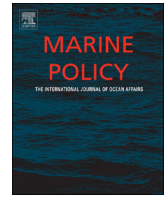




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Analysis of the economic impact of climate change and climate change adaptation strategies for fisheries sector in Pacific coral triangle countries: Model, estimation strategy, and baseline results



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ABSTRACT

This paper presents a supply-and-demand model for the fisheries sector developed to assess the effect of climate change and related adaptation strategies in four Pacific coral triangle (CT) countries—Fiji, Solomon Islands, Timor-Leste, and Vanuatu. The modeling approach used in this paper represents climate change in terms of supply shocks, and works out its economic consequences using the microeconomic tools of supply and demand. The analysis has considered three time periods: current (represented by the average data of the three most recent available years 2006–2009), medium term (2035), and long term (2050). The study covers all fisheries and aquaculture species, grouped into six key subsectors: tuna, other oceanic finfish, coastal finfish, coastal invertebrates, freshwater finfish, and freshwater invertebrates. Results of the baseline model indicate that with rising per capita income and population, fish demand is expected to increase substantially up to 2050. In contrast to significant growth in fish demand, growth in domestic fish production is projected to be slow due to climate change and other constraints. There is a strong likelihood that many Pacific countries will become large net importers of fish under the baseline scenario (i.e., without implementing climate change adaptation strategies). Likewise, per capita consumption of domestically produced fish is projected to decline under the baseline scenario.

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1. Introduction

There is concern around the globe about the likely biophysical and economic impacts that the future changes to climate will have on aquaculture and fisheries (see, for example, [1–14]). The biophysical impact of climate change on aquaculture and fisheries has been closely studied by a number of groups (see, for example, [4–6], [15–20]). This and other papers of this special section of Marine Policy contribute to the growing, but still limited, body of knowledge on economic impact of climate change on aquaculture and fisheries. The geographic focus of this study is four Pacific coral triangle (CT) countries (Fiji, Solomon Islands, Vanuatu and Timor-Leste), which are highly exposed and vulnerable to the impacts of climate change.

The two broad approaches used to analyze the economic impact of climate change in fisheries and aquaculture are bioeconomic modeling and market supply and demand [21]. One benefit of bioeconomic modeling is that it can incorporate climate change scenarios by altering an appropriate set of ecosystem or population parameters. However, much of the required information on resource and ecosystem interactions is not available for Pacific Island countries. The market supply–demand approach represents climate change in terms of supply shocks, and works out its economic consequences using the microeconomic tools of supply and demand. Briones [22], Delgado et al. [23], World Bank [24] have effectively used this approach to analyze the “fisheries collapse”/“climate change” scenarios. One main advantage of the market supply–demand approach is that it incorporates price responses of market agents (such as producers and consumers) and interactions across sectors (for example, different fish species groups). Some studies [22,25] incorporated both bioeconomic and supply–demand approaches in analyzing the effect of climate change on fish production and consumption. Given the scarcity of data regarding

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the biological and physical responses to climate change in the Pacific Islands, this study has developed and used a market fish supply–demand model for Fiji, Solomon Islands, Vanuatu and Timor-Leste.

The paper is organized as follows. Section 2 discusses the modeling methodology and describes the data. Section 3 reports the country-specific empirical results for medium term (2035) and long term (2050) under baseline scenarios. Finally, Section 4 contains concluding remarks and policy implications for the economies of the four Pacific CT countries.

2. Overview of the model

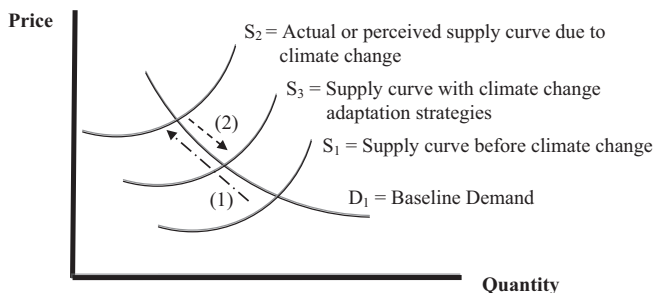
2.1. Conceptual framework

The study has followed a three-step procedure to measure the potential impacts of various climate change adaptation strategies: (1) development of a baseline model of the fisheries sector for each country; (2) collection and construction of data sets for model parameters, exogenous variables, and *ex ante* impact indicators of various climate change adaptation strategies; and (3) analysis of the overall impact of climate change adaptation strategies by incorporating the *ex ante* impact indicators into the fisheries sector model.

Fig. 1 represents the economic framework used in each of the four countries in the study (Fiji, Solomon Islands, Vanuatu and Timor-Leste), for assessing the impact of climate change adaptation strategies. As shown in Fig. 1, the framework considers three supply scenarios: scenario I (S_1)—before climate change; scenario II (S_2)—with climate change effects, but no adaptation strategy; and scenario III (S_3)—after adopting climate change adaptation strategies.

The supply curve for capture fisheries and aquaculture under scenario 1 (no climate change effect) is depicted by S_1 . The actual (or perceived) supply curve of farmers/fishers may shift to the left from the S_1 to the S_2 position as a result of the realized (or potential) negative impacts of climate change (scenario II). These impacts may be a reduction of catch per unit of effort, lower productivity, and higher cost per unit of fish produced or caught, among others. It is, however, important noting that the Fifth Assessment Report of the Inter-governmental Panel on Climate Change indicates that the impact of climate change on fisheries is uneven [26]; and as such, one can expect that natural productivity and fish stocks to increase for some species and decline for others. Impact of climate change on seafood supply is, therefore, indeterminate and climate change may also have positive effects on some sub-sectors of aquaculture/fisheries; in that case, the supply curve may shift to the right (i.e., the position of S_2 will be at the right side of S_1).

Nature of supply curve differs between aquaculture and



Note: Arrows with 1 and 2 indicate directions of shifts in supply curves due to changes in productivity and/or cost per unit of production.

Fig. 1. Shifts of supply curve due to climate change and adaptation strategies.

capture fisheries sub-sectors. Output, or total catch, of capture fisheries can increase or decrease due to changes in stock abundance and effort. Higher level of stock abundance (biomass) yields higher catch per effort, given all other factors held constant. Supply curve of a particular capture fishery under a specific scenario (S_1 or S_2) assumes a particular stock size (biomass), and underlying the changes in the supply curve of capture fisheries (from S_1 to S_2) there will be changes in biomass.

The adoption of various climate change adaptation strategies is expected to reduce the negative effects of climate change. As a result, the supply curve from capture fisheries and aquaculture (scenario III) may shift from the S_2 position to S_3 . Comparison of S_1 and S_2 shows the impact of climate change, while comparison of S_2 and S_3 shows the effect of climate change adaptation strategies.

This study has considered three time periods: current (represented by the average data of the three most recent available years 2006–2009), medium (2035), and long term (2050). Each of these periods is represented by a specific demand curve. As shown in Fig. 1, D_1 denotes the demand situation in the immediate past (2006–2009). The demand is likely to shift upward with the increase in population and income from D_1 to D_2 in 2035 and D_3 in 2050. D_2 and D_3 have not shown in the graph for ease of presentation.

2.2. Algebraic representation of the model

The fisheries sector model developed to evaluate the impact of climate change adaptation strategies is based on the modified balance-of-trade function approach suggested by Martin and Alston [27] and used by Dey et al. [28,29]. The basic form of the model formulated for this study for a national economy can be expressed as:

$$B^h = e(\mathbf{P}, u^h) - g(\mathbf{P}, \mathbf{V}, \lambda) - f \quad (1)$$

where

e = expenditure function of a national economy,

\mathbf{P} = vector of domestic prices of different fish groups,

u^h = level of utility exogenously specified to define Hicksian money-metric measures of welfare change,

g = function that defines maximum profit generated from capture fisheries and aquaculture in the national economy,

\mathbf{V} = vector of fixed factors,

λ = vector of technology and fisheries management variables representing the state of climate change and adaptation strategy, and

f = financial inflow (outflow) to (from) the non-fisheries/aquaculture sector.

The modified balance of trade function (B) provides a money metric measure of overall welfare. The impact of the climate change on welfare is obtained from Eq. (1) by comparing the net expenditures required to achieve a given level of utility (u^h) under the “no climate change” (scenario I), and the “climate change” (scenario II) situations. Similarly, the impact of the climate change adaptation strategy (new management practices/technologies) on welfare is obtained from Eq. (1) by comparing the net expenditures required to achieve a given level of utility (u^h) under the “climate change, but no climate change adaptation strategy” (λ_0) (scenario II), and under the “climate change adaptation strategy” (λ_1) (scenario III).

It is assumed that the climate change adaptation strategy leads to an improvement from a situation yielding utility level u^0 to one yielding utility level u^1 . An equivalent variation measure of the welfare change due to climate change adaptation is defined with

the utility level in the expenditure function held constant at the level achieved after implementing the climate change adaptation strategy (u^1):

$$B_1^1 - B_0^1 = B(\mathbf{P}_1, \mathbf{V}_1, \lambda_1, u^1) - B(\mathbf{P}_0, \mathbf{V}_0, \lambda_0, u^1) \tag{2}$$

A compensating variation version of the welfare measure is same as defined in Eq. (2), except that the utility level is held at u^0 rather than u^1 . The modified balance-of-trade function defined in Eqs. (1) and (2) shares the fundamental parameters of the behavioral system; it includes the parameters of the consumer expenditure system and the profit function.

The supply and supply systems of each of the country-specific models consider six groups: tuna, other oceanic finfish, coastal finfish, coastal invertebrates, freshwater finfish, and freshwater invertebrates. These fish groups are found in oceanic, coastal, and freshwater areas, as well as those produced in aquaculture.

It is assumed that fish production in a country can be represented by a normalized quadratic profit function. The profit function subsumes the effects of fixed factors and intermediate inputs into the constant terms, and the quadratic profit function can be expressed in this multiple product case as [27]:

$$\pi = a_n p_n' + \sum_{i=1}^{n-1} a_i p_i' + 0.5 \sum_{i=1}^{n-1} \sum_{j=1}^{n-1} b_{ij} \left[(p_i' p_j') / (p_n')^2 \right] \tag{3}$$

where

- π = profit (not normalized),
- p_i' = effective nominal price of the i th fish group, and
- p_n' = effective nominal price of the *numéraire* fish group.

The effective price of fish group i is defined as:

$$p_i' = p_i \lambda_i \tag{4}$$

where

- p_i = nominal price of the i th group of fish, and
- λ_i = an index of climate change and/or climate change adaptation strategies (new management practices/technologies) in farming/fishing of fish group i , set to unity in the base period.

For a specific scenario (I, II or III discussed earlier), the profit function represented in Eq. (3) assumes a given level of exogenous factors (Z) such as technology, stock size (for capture fisheries) and other biological and environmental factors. These exogenous factors are expected to change over time. Biological conditions (like stock abundance) and technology have been modeled as exogenous components that shift the level of production. It is considered that profits are an increasing function of the exogenous factors (Z); for capture fisheries, higher stock abundance will give higher profits.

The new management practices/technologies are assumed to be a disembodied, output-augmenting technical change. The technical change increases the "effective" quantity of fish associated with a given physical quantity, and there is a corresponding change in the effective price of the fish. This specification of technical change in the profit function leads to proportional shifts in the resulting supply curves and a shift in the intercept on the price axis.

This climate change adaptation index (λ) represents a proportional shift down of the supply function involving two proportional shifts: a λ percentage proportional shift in the quantity direction, and a λ percentage proportional shift in the price direction.¹ The proportional shift in the quantity direction results

from an increase in the output of product or species i achieved by reducing the output of other products or species, known as the competitiveness effect [27,30]. The proportional shift in the price direction results from increases in the output of one product or species (say, i) without any reduction in the output of other products or species, referred to in the literature as a pure productivity effect [27,30]. A λ percent output augmented by technical change, as assumed in this paper, will yield an increase in output that is larger than λ percent.

Following the envelope theorem, the supply functions for different fish groups are obtained by differentiating the profit function (Eq. (3)) with respect to effective prices. For each non-*numéraire* fish group, the equations can be written as:

$$q_i' = a_i' + \sum_{j=1}^{n-1} b_{ij} \left(\frac{p_j'}{p_n'} \right) \tag{5}$$

While for the *numéraire* group, the supply function takes the form:

$$q_n' = a_n' - 0.5 \sum_{i=1}^{n-1} \sum_{j=1}^{n-1} b_{ij} \left[(p_i' p_j') / (p_n')^2 \right] \tag{6}$$

On the consumption side, an Almost Ideal Demand System (AIDS) representation (Deaton and Muellbauer [34]) was used. The AIDS share equation can be expressed as:

$$w_i = \alpha_i + \sum_{j=1}^n \varphi_{ij} \ln p_j + \beta_i \ln \left(\frac{e}{P} \right) \tag{7}$$

where

- e = total expenditure on fish,
- p_j = price of the j th group of fish,
- w_i = share of total fish expenditure allocated to the i th fish group.

The price index (P) is:

$$\ln P = \alpha_0 + \sum_{j=1}^n \varphi_j \ln p_j + \frac{1}{2} \sum_{j=1}^n \sum_{k=1}^n \varphi_{jk} \ln p_j \ln p_k \tag{8}$$

The AIDS expenditure function can be written as:

$$\ln e = \ln P + u\beta_0 + \sum_{k=1}^n \ln p_k^{\beta_k} \tag{9}$$

The final equation needed to complete the model is the income-expenditure equation for equating production income with expenditure and any inflow (outflow) to (from) non-fishery/aquaculture activities:

$$e - \pi - f = 0 \tag{10}$$

2.3. Model parameters and data

The country models require (i) baseline data on demand, supply, and prices for each fish type; (ii) parameters for the fish supply and demand equations (Eqs. (5)–(9)); and (iii) data on exogenous variables, including climate change trend and climate change adaptation strategies. Baseline data on demand, supply, and prices

(footnote continued)

the same way a quasi-fixed factor would. The direct specification of technological and biological variables in the profit function would lead to the parallel shifts in the resulting supply functions [27]. See, for example, [27,30] and [31–33] for detailed discussions on the effect of a technological change in shifting the output supply curve.

¹ An alternative specification of the climate change and climate change adaptation strategy is the direct incorporation of these variables in the profit function, in

Table 1

Shift in supply curve^a (%) from Current (2006–2009) to 2035 and 2050 due to climate change in Fiji, Solomon Islands, Vanuatu and Timor-Leste. Sources: Authors. Calculated based on secondary literature [5,37–40], and primary data (EOS, FGD, post-survey validation meeting, expert consultations).

Species group	2035				2050			
	Fiji	Solomon Islands	Vanuatu	Timor-Leste	Fiji	Solomon Islands	Vanuatu	Timor-Leste
Tuna	15	3	10	0	15	3	10	0
Other oceanic finfish	15	3	10	0	15	3	10	0
Coastal finfish	–5	–5	–10	–5	–15	–10	–15	–10
Coastal invertebrates	–5	–5	–10	–5	–15	–10	–15	–10
Freshwater finfish	25	12.5	25	50	75	25	50	100
Freshwater invertebrates	25	25	25	50	75	25	50	100

^a This shift in supply curve for the baseline scenario has been denoted in Eq. (2) as (λ_0).

for various fish types were collected from various secondary sources and surveys of local markets in each country. As no published estimates of demand and supply elasticities for the fisheries sector are available, and the resources and time needed to estimate these elasticities were lacking, a subjective elicitation process and secondary data were used to make benchmark estimates. This process, using expert opinion surveys (EOSs) and focus group discussions (FGDs), is described in more detail in the subsequent country specific papers of this special section. The preliminary benchmark estimates were presented to various experts for validation in intensive validation meetings.

The slopes of the supply functions (Eqs. (5) and (6)) were inferred from the local price elasticities of supply, the relevant base period price, and quantity variables. The intercepts were then obtained by subtraction, and were used to calibrate the production system to the base data set. Following Martin and Alston [27], the demand system (Eqs. (7)–(9)) was parameterized based on market price and income elasticities of demand for various groups of fish; base period data on price, quantity, and expenditure shares of different groups of fish; and using the symmetry and homogeneity, and adding up restrictions of the demand system. The intercepts of the demand equations were also obtained by subtraction to calibrate the demand system to the base data set. The value of “ u ” is set at 0.5, consistent with other analyses.

As indicated earlier, the models developed and reported in this paper are country-specific fish sector models designed to analyze the effects of climate change and related adaptation strategies in individual countries. Global prices of different fish groups were used as exogenous variables in the modeling exercise. The most recent global projections of fish prices generated by the International Food Policy Institute (IFPRI) and research partners (see [24,35]) are used in the models. Given global fish prices and other exogenous variables, the models endogenously determine domestic fish prices, supply, demand, export, and import of various fish categories for each of the study countries.

For each time period, the model was run for a baseline scenario and for various adaptation strategies. The baseline scenario denotes the most likely case that was identified with respect to trends in the exogenous variables (including population, income growth, technological change in aquaculture/fisheries, climate change, etc.). For climate change trajectories under baseline scenarios (λ_0), this paper has followed low (B1) and high (A2) emission scenarios originally reported in the Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios [36] and subsequently used by Bell et al. [5]. However, countries differ in assumptions regarding the baseline scenario and adaptation strategies. The country-specific values of the shift in supply curve (%) from current (2006–2009) to 2035 and 2050 due to climate change (λ_0) in Fiji, Solomon Islands, Vanuatu and Timor-Leste are reported in Table 1.

The projection of the Spatial Ecosystem and Population

Dynamics Model (SEAPODYM)² was used as a reference for the likely effects of climate change on tuna catch under a relatively low emission (B1 scenario) and a relatively high emission scenarios (A2 scenario). The preliminary simulations of the potential impact of global warming on tuna populations using SEAPODYM are presently available only for skipjack and bigeye tuna, and are reported in [5,37]. Among the four main species of tuna (albacore, bigeye, skipjack and yellowfin), skipjack tuna is the highest contributor (more than 70%) of total tuna catch in the Pacific region.

The results of SEAPODYM model show that the concentrations of skipjack and bigeye tuna are likely to be located further east than in the past due to climate change. As reported in Lehodey et al. [37], catch of skipjack tuna in Fiji is likely to increase by 25.8%, relative to 1980–2000 (20 years) average, in 2035. The corresponding increase in Vanuatu is 18.4%. Tuna catch is expected to increase by 3.2% in Solomon Islands in 2035 [5]. This paper has used more conservative estimates of the likely effect of climate change on tuna catch (please see Table 1).

This paper has used Pratchett et al. [38], Gehrke et al. [39], and Pickering et al. [40] as the main references for projected direct effects of climate change in coastal fisheries, freshwater fisheries and aquaculture production, respectively. The reported values of (λ_0) were adjusted based on experts consultation. It is important to note that many studies on climate change impact have used expert consultation as a way to collect relevant information (see, for example, [38,41]).

Ex ante indicators of the direct impact of climate change adaptation strategies were constructed using data collected through FGDs and EOSs. The values of these indicators (λ_i) were computed by comparing the cost per unit of fish produced (cost per unit of catch for capture fisheries) and/or volume of fish produced/captured between scenarios II and III, as discussed earlier.

2.4. Tuna supply: catch by national and foreign fleets

Broadly speaking, there are three types of tuna and oceanic catches: catch by domestic/national fleets in national waters, catch by domestic fleets in international waters, and catch by foreign fleets in national waters. Because of the focus of this and the subsequent related papers on national food security, the supply volumes used in the analysis include catch by national fleets in both national and international waters, but do not include catch by foreign fleets in national waters. The models developed and reported in this paper project the behavior of fish production, consumption and trade sectors of four pacific countries under alternative scenarios. Tuna catch by foreign vessels is not determined by the economic factors of supply and demand that are analyzed in these papers. Rather, foreign catch is determined by international

² For details on SEAPODYM, see (<http://www.spc.int/oceanfish/en/ofpsection/ema/ecosystem-a-multispecies-modelling/80-seapodym/148-seapodym>).

and regional agreements, including regional agreements like the Pacific Islands Forum Fisheries Agency (FFA) and the Parties to the Nauru Agreement (PNA). Relative contributions of tuna catch by foreign fleets and that of national fleets in most of the case-study countries vary substantially over period, partly due to changes in bilateral/regional/international agreements. Therefore, catch by foreign fleets was treated as a residual sector, influenced by domestic demand and supply (which includes catches by national fleets outside national waters). The available data on tuna catch by foreign vessels supports this interpretation.

Among the four case study countries, foreign vessel catch in national waters is not very substantial in Fiji and Vanuatu. In fact, the total tuna catch by national fleets of Fiji and Vanuatu are higher than the total tuna catch in their respective national waters. For example, in 2008 total tuna catch by Fijian national fleets was 11,656 t whereas total tuna catch in Fijian national waters was only 8536 t. Similarly, in 2008 total catch by Vanuatu national fleets was 47,234 t, but the total tuna catch in Vanuatu national waters was only 6021 t (FFA database). Among the four case-study countries, tuna catch by foreign fleets is a significant source of government revenue only in Solomon Islands.

For Fiji and Vanuatu, where tuna catch by their national fleets are higher than the tuna catch in their respective national waters, the projections of tuna catch are within the sustainable limits of tuna population, particularly given the significant increase in tuna population projected under climate change. Solomon Islands and Timor-Leste are keen to develop their domestic tuna industry, and their aim is to access some of the tuna resources currently utilized by foreign vessels. The models for Solomon Islands and Timor-Leste reflect that reality, as also shown in the individual country papers of this special section. The projected tuna catches for Solomon Islands and Timor-Leste reported in this and the subsequent papers represent only a small share of total tuna resources available in their respective national waters.

2.5. Overall impact assessment

The *ex ante* indicators of the direct impact of climate change adaptation strategies were used in the fisheries sector model to estimate the effects of various adaptation strategies on fish supply, demand, price, and trade. The specified climate change adaptation strategies were used in the fish sector model to estimate the economic (welfare) gain to society. The fish sector model (Eqs. 3–10, which include behavioral models of supply relations, Marshallian demand equations, market-clearing conditions, and income–expenditure conditions) was solved using linear program solver in Excel 4.0.

An equivalent variation version of welfare measure was computed using Eq. (2), which can be written as follows:

$$B_1^1 - B_0^1 = [e(\mathbf{P}_1, \mathbf{u}^1) - e(\mathbf{P}_0, \mathbf{u}^1)] - [g(\mathbf{P}_1, \mathbf{V}_1, \lambda_1) - g(\mathbf{P}_0, \mathbf{V}_0, \lambda_0)] - [f_1 - f_0] \quad (11)$$

In Eq. (11), the total welfare change is equal to (i) the equivalent variation for the change in consumer welfare due to price change induced by the adoption of adaptation strategies (the first term in brackets) minus (ii) the increase in producer profit due to the adoption of adaptation strategies (the second term in brackets), minus (iii) changes in inflow (outflow) to (from) non-fishery/aquaculture activities (the last term in brackets).

The model (Eqs. (3)–(10)) was solved for three different time periods: current (2006–2009), medium term (2035) and long term (2050). The supply equations Eqs. (3)–(6) were shifted with various time period-specific values of λ_i , and the demand equations (Eqs. (7)–(9)) were shifted with time period-specific income and population. The values of fish supply, demand, net trade, and domestic fish prices for various fish species groups were estimated in

two time periods (2035 and 2050).

This paper followed comparative static analysis. Its focus was not to generate projections for key variables in the fisheries sector, but to examine how projections respond to various developments or events within and outside of the fisheries sector. The study accomplished this by implementing various country-specific climate change adaptation strategies. As in any other modeling effort, the outcomes are likely to be influenced by the assumptions that are adopted. For this reason, this study implemented a baseline scenario, and each of the adaptation scenarios, for two growth rates of per capita real income.

3. Baseline results

3.1. Fiji

For each time period (2035 and 2050), two baseline (most plausible) scenarios were implemented representing two annual growth rates of real per capita income: medium (1% per year) and high (2% per year) growth of real per capita income.³ The model considered a population of 977,586 in 2035 and 1,060,706 in 2050 [43].

Fig. 2 shows the projected quantities of production and consumption of different fish groups in Fiji for 2035 and 2050 under two baseline scenarios, with respective 1% and 2% annual growth rates of real per capita income. It indicates that oceanic production is expected to grow to some extent, and that supply is likely to be higher than demand during the projected years. However, projections are quite different for coastal fisheries. The model projects that coastal production will decline over time while demand for coastal fish will likely increase further. Though the supply from freshwater areas is projected to expand substantially, its share is expected to remain small. The projected supplies of different fish types are plausible, given the past trends. The main reason for the decline in supply from coastal areas is the anticipated negative effects of climate change and other adverse environmental factors.

Results show that the aggregated fish consumption is expected to rise substantially in 2035 and 2050, and the demand for fish is likely to be higher than the production. These results imply that the country may need to import fish to fulfill this deficit in production under the baseline scenario (i.e., without the technological and policy interventions analyzed here).

There are four important points regarding the projections presented in this section: (1) domestic production is projected to grow at a negligible rate; (2) domestic demand is projected to rise over the period; (3) as expected, higher income growth will be accompanied by higher rise in demand for fish; and (4) fish exports are expected to fall, fish imports are expected to increase, and, therefore, net trade (export minus import) is projected to decline over time. These results have serious food security implications, given that poor households mostly rely on coastal finfish for their fish consumption needs.

3.2. Solomon Islands

The model predicts that the supply of fish from oceanic and freshwater systems aggregate will increase marginally in the medium term (2035) and long term (2050) under the baseline scenarios. However, the supply from coastal fisheries is likely to decrease over time. On the other hand, the demand for different types of fish will increase over time as a result of an increase in

³ During 2008–2012, annual percentage growth rate of real per capita income in Fiji ranged from –2.3% to +1.4% [42].

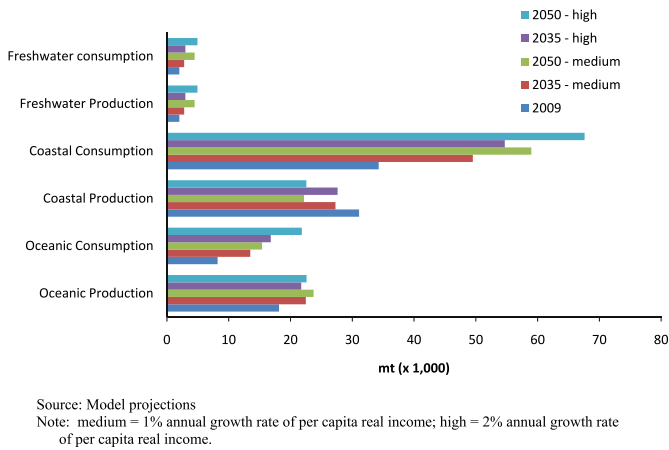


Fig. 2. Projected production and consumption of different types of fish under two baseline scenarios (1% and 2% annual growth rates of per capita real income) in Fiji, 2035 and 2050.

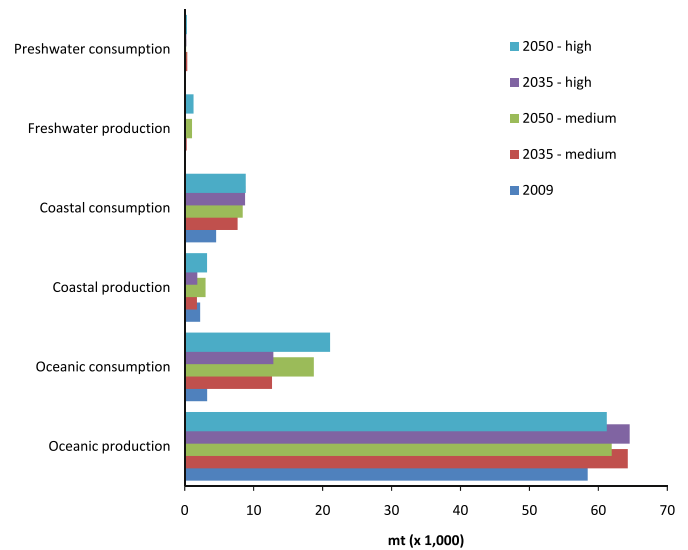


Fig. 4. Projected production and consumption of different types of fish under two baseline scenarios (1.5%, 2.5% annual growth rate of per capita real income) in Vanuatu, 2035 and 2050.

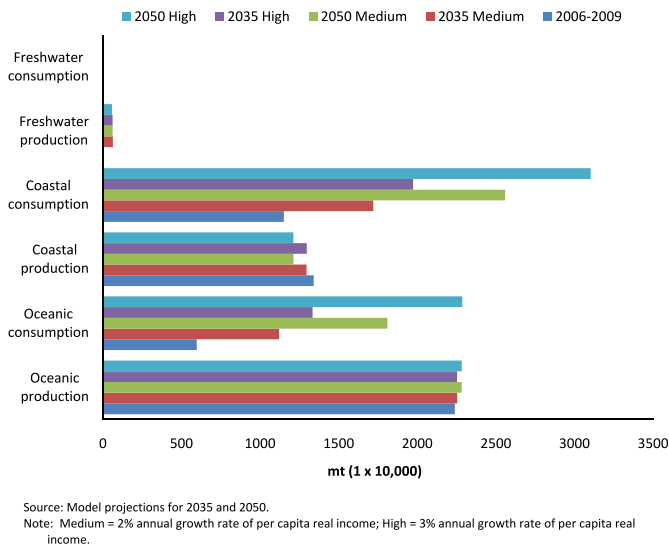


Fig. 3. Projected production and consumption of different types of fish under two baseline scenarios (2% and 3% annual growth rate of per capita real income) in Solomon Islands, 2035 and 2050.

population and per capita real income (Fig. 3). As expected, demand will be higher, with higher growth (3% per annum) in per capita real income. Results show that total demand is likely to surpass total domestic fish production in the long term (2050). Among various species groups, a major part of this increased demand will be for oceanic species, such as tuna. The modeling results reported in this paper imply that increases in domestic supply of tuna and other oceanic species will be helpful to meet the growing demand for this category of fish. If Solomon Islands cannot catch more oceanic fish than otherwise harvested by foreign vessels, the country may have to import fish in large volumes to meet the projected demand.

It is important to note that foreign vessels currently catch most of the tuna caught in Solomon Islands, and almost all of these fish are exported by foreign companies (not by Solomon Islands). The domestic production and net trade (difference between production and consumption) reported in this section cover only the domestic industry. Income from foreign vessels is considered as an outside income.

3.3. Vanuatu

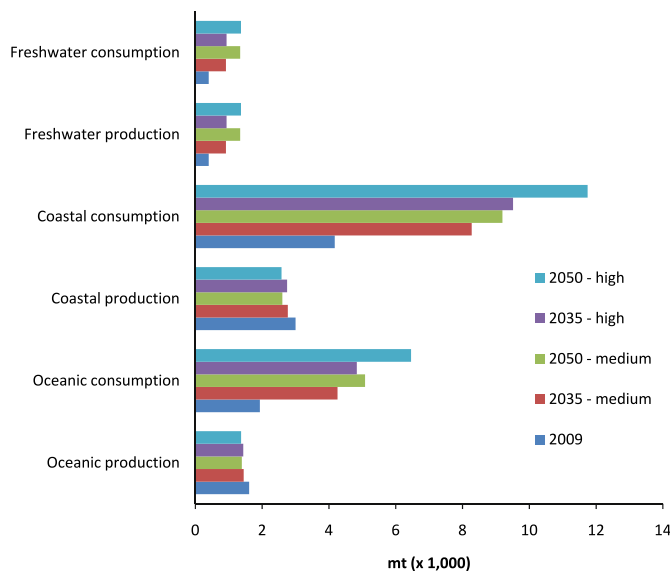
Fig. 4 shows the projected production, consumption, and net trade (difference between production and consumption) of different fish groups in Vanuatu for 2035 and 2050 under two baseline scenarios, with 1.5% and 2.5% annual growth rates of real per capita income. As shown in Fig. 4, the performance of various fisheries subsectors will not be uniform. During 2010–2050, production of oceanic fish is expected to increase, but production of coastal fish is projected to decline. Though the consumption of oceanic fish is expected to rise at a faster rate than any other sector, the model predicts that the oceanic fisheries sector will continue to be a net exporter. However, Vanuatu will have to import coastal fish to meet the increasing demand from population and income growth. Given that many of the poorer households rely on coastal fisheries for their consumption needs, this likely scenario has serious food security implications. The model projects that demand for freshwater fish will exceed domestic production in 2035 and 2050 under the baseline scenarios, and Vanuatu will need to rely on imports to meet this demand.

Currently, Vanuatu is a net exporter of fish and seafood, with domestic production far exceeding domestic consumption. The model analysis projects that the aggregated fish consumption in Vanuatu will rise substantially in 2035 and 2050, but the country will remain a net exporter by 2050.

3.4. Timor-Leste

Fig. 5 shows the projected quantities of production and consumption of different fish groups in Timor-Leste for 2035 and 2050 under two baseline scenarios, with 2% and 3% annual growth rates of real per capita income. The results indicate that fish supplies from oceanic and coastal ecosystems are likely to decrease during 2010–2050. The model predicts that only freshwater ecosystems will be able to supply more fish in the future. Given that oceanic and coastal fisheries supply about 94% of current fish consumption in Timor-Leste, this projected fish supply scenario has serious food security implications for the country.

Currently, Timor-Leste is a net importer of fish and seafood. The



Source: Model projections.

Note: medium = 2% annual growth rate of per capita real income; high = 3% annual growth rate of per capita real income.

Fig. 5. Projected production and consumption of different types of fish under two baseline scenarios (2% and 3% annual growth rate of per capita real income) in Timor-Leste, 2035 and 2050.

model predicts that total fish production will increase only marginally in the medium term (2035) and long term (2050) under the baseline scenarios. Aggregate fish demand is expected to rise substantially over time due to growth in population and real per capita income. This implies that the country will have to import more fish to fill this increasing deficit in domestic fish supply.

4. Conclusions and policy implications

This paper has developed a rigorous analytical tool that is capable of comparative analysis of alternative development scenarios, even under data-scarce situations. The model is utilized to analyze the potential effects of climate change and related adaptation strategies in the four PICT countries studied. This paper reports the model and discusses the baseline results. The subsequent three papers [44–46] apply the model to analyze the effect of various climate change adaptation strategies in the four countries under study.

The baseline results illuminate key differences across the four countries, mainly due to the fish trade regimes prevailing in different countries, the relative importance of various sectors in fish production and consumption, and producers' and consumers' behaviors in various countries as reflected through supply and demand elasticities.

Currently, Fiji, Solomon Islands, and Vanuatu are net exporters of fish and seafood, while Timor-Leste is a net importer of fish.⁴ The baseline projections indicate that Vanuatu will continue to be a net fish exporter and Timor-Leste will remain a net fish importer in the long term. For Solomon Islands, domestic demand for fish is likely to surpass the supply from domestic sources (i.e., the domestic fishing industry and aquaculture farms, but not including the catch of foreign fishing fleets) in the long term (2050). It is likely that, with high population and per capita income growth, Fiji may become a net importer of fish in the long run.

⁴ Seafood is the most traded food stuff and its international trade is rapidly increasing [47].

Similar to overall fish trade, all countries under consideration, except Timor-Leste, are currently net exporters of tuna and other oceanic fish. The model predicts that Fiji and Vanuatu will continue to be net exporters of oceanic fish in the long run. But Solomon Islands is unlikely to be able to meet domestic demand for oceanic fish from its domestic sources.

The baseline scenarios project that supply of tuna and other oceanic fish from the domestic fishing industry (not considering catch by foreign vessels) will increase over time in Fiji and Vanuatu, but will remain more or less the same in Solomon Islands. Tuna and oceanic fish supply is likely to decrease over time in Timor-Leste. It is important to note that various ecosystem-based tuna models (such as SEAPODYM) show that skipjack tuna is projected to move to the east (Eastern Pacific Ocean), and the biomass of adult tuna will decrease in the West and Central Pacific Ocean [37], consistent with the findings of this study.

With rising per capita income and population, demand for fish and seafood in various Pacific Island countries is expected to increase substantially for the period up to 2050.⁵ As indicated earlier, currently many Pacific Island countries (including Fiji, Solomon Islands, and Vanuatu) are net exporters of fish, excluding foreign tuna catch. Without any appropriate policy and/or technological intervention (as reflected in the baseline scenarios), fish exports from these countries are expected to decrease, fish imports are expected to increase, and net exports (export minus import) are likely to decline over time. This will lead to a decline in per capita consumption of domestically produced fish, which has serious negative food security implications for these countries.

In contrast to rising fish demand over time, supply of fish from coastal fisheries is expected to decline due to climate change and other adverse environmental effects. Therefore, there is an urgent need to increase the supply of fish in Pacific Island countries from their domestic sources by reversing the negative trends of coastal fisheries and/or increasing supply from oceanic and freshwater systems.

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⁵ Readers are referred to World Bank [24], Kobayashi et al. [35] and Lem et al. [48] for global projection of fish supply, demand and trade for the period up to 2030.

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