Bigger is Better: More Powerful Boats Improve Vietnam Fisheries' Efficiency

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Abstract

This study investigates the impact of boat engine power on Vietnam fishery output in 27 coastal provinces during 2000-06. The study shows that many fisheries are producing significantly under capacity. Inefficiencies arise from unregulated uses of small and less powerful boats, primarily for inshore and near-shore fishing, which leads to overcrowding, while leaving offshore fisheries largely underexploited. Mismanaged increases in the number of small fishing boats of less than 45 horsepower (HP) appear to have an adverse impact on total catches. More powerful vessels, especially vessels with an engine capacity of at least 150 HP for offshore fishing, are most efficient.

JEL Code: Q22, Q57, D24, F63
Keywords: stochastic production frontier, technical efficiency, fisheries, engine power

1 Background of Vietnam Fisheries

With 3200 kilometers of coastal lines and over one million square kilometers of exclusive economic zones, Vietnam possesses a huge potential in developing a fishery industry. Since the economic reform of 1986, the sector has averaged an annual 8.4-percent growth rate in the total fish volume, more than the average economic growth rate of 7 percent during the same period (Department of Fisheries-Vietnam, 2012). As of 2012, the fish sector, has employed over 4 million people, created approximately 150,000 new jobs every year, and contributed over $6bn (US dollars) to export revenue. The fisheries in Vietnam can be divided into three main sub-sectors including the marine capture, the inland capture, and aquaculture fisheries, among which the marine and aquaculture account for the lion's share of catch and value.

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The marine fisheries exist along six coastal regions - the North East (NE), the Red River Delta (RRD), the North Central Coast (NCC), the South Central Coast (SCC), the South East (SE), and the Mekong River Delta (MRD) - covering 28 provinces in Vietnam (Figure 1; provincial detail in Table 1). The fisheries are especially thriving in the Southern-most regions of Mekong River Delta, which provide up to a half of total marine landings. The Northern and Southern area have relatively shallow water. Meanwhile the Central areas have more deep-water and thus more deep-water fishing (Son and Thuoc, 2003). Because Vietnam territory mainly spans from north to south, the climate poses a very different working environment in each region. The South experiences one season throughout the majority of the year, while the North follows a more typical four-season pattern. Northern regions and the Gulf of Tonkin are very cold during the last quarter of the year, while the climate in the Southern-most area is warmer and steady yearlong. There is also a dense network of lakes, lagoons, and rivers - which supports local fish culture - in the South, especially in the Mekong Delta region. Marine aquaculture fisheries are dependent on catching and raising young wild fishes in cages to commercial size (Food and Agriculture Organization, 2005). Inshore fisheries are primarily owned by private fishermen using small boats, while offshore fisheries relying heavily on high-power vessels with engine capacity of at least 90 HP are often operated by medium-sized firms or state-owned enterprises.

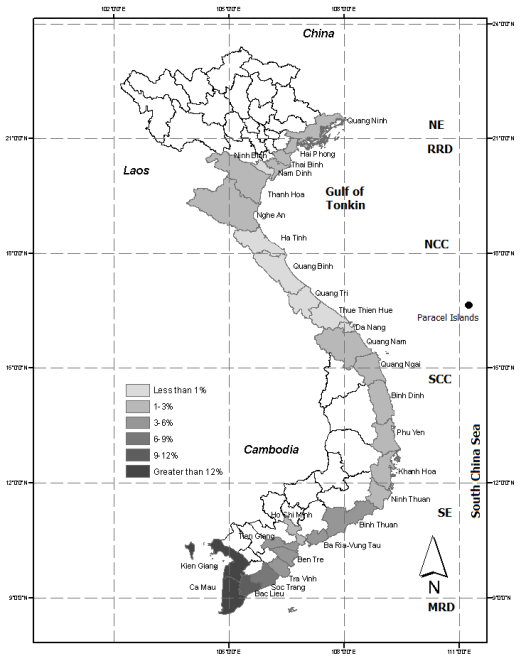


Figure 1: Share (%) in Total Revenue of the Fisheries in 28 Coastal Provinces between 2002-2011.

Due to a large number of fishermen working inshore, there is a strain on the fisheries in near-shore fisheries (Pomeroy et al., 2009). Over time, fishermen have been able to modernize the fleets with more modern and high-power boats. A report published by the University of Copenhagen in 2010 estimates a seven-fold increase in the total horsepower accompanied by only a three-fold increase in production since 1990s. The problem is more severe for near-shore water which accounts for approximately 60 percent of the total catch utilizing 86 percent of the number of operating vessels, in an area of just 25 percent of the total exclusive economic zone (University of Copenhagen and Central Institute for Economic Management, 2010). Especially since 1997 Vietnam has adopted a policy to lend fishermen with preferential terms to build high-capacity boats for offshore fishing (Ministry of Fisheries and the World Bank report, 2005). As

a result, a large number of boats was built in the following decade. For example, counting only 90-HP boats or bigger, the total fleet capacity almost tripled from 1.6 million HP in 2001 to 4.4 million HP in 2011. As of yet, it is unclear if this strategy has been successful. High operating cost, obsolete operations, and a lack of domestic markets for high-value species continue to be major challenges in the sector (Duan et al., 2009; Long et al., 2008). A field survey indicates that even with government's subsidies of fuels, gill-net fishermen in Nha Trang in the center of Vietnam still make a loss (Duy et al., 2010). Long (2010) reports that fuel costs account for a large share in variable fishing cost among three fishing gears including trawl net, gill net and purse seine, exposing fishermen to fuel price shocks. However, long-line fishing of tuna remains highly profitable in Khanh Hoa and Phu Yen in south central Vietnam (Gam and Gao, 2010), even with known disadvantages including low mechanization and backward technologies (Long and Dzung, 2010).

A consequence of the rapid expansion of the fleet size is the decrease in productivity the country has recently observed. The offshore fishing productivity measured as average catch per HP has fallen to almost half after 11 years, from 0.71 ton/HP/year in 2000 to less than 0.39 ton/HP/year in 2011. This raises a question of if the increasing capitalization in the fishing sector has come with more inefficient uses. It is important to know that although Vietnam has had a regulatory framework for sustainable fisheries for many years (Long, 2003), the fisheries are still best described as open-access resources. Input controls (including gear type, gear size and fishing licenses) and total allowable catch policies are often ignored due to ineffective monitoring and enforcement. In addition, a large number of local residents and small villages makes a living by fishing along the coastal lines and inland rivers without registering with the government or applying for licenses.

A stochastic production frontier model is a useful tool for analyzing technical efficiency, and was extensively used for rice production analysis in Vietnam. Notably, Kompas finds a significant impact of price incentive on rice productivity in 60 provinces in Vietnam during the reform years from late 1980s to early 1990s (Kompas, 2002a). The study also shows that the increasing use of tractors will enhance farming efficiency, yet the restriction on farm size, which Vietnam has still insisted as a constitutional issue since after the Indochina conflict ended in 1954, may prohibit further efficiency improvement. Using the same framework, Kompas concludes that placing restrictions on vessel capacity leads to lower efficiency and substitution toward unrestricted inputs in the Australian Northern prawn fisheries (Kompas, 2002b). The study was conducted with an unbalanced panel data of 37 vessels observed over 7 years. This finding is interesting because Vietnam fisheries may not face the same restriction, due to either a lack of regulations or ineffective enforcement, yet high-capacity boats are less common perhaps due to inexperience or financial constraints. Microeconomic analysis at the farm level revealed large inefficiencies among Vietnam's private fish farmers. For example, Den et al. (2007) study

193 prawn farms in the Bac Lieu province, and find that the average technical efficiency was low, only 46 percent. Even accounting for a third of agricultural outputs, one in three prawn farms experienced economic losses. Using information collected from 32 registered offshore long-line vessels operating in the South China Sea, Long et al. (2008) concludes that the optimal hull length for the highest annual revenue and income is about 15 meters, which belongs to the group of boats with an intermediate engine power in between 9-140 HP.

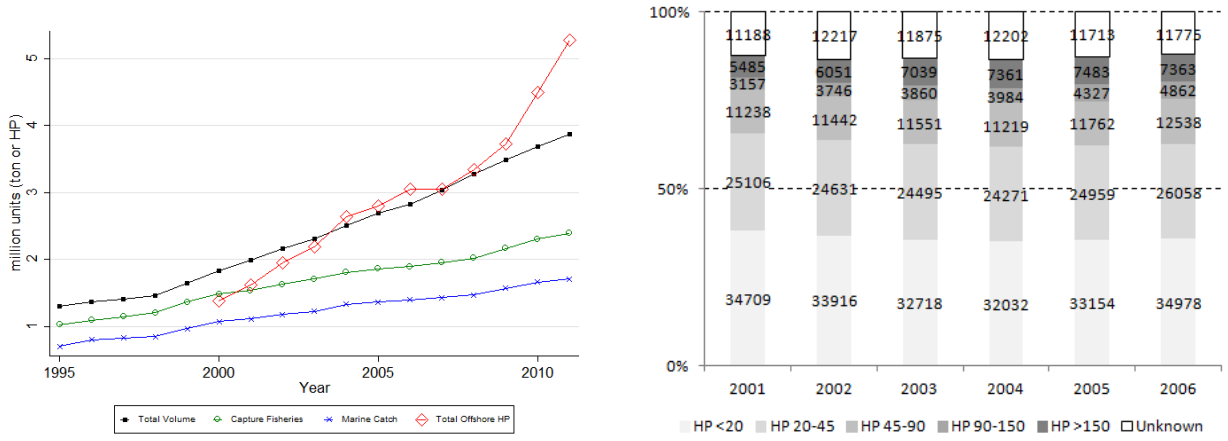
Using provincial data collected during 2000-2006, this study shows that the choice of engine size is strongly related to the efficiency of the fisheries sector in Vietnam. Increasing engine size raises the efficiency, but only if the investment is put in building the most capable vessels for offshore fishing such as those with an engine capacity of at least 150 HP. More powerful vessels used in inland capture only result in overcrowding of already strained resources and further reduce efficiency. The study is structured as follows: section 2 will review the data and observed trends in Vietnam fishery sector; section 3 presents a theoretical model of fishery production and technical efficiencies, followed by empirical estimations and discussions in section 4. The paper concludes with some policy remarks in section 5.

2 Data Sources and Observed Trends

The data is aggregated at the provincial level and includes the total volume of capture and culture fisheries, the total revenue, and inputs such as the number of fishing boats, the total engine power, and laborers worked in capture and aquaculture. The Vietnam's General Statistics Office provides free access to annual aggregate statistics during 1995-2011. In addition, I obtained the most detailed data available about fishing boat's engine power from the Fisheries Information Center, Department of Fisheries, Ministry of Agriculture and Rural Development, which included data from 2001-2006. This information includes the number of boats with engine capacity less than 20 HP, between 20-45, 45-90, 90-150, greater than 150 HP, and an extra category for unknown engine power. Unfortunately, after the integration of the now-ex Ministry of Fisheries to the Ministry of Agriculture and Rural Development in 2007, these statistics were no longer provided for public access.

National aggregate trends are presented in Figure 2-Left, and are available on the province level in Figures 5 and 6. Northern provinces produce less than 17 percent of total fish volume, while the Mekong Delta region alone accounts for more than 50 percent in 2010. It is not surprising that low-to-medium power boats (less than 90 HP) take up to three quarters of all boats. Those boats are often operated by individual fishermen or small firms, who take advantage of relatively inexpensive investment and operating costs. Also the Mekong Delta area operates more powerful boats than any other regions. Yet, relative to the total value produced, the South East and South Central coast provinces have more high-power boats due

Figure 2: Trend in Total Volume, Capture Fisheries, Marine Catch, and Total Offshore Power in 28 Coastal Provinces (Left).
Number and Share of Boats by Engine Capacity in 28 Coastal Provinces (Right).



to deep-water fishery characteristics near the Central. The largest growth rate in the number of boats belongs to the category of boat over 90 HP and less than 150 HP, suggesting that offshore fishing is becoming more important. Strictly speaking, its effect on total output may not be large, since the number of low-power boats of less than 20 HP are much larger, thus a small percentage increase would translate to a much higher number. For example, counting all fishing boats throughout the country during 2001-2011, the number of boats equipped with engines of less than 20 HP increased from 29,586 to 62,031, averaging an annual growth rate of 9.1 percent. Meanwhile, boats with engine capacity of more than 90 HP quadrupled from 6,005 to 24,970, achieving a 13-percent annual growth rate. Restricted to the coastal provinces, the number of the least powerful fishing boats remained almost unchanged during 2001-2006, while boats equipped with engine of at least 90 HP increased by about 40 percent (Figure 2-Right). This study will attempt to quantify the impact of these observed trends of boat's engine power on the efficiency of the fishery sector.

3 A Model of Stochastic Fishery Output and Inefficient Engine Sizes

3.1 Theoretical Framework

Following the classical framework in Coelli et al. (1998) and Kumbhakar and Lovell (2000), a deterministic production function specifies the technological relationship between the level of inputs and the resulting level of outputs $Y_D = f(X\beta)$, where X is the vector of inputs.

A stochastic production frontier incorporates some degree of randomness to the deterministic production function to account for measurement errors and other random factors by an error term v. The random shock v, assumed to be normally independently identically distributed *iid*, can introduce beneficial or harmful variations to the output, so the stochastic production frontier $Y_S = f(X\beta)e^v$ can be above or below the deterministic output. However, the stochastic production frontier is not observed due to the randomness of v. Because the production is not always fully efficient, the actual output is normally less than the maximum possible output. A non-negative technical inefficiency term u is included to determine how efficiently a firm is operating in respect to the frontier. Thus, a stochastic production frontier with technical inefficiency can be written as $Y_E = f(X\beta)e^{v-u}$. Since u is non-negative, observed outputs are always less than the maximum possible output or at best equal to the maximum possible output on the frontier.

Figure 3 helps to explain the framework used in estimating the stochastic production frontier with the total marine catch as the output (Y) and the total engine capacity (HP) as one of two inputs. The other input is labor (L) - the number of fishermen employed in the sector. The deterministic output is a function of the total engine capacity as illustrated. Observed outputs and corresponding total engine capacities are shown as scattered points. The gap between the deterministic output and observed output is an exponential function of the composite error term $v - u$.

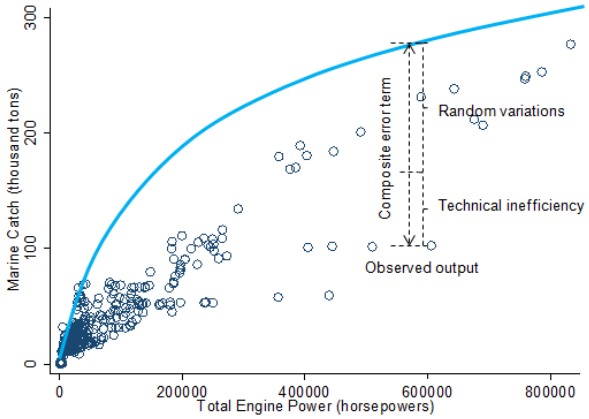


Figure 3: Marine Catch Function Based on the Total Engine Power.

Using the Cobb-Douglas production function in logarithmic form, the output of province i and year t is:

$$\mathrm{lnY_{it}} = \beta_0 + \beta_1 \mathrm{lnL_{it}} + \beta_2 \mathrm{lnHP_{it}} + \mathrm{v_{it}} - \mathrm{u_{it}} \tag{1}$$

The technical inefficiency is estimated from provincial determinants, which include the choice of boat engine capacity and the average engine power among other factors:

$$\mathrm{u_{it}} = \sum_{\mathrm{j}} \omega_{\mathrm{j}} \mathrm{Z_{it}^{j}} + \varepsilon_{\mathrm{it}} \tag{2}$$

where Z_{it}^{j} are j provincial characteristics. ε_{it} is the error term, assumed to be *iid* normally distributed. A set of regional dummies can be included in Z to capture location-specific fixed

effects such as the climate or local infrastructure.

3.2 Econometric Specifications

This study examines three production models. The first model estimates a stochastic production frontier of the entire fishery sector including both capture fisheries and aquaculture. The second model analyzes capture fisheries, which does not separate inshore and offshore capture. The third model focuses solely on offshore fisheries. The stochastic production functions are estimated from the total engine capacity and the size of the labor force; meanwhile the average engine power and choices of engine power are used as determinants in the technical inefficiency model. There are a couple of notes about these models worth highlighting.

The first assumption is that the fisheries are using the same technology. When using the total engine capacity as an input in the production function, engine powers are aggregated across different type of boats, assuming that the effect of a horsepower derived from a small boat is the same as one from a bigger boat. In reality that may not actually be feasible. The technical inefficiency model is thus specified in a way that allows us to distinguish different utilization rates between less powerful and more powerful boats. Second, for other inputs such as the number of fishermen, since it is difficult to observe fishing efforts such as working days, this study assumes that labor is the same across the country. Third, differences in other characteristics related to efficiency are assumed to be fully captured by location's fixed-effects.

Model 1. Whole-Sector Analysis

Stochastic Production Function Model

$$\ln\text{OUTPUT}_{\text{it}} = \beta_0 + \beta_1 \ln\text{LABOR}_{\text{it}} + \beta_2 \ln\text{HP}_{\text{it}} + \beta_3 \ln\text{SURFACE}_{\text{it}} + t\text{T} + \text{v}_{\text{it}} - \text{u}_{\text{it}} \quad (3)$$

Technical Efficiency Model

$$\text{u}_{\text{it}} = \omega_0 + \omega_1 \ln\overline{\text{L}}_{\text{it}} + \omega_2 \ln\overline{\text{HP}}_{\text{it}} + \sum_{\text{j}=2}^{6} \sigma_{\text{j}} \text{D}_{\text{REGION}_{\text{j}}} + \varepsilon_{\text{it}} \quad (4)$$

where OUTPUT, CAPTURE and MARINE are the total output of the whole fisheries sector, the total capture volume, and the total marine capture volume, respectively. LABOR, HP, and SURFACE are the total labor force, boat capacity, and surface area used for aquaculture. $\overline{\text{L}}, \overline{\text{HP}}$ is the average number of fishermen per boat, and average engine power per boat. D_{REGION} is the regional dummy, for region from 2 to 6 corresponding to the North East, North Central Coast, South Central Coast, South East, and Mekong River Delta. The Red River Delta is by default the base. Regional details are provided in Table 1. T is the index for time trend. i, t

are the index for province i in year t.

Model 2. Capture Fisheries

$$\ln\text{CAPTURE}_{\text{it}} = \beta_0 + \beta_1 \ln\text{LABORCAP}_{\text{it}} + \beta_2 \ln\text{HP}_{\text{it}} + t\text{T} + \text{v}_{\text{it}} - \text{u}_{\text{it}} \tag{5}$$

$$\text{u}_{\text{it}} = \omega_0 + \sum_{\text{s}=1}^{5} \omega_{\text{s}} \ln\text{HP}^{\text{s}}_{\text{it}} + \sum_{\text{j}=2}^{6} \sigma_{\text{j}} \text{D}_{\text{REGION}_{\text{j}}} + \varepsilon_{\text{it}} \tag{6}$$

where CAPTURE is the total capture volume including inshore and offshore capture. LABORCAP and HP are the total labor force and total engine power employed in capture fisheries. HP^{s} is the share of boats with engine capacity in category s, corresponding to 20-45, 45-90, 90-150, greater than 150 HP, and unknown capacity. The base is the share of boats with engine power less than 20 HP.

Model 3. Offshore Fisheries

$$\ln\text{OFFSHORE}_{\text{it}} = \beta_0 + \beta_1 \ln\text{LABORCAP}_{\text{it}} + \beta_2 \ln\text{OFFSHOREHP}_{\text{it}} + t\text{T} + \text{v}_{\text{it}} - \text{u}_{\text{it}} \tag{7}$$

$$\text{u}_{\text{it}} = \omega_0 + \sum_{\text{s}=1}^{4} \omega_{\text{s}} \ln\text{HP}^{\text{s}}_{\text{it}} + \sum_{\text{j}=2}^{6} \sigma_{\text{j}} \text{D}_{\text{REGION}_{\text{j}}} + \varepsilon_{\text{it}} \tag{8}$$

where OFFSHORE is the total offshore capture volume. OFFSHOREHP is the total engine power used for offshore fishing.

4 Empirical Results and Discussions

Results are available in Table 2 and 3. Table 2 shows the estimates of the entire fishery sector, one for the total volume (capture and aquaculture included) and the other for the total sales value. The volume model truly represents a production frontier, whereas the value model is more like a profit frontier, assuming profit is proportional to sales. The reason for estimating a value model is that fisheries might be different between regions, and a low catch volume relative to input levels may not necessarily indicate low efficiency if fishers target some certain species that are valued higher. Value data is deflated to 1994 constant price to remove any price effects. Since relative price changes may affect fishing strategy, the estimated efficiency may represent both allocative (wrong output mix) and technical inefficiency. However, this potential issue is

unlikely to be large, according to Squires (1987), and Sharma and Leung (1999). The ability to switch production based on price expectations is low, since there is a large fixed cost and time requirement associated with switching.

Table 3 presents the capture and offshore fishery models. The technical efficiency models allow for estimating the impact of boat categories on catches by decomposing boat engines to six different categories: less than 20 HP, between 20-45 HP, 45-90 HP, 90-150 HP, greater than 150 HP, and unknown capacity, with the base being the least powerful engine category. The dependent variables for these two models are the total capture volume and the offshore capture volume, respectively. The offshore fisheries are a segment of the capture fisheries, with a focus on offshore fishing at distant locations up to the 200 nautical mile exclusive-economic-zone boundaries and farther.

Estimated Stochastic Production Functions

The Cobb-Douglas specification of the production function appears appropriate for all models. The estimated coefficients of all inputs are significant with the expected signs in all models, with the exception of the labor input in the value model. Since inputs and output are in logarithmic form, the estimated coefficients can be interpreted as a measure of elasticity. For example, in the model of the entire fisheries sector (model 1), both volume and value is more elastic to increasing total engine capacity (elasticity is .42 and .34, correspondingly), and less elastic to increasing the labor force or the total aquaculture area (for the volume model, elasticity of output to labor and culturing area is similar at .13, while for the value model these are .16 and .37). Yet, in the capture and offshore fisheries, the output is about equally sensitive to changes in labor force or engine inputs, from .42 to .47.

The time trend is significant throughout the entire sector models, as well as the offshore fishery model, which has several important implications. An increasing trend could be a component of the total factor productivity which explains for technological progress over time. In the Cobb-Douglas production function, this is called the Hicksian-neutral technological change because it does not lead to changes in the optimal input ratio. For the fisheries as a whole, about a 5-8 percent annual growth rate in the total factor productivity is observed - a rather high number but not unreasonable for a developing country. For the offshore fisheries alone, the trend is significant and much smaller, at 1.8 percent. However, the trend is negligible for the capture fishery model. These estimates suggest that limited technological progress might be restricted to a segment of capture fisheries, primarily the newly established offshore fishery sector. A strong increasing productivity trend for the fishery sector as a whole may arise from significant improvements in aquaculture such as more productive species, free training programs provided by the government, and learning by doing.

To test for the presence of technical efficiency effects, a generalized one-sided LR test was conducted. The test statistics has a mixed χ^2 distribution with the degrees of freedom equal the number of restrictions in each model (under $H_0 : \omega_i = \sigma_j = 0$): 9, 12, and 11 corresponding to model 1, 2, and 3. The corresponding statistics are 162, 99, 204, and 121, which ensures a rejection of the null at a 99 percent confidence level. This confirms the need for a stochastic production frontier modelling approach. For comparison, a random-effect model of the entire fishery sector is presented in Table 2. The estimated coefficients of the random-effect model in column [6] and [7] are comparable with that of the stochastic production function in column [2] and [3]. The variations due to individual effects, $\rho = .95$, seem to agree that most deviations in output are due to efficiency effects.

Estimated Technical Efficiencies

In the model representing the entire sector (model 1), the parameter of average boat power is highly significant, indicating that more engine power on average would increase overall efficiency. However, more fishermen per boat do not have an impact on efficiency. Note that the technical efficiency effect is calculated as $TE_{it} = e^{-u_{it}} = e^{-\sum_j \omega_j Z^j_{it} - \varepsilon_{it}}$, therefore a negative sign of the average boat engine coefficient would indicate higher efficiency in provinces with a higher average HP/boat. This result is perhaps as expected. Vietnam has an abundant labor supply, and many people do not have a permanent job. They join the fisheries during fishing season then switch work after the season ends (Anh et al., 2003; Brown, 2011). The temporary workers often do not possess any capital or sufficient skills to work independently. Instead, they rely on close-knit partnerships with family relatives or community members. Therefore, their participations in fishery activities are unlikely to improve efficiency.

The capture and offshore fishery models (model 2 and 3) offer more detail on engine sizes and efficiency. Only the share of boats with engine capacity greater than 150 HP in both model would improve efficiency relative to the base, the least powerful boats with engine capacity of less than 20 HP. In addition, boats with engine capacity in between 20-45 HP appear to be most inefficient for offshore fishing. The unknown engine capacity coefficient in the capture fisheries (model 2) needs some further explanation. This category of boats appears to reduce efficiency as suggested by a marginally positive yet significant coefficient. The boats represented in this category are most likely small boats used by local villagers for capture fisheries. A large number of villagers makes a living on their boats near water. Many of them do not have a permanent home or possess any land. Their boats are normally powered by small engines such as Vietnam war-era Kohler long-tail motors or domestic Bong Sen (Lotus) 12-HP diesel engines. Apparently, their subsistent livings contribute little to the overall statistics. Therefore, this category of boats with unknown engine capacity was excluded in the offshore fishery model

(model 3).

There are several possible explanations for these findings. First, for offshore fishing, boat power is a decisive factor of catchability and the ability to work on site for a considerable amount of time before returning to dispose cached fishes. Second, the current average engine power is low because a considerable portion of the fishery sector relies heavily on a large number of private fishermen and small firms who do not have enough capital or skills to operate expensive, high-power vessels. Their working areas are inland rivers or near the coastal line, and most do not have the capability to work far from the shoreline. As a result, any fishery policy aiming at improving efficiency should focus on raising the average engine capacity. This can be done by introducing more boats equipped with powerful engine of at least 150 HP specifically designed for offshore fishing. By and large, this result agrees with the previous assessment that inland and near-shore fisheries are over-exploited (Pomeroy et al., 2009), while offshore fisheries are still not fully tapped. More investment in building high-capacity boats, better trained crews, and more convenient support facilities would attract more fishermen to work offshore, which in turn has a positive externality on inland resources.

Many location fixed effects are significant, indicating that the Northern areas are generally less favorable then the Southern areas in developing the fisheries industry. The South East and South Central coast are most suitable for capture fisheries due to the deep-water advantage. The Mekong River Delta is particularly not suited to offshore fishing due to shallow water. From the North to the South, fishing seasons and the availability of support facilities vary significantly. Beside favorable weather, the South has significant advantages in the number of ports and port capacity to accommodate large vessels. There are about 60 landing places for mechanized boats, but not many are suitable for large vessels. Local fishermen dump their output on local markets and beach-side villages. Support services such as ice blocks, fuel, maintenance, and processing plants are only located near port areas, posing a challenge to traditional fishing activities, especially inshore and near-shore private fishermen who work sparsely along inland rivers or the coastal line.

The average technical efficiencies in all three models range from 54 to 63 percent (Table 4). Regional differences are stark. Estimated efficiencies are lowest in the North East and on the North Central Coast. Meanwhile, many provinces in the South East, the South Central, and the Mekong Delta are among the most efficient. Note that the estimated efficiency of near 100 percent or so in a few provinces should be interpreted with caution. These are the results of extreme observations such as the presence of a few large and efficient provinces in the South and the Mekong River Delta. For example, the estimated efficiency of Kien Giang province is 90 percent, and this province alone accounts for 11.5 percent of the total value during 1995-2011. Similarly, Bac Lieu province takes up to 10.7 percent of the total value and is 81 percent efficient. Capture fisheries, including both inshore and offshore capture, appear to be the least

efficient sector. However, considering solely offshore capture, the estimated efficiency is actually the highest. This is further evidence to corroborate the assessment that inshore fisheries are least efficient, perhaps due to the overcrowding of inland fishing grounds. Weather could be partly to blame for low efficiency in the North. Very cold seasons persist throughout the year except the summer, constraining fishermen and the use of equipments. Another possible reason is that Quang Ninh and Ha Long, used to have a flourished fishery sector prior to the economic reform in 1986, have switched to more lucrative tourism and mining industries.

5 Concluding Remarks

This study examines the impact of boat engine power on Vietnam's fishery efficiency. The impact of a fast growing fleet size and ineffective management has resulted in low efficiency as indicated by significantly faster rising inputs relative to the total catches observed in the last decade. Nearly open-access fisheries attract a large number of private fishermen and small firms to work inshore and near-shore, threatening the sustainability of local resources. At the same time, the offshore fishing potential has not been adequately tapped. The study finds that investment in high-capacity boats of at least 150 HP for offshore fishing will be most effective to raise the efficiency.

In relation to fisheries policy, the Vietnam government has already had some uncoordinated efforts to develop the offshore fishing sector since the late 1990s. Generally, fishery policies have been to lower the cost of building and operating high-power offshore vessels and local support facilities, in addition to providing crew training and accessing to bigger markets for high-value offshore species. The benefit of such policies, if properly implemented, would be two-fold: first, it would help increase the sector's currently low efficiency, and second, it would help protect the fisheries from overfishing and destruction of inland and near-shore resources. Admittedly, the implementation of such a policy would be a challenge for local governments already facing multiple constraints with limited resources. Future work will need to account for the microeconomic perspectives of the engine choice, i.e. which factors influence the fishermen's decision to use some certain category of engine size: is that a pure cost-benefit problem, or other constraints such as lack of support from local manufacturers for parts or repair, or skills to operate more powerful boats?

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Table 1: Provinces and Region Dummies

Region	Province
Red River Delta	Hai Phong, Nam Dinh, Thai Binh, Ninh Binh*
North East	Quang Ninh
North Central Coast	Thanh Hoa, Nghe An, Ha Tinh, Quang Binh, Quang Tri, Thua Thien-Hue
South Central Coast	Da Nang, Quang Nam, Quang Ngai, Binh Dinh, Phu Yen, Khanh Hoa
South East	Ho Chi Minh, Ninh Thuan, Binh Thuan, Ba Ria- Vung Tau
Mekong River Delta	Tien Giang, Ben Tre, Tra Vinh, Soc Trang, Bac Lieu, Ca Mau, Kien Giang

*Ninh Binh was not used in the analysis due to missing all detail on engine capacity. This is unlikely to affect the overall result because this province only accounts for .4 percent of the total value or .5 percent of the total volume of the whole fisheries between 1995-2011.

Table 2
Model 1: Whole-Sector Analysis

	Volume†		Value†		RE†	
Explanatory Variables	Coefficient	*t-stat*	Coefficient	*t-stat*	Coefficient	*z-stat*
[1]	[2]	[3]	[4]	[5]	[6]	[7]
Stochastic Production Function						
Total Labor (TL)	.13*	1.94	.16	1.40	.09	.49
Total Engine Power (HP)	.42***	33.99	.34***	4.15	.36***	3.02
Total Culturing Surface (SURFACE)	.13***	10.32	.37***	6.14	.19***	2.88
Time Trend (T)	.05***	5.46	.08***	3.68	.05***	5.59
Constant	-3.20***	24.84	.67*	1.93	-3.53***	5.11
Efficiency Model						
Average HP/Boat	-.006**	2.21	.0058	.37		
Fishermen/Boat	-.011	.01	-.017	.02		
Region						
North East	.59***	3.22	.94*	1.66		
North Central Coast	.34***	4.24	.63	1.56		
South Central Coast	.056	.45	-.93**	2.00		
South East	-.48***	3.94	-.64	.99		
Mekong River Delta	-.36***	2.60	-.59	1.18		
Constant	.81***	6.02	.54	.69		
Variance and Hypothesis Testing‡						
σ^2	.056***	6.64	.37***	6.55		
γ	.99		.99		.95	
LR-test	162		99			
Number of Restrictions	9		9			
Number of Observations	154		154		154	

Legend:
*, **, *** denotes statistically significant at 10, 5, and 1% levels, respectively.
† The dependent variable is the total volume (column [**2**] and [**3**]) and total value (column [**4**] and [**5**]). For comparison purpose, a random-effect model of the total volume is presented in column [**6**] and [**7**]. Thus, *gamma* coefficient in column [**6**] is the fraction of variance due to individual effects, or the ρ coefficient in panel data regression.
‡ To test whether a stochastic modelling is necessary, i.e. there are technical inefficiency effects in place, the null hypothesis $H_0 : \sigma_u^2 = 0$ was tested against $H_1 : \sigma_u^2 > 0$, or equivalently, $H_0 : \gamma = 0$ against $H_1 : \gamma > 0$, where gamma is the ratio of the variance of u_i over the sum of variance of u_i and v_i, $\gamma = \frac{\sigma_u^2}{\sigma_u^2+\sigma_v^2}$. A one-sided generalized likelihood ratio test is calculated by:

$$\mathbf{LR} = -2\mathbf{Ln}[Ł(H_0)/Ł(H_1)] = -2\{\mathbf{Ln}[Ł(\mathbf{H_0})] - \mathbf{Ln}[Ł(\mathbf{H_1})]\}.$$

The stochastic models were estimated using package `FRONTIER 4.1` provided by Coelli (1996). The panel regression with random effects was estimated by Stata `xtreg` program with Huber-White robust standard errors. The dataset and replication code is available from the author upon request.

Table 3
Model 2 and 3: Capture and Offshore Fisheries Analysis

	Capture †		**Offshore** †	
Explanatory Variables	Coefficient	*t-stat*	Coefficient	*t-stat*
[1]	**[2]**	**[3]**	**[4]**	**[5]**
Stochastic Production Function				
Labors in Capture Fisheries (LCAP)	.47***	15.11	.46***	15.39
Total Engine Power (HP)	.43***	26.43		
Total Offshore Engine Power (OHP)			.42***	26.98
Time Trend (T)	.00016	.02	.018**	2.02
Constant	-2.50***	14.10	.14	1.33
Efficiency Model				
Region				
North East	.53***	4.61	-.18	.90
North Central Coast	.44***	6.29	.10	.71
South Central Coast	-.31e-2	.04	-.38**	2.35
South East	-.07	.81	-.35*	1.85
Mekong River Delta	-.14	1.39	.65***	3.73
Share of Boats by Engine Power				
between 20-45 HP	.75e-3	.36	.55e-2*	1.78
between 45-90 HP	-.13e-2	.58	.17e-2	.38
between 90-150 HP	.95e-2	1.42	.02	1.39
greater than 150 HP	-.03***	5.20	-.05***	4.46
unknown capacity	.52e-2***	3.64	*na*	*na*
Constant	.71***	9.09	.50***	3.52
Variance and Hypothesis Testing				
σ^2	.04***	9.01	.09***	5.62
γ	.99		.99	
LR-test	204		121	
Number of Restrictions	12		11	
Number of Observations	143		154	

Legend:
*, **, *** denotes statistically significant at 10, 5, and 1% levels, respectively.
†The dependent variable is the total capture volume in model B, and the total marine fish volume in model C.

Table 4: Summary of Estimated Technical Efficiency

Province	Whole Sector	Capture Fisheries	Offshore Fishing
Red River Delta			
Hai Phong	0.45	0.37	0.36
Nam Dinh	0.71	0.57	0.76
Thai Binh	0.65	0.58	0.63
North East			
Quang Ninh	0.34	0.28	0.57
North Central Coast			
Thanh Hoa	0.48	0.44	0.58
Nghe An	0.37	0.31	0.54
Ha Tinh	0.37	0.39	0.59
Quang Binh	0.27	0.24	0.33
Quang Tri	0.30	0.32	0.68
Thua Thien Hue	0.31	0.24	0.39
South Central Coast			
Da Nang	0.51	0.48	0.69
Quang Nam	0.50	0.48	0.68
Quang Ngai	0.82	0.70	0.79
Binh Dinh	0.64	0.51	0.52
Phu Yen	0.33	0.29	0.50
Khanh Hoa	0.54	0.43	0.87
South East			
Ho Chi Minh	0.76	0.69	0.81
Ninh Thuan	0.52	0.53	0.76
Binh Thuan	0.94	0.61	0.64
Ba Ria-Vung Tau	0.97	0.90	0.97
Mekong River Delta			
Tien Giang	0.81	0.63	0.53
Ben Tre	0.71	0.60	0.56
Kien Giang	0.90	0.98	0.90
Tra Vinh	0.94	0.82	0.34
Soc Trang	0.64	0.41	0.34
Bac Lieu	0.81	0.91	0.82
Ca Mau	0.67	0.83	0.85
Mean TE	**0.60**	**0.54**	**0.63**

Supplementary Figures

Figure 5: Trends in Total Engine Power and Number of Boats by Province

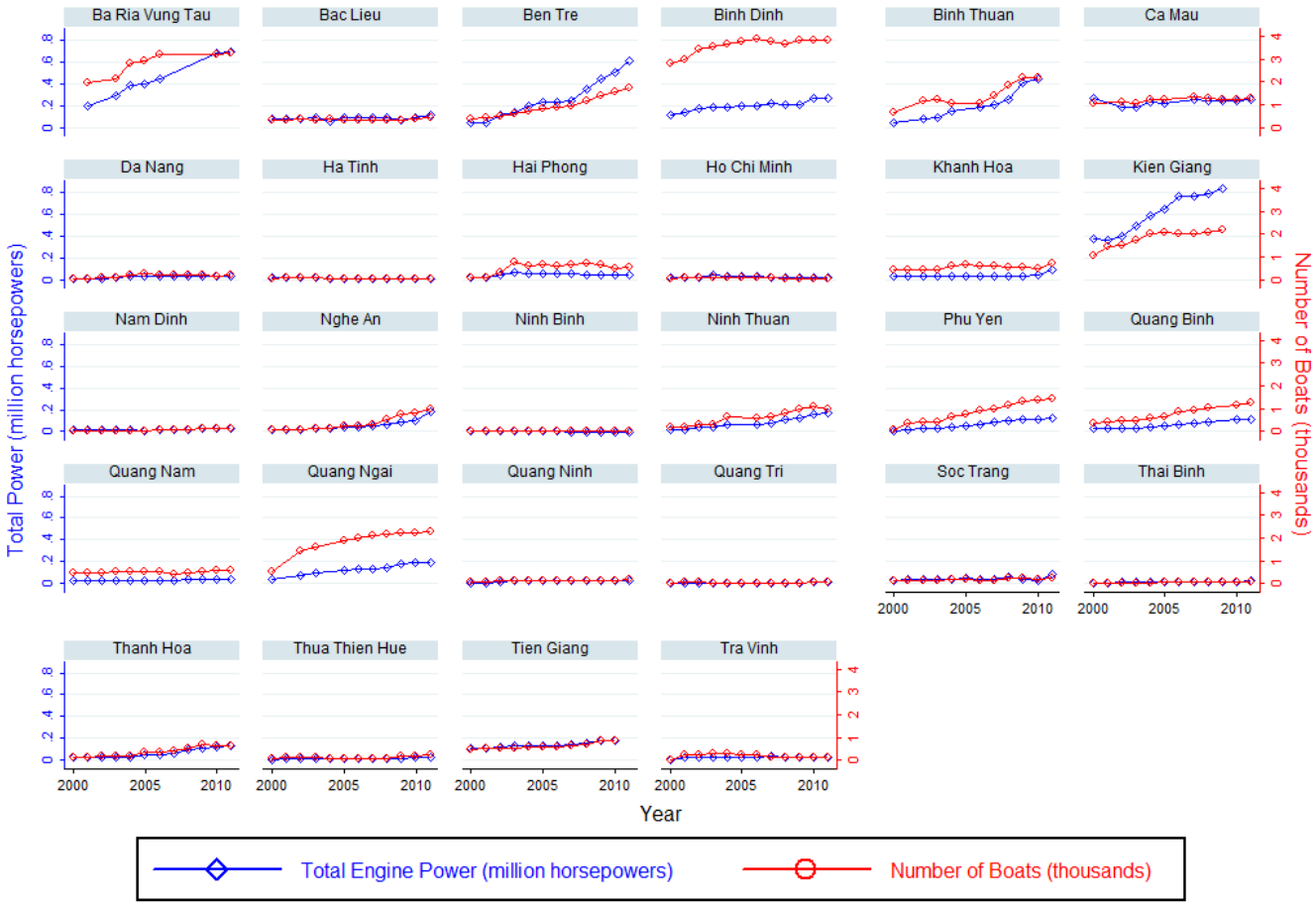


Figure 6: Trends in Total Volume, Total Capture Volume, and Offshore Catches by Province

