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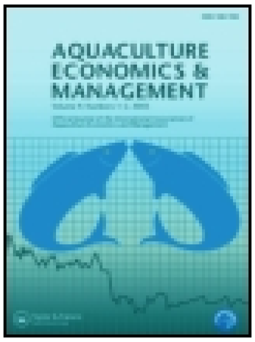

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The estimate of world demand for Pangasius catfish (*Pangasiusianodon hypopthalmus*)

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ABSTRACT

This research described in this article aimed to investigate international market potentials for Pangasius catfish (*Pangasianodon hypopthalmus*). The monthly export data from Vietnam, which accounts for more than 95% of the global export value, in the period 2007 to 2014, were used to estimate a non-linear Inverse Almost Ideal Demand System of the seven market regions. Prices in all markets are found very inflexible, with own-price flexibilities on −0.200 to −0.917, or −0.419 on average, revealing the option of expanding global production and export without inducing a substantial price reduction. Consumers in all markets except Latin America evaluate Pangasius as a necessary good, indicating that the Pangasius industry is relatively little affected by recessions and booms in the world economy. The major markets are substitutes for each other; therefore, if demand at one market region is reduced, the presence of substitution leads suppliers to find other markets. The results reveal that demand provides stable framework conditions for the Pangasius industry.

KEYWORDS
IAIDS; market potential; market substitution; Mekong Delta; Pangasius catfish; price flexibility

Introduction

The rapid growth of global aquaculture requires increasingly reliable and timely information on both production and market to formulate and monitor sound policies and development plans. The purpose of this research was to understand the world market demand for Pangasius catfish *(Pangasius hypophthalmus)*, which is one of the fastest-growing aquaculture species globally (FAO, 2010). The production was 1.6 million tons in 2012 (FishStatJ, 2014), and Pangasius is one of the few species where the production exceeds 1 million tons per year. Vietnam is the major producer, representing more than 75% of global production. Production in other countries in Asia, such as Indonesia, Malaysia, Cambodia, Bangladesh, China and Laos, are growing both for local consumption and export (FAO, 2010; Globelfish, 2015).

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However, the potential decrease in export price that might follow production growth and the low marginal profit experienced in recent years is of concern to producers (Globelfish, 2015). We apply an inverse demand approach to investigate the effects of production growth on market price, market substitutions and impact of consumption scale on the demand.

Given the existing import markets, the production growth of Pangasius is expected to have a substantial negative effect on the price, thereby negatively affecting earnings in the industry. It is found that all own-price flexibilities are statistically significant at the 1% level, have negative signs and are between −0.200 to −0.917, a weighted average flexibility of −0.419. However, because the absolute values of the flexibilities are far below 1, a 1% production and export growth induces a price reduction of 0.2% to 0.917%, or 0.419%, on average. In addition, Pangasius is evaluated as a necessary good in almost all existing markets and the major export markets such as Europe and North America are substitutes for each other.

Our findings are important information for Pangasius producers and policymakers. That the prices in all import markets are very inflexible reveals a high possibility for exporting countries to expand production without inducing a significant price reduction. As a necessary good, the price is less responsive to changes in consumption scale. Therefore, the global Pangasius industry is relatively little affected by recessions and booms of the world economy. In addition, Pangasius companies may supply new markets in developing regions such as South Asia, South America and Africa because Pangasius is most often consumed by low-income households. Finally, our results indicate that global Pangasius production and export can grow at a relatively stable rate, without companies facing risks of substantial price reductions. The reason is that if demand in one market region is reduced or market barriers are raised, the presence of substitutions leads suppliers to find other markets. The choice between estimating an inverse demand system or a regular demand system depends both on specific purpose of the study and the empirical results. We used the inverse demand system based on three reasons. First, agricultural products are perishable and deteriorate quickly, leading to the need for producers to sell products quickly; farmers are price takers (Barten & Bettendorf, 1989). This disadvantage also applies to Pangasius producers and exporters. The majority of Pangasius processors in Vietnam are small- to medium-scale enterprises. They have limited capacity in terms of storage and capital. After processing, processors and exporters competing in the market and domestic firms make the sector vulnerable (VASEP, 2015).

In other words, competition among Pangasius processors for export lead the Vietnamese industry as a whole to be price-takers in world markets. This means that total supply is inelastic in the short term. Second, we have estimated both inverse and regular demand systems and compared the results. The regular Almost Ideal Demand System (Deaton & Muellbauer, 1980a) provided a poor result as it only revealed a few statistically significant parameters. Two estimates suggest that IAIDS is the best-fit model. Third, the main objective of our article is to reveal the market potential for Pangasius producers. That is, we address the critical question whether Pangasius countries (Vietnam and others) should expand global production and export. This is useful information for policymakers in these countries. To achieve this objective, the inverse demand is appropriate.

Furthermore, in theory the own-price flexibilities identified in inverse demand systems and the own-price elasticities estimated by ordinary demand systems, are equal according to economic theory. However, empirical studies show that own-price flexibilities are systematically closer to zero than inverted own-price elasticities (Houck, 1966; Huang, 1994). Houck (1966) explains this result by concluding that the reciprocal value "depends upon the strength of the cross effects of substitution and complementarity." Huang (1994) further concludes "by using inverted elasticities to represent flexibilities or vice versa, sizeable measurement errors may be committed." Hence, the main explanation of the difference is the different degree of substitutability with respect to other goods included in the two models. In the ordinary models the exogenous prices are influenced by several substitutes, which are therefore indirectly included in the models. In the inverse models only sector-specific relations influence the exogenous quantities, and substitutes are therefore not included in the models. Therefore, it is important to choose the correct model in practical analyses, and because the focus in this article is to uncover market potential and expand production and export, the inverse demand system is applied.

There are a variety of studies using an inverse system for demand analysis of agricultural products. Bell (1968), Anderson (1980) and Barten and Bettendorf (1989) were among the first to use the inverse demand system for fish. Barten and Bettendorf (1989) identified inverse demand for fish landed at Belgian ports. Eales and Unnevehr (1994) classified the Inverse Almost Ideal Demand System (IAIDS) and applied the system to a study of U.S. meat demand. Eales, Durham, and Wessells (1997) and Nielsen, Jensen, Setälä, and Virtanen (2011) used both the ordinary and the inverse demand system to investigate, respectively, the Japanese preference for fish and German demand for trout and substitutes. They found, in most studied cases, that inverse demand systems dominate the ordinary demand systems in its ability to forecast performance. Thong (2012) and Pei (2015) applied IAIDS to reveal the demand for mussels in the EU and blue crab in the Chesapeake Bay, respectively. Nielsen, Smit, and Guillen (2012) identified price effects of changing quantities supplied at the integrated European-wide fish market. Sjöberg (2015) revealed the importance of fish size that was landed and sold in Sweden. To the best of our knowledge, there is no previous study investigating the demand for seafood on a global scale, with earlier studies focusing on regions or countries. In this study, we used export data to estimate the global demand for Pangasius.

We briefly present the IAIDS and the relevant calculations, followed by our data collection methods, the estimation of results and discussion.

Model

The IAIDS is derived from the specification of a distance function (Eales & Unnevehr, 1994) and is similar to the structure of the original AIDS developed by Deaton and Muellbauer (1980a). However, the AIDS and IAIDS are different from one another with respect to the right-hand exogenous variables. The general form of IAIDS is:

$$w_i = \propto_i + \sum_j \gamma_{ij} lnq_j + \beta_i lnQ \quad (1)$$

where w_i is the expenditure share of the ith commodity, q_j is the demanded quantity, and lnQ is the quantity index defined by:

$$lnQ = \propto_0 + \sum_j \propto_j lnq_j + 0.5 \sum_i \sum_j \gamma_{ij} lnq_i lnq_j \quad (2)$$

The basic restrictions on the demand system (namely, adding up, homogeneity, and symmetry) are expressed as follows in terms of the model coefficients:

Adding up: $\sum_i \propto_i = 1$, $\sum_i \gamma_{ij} = 0$, and $\sum_i \beta_i = 0$

Homogeneity: $\sum_j \gamma_{ij} = 0$

Symmetry: $\gamma_{ij} = \gamma_{ji}$ for any $i \neq j$

Equations (1) and (2) combined imply that the inverse demand model takes a non-linear structure. To avoid having to estimate this complicated non-linear system, many empirical studies usually replace lnQ with $LnQ^* = \sum_i w_i ln(q_i)$, which is a quantity index. The quantity index has the same structure as the price index in the ordinary AIDS suggested by Deaton and Muellbauer (1980a). In this study, we do not use the index and estimate the non-linear IAIDS directly, which avoids possible biased results (Moschini, 1995; Thong, 2012).

From differentiation of Equation (1) with respect to lnq_j follows the flexibilities, see Eales and Unnevehr (1994) for details on deriving the flexibilities. Two types of flexibilities may be calculated based on estimated parameters of IAIDS:

Own- and cross-price flexibility:

$$f_{ij} = -\delta_{ij} + \frac{\left\{\gamma_{ij} + \beta_i\left(w_j - \beta_j lnQ\right)\right\}}{w_i} \quad (3)$$

Scale flexibility:

$$f_i = -1 + \frac{\beta_i}{w_i} \tag{4}$$

where f_{ij} and f_i are price and scale flexibilities, respectively; δ_{ij} is the Kronecker delta ($\delta_{ij} = 1$ for $i = j$, and $\delta_{ij} = 0$ otherwise); and the other terms on the right-hand side are taken from Equations (1) and (2).

To be consistent with theory, the flexibilities must be checked to satisfy the following aggregation relationships: $\sum_j f_{ij} = f_i$ (homogeneity), $\sum_j w_i f_{ij} = -w_j$ (Cournot), and $\sum_i w f_i = -1$ (Engel). The total change (or effect) in prices associated with an increase in one quantity can be broken into substitution and scale effects. The compensated flexibilities can be computed directly from the uncompensated flexibilities shown in Equation (3) as $f^*_{ij} = f_{ij} - w_j f_i$ (Eales & Unnevehr, 1994; Thong, 2012).

Flexibilities can be interpreted in a manner similar to interpreting elasticity. Own-price flexibility less than 1 in absolute terms indicates the inflexible demand for respective commodity. Negative and positive cross-price flexibilities indicate gross quantity-substitutes and quantity-complements, respectively. Scale flexibilities explain the price variation subject to the expansion of consumption. Scale flexibilities are less than −1 for necessary goods and greater than −1 for luxury goods (Eales & Unnevehr, 1994; Park & Thurman, 1999).

We estimate the non-linear system presented in Equations (1) and (2) based on seemingly unrelated regression (SUR). To avoid the singular problem of budget shares summing up to unity, we estimate only *n-1* equations, the randomly omitted equation will be retrieved using the adding up condition. The maximum likelihood (ML) estimates in the *n-1* equations system are invariant to the deleted equation only if the disturbances are serially independent (Deaton & Muellbauer, 1980b). We apply a procedure suggested by Berndt and Savin (1975) to correct for the first autocorrelation (AR(1)) problem. See Thong (2012) for a detailed explanation of the procedure.

Data

Monthly export data for Vietnamese Pangasius are available from the website of the International Trade Center (www.trademap.org), WTO, for the period of 2007–2014. Pangasius product, i.e., frozen fillet has been classified by two separate codes: HS030429 (frozen fish fillets) for the period 2007–2012 and HS030462 (frozen fillets, Pangasius species) after 2012. Although the product code HS030429 applied to all types of frozen fish fillets, cross checking the data prior to 2012 revealed that more than 95% of frozen fish fillets exported from Vietnam were Pangasius. The monthly data on exported value ($) and quantity (kg) distributed on import countries were obtained.

The data of the importing countries were aggregated into the data of seven market regions, based on geographical locations. The seven regions include ASEAN and Eastern Asian (10 Asian countries, and China, Hong Kong, Japan, Taiwan, and Korea), North American (Canada and USA), Oceania (Australia and New Zealand), Russia and Eastern EU (Russia and former Soviet Union countries), South and Central America, Western EU, and Rest of the World (ROW). Figure 1 presents average export prices ($/kg) of the seven market regions. There is a decreasing trend in export price in the period 2007–2014. The highest export price is to North America, the lowest is to Russia and Eastern EU, and the price to ROW is the most fluctuating.

To ensure the aggregated data of seven regions were valid, we conducted aggregation tests based on the General Composite Commodity Theorem (GCCT) of Lewbel (1996). (We acknowledge one of anonymous reviewers who raised the concern on this issue). The method has been applied widely in food demand studies (e.g., Davis, Lin, & Shumway, 2000; Reed, Levedahl, & Hallahan, 2005; Xie & Myrland, 2011). We define $\rho_i = r_i - R_I$ as the *i*th relative price, where r_i is log of export price *i* to market region *I* (i.e., log (p_i)) and R_I is log of the price of the region *I* (log (P_I). According to GCCT, a valid aggregation requires the independence of ρ_i on R_I. We tested the valid aggregation based on a two-step procedure (Xie & Myrland, 2011): (1) using the Dickey–Fuller test (ADF) to conduct the unit root test on each ρ_i and R_I; (2) applying an appropriate method to test the independence between ρ_i and R_I. If both ρ_i and R_I are stationary, Spearman's rank correlation test is conducted; if both ρ_i and R_I are non-stationary, Johansen's co-integration test is used; if ρ_i or R_I stationary and another is not, no test is required.

Because we formulated the region data based on 79 country import-data, the tests conducted for all countries are time consuming and may not be

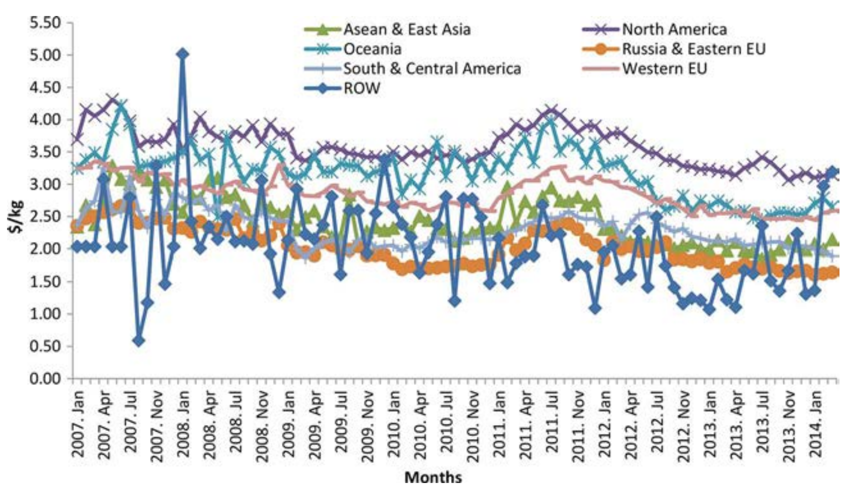

Figure 1. Average exported price to world markets in period of 2007-2014 (Source: ITC 2015).

necessary. Except for Oceania, we selected only two countries representing each region to include in the test; these countries have the highest market shares. Basing on ADF test results, we found that most pair tests of the independence in step 2 are not necessary and our geographic aggregations are valid. Table A1 in the appendix presents the results of aggregation tests.

Results

We first estimated the non-linear IAIDS presented in Equations (1) and (2) assuming no autocorrelation between disturbances. We then predicted the disturbances of the seven equations and calculated the Durbin–Watson (DW) statistics manually for each equation. The DW statistics range from 0.33 to 0.98, the values are quite far from 2.0, indicating severe autocorrelation problems for the equations. We re-estimated IAIDS by imposing a single autocorrelation parameter for all of the equations, as suggested in the study of Berndt and Savin (1975) and one applied in an earlier study by Thong (2012) for a similar IAIDS. The single autocorrelation parameter, ρ (rho), for the final estimated model is close to 1 (0.739), indicating the appropriateness of imposing the autocorrelation parameter in the system.

The likelihood ratio (LR) was employed to test for significance of the theoretical restrictions (i.e., homogeneity and symmetry) imposed on the system. We performed the LR for the full restricted model against a model without both homogeneity and symmetry, a model without symmetry, and a model without homogeneity. The results reject the null hypothesis of consistency between consumer theory and the empirical model. The violation of the theoretical restrictions is prevalent among existing empirical studies for seafood demand (e.g., Xie & Myrland, 2011; Nguyen, Hanson, & Jolly, 2013, and see Thong, 2012 for a discussion). We applied the same approach as Xie, Kinnucan, and Myrland (2008) and Thong (2012) in their seafood demand study that we estimated both unrestricted and restricted models without further investigation to determine whether the parameters were unduly affected. The uncompensated price and scale flexibility of the model without restrictions are presented in Table A2 for further consideration. Similar to previous studies, we reveal that imposition of restrictions has little effect on the parameters. The weighted average own price flexibilities of the two models are very close, i.e., −0.419 in the restricted vs. −0.436 in the unrestricted model. Moreover, the standard errors of the estimated coefficients and the calculated flexibilities in the restricted model are a little bit smaller than those of the unrestricted model.

We present the estimated parameters of the non-linear IAIDS for the seven regions with homogeneity and symmetry restrictions in Table 1. Overall, the model specified appears to fit well with the monthly data in the period of 2007–2014, as indicated by high R^2 and t-statistics of the estimated parameters.

Table 1. Non-linear parameter estimates of IAIDS with homogeneity and symmetry constraints (a).

		Log of quantity								
Equations	Intercept αi	Asean & East Asia $\gamma 1i$	North America $\gamma 2i$	Oceania $\gamma 3i$	Russia & Eastern EU $\gamma 4i$	South & Central America $\gamma 5i$	Western EU $\gamma 6i$	ROW $\gamma 7i$	LnQ βi	R2
w1	2.689	0.552							−0.091	0.99
	0.572	0.032							0.036	
w2	7.844	−0.124	1.841						−0.344	0.99
	0.927	0.038	0.094						0.059	
w3	1.482	−0.002ns	−0.100	0.272					-0.037^{ns}	0.98
	0.376	0.023	0.025	0.046					0.024	
w4	4.050	-0.041^{ns}	−0.164	-0.007^{ns}	0.851				−0.167	0.99
	0.862	0.023	0.048	0.015	0.046				0.055	
w5	−14.337	−0.241	−0.862	-0.083^{ns}	−0.357	2.572			1.023	0.97
	0.783	0.072	0.130	0.047	0.107	0.176			0.049	
w6	8.238	−0.150	−0.587	−0.077	−0.275	−1.012	2.097		−0.401	0.99
	1.002	0.039	0.065	0.027	0.049	0.129	0.110		0.064	
w7	0.035^{ns}	0.005^{ns}	-0.004^{ns}	-0.004^{ns}	-0.007^{ns}	-0.017^{ns}	0.004^{ns}	0.022	0.017^{ns}	0.91
	0.437	0.007	0.020	0.004	0.011	0.055	0.023	0.005	0.028	

[a] Coefficients and their standard errors are multiplied by 10; standard errors are in parentheses. ^{ns}Indicate the parameter is not statistically significant at the 5% level. Rho estimate is 0.739(0.0295) and statistically significant at the 1% level.

Twenty-nine out of 42 coefficients (including the intercepts) are statistically significant at the 5% level or lower. The non-significant coefficients (*i.e.*, at the 10% level) are mostly associated with the ROW share equation and cross-effect coefficients. The explanatory powers of the equations (R^2) are very high, ranging from 0.91 to 0.99. The high R^2 may raise concerns of a spurious regression problem. However, the high R^2 is commonly found in demand system approaches, especially for time series data and estimated by the SUR procedure. In our case, the high R^2 was also found in the model without the autoregressive parameter, in the range of 0.97–0.99.

It is widely recognized that price (i.e., demand side) is affected both by supply and consumption scale. An increase of supply will reduce the price while an increase of consumption scale will increase the demand. These two effects are measured in our IAIDS by own-price flexibilities (negative sign) and scale flexibilities (positive sign). The uncompensated price and scale flexibilities associated with their standard error are presented in Table 2. The flexibilities were calculated at the sample mean. All of the own-price and scale flexibilities are significant at the 1% level and have the expected sign. More than half of the 42 cross-price flexibilities are significant at the 5% level or lower.

Subsequent analysis rejects the null hypothesis that the uncompensated own-price flexibilities are equal to −1. As shown in Table 2, all own-price flexibilities are far below 1 in absolute terms, except for the ROW. The results indicate that demand for Pangasius in these markets is inflexible. For instance, a 1% increase in the exported quantity to each of these markets is associated with a decline of 0.289%, 0.354%, 0.270%, 0.248%, 0.200%, and 0.575% in the exported price to ASEAN and East Asian, North America, Oceania, Russia and Eastern EU, South and Central America, and Western EU markets, respectively. The average own-price flexibility (i.e., calculated by $\sum w_i f_{ii}$) is −0.419. The result indicates a large potential for Pangasius producers to increase their export volumes to existing markets.

The cross-price flexibilities represent cross-effects between two different import markets. Negative cross-price flexibility represents quantity substitutability between two markets, while positive flexibility implies quantity-complementarity (Eales & Unnevehr, 1994; Park & Thurman, 1999; Thong, 2012). Interestingly, cross-flexibilities between North America and Western EU, the two most important markets, are statistically significant at the 1% level, have negative signs and high magnitude. The cross-flexibilities of North America and Western EU with other markets are also highly significant, have negative signs and considerable magnitude. The results indicate that West EU and North American are substitutes for each other. Further, new markets such as ASEAN and East Asia, Russia and East EU, Oceania, and South America are substitutes for North America and West EU markets.

Market substitution indicates potential as to whether exporters can switch their exports to substitute markets if faced with disadvantages in the existing

Table 2. Uncompensated price and scale flexibility of Pangasius exported to the world markets.

		Quantity							
Import markets	Scale fi	Asean & East Asia f1i	North America f2i	Oceania f3i	Russia & Eastern EU f4i	South & Central America f5i	Western EU f6i	ROW f7i	Value Share wi
Asean & East Asia	−1.122	−0.289	−0.083	-0.028^{ns}	−0.075	-0.008^{ns}	−0.061	0.034^{ns}	7.5%
	0.049	0.039	0.011	0.041	0.019	0.016	0.008	0.019	
North America	−1.142	−0.265	−0.354	−0.353	−0.286	-0.027^{ns}	−0.231	0.036^{ns}	24.2%
	0.025	0.036	0.021	0.048	0.028	0.029	0.012	0.036	
Oceania	−1.100	-0.015^{ns}	−0.055	−0.270	-0.022^{ns}	0.014^{ns}	−0.029	-0.007^{ns}	3.7%
	0.065	0.020	0.007	0.043	0.013	0.010	0.006	0.012	
Russia & Eastern EU	−1.160	−0.101	−0.122	-0.057^{ns}	−0.248	0.027^{ns}	−0.109	-0.002^{ns}	10.5%
	0.053	0.026	0.012	0.037	0.032	0.022	0.010	0.027	
South & Central America	−0.151	−0.130	−0.133	-0.068^{ns}	−0.090	−0.200	−0.097	−0.164	12.1%
	0.041	0.028	0.016	0.038	0.027	0.042	0.011	0.057	
Western EU	−1.102	−0.330	−0.393	−0.314	−0.431	0.058^{ns}	−0.575	0.082^{ns}	39.4%
	0.016	0.048	0.022	0.068	0.042	0.038	0.019	0.050	
ROW	−0.937	0.007^{ns}	-0.002^{ns}	-0.009^{ns}	-0.007^{ns}	-0.015^{ns}	0.001	−0.917	2.7%
	0.105	0.006	0.004	0.008	0.007	0.010	0.003	0.019	

^{ns}indicate the parameter is not statistically significant at the 5% level. Standard errors are in parentheses.

market. We confirm the market substitutes by conducting a simple analysis that regress the pair-log prices of market regions, i.e., $\ln p_{1t} = \alpha + \beta \ln p_{2t}$. The significant and positive coefficients indicate the substitution between products (Asche, Jaffry, & Hartmann, 2007), or substitution between markets in our study. We found that the regression coefficients are highly significant, positive and in the range of 0.65 to 1.26, except for the pair-regressions with ROW. The results indicate the market substitution or market integration.

Scale flexibilities describe how marginal valuations change with expansions in the consumption bundle (Park & Thurman, 1999). In other words, the scale flexibilities indicate whether consumers would increase or decrease their consumption of the product according to their expenditure expansion. When consumers' income increases, luxury products will gain an increasing share of the consumption, whereas necessity commodities will suffer from a decrease in consumption. For Pangasius, if the consumption scale increases by 1% (i.e., all quantities consumed increase by 1%), the export prices of Pangasius will decline by 1.12% in ASEAN and East Asia, 1.14% in North America, 1.10% in Oceania, 1.160% in Russia and East EU, 0.15% in South and Central America, 1.10% in West EU, and 0.94% in ROW markets. The results indicate that consumers in all markets except for South and Central America perceive Pangasius as a necessity good. The consumers in South and Central America consider Pangasius as a luxury product, possibly because Pangasius has just penetrated the market, with an export growth in recent years of around 7% per month. The low absolute values of both scale flexibility and own-price flexibility indicate that South and Central American market is highly promising for the Pangasius export.

We re-estimated the IAIDS with data specific to country importers to examine the consistence and stability of the model and to be able to provide more detailed information for policy implications. We selected six import countries including the United States, Spain, Netherlands, Poland, Australia and Japan. These countries account for 50% of total export value of Pangasius from Vietnam. The countries were selected because they have a high import share, represent the market regions, and have no or few missing values in the study period. Unfortunately, we cannot find any import country representing the South and Central American region that satisfy these criteria. Uncompensated price and scale flexibilities of Pangasius exported to these selected countries are presented in Table 3.

Consistent with the results estimated for market regions, all scale and own-price flexibilities are significant at the 1% level and have the expected sign. All own-price flexibilities are much lower than 1 and lower than the respective own-price flexibilities of market regions in absolute terms. The results indicate again the existence of great demand potential for Pangasius in world markets. The increase in export volume will decrease the price but to a lesser degree. Except for the market in Poland, all scale flexibilities are not different

Table 3. Uncompensated price and scale flexibility of Pangasius exported to the world importers.

		Quantity							
Importers	Scale fi	USA f1i	Spain f2i	Netherlands f3i	Poland f4i	Australia f5i	Japan f6i	ROW f7i	Value Share wi
USA	−0.908	−0.223	−0.211	−0.195	−0.214	−0.235	−0.284	−0.217	21.7%
	0.039	0.019	0.024	0.034	0.060	0.046	0.094	0.011	
Spain	−1.008	−0.088	−0.177	−0.175	−0.102	−0.141	0.134^{ns}	−0.085	10.1%
	0.055	0.011	0.030	0.030	0.035	0.047	0.075	0.007	
Netherlands	−0.972	−0.060	−0.128	−0.079	−0.084	-0.082^{ns}	0.046^{ns}	−0.067	7.2%
	0.077	0.011	0.022	0.032	0.034	0.044	0.076	0.007	
Poland	−1.318	−0.030	−0.036	−0.042	−0.185	-0.038^{ns}	-0.010^{ns}	−0.054	5.2%
	0.207	0.011	0.017	0.023	0.066	0.032	0.069	0.007	
Australia	−1.060	−0.033	−0.048	−0.037	-0.035^{ns}	−0.191	−0.119	−0.021	3.6%
	0.100	0.007	0.015	0.021	0.022	0.045	0.055	0.004	
Japan	−1.170	−0.015	0.021	0.012^{ns}	-0.005^{ns}	−0.045	−0.493	−0.010	1.4%
	0.229	0.005	0.010	0.014	0.018	0.022	0.050	0.003	
ROW	−1.001	−0.459	−0.430	−0.455	−0.693	−0.329	−0.445	−0.547	50.8%
	0.023	0.026	0.034	0.046	0.103	0.064	0.135	0.015	

Note. ^{ns}Indicate the parameter is not statistically significant at the 5% level. Standard errors are in parentheses.

or higher than 1 in absolute terms, again indicating that the Pangasius is a necessity good in these markets. All cross-price flexibilities between the United States and other markets and between ROW and other markets are significant at 1% of the level and have negative signs and high magnitudes, revealing a strong substitute among these markets.

Discussion

The monthly export data of Vietnamese Pangasius fit well to the non-linear IAIDS of seven equations representing the relationship between export shares and quantities. Our estimates indicate that the international demand for Pangasius is price inflexible to the export volume. Import markets are substitutes for each other and Pangasius catfish is significantly preferable by the low-income consumers. These findings are meaningful for Vietnam as well as other start-up farming countries. Vietnamese officials currently call for reducing production (SgTime, 2015) to increase export prices. However, this suggestion is not backed by any scientific evidence. Our study concludes that a supply control strategy will worsen conditions for the industry because 1% of the supply cut-off leads to less than 1% increase of the price. Productivity growth leading to higher production and lower price is typical in all successful aquaculture sectors (Asche, 2008). As expected, the price reduction is much smaller than the proportion of the production expansion. Hence, it is possible to have growth in global Pangasius aquaculture without substantial price reductions. Other countries such as Bangladesh, Indonesia, Malaysia and Cambodia may decide to develop the Pangasius production to industrial scale to satisfy the demand in both local and export markets.

Pangasius production was started in the Mekong river delta of Vietnam at the end of the 1990s and the early 2000s, when the product was dependent on the U.S. market. The sector was about to shut down when facing questionable anti-dumping duties from the U.S government in 1995 (Brambilla, Porto, & Tarozzi, 2012; De Silva & Phuong, 2011; Duc, 2010). Vietnam did not decrease production and producers found new substitute markets such as the EU. Our research results confirm that export markets are significant substitutes for each other, especially between the West EU and North America. This implies that Pangasius exporters have the capacity to select export markets to deal with the uncertainties that may appear in a given market.

The scale flexibilities indicate whether consumers in the import regions would increase or decrease their consumption of Pangasius according to their expenditure expansion. The scale flexibility, however, is identified for a constant share of income used on Pangasius. Whether the results on the effect of income on prices are realistic relies on whether this share remains constant. Hence, results on the effect of income on prices are assessed more realistically in countries where food and (in particular) Pangasius form a relatively small share of total consumption. Pangasius has been exported to most developed countries, e.g., North America and Western Europe. The export shares of these countries cover 65% of total export value of Vietnam. However, this study found that the Pangasius is perceived as a necessary good, except for countries in South America where the product has just penetrated in recent years. This means that the product consumption would not be responsive to changes in the overall consumption scale (i.e., income). In addition, Pangasius is favored by low-income groups, possibly because its price is lower than that of other whitefish. This finding suggests that Vietnam and other countries have potential to expand their export to not only the current markets but also new markets of less-developed countries in South Asia, Africa and South America.

The sustainability of the Pangasius sector is crucial to the Vietnamese economy and the development of the Mekong Delta. However, it seems that Vietnam has not fully exploited the advantages of favorable production conditions and market presence. The sector has suffered severe problems from spontaneous development and poor investment in product development. For example, our data show that over 80% of the export products are frozen fillets and these products are preferred by low-income households, leading to low market margins and vulnerability for the producers. We think that the sector should consider diversifying their products, focusing on quality control, making the market transparent, and developing marketing strategies to upgrade the industry in the global value chain. Upgrading the global value chain can promote Pangasius purchases to higher-income households and thereafter expand the market potentials. The other countries (e.g., Bangladesh and Indonesia) that are seeking export markets for Pangasius can take lessons from the example of Vietnam.

Conclusions

In this study, we estimated an inverse demand model for Pangasius catfish (*Pangasianodon hypopthalmus*) to identify the effect of production growth on prices. All own-price flexibilities and scale flexibilities are statistically significant at the 1% level and have the expected signs. The own-price flexibilities are all lower than 1 in absolute value, i.e., between 0.200 and 0.917 and a weighted average of 0.419, revealing the price inflexibility for Pangasius. Pangasius is evaluated as a necessary good in all markets, except for the Latin America, and the major markets (e.g., Europe and North America) are substitute for each other.

Furthermore, our study reveals that the market for Pangasius is stable in relation to all factors studied in this article. Hence, the global Pangasius industry can grow rapidly without worrying about a substantial price reduction. Pangasius companies are less affected by market barriers and economic recession because of substitution between market regions and because of

Pangasius being a necessary good. Market stability is one of the secure factors for Pangasius producing countries to expand their production.

Although we haven't noticed any previous studies on substitution or market integration between Pangasius and whitefish (e.g., cod, haddock, pollock and tilapia), we presume that Pangasius may be a part of the wider whitefish market, although the lack of including other whitefish in the demand model is one of our research limitations. However, the small and significant own price-flexibilities in our estimate indicate potential imperfect substitutions, instead of perfect substitution, between Pangasius and other whitefish. Our finding of market stability might therefore well be reliable information in a policy setting.

The export demand may be affected by other factors such as exchange rate fluctuations (Xie et al., 2008), type of currency (Straume, 2014), distance to import markets (Eaton & Kortum, 2002; Asplund, Friberg, & Wilander, 2007), tariffs (Kinnucan & Myrland, 2005) and non-tariff barriers raised in import markets (Duc, 2010) and seasonal effects (Wessells & Wilen, 1994). However, classical consumption theories assume that consumers maximize their utilities formulated on quantity consumption under budget constraints. Thus, the effects of other trading factors on the demand may have importance, but they must be of high magnitude and count in the same direction to outweigh the important factors identified in this article. We suggest that future research complement this analysis by using,k e.g., discrete choice models and market integration tests that include substitution effects between Pangasius and other fish species.

Although the Pangasius industry forms an important part of global aquaculture, the sector has not captured the attention of researchers in the social sciences. Various aspects of the industry have not yet been investigated, including market structure and institutions, market coordination, value chain governance, producer self-governance, price formation and marketing margin, production equilibrium and efficiency, market information and risk management, and marketing and branding. These aspects of the industry also offer opportunities for future research.

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Appendix

Table A1. Valid aggregation test.

Log of price	ADF test		Independence test		Valid aggregation
	Test statistics*	Result	Test	Spearman's ρ (rho)	
Assia & East Asia	−3.058	I(0)			
Japan	−4.528	I(0)	Correlation	−0.023	Yes
Thailand	−7.922	I(0)	Correlation	0.176	Yes
North America	−2.248	I(1)			
USA	−4.999	I(0)	Not necessary		Yes
Canada	−6.092	I(0)	Not necessary		Yes
Ocean	−3.901	I(0)			
Australia	−9.591	I(0)	Correlation	−0.033	Yes
Russia & Eastern EU	−2.126	I(1)			
Poland	−4.268	I(0)	Not necessary		Yes
Russia	−3.906	I(0)	Not necessary		Yes
South & Central America	−2.902	I(1)			
Colombia	−5.885	I(0)	Not necessary		Yes
Mexico	−3.814	I(0)	Not necessary		Yes
Western EU	−2.433	I(1)			
Spain	−4.468	I(0)	Not necessary		Yes
The Netherland	−7.139	I(0)	Not necessary		Yes

Note. *5% critical value is −2.89; I(0) = stationary; I(1) = non-stationary.

Table A2. Uncompensated price and scale flexibility of IAIDS without restrictions.

Import markets	Scale fi	Quantity							Value Share wi
		Asean & East Asia f1i	North America f2i	Oceania f3i	Russia & Eastern EU f4i	South & Central America f5i	Western EU f6i	ROW f7i	
Asean & East Asia	−1.242	−0.263	−0.091	0.015^{ns}	−0.045^{ns}	0.102	−0.035	−1.017	7.5%
	0.061	0.038	0.015	0.061	0.027	0.031	0.012	0.222	
North America	−1.210	−0.302	−0.375	−0.511	−0.163	0.312	−0.159	−2.516	24.2%
	0.031	0.051	0.032	0.121	0.063	0.076	0.027	0.348	
Oceania	−1.203	0.006^{ns}	−0.078	−0.273	−0.002^{ns}	0.061	−0.016	−0.340	3.7%
	0.082	0.030	0.018	0.040	0.015	0.018	0.007	0.171	
Russia & Eastern EU	−1.121	−0.076	−0.080	−0.014^{ns}	−0.242	0.123	−0.107	−0.984	10.5%
	0.070	0.033	0.022	0.040	0.032	0.045	0.019	0.292	
South & Central America	0.010^{ns}	0.014^{ns}	0.008^{ns}	0.055^{ns}	0.005^{ns}	−0.881	−0.207	2.284	12.1%
	0.046	0.043	0.032	0.051	0.043	0.125	0.034	0.497	
Western EU	−1.083	−0.249	−0.310	−0.221	−0.419	−0.245	−0.564	0.122^{ns}	39.4%
	0.023	0.058	0.037	0.073	0.066	0.119	0.021	0.199	
ROW	−1.001	−0.372	−0.285	−0.254	−0.256	0.536	0.006^{ns}	1.450	2.7%
	0.138	0.080	0.039	0.126	0.075	0.112	0.015	0.671	

Note. ^{ns}Indicate the parameter is not statistically significant at the 5% level. Standard errors are in parentheses.