village meetings (number of meetings attended per year)	Number	2.64	2.00	2.38	3.61***
		(3.15)	(2.69)	(3.25)	(3.31)
Distance to the nearest road	km	1.82	1.37	2.74	1.29
		(4.90)	(1.82)	(7.79)	(2.44)
Observations		166	56	57	53

Note: All values are for 2010. All variables are continuous apart from education and off-farm employment, marked by 1/0. Non-integrated farms are the farms that sell on the spot market, vertically integrated farms are processor-owned farms and contract farmers are households producing catfish on contract with the processing companies. There is no overlap between categories: one household can belong to only one category. Non-integrated farms are the base category. Significance levels: * $p<0.10$, ** $p<0.05$, *** $p<0.01$. Standard deviation is in parentheses. All values are expressed in Vietnamese Dong (VND) million. 1 USD ≈ 20,500 VND. Source: Author's calculation.

Table 2. Determinants of vertical coordination

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	VI[a]	Contract	VI	Contract	VI	Contract
Estimator	Multinomial logit		MSL[b] first stage		2SLS[c] first stage	
Aquaculture area size (log)	0.028	-0.128***	0.526	-1.442***	0.093***	-0.162***
	(0.020)	(0.020)	(0.704)	(0.368)	(0.025)	(0.031)
Labor (log)	-0.007	0.049**	-0.094	0.596**	-0.028	0.077**
	(0.010)	(0.020)	(0.320)	(0.250)	(0.022)	(0.031)
Cost of feed per hectare (log)	0.003	-0.008	0.050	-0.085	0.005	-0.005
	(0.003)	(0.006)	(0.076)	(0.059)	(0.006)	(0.006)
Age of the farm operator	-0.004***	0.001	-0.108***	0.005	-0.009***	0.002
	(0.001)	(0.002)	(0.034)	(0.027)	(0.003)	(0.003)
Education	-0.095***	0.280***	-2.048**	3.077***	-0.193***	0.306***
	(0.035)	(0.065)	(0.963)	(0.976)	(0.051)	(0.074)
Off-farm employment	-0.021	-0.070	-0.819	-0.891	-0.027	-0.082
	(0.030)	(0.071)	(0.899)	(0.836)	(0.054)	(0.083)
Village meetings	0.011**	0.017***	0.389***	0.227***	0.016*	0.018*
	(0.005)	(0.007)	(0.123)	(0.080)	(0.009)	(0.010)
Distance to the nearest road (log)	-0.007	-0.004	-0.195	-0.041	-0.024*	-0.007
	(0.006)	(0.017)	(0.211)	(0.192)	(0.012)	(0.018)
Number of vertically integrated farms in a village	0.077***	0.053*	2.365***	0.745	0.111***	0.013
	(0.011)	(0.032)	(0.808)	(0.460)	(0.020)	(0.017)
Years since the first contract in a village	-0.408***	0.127***	-36.741***	0.316*	-0.034***	0.040**
	(0.116)	(0.036)	(1.483)	(0.167)	(0.009)	(0.018)
Constant	1.521	-3.428*	1.556	-4.519**	0.718***	-0.178
	(1.336)	(2.030)	(1.531)	(2.101)	(0.184)	(0.169)
N	166	166	166	166	166	166
Pseudo-R^2	0.61	0.61			0.63	0.44
Cragg-Donald Wald *F* statistic					7.40	7.40

Note: [a] VI stands for vertically integrated. [b]MSL stands for maximum simulated likelihood treatment regression. [c]2SLS stands for two-stage least squares. Significance levels: * p<0.10, ** p<0.05, *** p<0.01. Robust standard errors are in parentheses. Source: Author's calculation.

Table 3. The effect of vertical coordination on farm performance: estimations with additional control variables

	(a) Dependent variable: yield (log)			(b) Dependent variable: revenue per hectare (log)		
	(1) OLS	(2) MSL[a]	(3) 2SLS[b]	(4) OLS	(5) MSL	(6) 2SLS
Vertically integrated farm	0.481**	0.482**	0.535*	0.554**	0.555***	0.699**
	(0.215)	(0.204)	(0.315)	(0.218)	(0.208)	(0.295)
Contract farm	0.140	-0.062	-0.604	0.199	-0.035	-0.334
	(0.271)	(0.178)	(0.839)	(0.264)	(0.178)	(0.805)
Aquaculture area size (log)	-0.494***	-0.540***	-0.669***	-0.445***	-0.498***	-0.591***
	(0.075)	(0.084)	(0.207)	(0.096)	(0.098)	(0.209)
Labor (log)	0.315***	0.336***	0.395***	0.231**	0.255**	0.296**
	(0.065)	(0.063)	(0.104)	(0.110)	(0.106)	(0.137)
Cost of feed per hectare (log)	-0.001	-0.001	-0.002	-0.004	-0.004	-0.006
	(0.012)	(0.012)	(0.013)	(0.012)	(0.012)	(0.013)
Age of the farm operator	-0.011	-0.010	-0.007	-0.013*	-0.012*	-0.008
	(0.007)	(0.007)	(0.006)	(0.007)	(0.007)	(0.007)
Education	-0.114	-0.049	0.145	-0.167	-0.092	0.046
	(0.164)	(0.147)	(0.249)	(0.171)	(0.155)	(0.257)
Off-farm employment	-0.132	-0.144	-0.184	-0.051	-0.066	-0.087
	(0.178)	(0.169)	(0.149)	(0.192)	(0.183)	(0.167)
Village meetings	-0.017	-0.014	-0.003	-0.010	-0.007	-0.001
	(0.049)	(0.045)	(0.031)	(0.048)	(0.044)	(0.030)
Distance to the nearest road	0.041	0.040	0.040	0.036	0.036	0.038
(log)	(0.027)	(0.027)	(0.033)	(0.031)	(0.032)	(0.037)
Constant	5.516***	5.474***	5.288***	22.504***	22.455***	22.225***
	(0.388)	(0.376)	(0.453)	(0.396)	(0.389)	(0.452)
N	166	166	166	166	166	166
R^2	0.25		0.17	0.20		0.18
F	5.34		4.80	3.87		4.13
λ_1 (vertically integrated farms)		-0.179**			-0.210**	
		(0.088)			(0.086)	
λ_2 (contract farms)		0.349**			0.404**	
		(0.172)			(0.165)	

Note: Robust standard errors are in parentheses. Significance levels: * p<0.10, ** p<0.05, *** p<0.01. [a] MSL stands for maximum simulated likelihood treatment regression. [b]2SLS stands for two-stage least squares. Source: Author's calculation.

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