Some Effects of Income and Population Growth on Fish Price and Welfare

Nguyen Ly, and Kinnucan Henry

Selected Poster prepared for presentation at the Southern Agricultural Economics Association (SAEA) Annual Meeting, San Antonio, Texas, February 6-9, 2016

Some Effects of Income and Population Growth on Fish Price and Welfare

Abstract. A simple excess supply-demand model is used to determine the effects of income and population growth on the international price of fish, and on welfare in net exporting and importing regions of the world. Stochastic simulations of the model suggest fish price increases by between 0.25% and 1.07% for each 1% increase in world income, and by between 0.30% and 1.20% for each 1% increase in world population. Combining these elasticity estimates with the actual growth in income and population for 1999-2013, results suggests income and population growth together caused the world price of fish to rise by between 1.0% and 4.1% per year, for a best-bet estimate of 2.1% per year. The actual average annual rise in fish price over the last 12 years was 0.9%. This suggests supply growth due to aquaculture moderated to a significant extent price pressure due to demand growth. Higher fish prices increase welfare in net exporting countries at the expense of welfare in net importing countries. However, our results suggest net gains to producers and consumers in the two regions combined are positive.

Key words: fish price, fish trade, welfare

JEL Code: F1

Some Effects of Income and Population Growth on Fish Price and Welfare

The surge in world food prices that began in 2003 has been the subject of much analysis and debate in the scholarly literature (Headey and Fan 2008, Ivanic and Martin 2008, de Hoyos and Medvedev 2011, Headey 2014). What has received less attention, but in some ways is more profound, is the increase in fish price (figure 1). Trend regressions show an average annual rate of increase in the real price of fish of 1.4% between 1990 and 2002 and 0.9% between 2003 and 2014 (table 1). Real food and meat prices, by contrast, show no trend in the 1990-2002 period, and an average annual increase of 1.3% and 1.1%, respectively, in the 2003-2014 period. In essence, the rapid rise in food and meat prices in the surge period has been largely cancelled by declines, resulting in an average annual rate of increase only moderately above the rate of increase in fish price.

That the real price of fish in world markets has increased steadily over the last two and half decades is a boon to fisherman, to fish farmers, and to small coastal communities in the United States and elsewhere where fishing is a traditional way of life. For fish consumers, however, the rise in price is less of a good thing, especially for the urban poor in less developed countries such as Bangladesh where consumers rely on fish for the lion's share of their animal protein intake.[1] In these countries, a rise in fish price can increase the incidence of undernutrition, but also poverty (Headey *et al*. 2015).

The purpose of this research is to determine the effects of income and population growth on the international price of fish. A secondary goal is to determine how such price changes affect the welfare of producers and consumers in net exporting and importing countries of fish. Income and population growth have been long recognized as major drivers of fish demand (World Bank 2013; FAO 2014). Yet research to determine their effects on price is limited. Studies based on inverse demand systems have quantified the effects of changes in fish supply on price (e.g., Barten and Bettendorf 1989; Eales Durham and Wessells 1997; Holt

[1] According to FAO Globefish, Bangladesh consumers rely on fish for 56.2% of their animal protein intake (http://www.globefish.org/total-fish-consumption-per-capita-kg-and-fish-contribution-to-total-proteins-percent.html). Other counties where fish account for more than 50% of animal protein intake include Cambodia, Sierra Leone, Indonesia, Ghana, Sri Lanka, French Guiana, British Virgin Islands, Guadeloupe, and the Maldives.

and Bishop 2002; Nielsen *et al*. 2012; Moore 2015). However, such studies are region and species specific and thus do not address global and aggregate impacts. Global price determination is considered in the IMPACT model developed by the International Food Policy Research Institute that serves as the basis for the World Bank's *Fish to 2030* report (World Bank 2013). Global price determination is also considered in the FAO Fish Model developed jointly with the Organization for Economic Cooperation and Development that serves as the basis for FAO's outlook report on fisheries and aquaculture. But neither of these models isolates the effects of income and population growth on fish price, the major focus of the present study.

The next section discusses the model and relevant data. The model is then calibrated and simulated to gauge the extent to which observed increases in population and income have affected fish price over the last 15 years. The welfare effects of price increases are measured in the next section. The paper concludes with a discussion of key findings and implications.

Model

A unique aspect of fish as a food commodity is that it is highly traded. For example, the proportion of the world's fish production traded internationally in 2013 was 37% (FAO Globefish 2014). This suggests there are large regional imbalances in supply and demand that must be resolved through the price mechanism (Anderson 2003, World Bank 2013, p. xiv). Accordingly, to model fish price we adopted a simple two-country excess supply and demand framework similar to the one used by Chambers and Just (1979) to analyze the effects of currency devaluation on agricultural trade. An advantage of this framework is that countries that are net exporters of fish can be clearly distinguished from countries that are net importers of fish. This is useful because some countries that are considered major exporters (importers) of fish are actually net importers (exporters) when imports and exports are combined to determine the trade balance. For example, China commonly is cited as the world's largest exporter of fish. In reality, as shown in table 1, it is a net importer of fish. The reason, of course, is that China is also a major importer of fish, and when fish for non-human consumption are included in the trade flows (as is the case in our data), China becomes a net importer. Correctly classifying countries as net importers and net exporters is important because it changes somewhat the stylized fact that fish in world markets flow from the "poor" South to the "rich"

North (e.g., Nhuong *et al*. 2011 and references therein). Although there is some truth to this characterization, a perusal of table 1 will show some rich Northern countries in the net exporter category (e.g., Norway, Iceland, Canada) as well as some poor Southern countries in the net importer category (e.g., Nigeria, Egypt, Ghana). Consequently, the income gaps between the categories are not as large as might be supposed, an issue addressed later.

The basic model consists of two structural equations and a clearing condition

$$D = D(P, Y_m, N_m) \qquad \frac{\partial D}{\partial P} < 0, \ \ \frac{\partial D}{\partial Y_m} > 0, \ \frac{\partial D}{\partial N_m} > 0 \tag{1}$$

$$S = S(P, Y_x, N_x) \qquad \frac{\partial S}{\partial P} > 0, \ \ \frac{\partial S}{\partial Y_x} < 0, \ \frac{\partial S}{\partial N_x} < 0 \tag{2}$$

$$D = S = Q \tag{3}$$

where D is the world's excess demand for fish taken to be a function of the market price of fish P and the levels of income Y_m and population N_m in the net importing region. S is the world's excess supply of fish taken to be a function of the market price of fish P and the levels of income Y_x and population N_x in the net exporting region. Q is the quantity of fish traded. The excess demand curve is downward sloping, and shifts to the right with increases in income and population in the net importing region. The excess supply curve is upward sloping, and shifts to the left with increases in income and population in the net exporting region. The model abstracts from transportation costs and other barriers to trade, and assumes that, in equilibrium, the law of one price holds and fish is a homogeneous commodity. Cross-price effects, which play a central role in Chamber and Just's (1979) model, are ignored. A justification for this is the fish are a staple commodity that will be little affected by the prices of related commodities in international trade, at least as a first approximation.

Taking the total differential of equations (1) – (3) and converting partial derivatives to elasticities yields

$$D^* = \eta_P P^* + \eta_Y Y_m^* + \eta_N N_m^* \tag{4}$$

$$S^* = \varepsilon_P P^* - \varepsilon_Y Y_x^* - \varepsilon_N N_x^* \tag{5}$$

$$D^* = \ S^* = Q^* \tag{6}$$

where the asterisk (*) denotes proportionate change (e.g., $P^* = dP/P$); $\eta_P \ (< 0)$, $\eta_Y \ (> 0)$ and $\eta_N \ (> 0)$ are elasticities of excess demand with respect to fish price, income in the net importing region, and population in the net importing region, respectively; and $\varepsilon_P (> 0)$,

$\varepsilon_Y(> 0)$, and $\varepsilon_N(> 0)$ are elasticities of excess supply with respect to fish price, income in the net exporting region, and population in the net exporting region, respectively. Equations (4) – (6) constitute an equilibrium displacement model or EDM. For a good discussion of EDMs, including their limitations, see Piggott (1992), Davis and Espinoza (1997), and Wohlgenant (2011). Note that an increase in income or population in exporting countries causes the excess supply curve to shift to the left. The reason is that fish consumption in those countries increase with increases in income or population, which reduces the quantity of fish that enters international trade, *ceteris paribus*.

The model contains two endogenous variables (P^* and Q^*) and four exogenous variables (Y_m^*, Y_x^*, N_m^*, and N_x^*). At issue is the effect of isolated changes the exogenous variables on fish price. To determine that, we solve equations (4) - (6) simultaneously to yield the reduced-form equation

$$P^* = \left(\frac{\eta_Y}{\varepsilon_P - \eta_P}\right) Y_m^* + \left(\frac{\varepsilon_Y}{\varepsilon_P - \eta_P}\right) Y_x^* + \left(\frac{\eta_N}{\varepsilon_P - \eta_P}\right) N_m^* + \left(\frac{\varepsilon_N}{\varepsilon_P - \eta_P}\right) N_x^*. \quad (7)$$

Income and population growth increase price. And this is true regardless of its source. Two useful principles can be deduced from the reduced form. First, the relative responsiveness of fish price to income and population growth in net exporting and importing countries depends strictly on the relative size of the structural elasticities η_Y and ε_Y and η_N and ε_N, as the numerators in equation (7) are identical across all shift variables. Second, a shift in a less elastic supply or demand curve always results in a larger price effect than a shift a more elastic supply or demand curve. Stated differently, the flatter the excess supply and demand curves for fish are in the world market, the smaller the price effects of income and population growth, *ceteris paribus*.

The price of fish is relatively stable (figure 1). For example, the standard error of the trend regression for fish (0.030) is one third the standard error for meat (0.097), and one-fifth the standard error for food (0.110) (table 1). A stable world price suggests the excess supply and demand curves are relatively flat. Insight into why this might be so can be obtained by considering the following analytical expressions for ε_P and η_P (derived in the appendix):

$$\varepsilon_P = \frac{\bar{\varepsilon}_P - (1 - k_x)\bar{\eta}_P}{k_x} > 0 \quad (8)$$

$$\eta_P = \frac{\tilde{\eta}_P - (1 - k_m)\tilde{\varepsilon}_P}{k_m} < 0. \quad (9)$$

In these expressions, $\bar{\eta}_P (< 0)$ and $\bar{\varepsilon}_P$ (> 0) are the *domestic* demand and supply elasticities for fish with respect to price in the net exporting region; $\tilde{\eta}_p (< 0)$ and $\tilde{\varepsilon}_P$ (> 0) are the corresponding elasticities in the net importing region; k_x is the share of domestic production in the net exporting region that is exported; and k_m is the share of domestic consumption in the net importing region that is imported. For given values of the domestic supply and demand elasticities, the excess supply and demand curves flatten as trade share decreases (smaller k_x and k_x). Our analysis based on data for 2000-2011 indicates $k_x = 0.19$ and $k_m = 0.12$ (table 2). These *net* trade shares are sufficiently small to suggest that the excess demand and supply for fish in international markets are elastic, an issue to be addressed in more detail later.

Trade shares are also important determinants of the excess supply and demand elasticities with respect to income and population. To see this, consider the following analytical expressions for the elasticities in question (see appendix for derivation):

$$\varepsilon_Y = \frac{(1-k_x)\bar{\eta}_Y}{k_x} > 0 \quad (10)$$

$$\eta_Y = \frac{\tilde{\eta}_Y}{k_m} > 0 \quad (11)$$

$$\varepsilon_N = \frac{(1-k_x)\bar{\eta}_N}{k_x} > 0 \quad (12)$$

$$\eta_N = \frac{\tilde{\eta}_N}{k_m} > 0. \quad (13)$$

In these expressions, $\bar{\eta}_Y$ (> 0) and $\bar{\eta}_N$ (> 0) are *domestic* demand elasticities for fish with respect to income and population, respectively, in the net exporting region; and $\tilde{\eta}_Y (> 0)$ and $\tilde{\eta}_N (> 0)$ are the corresponding elasticities for the net importing region. Excess supply and demand elasticities with respect to income and population are inversely related to trade share. This is especially true for the elasticities corresponding to the net exporting region, as the relevant analytical expressions have trade share in the numerator as well as the denominator (compare equations (10) and (12) with equations (11) and (13)). To illustrate, consider a situation where preferences for fish in net exporting and importing regions are homothetic such that $\bar{\eta}_Y = \tilde{\eta}_Y = 1$. Let trade shares be equal such that $k_x = k_m = 0.20$. In this situation, $\varepsilon_Y = 4$ and $\eta_Y = 5$. The rightward shift in the excess demand curve associated with a 1% increase in income in the importing region is 25% larger than the leftward shift in the excess supply curve associated with a 1% increase in income in the net exporting region. And this is true despite identical preferences for fish in the two regions, and identical trade shares. The upshot is that there is an inherent bias that favors demand shocks originating from net importing counties having a larger effect on price than supply shocks originating from net exporting countries.

Model Calibration

To simulate the model, it needs to be calibrated. For this purpose, we surveyed the empirical literature to determine "best-bet" values for domestic supply and demand elasticities for fish with respect to price, income, and population. These values are then combined with the average trade shares in table 1 to compute the excess supply and demand elasticities using equations (8) – (13). Given the inherent uncertainty in the parameter values so obtained, stochastic simulations are performed under the assumption that each parameter follows a GRK distribution with minimum and maximum values equal to one-half and twice its best-best value. The GRK distribution is an empirical substitute for the triangle distribution that allows observed values to fall below the minimum value and above the maximum value 2% of the time. As such, the GRK distribution avoids the understatement of downside risk inherent in the Triangle distribution (Richardson 2005, Chapter 5).

Focusing first domestic demand elasticities, estimates of own-price and income elasticities for net exporting countries include studies by Rickertsen (1996), Andersen *et al*. (2008), and Dey *et al*. (2008) and for net importing countries include studies by Wellman (1992), Eales *et al*. (1997), Nielsen (1999), ABARE (2000), Asche *et al*. (2005), and Singh *et al*. (2014). Based on a careful review of these studies, we set $\bar{\eta}_P = -0.87$ and $\bar{\eta}_Y = 0.60$ as the best-bet values of these parameters for the net exporting region, and $\tilde{\eta}_P = -1.27$ and $\tilde{\eta}_Y = 1.02$ as the best-bet values for the net importing region. Studies of domestic supply elasticities for fish are relatively scarce and include Kouka and Engel (1998), Dey *et al*. (2004), Kumar et al. (2006), Asche *et al*. (2007), Andersen *et al*. (2008), and Asche (2009). Based on a review of these studies, we set $\bar{\varepsilon}_P = 0.54$ and $\tilde{\varepsilon}_P = 0.50$ as the best-bet value of these parameters.

Estimates of the effects of population size on fish demand are even rarer than supply studies. Cheng and Capps (1998) estimate household size elasticity in the range of range of 0.13 to 0.33 for fresh and frozen seafood in the United States. Similar estimates by Lanfranco *et al*. (2002) for Hispanics indicate a range from 0.10 to 0.36. Salvanes and Devoretz (1997) and

Myrland *et al*. (2000) find that household seafood consumption increases with increasing household size but do not provide elasticities estimates. Because of the lack of explicit empirical estimates to indicate the responsiveness of fish demand to population size, we set $\bar{\eta}_N = \tilde{\eta}_N = 1$. This implies a 1% increase in population increases domestic demand for fish by 1% in both the net exporting and net importing regions. The assumption is not inconsistent with most empirical studies of demand in which quantity is defined on a per-capita basis.[2] The parameter values used to simulate the model are summarized in table 3.

Simulation Results

Simulation proceeds in two steps. In the first step, stochastic simulations of equation (7) are performed to develop 90% confidence intervals for the reduced-form elasticities implied by the equation.[3] The simulations are performed using the software SIMETAR with the number of iterations set to 1,000 (Richardson 2005). In the second step, the reduced-form elasticities obtained in the first step are combined with observed changes in income and population in the net importing and exporting regions to determine the actual effects of income and population growth on fish price. The changes in income and population are computed for three five-year intervals covering the period 1999 to 2013. The separation of growth effects into five-year intervals permits an assessment of how the effects may have changed over time.

Reduced-Form Elasticities

Demand shocks originating in net importing countries have larger effects on world fish price than supply shocks originating in net exporting countries (table 4). Specifically, the 90% confidence intervals for $\frac{P^*}{Y_m^*}$ and $\frac{P^*}{N_m^*}$ are [0.19, 0.83] and [0.20, 0.80], with mean values of 0.41 and 0.40, respectively. The corresponding intervals for $\frac{P^*}{Y_x^*}$ and $\frac{P^*}{N_x^*}$ are [0.06, 0.24] and [0.10, 0.40], with mean values of 0.12 and 0.20, respectively. A 1% increase in income or population in net importing countries has about twice the effect on fish price as a 1% increase in income or population in net exporting countries. Still, the effects overall are relatively modest, as the

[2] For example, let the per-capita demand function for fish in the net exporting region be defined as $Q_d/N_x = D(P, Y_x)$. Writing this function in proportionate change form yields $Q_d^* = \bar{\eta}_P P^* + \bar{\eta}_Y Y_x^* + N_x^*$. Clearly, the per-capita specification implicitly assumes the elasticity of total fish consumption in exporting region with respect to population is 1. A similar analysis applies to the demand function of the net importing region.

[3] For a cogent discussion of the advantages and caveats associated with stochastic simulation of equilibrium displacement models, see Davis and Espinoza (1998).

upper limits of the confidence intervals are less than 1. In other words, the model suggests fish price will increase at a slower pace than income and population in the respective regions.

Combining the estimates, it appears that population growth has a slightly larger effect on fish price than income growth. Specifically, an isolated 1% increase in population worldwide is projected to increase fish price by between 0.30% and 1.20%, with a best-bet estimate of 0.60%. An isolated 1% increase in income worldwide is projected to increase fish price by between 0.25% and 1.07%, with a best-bet estimate of 0.53%. The best-bet estimates suggest fish price will increase at about half the pace of income and population growth worldwide.

Simulated Price Effects

To what extent might income and population growth explain the rise in fish price evident in figure 1? To answer the question, we first computed the level of real income and population in the net importing and exporting regions as shown in table 5. These data confirm that net importing countries are richer than net exporting countries. The aggregate income of net exporting countries is only 60% as large as the aggregate income of net importing countries, and this percentage has changed little over the 15 year study period. Next, we computed percentage changes in real income and population for selected time intervals as shown in table 6. The middle period five-year period 2004-2008 showed faster rates of growth for both income and population than the first and third five-year periods, 1999-2003 and 2009-2013. The one exception is for population in net exporting countries, which grew at a slightly slower rate in the middle period (6.9%) relative to the first (7.3%) and third (7.0%) periods.

Predicted price effects were obtained by multiplying the aforementioned growth rates by the reduced-form elasticities as shown in the last three columns of table 6. Results suggest income growth in net importing countries had the largest cumulative effect on fish price over the 15 year period (14.1%), followed by population growth in net importing countries (8.6%). The price pressure exerted by income and population growth in net exporting countries at 3.8% and 4.3%, respectively, by comparison is relatively modest. Adding these effects together gives a cumulative price effect for the 15-year study period of 30.8%, which equates to an average annual price effect of 2.1%. The 90% confidence interval for this estimate is [1.0, 4.1], which suggests income and population growth, when taken together, increased fish price over the study period by between 1.0% and 4.1% per year.

The confidence interval underscores the caution that must be exercised in basing predictions on point estimates generated from a model of the type used in this study, as they inherently are imprecise. Still, it is interesting to note that the predicted price effect is not out of line with the trend growth in fish price indicated in table 1 (1.4% for the 1990-2002 period, and 0.9% for the 2003-2014 period). That fish price rose more slowly than the best-bet prediction from our model (2.1%) suggests productivity growth in the fish-farming sector was instrumental in moderating the price pressure stemming from income and population growth.[4] Overall, income growth accounted for 59% of the price rise predicted by the model compared to 41% for population growth. Consequently, for the 15 year period ending in 2013 income growth appears to be a more important driver of the observed increase in fish price than population growth, although clearly both played prominent roles.

Welfare Effects

An increase in the price of fish benefits producers at the expense of consumers. The welfare effects in the context of the present model are shown in figure 2. Panel A shows the welfare gain in net exporting countries from a price rise associated with an increase in income or population in net importing countries. Panel C shows the welfare loss in net importing countries from a price rise associated with an increase in income or population in net exporting countries. At issue is whether the gain to the domestic economies in the two regions from a combined 1% increase in income or population is positive or negative. In geometric terms, is quadrilateral *abcd* in Panel A larger or smaller than quadrilateral *efgh* in Panel C?

To answer the question, changes in producer, consumer, and total surplus in the net exporting region were measured using the following formulas:[5]

$$\Delta CS_x = -P^0 \bar{Q}_d^0 P^* (1 + \tfrac{1}{2} \bar{Q}_d^*) \tag{14}$$

[4] *The Economist* (2013) reports that the quantity of wild fish required to produce one pound of farmed salmon dropped from 10 pounds in the early days of the industry to five pounds today. The farms also became more energy efficient, and disease control improved. Indeed, thanks to productivity gains, the production of farmed fish worldwide now exceeds the production of beef. Meanwhile, due in part to overfishing, wild fish captured globally peaked in the late 1980s at about 90 million tons per year. The production of fish between 2010 and 2012 averaged 153 million tons per year (FAO, 2014, p. 200), which means some 42% of world demand is satisfied by aquaculture.

[5] The formulas assume that supply and demand shifts are parallel. For a general discussion of applied welfare analysis using an EDM, see Alston *et al*. (1995) and Wohlgenant (2011). For a specific application, see Kinnucan and Cai (2012).

$$\Delta PS_x = P^0 \bar{Q}_s^0 P^* (1 + \tfrac{1}{2} \bar{Q}_s^*) \qquad (15)$$

$$\Delta TS_x = \Delta CS_x + \Delta PS_x. \qquad (16)$$

where P^0 is price in the initial equilibrium, i.e., before the shift in the excess demand curve due to a given change in income or population; $\bar{Q}_d^0$ is the level of fish consumption in the net exporting region in the initial equilibrium; $\bar{Q}_s^0$ is the corresponding level of fish production; $\bar{Q}_d^* = \bar{\eta}_p P^*$ is the change in domestic consumption in net exporting region associated with the change in price induced by a 1% change in income or population in the net importing region; and $\bar{Q}_s^* = \bar{\varepsilon}_p P^*$ is the corresponding change in domestic production.

A similar set of equations is used to measure the changes in economic surplus in the net importing region induced by a 1% change in income or population in the net exporting region, to wit:

$$\Delta CS_m = -P^0 \tilde{Q}_d^0 P^* (1 + \tfrac{1}{2} \tilde{Q}_d^*) \qquad (17)$$

$$\Delta PS_m = P^0 \tilde{Q}_s^0 P^* (1 + \tfrac{1}{2} \tilde{Q}_s^*) \qquad (18)$$

$$\Delta TS_m = \Delta CS_m + \Delta PS_m. \qquad (19)$$

where $\tilde{Q}_d^0$ and $\tilde{Q}_s^0$ are initial equilibrium levels of fish consumption and production in the net importing region; $\tilde{Q}_d^* = \tilde{\eta}_p P^*$ is the change in domestic consumption in net importing region associated with the change in price induced by 1% change in income or population in the net exporting region; and $\tilde{Q}_s^* = \tilde{\varepsilon}_p P^*$ is the corresponding change in domestic production.

In applying equations (14) – (19) the price and quantity variables were set to their sample means for the period 2000-2011. Changes in price were computed using the reduced-form elasticities in table 4, and changes in domestic production and consumption were computed using the appropriate elasticities in table 3. Values are reported in real (2002-04) U.S. dollars. For the time period in question, the average annual real price of fish is $2,328/ton.

Results suggest gains to fish producers from income and population growth outweigh losses to fish consumers (table 7). The price rise associated with a 1% increase in the combined income of net exporting and importing regions decreases consumer surplus in the combined regions by between $36 billion and $153 billion (table 7, row 3). However, the associated gains to fish producers, which are estimated to range from $40 billion to $170 billion (row 6), are sufficient to offset the losses to consumers and provide a net welfare gain to the combined economies of between $4 billion and $17 billion (row 7). A similar result obtains for a 1% increase in population, although the net gains are more modest – between $3 billion and $12 billion (row 14). Thus, it would appear that income and population induced increases in fish price are welfare increasing from a global perspective.

Although global gains are positive, producers gain at the expense of consumers, and these distributional consequences can be important. For example, each 1% increase in income (population) in net importing countries is estimated to reduce consumer surplus in net exporting countries by between $22 billion and $96 billion (row 1) ($23 billion and $93 billion (row 8)). For the poorer countries in this group that also rely on fish for the major share of their protein intake, such losses can take a significant human toll, as noted by Headey (2014) and references therein. A similar inference applies to the effects of income and population growth in net exporting countries on consumers in net importing countries. Here, however, the consequences are less severe owing to smaller effects (compare rows 1 and 2) and the higher average income level of net importing countries as shown in table 5.

Concluding comments

The real price of fish in global markets has increased steadily for some 25 years now. Our analysis suggests income and population growth were major contributing factors to the price rise. Income growth is estimated to have increased fish price by an average of 1.2% per year, and population growth by an average of 0.9% per year, for a combined effect of 2.1% per year. The actual annual rate of increase over the last decade was about 0.9%, which suggests supply increases associated with productivity gains in the aquaculture sector moderated the price pressure exerted by income and population growth. To the extent this is true, the projected decline in the annual rate of growth of fish from aquaculture -- from 6.1% in 2003-2012 to 2.5% in 2013-2022 (FAO, 2014, pp. 201-202) -- augers for increased price pressure in the years to come.

Welfare gains from rising fish prices are positive for the world as a whole, but the transfer of surplus from consumers to producers is nontrivial. Point estimates from stochastic simulations of the model indicate that for each 1% increase in income (population), producer surplus in global fish markets increases by $84 billion ($100 billion) and consumer surplus decreases by $76 billion ($94 billion), for a net gain of $8 billion ($6 billion). Thus, while the gains to producers from higher fish prices outweigh losses to consumers, the net gain is modest, less than 10% of the redistributed surplus.

A caveat in interpreting our results is that they rest on the assumption that price transmission from world to local markets is perfect. If price transmission is imperfect, i.e., if a 1% increase in the world price of fish causes the domestic price of fish to rise by less than 1%, the excess demand elasticity η_P will be overstated in absolute value, and the excess supply elasticity ε_P will be understated.[6] Depending on the relative magnitudes of the potential biases, the price effects indicated by the model may overstate or understate actual effects. Sensitivity analysis indicated that the confidence intervals reported in table 4 are not much affected by price transmission elasticities in the range of 0.4 to 1.0. For smaller values of the transmission elasticities, the simulated price effects changed in a non-linear fashion. Thus, this caveat would appear most appropriate in situations where domestic prices are insulated from world prices due to border policies, as might be true for specific countries.

[6] These results are developed in an appendix available upon request from the authors. They extend the analysis of Bredahl *et al*. (1979), which shows $|\eta_P| \to 0$ as the international price transmission elasticity approaches zero.

References

Alston, J. M., G. W. Norton, and P. G. Pardey. 1995. *Science Under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting*. Ithaca and London: Cornell University Press.

Andersen, B.T., K.H. Roll, and S. Tveterås. 2008. "The Price Responsiveness of Salmon Supply in the Short and Long Run." *Marine Resource Economics* 23: 425–437.

Anderson, J. L. 2003. *The International Seafood Trade*. Cambridge, U.K.: Woodhead Publishing Ltd.

Asche, F. 2009. "Adjustment Cost and Supply Response in a Fishery: a Dynamic Revenue Function." *Land Economics* 85(1): 201-215.

Asche, F., T. Bjorndal, and D.V. Gordon. 2005. "Demand Structure for Fish." Working paper, Institute for Research in Economics and Business Administration, Bergen.

Asche, F., K.G. Salvanes, and F. Steen. 1997. "Market Delineation and Demand Structure." *Amer. J. Agr. Econ.* 79: 139-150.

Asche, F., S. C. Kumbhakar, and R. Tveterås. 2007. "Testing Cost vs. Profit Function." *Applied Economics Letters*. 14: 715-718.

Australian, Bureau of Agricultural and Resource Economics (ABARE). 2000. *Seafood Trade Liberalization in the APEC Region*. Canberra: Research Report.

Barten, A. P. and L. J. Bettendorf. 1989. "Price Formation of Fish: An Application of an Inverse Demand System." *European Economic Review*. 33: 1509-1525.

Bredahl, M. E., W. H. Meyers and K. J. Collins. 1979. "The Elasticity of Foreign Demand for U.S. Agricultural Products: The Importance of the Price Transmission Elasticity." *American Journal of Agricultural Economics*. 61: 58-63.

Chambers, G.R., and R.E. Just. 1979. "A Critique of Exchange Rate Treatment in Agricultural Trade Models." *American Journal of Agricultural Economics* 61(2): 249-257.

Cheng, H., and O. Capps. 1988. "Demand Analysis of Fresh and Frozen Finfish and Shellfish in the United States." *American Journal of Agricultural Economics* 70(3): 533-542.

de Hoyos, R. E. and D. Medvedev. 2011. "Poverty Effects of Higher Food Prices: A Global Perspective." *Review of Development Economics*. 15: 387-402.

Dey, M.M., Y.T. Garcia, P. Kumar, S. Piumsombun, M.S. haque, L. Li, A. Radam, A. Senaratne, N.T. Khiem, and s. Koeshendrajana. 2008. "Demand for Fish in Asia: a Cross-Country Analysis." *The Australian Journal of Agricultural and Resource Economics* 52: 321-338.

Dey, M.M., P.U. Rodriguez, M.R. Briones, O.C. Li, S.M. Haque, L. Li, P. Kumar, S. Koeshendrajana, S.T.Yew, A. Senaratne, A. Nissapa, T.N. Khiem, and M. Ahmed. 2004. "Disaggregated Projections on Supply, Demand, and Trade for Developing Asia: Preliminary Results from the Asiafish Model". IIFET 2004 Japan Proceedings.

Eales, J., C. Durham, and C.R. Wessells. 1997. "Generalized Models of Japanese Demand for Fish." *American Journal of Agricultural Economics* 79: 1153-1163.

FAO. 2014. *The State of the World Fisheries and Aquaculture*. Rome: Food and Agricultural Organization of the United Nations.

FAO Globefish. 2014. "World Fish Trade to Set New Records." February 21. (http://www.fao.org/news/story/en/item/214442/icode/ accessed 6 June 2015.)

Goldburg, J.R. 2008. "Agriculture, Trade, and Fisheries Linkages: Unexpected Synergies." *Globalizations* 5(2): 183-194.

Headey, D. 2014. *Food Prices and Poverty Reduction in the Long Run.* IFPRI Discussion Paper 01331. Washington, D.C.: International Food Policy Research Institute.

Headey, D. and S. Fan. 2008. "Anatomy of a Crisis: The Cause and Consequences of Surging Food Prices." *Agricultural Economics* 39: 375-391.

Headey, D., J. Hoddinott, D. Ali, R. Tesfaye, and M. Dereje. 2015. "The Other Asia: Explaining the Rapid Reduction of Undernutrition in Bangladesh." *World Development.* 66: 749-761.

Holt, M. T. and R. C. Bishop. 2002. "A Semiflexible Normalized Quadratic Inverse Demand System: An Application to the Price Formation of Fish." *Empirical Economics*. 27: 23-47.

Houck, P.J. 1986. Elements of Agricultural Trade Policies. Illinois: Waveland Press Inc.

Ivanic, M. and W. Margin. 2008. "Implications of Higher Global Food Prices for Poverty in Low-Income Countries." *Agricultural Economics* 39: 405-416.

Kinnucan, H. W. and H. Cai. 2011. "A Benefit-Cost Analysis of U.S. Agricultural Trade Promotion." *American Journal of Agricultural Economics*. 93: 194-208.

Kouka, P.J., and C.R. Engle. 1998. "An Estimation of Supply in the Catfish Industry." *Journal of Applied Aquaculture* 8: 1–15.

Kumar, P., M. M. Dey and F. J. Paraguas. 2006. "Fish Supply Projections by Production Environments and Species Types in India." Agricultural Economics Research Review. 19: 327-351.

Lanfranco, B.A., G.C. Ames, and C.L. Huang. 2002. "Comparisons of Hispanic Households' Demand for Meats with other Ethnic Groups." *Journal of Food Distribution Research* 33(1): 92-101.

Moore, C. C. 2015. "Welfare Analysis in a Two-Stage Inverse Demand Model." Conference Paper, American Economics Association Meetings, January 5th. Boston, Massachusetts.

Myrland, O., T. Trondsen, R.S. Johnston, and E. Lund. 2000. Determinants of Seafood Consumption in Norway: Lifestyle, Revealed Preferences, and Barriers to Consumption. *Food Quality and Preference* 11(3): 169-188.

Nielsen, M. 1999. "EU Seafood Demand." Paper presented at the XIth annual conference of the European Association of Fisheries Economists, Dublin, 6 – 10 April.

Nielsen, M., J. Smit and, and J. Guillen. "Price Effects of Changing Quantities Supplied in the Integrated European Fish Market." *Marine Resource Economics*. 17: 165-180.

Piggott, R. R. 1992. "Some Old Truths Revisited." *Australian Journal of Agricultural Economics* 36: 117-140.

Richardson, J. W. 2005. *Simulation for Applied Risk Analysis with SIMETAR*. Department of Agricultural Economics, College Station: Texas A&M University.

Rickertsen, K. 1996. "Structural Change and the Demand for Meat and Fish in Norway." *European Review of Agricultural Economics* 23: 316-330.

Salvanes, K. G. and D. J. DeVoretz. 1997. "Household Demand for Fish and Meat Products: Deparability and Demographic Effects." *Marine Resources Economics* 12 (1): 37-56.

Singh, K., M. M. Dey, and P. Surathkal. 2014. "Seasonal and Spatial Variations in Demand for and Elasticities of Fish Products in the United States: An Analysis Based on Market-Level Scanner Data." *Canadian Journal of Agricultural Economics* 62: 343-363.

The Economist. 2013. "The Price of Fish: Different Scales." August 10, print edition. http://www.economist.com/node/21583296/print.

Tran, V. N, C. Bailey, and N. Wilson. 2011. "Governance of Global Value Chains Impacts Shrimp Producers in Vietnam" Global Aquaculture Advocate, November/December, pp. 44-47.

Wellman, F. K. 1992. "The US Retail Demand for Fish Products: an Application of the Almost Ideal Demand System." *Applied Economics* 24: 445-457.

Wohlgenant, M. K. 2011. "Consumer Demand and Welfare in Equilibrium Displacement Models." In *The Oxford Handbook of The Economics of Food Consumption and Policy*, Lusk, J. L., J. Roosen and J. F. Shogren (editors). New York: Oxford University Press, Chapter 11, pp. 292-318.

World Bank. 2013. *Fish to 2030: Prospects for Fisheries and Aquaculture.* Report Number 83177-GLB. Washington, DC: World Bank.

Table 1. OLS Estimates of the Trend Equation $\ln PRICE = \alpha + \beta\, TIME + \gamma\, TIME \cdot D + u$, Annual Data, 1990 – 2014[a]

Item	α	β	γ	R^2	DW	S. E. of Regression
Food Price	4.56	0.0054	0.0128	0.72	0.67	0.1104
	(75)[b]	(0.70)	(2.27)			
Meat Price	4.72	-0.0068	0.0113	0.38	0.64	0.0974
	(87)	(-0.99)	(2.28)			
Fish Price	4.47	0.0141	-0.0041	0.85	1.62	0.0298
	(271)	(6.86)	(-2.71)			

[a] D is a binary variable that equals zero for 1990-2002 and one for 2003-2014. For a graphical display of the price data and source, see Figure 1.

[b] Numbers in parentheses are t-ratios.

Table 2. Fish Production, Consumption and Trade Shares for Net Exporting and Importing Countries, Metric Tons, Annual Average for 2000-2011

Net Exporters				Net Importers			
Country	Production	Net Exports	Export Share	Country	Consumption	Net Imports	Import Share
Peru	7,840,830	2,084,601	0.27	EU	10,727,907	3,504,196	0.33
Norway	3,419,328	1,502,113	0.44	Japan	8,427,287	2,715,307	0.32
Chile	4,894,395	1,168,219	0.24	USA	6,126,019	833,315	0.14
Viet Nam	3,713,745	625,155	0.17	Korea	3,607,136	712,349	0.20
Indonesia	7,850,793	619,899	0.08	China	54,216,336	553,146	0.01
Iceland	1,595,638	578,883	0.36	Nigeria	974,407	351,735	0.36
India	6,894,129	543,567	0.08	Ukraine	614,710	338,733	0.55
Argentina	935,858	468,292	0.50	Egypt	1,221,045	243,176	0.20
Russian	3,667,060	461,929	0.13	Côte d'Ivoire	303,999	241,475	0.79
Morocco	998,614	356,957	0.36	Australia	465,705	211,936	0.46
Ecuador	613,734	312,479	0.51	Ghana	589,512	199,186	0.34
Faroe Islands	556,639	298,408	0.54	Hongkong	352,675	185,447	0.53
Namibia	500,272	294,953	0.59	Brazil	1,210,516	142,767	0.12
Taiwan	1,314,498	282,389	0.21	Malaysia	1,768,645	140,570	0.08
New Zealand	606,676	274,364	0.45	Cameroon	263,075	133,997	0.51
Myanmar	2,498,435	259,211	0.10	Singapore	137,239	129,734	0.95
Thailand	3,638,847	250,501	0.07	Saudi Arabia	198,692	122,533	0.62
Canada	1,216,388	148,667	0.12	Belarus	132,450	121,789	0.92
Greenland	208,684	119,691	0.57	Dominican	121,788	105,886	0.87
Pakistan	583,706	114,476	0.20	Sri Lanka	390,730	70,711	0.18
ROW	8,477,238	1,160,827	0.14	ROW	9,321,426	867,594	0.09
Total	62,025,506	11,925,582	0.19	Total	101,171,299	11,925,582	0.12

Source: FAO, 2015. ROW = Rest of World. Note: based on the original data, net exports fell short of net imports by 1.2%. Thus, to get the numbers to balance so that net exports = net imports, net exports for ROW were adjusted upward slightly.

Table 3. Parameter Values Used to Calibrate the Model

Parameter	Definition	Value
k_m	Share of fish consumption in net importing region that is imported	0.12
k_x	Share of fish production in net exporting region that is exported	0.19
$\tilde{\varepsilon}_P$	Domestic supply elasticity for net importing region	0.50
$\bar{\varepsilon}_P$	Domestic supply elasticity for net exporting region	0.54
$\tilde{\eta}_P$	Domestic demand elasticity for net importing region	-1.27
$\bar{\eta}_P$	Domestic demand elasticity for net exporting region	-0.87
$\tilde{\eta}_Y$	Domestic income elasticity for net importing region	1.02
$\bar{\eta}_Y$	Domestic income elasticity for net exporting region	0.60
$\tilde{\eta}_N$	Domestic population elasticity for net importing region	1.00
$\bar{\eta}_N$	Domestic population elasticity for net exporting region	1.00

Source: Best-bet values based on empirical estimates in the literature and authors' computations.

Table 4. Reduced-Form Elasticities

Item	Price with respect to Income (P^*/Y_i^*)			Price with respect to Population (P^*/N_i^*)		
	5% Limit	Mean	95% Limit	5% Limit	Mean	95% Limit
Net Importers	0.19	0.41	0.83	0.20	0.40	0.80
Net Exporters	0.06	0.12	0.24	0.10	0.20	0.40
Combined Effect	0.25	0.53	1.07	0.30	0.60	1.20

Note: elasticities are based on the GRK stochastic distribution.

Table 5. Real Income and Population in Net Exporting and Importing Countries of Fish, Five-year Intervals, 1999-2013

Item	Net Exporting Countries	Net Importing Countries	Ratio
Per Capita Income (in USD)[a]			
1999-2003	6,210	7,062	0.88
2004-2008	6,972	7,858	0.89
2009-2013	7,201	8,123	0.89
Population (in millions)			
1999-2003	2,396	3,647	0.66
2004-2008	2,571	3,846	0.67
2009-2013	2,748	4,050	0.68
Total Income (in billion USD)[a]			
1999-2003	14,879	25,755	0.58
2004-2008	17,925	30,222	0.59
2009-2013	19,788	32,898	0.60

[a]Expressed in constant 2005 dollars.

Table 6. Predicted Effects of Income and Population Growth on International Fish Price, Five-Year Intervals, 1999-2013

Causal Factor	Observed Change (%)	Predicted Price Effect[a] 5% Limit	Mean	95% Limit
Income – Importing countries:				
1999 – 2003	8.8	1.7	3.6	7.3
2004 – 2008	15.8	3.0	6.5	13.1
2009 – 2013	9.7	1.8	4.0	8.1
Cumulative effect	34.3	6.5	14.1	28.5
Average annual effect	2.3	0.4	0.9	1.9
Income – Exporting countries:				
1999 – 2003	7.0	0.4	0.8	1.7
2004 – 2008	13.8	0.8	1.7	3.3
2009 – 2013	11.0	0.7	1.3	2.6
Cumulative effect	31.8	1.9	3.8	7.6
Average annual effect	2.1	0.1	0.3	0.5
Population – Importing countries:				
1999 – 2003	6.9	1.4	2.8	5.5
2004 – 2008	8.1	1.6	3.2	6.6
2009 – 2013	6.5	1.3	2.6	5.2
Cumulative effect	21.5	4.3	8.6	17.3
Average annual effect	1.4	0.3	0.6	1.2
Population – Exporting countries:				
1999 – 2003	7.3	0.7	1.5	2.9
2004 – 2008	6.9	0.7	1.4	2.8
2009 – 2013	7.0	0.7	1.4	2.8
Cumulative effect	21.2	2.1	4.3	8.5
Average annual effect	1.4	0.1	0.3	0.6
Combined average annual effect:				
Income	--	0.6	1.2	2.4
Population	--	0.4	0.9	1.7
Income + Population	--	1.0	2.1	4.1

Table 7. Effects of a 1% Increase in Income and Population on Economic Surplus

Causal Factor	Row	Welfare Gain (billion USD) 5% Limit	Mean	95% Limit
Income:				
$\frac{\Delta CS_x}{Y_m^*}$	1	-22	-48	-96
$\frac{\Delta CS_m}{Y_x^*}$	2	-14	-28	-56
$\frac{\Delta CS}{Y^*}$	3	-36	-76	-153
$\frac{\Delta PS_x}{Y_m^*}$	4	27	59	120
$\frac{\Delta PS_m}{Y_x^*}$	5	12	25	50
$\frac{\Delta PS}{Y^*}$	6	39	84	170
ΔTS_Y (rows 3 + 6)	7	**3**	**8**	**17**
Population:				
$\frac{\Delta CS_x}{N_m^*}$	8	-23	-47	-93
$\frac{\Delta CS_m}{N_x^*}$	9	-24	-47	-94
$\frac{\Delta CS}{N^*}$	10	-47	-94	-187
$\frac{\Delta PS_x}{N_m^*}$	11	29	58	116
$\frac{\Delta PS_m}{N_x^*}$	12	21	42	83
$\frac{\Delta PS}{N^*}$	13	50	99	199
ΔTS_N (rows 10 + 13)	14	**3**	**5**	**12**

Note: Welfare gains are based on the following initial equilibrium values: P^0 = \$2,328/metric ton, $\bar{Q}_d^0$ = 50,099,924 metric tons, $\bar{Q}_s^0$ = 62,025,506 metric tons, $\tilde{Q}_d^0$ = 101,171,299 metric tons, and $\tilde{Q}_s^0$ = 89,245,718 metric tons. See text for details.

Appendix Table: Data Sources

No.	Item	Source
1	Food, meat, and fish price indices (2002-04 = 100)	FAO Globefish
		http://www.globefish.org/fao-fish-price-index-jan-2015.html
		https://www.google.com/?gws_rd=ssl#q=annual+food+price+index+fao
2	Fish production, consumption, and trade quantity	FAO FishstatJ
		http://www.fao.org/fishery/statistics/software/fishstatj/en
3	GDP per capita (constant USD, 2005 =100)	The World Bank
		http://data.worldbank.org/indicator/NY.GDP.PCAP.KD
4	Population, total and growth	The World Bank, 2015
		http://data.worldbank.org/indicator/SP.POP.TOTL

Figure 1. Real International Price of Food, Meat and Fish, 1990 – 2015

(Note: The 2015 price is for January. All prices are deflated by the Manufacturers Unit Value Index developed by the World Bank. The MUV Index is rescaled so that that 2002-04 = 100 instead of 2010 = 100. See appendix table for data sources.)

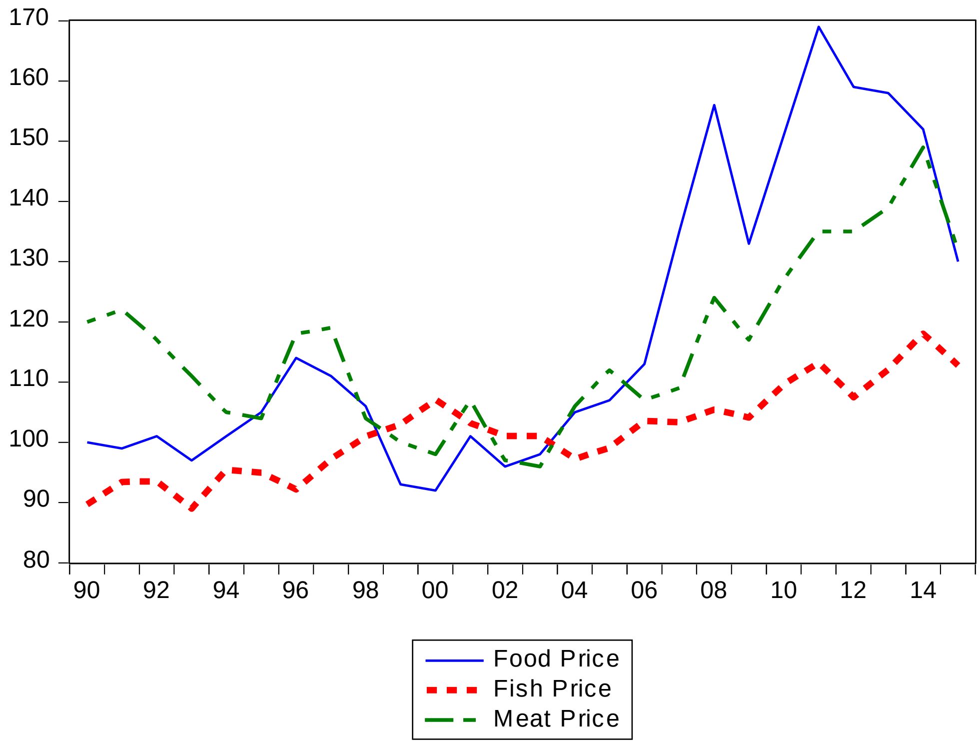
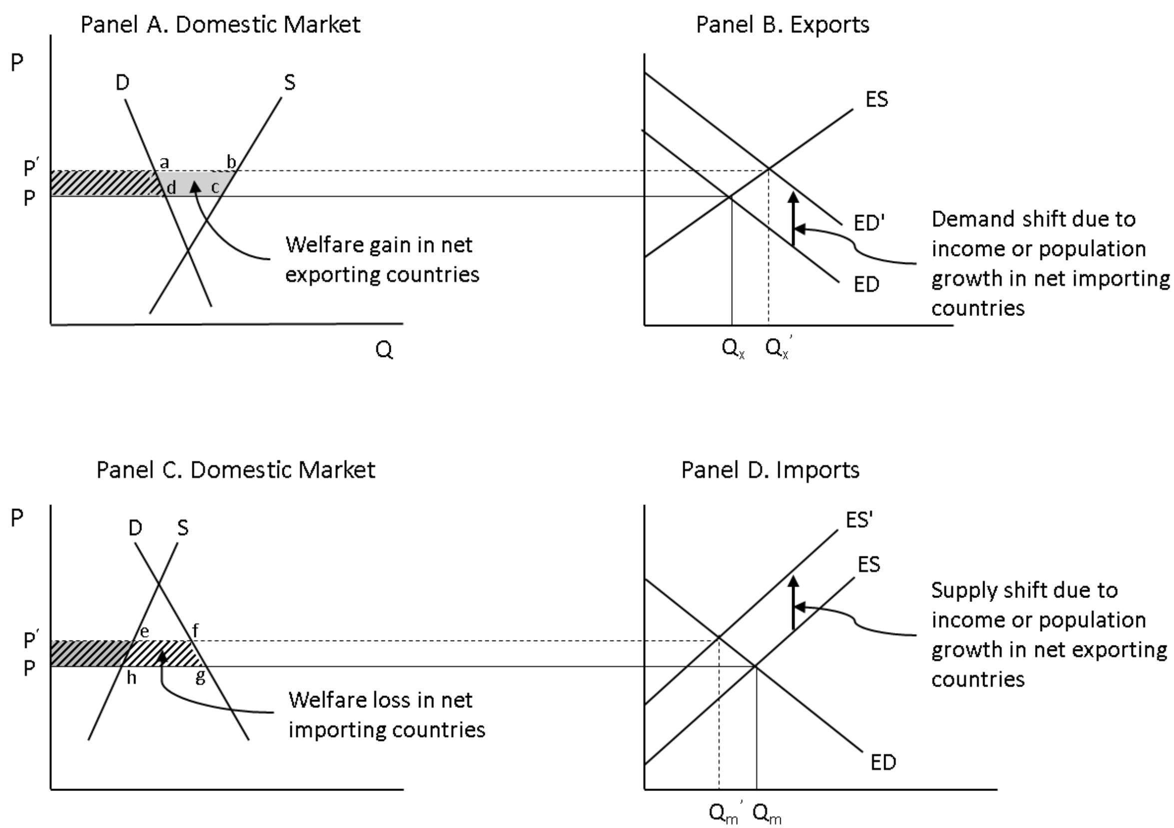


Figure 2. Welfare Effects of Income and Population Growth in World Fish Markets



Appendix. Derivation of Analytical Expressions for Excess Demand and Supply Elasticities

Net Importing Region

Let the structural model for the net importing region be defined as follows

(A1) $Q_d^* = \tilde{\eta}_P P^* + \tilde{\eta}_Y Y_m^* + \tilde{\eta}_N N_m^*$ (domestic demand)

(A2) $Q_s^* = \tilde{\varepsilon}_P P^*$ (domestic supply)

(A3) $Q_m^* = \varepsilon_P P^*$ (import supply)

(A4) $Q_d^* = k_m Q_m^* + (1 - k_m) Q_s^*$ (market clearing)

The excess demand curve for the net importing region is obtained by dropping equation (A3) (to treat P^* as temporarily exogenous) and solving the remaining equations simultaneously for Q_m^* in terms of the exogenous variables to yield

(A5) $$Q_m^* = \left(\frac{\tilde{\eta}_P - (1-k_m)\tilde{\varepsilon}_P}{k_m}\right) P^* + \left(\frac{\tilde{\eta}_Y}{k_m}\right) Y_m^* + \left(\frac{\tilde{\eta}_N}{k_m}\right) N_m^*.$$

Letting $Q_m^* = D^*$ and changing notation, equation (A5) can be written more simply as

(A6) $D^* = \eta_P P^* + \eta_Y Y_m^* + \eta_N N_m^*$

where

(A7) $\eta_P = \frac{\tilde{\eta}_P - (1-k_m)\tilde{\varepsilon}_P}{k_m} < 0$

(A8) $\eta_Y = \frac{\tilde{\eta}_Y}{k_m} > 0$

(A9) $\eta_N = \frac{\tilde{\eta}_N}{k_m} > 0$

are excess demand elasticities expressed in terms of domestic demand and supply elasticities and import share.

Net Exporting Region

Let the structural model for the net exporting region be defined as follows

(A10) $Q_d^* = \bar{\eta}_P P^* + \bar{\eta}_Y Y_x^* + \bar{\eta}_N N_x^*$ (domestic demand)

(A11) $Q_s^* = \bar{\varepsilon}_P P^*$ (domestic supply)

(A12) $Q_x^* = \eta_P P^*$ (export demand)

(A13) $Q_s^* = k_x Q_x^* + (1 - k_x) Q_s^*$ (market clearing)

The excess supply curve for the net exporting region is obtained by dropping equation (A12) (to treat P^* as temporarily exogenous) and solving the remaining equations simultaneously for Q_x^* in terms of the exogenous variables to yield

(A14) $$Q_x^* = \left(\frac{\bar{\varepsilon}_P-(1-k_x)\bar{\eta}_P}{k_x}\right)P^* - \left(\frac{(1-k_x)\bar{\eta}_Y}{k_x}\right)Y_x^* - \left(\frac{(1-k_x)\bar{\eta}_N}{k_x}\right)N_x^*.$$

Letting $Q_x^* = S^*$ and changing notation, equation (A14) can be written more simply as

(A15) $$S^* = \varepsilon_P P^* - \varepsilon_Y Y_m^* - \varepsilon_N N_m^*$$

where

(A16) $$\varepsilon_P = \frac{\bar{\varepsilon}_P-(1-k_x)\bar{\eta}_P}{k_x} > 0$$

(A17) $$\varepsilon_Y = \frac{(1-k_x)\bar{\eta}_Y}{k_x} > 0$$

(A18) $$\varepsilon_N = \frac{(1-k_x)\bar{\eta}_N}{k_x} > 0$$

are excess supply elasticities expressed in terms of domestic demand and supply elasticities and export share.