Economic value assessment of Seychelles tuna fisheries

December 2018

Frozen yellowfin tuna (Thunnus albacares) condenses the hot, humid Seychelles air as it is unloaded from the Dolomieu (La Reunion) in Victoria, Mahé Island, Seychelles. Industrial commercial fishing is one of the primary industries driving the Seychelles's economy. Photo credit: Jason Houston

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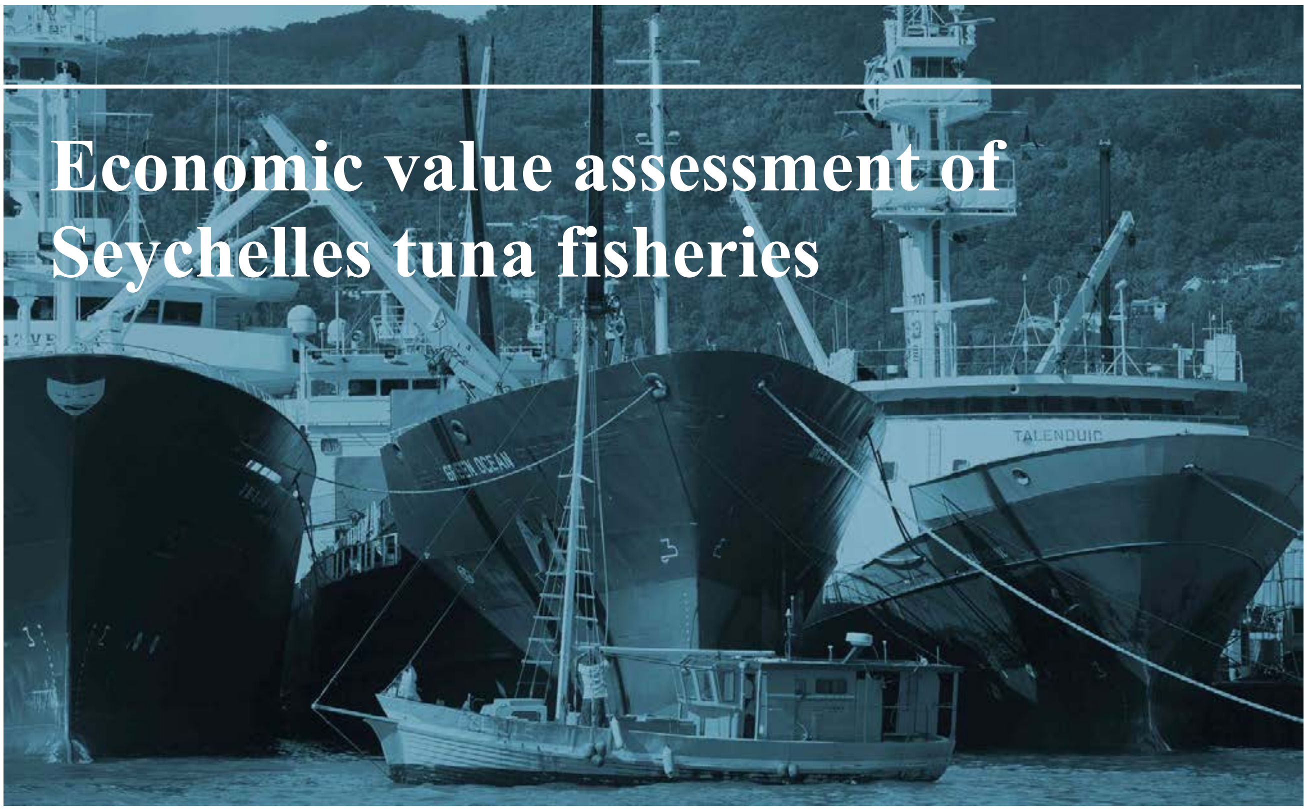

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The Nature Conservancy

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Highlights

- In 2017, the direct revenue of licensing fees for the Seychelles government from national and foreign tuna fishing fleets was estimated to be >12 million USD;
- About one order of magnitude separates the annual tuna production of the Seychelles fleets, i.e. ~1,000 t for semi-industrial longline, ~10,000 t for deep-water longline and ~100,000 t for purse seine;
- In recent years, the ex-vessel value of tuna caught by Seychelles fleets was >200 million USD and the value of the tuna catch in Seychelles waters was ~175 million USD;
- The purse seine fishing fleet annually spends ~100 million USD in fuel and >17 million USD in services (e.g. stevedoring, shipchandling) in Port Victoria;
- We modeled the monetary flows between the macro-economic agents of the Seychelles to assess the direct, indirect and induced effects of industrial fisheries on the national economy;
- Fishing is the economic sector that has the greatest output multiplier effect for the Seychelles;
- The fish production sector and the food manufacturing sector driven by the cannery have cumulative economic effects of ~50 and ~530 million USD, respectively;
- The fish-related sectors contribute directly or indirectly to nearly 10% of the Seychelles Gross Domestic Product and to >8% of national employment;
- We simulated the effect of the implementation of High Biodiversity Protection Areas of the Seychelles Marine Spatial Plan as an external shock on the national economy based on different assumptions about fishing effort strategies and licensing agreement negotiations;
- We found that the reduction in tuna fisheries catch and licensing revenues resulting from the MSP would have very limited effects on the economic activities and Gross Domestic Product of the Seychelles.

Executive summary

The Seychelles tuna fishery is composed of three distinct fleet components: (i) a domestic semi-industrial longline fleet that mainly operates in the national waters for the fresh tuna market, (ii) a Taiwanese-owned deep-water longline fleet that operates in the whole Indian Ocean for the frozen tuna market, and (iii) a European-owned purse seine fleet that operates in the Western tropical Indian Ocean essentially for the canning market. About one order of magnitude separates the annual tuna production of the Seychelles fleets: about 1,000 t for fresh longline tuna, about 10,000 t for frozen longline tuna and about 100,000 t for purse seine tuna. During 2012-2017, Seychelles deep-water longliners and purse seiners paid annual licensing fees of about 2 million USD and took about 30% and 15% of their tuna catch in the Seychelles waters, respectively. Every year, more than 150 foreign fishing vessels also access the Seychelles Exclusive Economic Zone (EEZ) through licensing agreements. In recent years, these foreign vessels annually caught more than 50,000 t of tuna in the Seychelles waters and paid more than 10 million USD to the government for accessing the Seychelles fishing grounds. Based on time series of import, we estimate that the annual ex-vessel value of the Seychelles fleet catch was larger than 200 million USD and the value of the total catch in Seychelles waters was about 175 million USD in recent years. These values are biased by the costs of insurance and freight since free-on-board prices for tuna caught in the Indian Ocean were not available for this study. Information available from the Seychelles Petroleum Company, the Seychelles Port Authority and the local agents of the fishing companies shows that the purse seine fishing fleet annually spends about 100 million USD in fuel and more than 17 million USD in services (e.g. stevedoring, shipchandling) in Port Victoria. Expenditures of the semi-industrial longline fleet are not well monitored but are negligible relative to purse seine. Deep-water longliners play a very minor role in the national economy as they get fuel and unload and transship their catch outside the Seychelles.

To assess the direct, indirect and induced effects of industrial fisheries on all the sectors of the Seychelles economy, we modeled the monetary flows between the macro-economic agents of the country with an Input-Output Table and a Social Accounting Matrix. Some strong assumptions were made about the structure of some expenditures and incomes because no supply-use or input-output tables are available yet for the Seychelles. Overall, we found that the fishing and fish processing sectors contribute directly or indirectly to nearly 10% of the Seychelles Gross Domestic Product. Our results show that the fishing sector is the economic activity that has the greatest output multiplier impact for the country. Stimulated by the sole demand for fishery products in 2014, the Seychelles economy would create a total output value of about 40 million USD and contribute to the Gross Domestic Product by an additional amount of about 9.5 million USD, thus generating a cumulative economic effect of almost 50 million USD. The food manufacturing sector of the Seychelles is largely predominated by the Indian Ocean Tuna Ltd. cannery. Although the total multiplier of this sector is smaller than for fish production, the final demand for manufactured goods is far more important than for fishery products, resulting in a higher impact on the Seychelles economy. Stimulated by the mere final demand for manufactured food products in 2014 (i.e. mostly exports of canned tuna), the Seychelles economy would create a total output value of about 435 million USD and contribute to the Gross Domestic Product by an additional amount of about 100

million USD, thus generating a cumulative economic effect larger than 530 million USD. In terms of employment, our results show that one additional job is created for any worker hired in both the harvest and post-harvest sectors of the fishing industry. National statistics indicate that the total amount of full-time equivalent workers employed in fishing and food-manufacturing industries was 234 and 1,765 in 2014, respectively. If the domestic economy was only stimulated by the final demand for products made in these two industries, the total number of full-time jobs created in the Seychelles economy would be larger than 4,000, i.e. more than 8% of national employment.

We used the Social Accounting Matrix to model the impact of the implementation of High Biodiversity Protection areas delineated through the Seychelles Marine Spatial Plan (MSP). Recent historical catch of the Seychelles fleets in these areas was small, i.e. about 4.2%, 4%, and 1.5% of the tuna catch during 2012-2017 for semi-industrial longline, deep-water longline, and purse seine, respectively. We sequentially considered a reduction of the fishing grounds by 5.3% and 17.4% consistently with the areas gazetted in February 2018 and recently proposed for discussion among the different MSP stakeholders. Our findings show that the socio-economic effects of the implementation of High Biodiversity Protection areas would be very limited in case of reduction of fishing effort proportional to that observed in these areas during 2012-2017, and negligible in case of effort reallocation, this latter option being highly likely. By contrast, the implementation of a quota on the yellowfin purse seine fishery by the Indian Ocean Tuna Commission since has had a substantial impact on the fleet production and landings in Port Victoria. The overall macro-economic effects of the quota and limited supply of yellowfin to the Seychelles cannery could be explored with the methodological approach employed here. Additional scenarios could be constructed in the future to account for the environmental benefits of the Seychelles MSP. Valuing the supporting, regulating and cultural services provided by the national marine ecosystems (e.g. coral reef habitats, biodiversity, CO_2 sequestration) would be an essential first step to properly assess the role of such ecosystem services in the whole Seychelles economy. Another way of extending the present study would be to develop a Computable General Equilibrium Model from the Social Accounting Matrix in order to separate the quantity and price effects of an external shock into the domestic economy. Such modeling approach is data-demanding but instrumental in assessing the outcomes of alternative options for the Seychelles economic policy.

List of acronyms

Acronym	Definition
BLI	Backward Linkage Index
BOP	Balance of Payments
CBS	Central Bank of Seychelles
CIF	Cost-Insurance-Freight
CPUE	Catch Per Unit Effort
FAD	Fish Aggregating Device
EEZ	Exclusive Economic Zone
EU	European Union
FOB	Free-On-Board
FPA	Fisheries Partnership Agreement
FLI	Forward Linkage Index
GDP	Gross Domestic Product
IOT	Input-Output Table
IOTC	Indian Ocean Tuna Commission
IOTL	Indian Ocean Tuna Ltd
ISIC	International Standard Industrial Classification
MCS	Monitoring, Control, and Surveillance
MPA	Marine Protected Area
MSP	Marine Spatial Plan
MSY	Maximum Sustainable Yield
NBS	National Bureau of Statistics
PUC	Public Utility Corporation
SAM	Social Accounting Matrix
SCR	Seychellois Rupee
SEYPEC	Seychelles Petroleum Company
SFA	Seychelles Fishing Authority
SPA	Seychelles Port Authority
SUT	Supply Use Table
TFA	Top Fortune Agreement
TTA	Taiwan Deep-sea Tuna Longline Boat Owners and Exporters Association
USD	United States Dollar
VMS	Vessel Monitoring System

Introduction

The Seychelles' Gross Domestic Product (GDP) increased annually between 3% and 7% during the 2010s and the country graduated to high-income country status in July 2015. In 2014, the GDP at current and basic prices reached 14.3 billion Seychelles rupees (SCR), i.e. about 1.12 billion US dollars (USD). With an unemployment rate at 4.1% (World Bank 2017), the Seychelles appear to be at full employment level since the residual part of unemployment can be considered as frictional or unintentional. There is however a certain closeness between low-skilled employment and poverty, 40% of the population being under the extreme poverty threshold with a daily income of less than 1.90 USD. The Seychelles are characterized by a strong level of inequality with regard to income distribution. In addition, the economy is described by some typical characteristics of Small Island Developing Countries, including the properties of islandness with a specific sense of community, a small domestic market – less than 100,000 residents - and remoteness, which is deemed to constitute a comparative disadvantage to benefit actively from economies of scale and international trade (Winters & Martins 2004). However, the high standards of institutions and facilities make this country appealing for foreign investors, particularly in the tourism and fishing sectors which are the two pillars of the economy.

The Seychelles archipelago lies at the heart of Indian Ocean tuna fishing grounds. The fishing sector is a major source of employment in the pre-harvest sector for the artisanal and semi-industrial domestic fisheries and post-harvest sector for the industrial purse-seine fishery (Jupiter & Michaud 2018). The port of Victoria is equipped with good infrastructures, equipment and services that have been mainly developed for large-scale tuna purse seiners. The Seychelles tuna fishery is composed of three distinct components that target different markets. First, the domestic semi-industrial longline fleet mainly harvests tuna and billfish with medium-sized vessels that operate in the Seychelles waters, unload all their catch in Victoria, and export fresh products mainly to Russia, the EU, and the USA. Second, the foreign-owned industrial longline fleet is composed of large ultra-low temperature freezer vessels that mainly target bigeye (*Thunnus obesus*) and yellowfin (*Thunnus albacares*) in the western and central Indian Ocean for the Japanese sashimi market. These vessels transship about 2/3 of their catch on reefers in international waters and the rest in Port Louis (Mauritius), Cape Town (South Africa), Kaohsiung (Taiwan), and Colombo (Sri Lanka). Third, a fleet of foreign-owned large-scale purse seiners assisted by several support vessels targets adult yellowfin in free-swimming schools and schools of skipjack (*Katsuwonus pelamis*) mixed with juveniles of yellowfin and bigeye associated with floating objects for the canning market. The purse seiners unload less than one fourth of their catch to the Seychelles cannery Indian Ocean Tuna Ltd. (IOTL) while the rest is exported all over the world in reefers and refrigerated containers. In addition to Seychelles tuna fleets, more than 130 foreign deep-water longliners and 30 purse seiners operate every year within the Seychelles exclusive economic zone (EEZ) through licensing agreements. The Blue Economy has been selected as a key priority for the economic development of Seychelles. In particular, tuna fisheries represent a major source of revenue for the country: the canning plant IOTL creates directly or indirectly 4,000 jobs, canned tuna represents more than 95% of exported goods, and foreign fleets and reefers spend around 2 billion SCR (i.e. 156 million USD) in goods and services at port calls (SFA 2017).

In 2014, the Seychelles initiated the development of a comprehensive Marine Spatial Plan (MSP) to ensure representative species and habitats have long-term protection, to improve resiliency of coastal ecosystems with a changing climate, and to ensure economic opportunities for fisheries, tourism and other uses. In February 2018, the marine zones delineated during Phase 1 of the project were gazetted and represented a total of 74,000 km^2 of High Biodiversity Protection Areas (Zone 1) and 137,000 km^2 of Medium Biodiversity Protection and Sustainable-Uses Areas (Zone 2), amounting to 15% of the total Seychelles EEZ. The ongoing Phase 2 of the MSP aims to complement the 30% target of protected areas by extending the zoning to cover 30% of the EEZ by 2020. The protection of marine areas through improved spatial management is expected to result in higher value of ecosystem services as well as increased earnings with more tourists visiting the archipelago for instance. There are several other possible benefits of the MSP, including improved transparency and participation in decision-making, increased business certainty for future economic development, availability of data for decision-making (Morphet 2010). From a more negative perspective, the MSP might reduce some revenues of the Government of Seychelles on the short-term since the fishing fleets currently operating within the Seychelles EEZ may re-negotiate access fees in compensation for reduced fishing opportunities. National and foreign fishers may also reduce their landings in Port Victoria, resulting in decreasing expenditures related to port services (bunkering, port dues, shipchandling, stevedoring, etc.) and creating potential shortage of frozen tuna for the domestic canning plant IOTL which has already been hit by shortage in supply due to the quota on yellowfin catch implemented by the Indian Ocean Tuna Commission (IOTC) since January 2017.

The overarching objectives of the study are to assess the economic value of the tuna sector in the Seychelles prior to MSP implementation as well as to estimate the potential consequences that the MSP could have on the Seychelles economy. In this study, we focus on High Biodiversity Protection Areas (Zone 1) where fishing will not be authorized and do not consider the potential impact of implementing Medium Biodiversity Protection and Sustainable-Uses Areas (Zone 2) since conditions of access for fishing vessels have not yet defined for these areas. First, we describe the activities of the Seychelles tuna fleets as well as all the fleets operating within the Seychelles EEZ during 2004-2017 and provide a tentative estimate of tuna catch value based on time series of prices available on international markets. Second, we compile information on licensing fees for each fleet component to estimate the annual value perceived by the Government of Seychelles through fishing agreements. Third, we analyze the main expenditures of the purse seine fleet in Victoria, i.e. port charges, bunkering, and stevedoring, to establish a link between vessel activities and economic value generated by port services. Fourth, we build on the previous steps to define scenarios of expected change in both the amount of license fees and fishing activities which could affect the national economy through direct and indirect effects. Fifth, we construct an Input-Output Table (IOT) and a Social Accounting Matrix (SAM) to (i) describe the economic flows (i.e. incomes and expenditures) of Seychelles, (ii) estimate the added value and the relationships between activities within the domestic economy and between the national economy and the rest of the world, and (iii) calculate output, Gross Domestic Product (GDP), and employment multipliers of the Seychelles economy. In a final step, we use the SAM to simulate the different scenarios as external shocks affecting the national economy through a decreased final demand of public (i.e. lower license revenues) and private services (e.g. bunkering, stevedoring). The non-monetary environmental impact of the MSP providing positive externalities for the whole economy is beyond the scope of the present study and should be the focus of future work dealing with the effects of the MSP.

Materials & Methods

Licensing fees

We estimated the total annual value perceived by the Government of Seychelles in 2017 through fishing agreements, which are assumed to be close to the 2014 figures. Licensing is required for both foreign and Seychelles-flagged industrial fishing vessels to operate within Seychelles national waters. Registration of foreign fishing vessels to fly the Seychelles flag is governed by the Merchant Shipping Act (1992). Fishing vessels eligible for registration under the Seychelles flag must be wholly owned by a Seychellois citizen or a Seychelles Body Corporate established either as an International Business Company with the Financial Services Authority or as a Domestic company with the Registrar of Companies. Annual fees to register under the Seychelles flag include fixed costs (registration, mortgage, and authorization to fish) as well as a tonnage fee that varies with vessel gross tonnage. In recent years, access to the Seychelles national waters was granted to Taiwanese, Chinese, and Seychelles-flagged longliners without any limit on fish catch through two main fishing agreements representing different fishing companies: the Taiwan Deep-sea Tuna Longline Boat Owners and Exporters Association agreement and the Top Fortune Agreement. Two different types of agreements are currently in place for purse seiners. First, fixed annual license fees with no catch limit are paid by Seychelles-flagged purse seiners, Korean-flagged purse seiners under private agreements, and Mauritius-flagged purse seiners under the 2-year bilateral, reciprocal, cooperation Seychelles-Mauritius Fisheries agreement. Second, the protocol of the Fisheries Partnership Agreement (FPA) between Seychelles and the EU concerns all purse seiners flying the flag of a Member State, i.e. France, Spain and Italy in recent years. The current 6-year protocol between the EU and Seychelles will run until January 2020 and provides an annual contribution of 6.2 million USD split between access right and sectoral support. In addition, shipowners contribute to fishing rights with an annual advance payment fee set to 700 metric tons (t) per vessel and a unit price annually increasing from 68 USD per ton in 2014 to 87 USD per ton in 2019. Payment of fees for catches above the annual reference tonnage of 50,000 t are split between shipowners and the EU as defined in the current protocol. Annual license fees of 5,000 USD are required for any support vessel assisting purse seiners within the Seychelles EEZ whatever their flag.

Fisheries monitoring

The Seychelles Fishing Authority (SFA) monitors both national and foreign tuna fishery components operating within the Seychelles EEZ through licensing agreements. The monitoring of the purse seine component is conducted in collaboration with the French national research institute for sustainable development (IRD), Spanish Institute of Oceanography (IEO) and AZTI-Tecnalia (AZTI) for the French and Spanish fleets, respectively. The Monitoring, Control and Surveillance section of the SFA monitors entries and exits in the Seychelles EEZ and fishing activities with Vessel Monitoring System (VMS) installed on all vessels >12 m since the 2000s. The statistical section of the SFA is in charge of the collection and curation of logbooks, unloading reports, and sampling of the catch. Positions of vessel activities are controled with VMS and logbook declarations are checked against unloading reports. Operational-level catch and effort data are available for all fishing activities having occurred during 2004-2017 in the Seychelles waters. We estimated the annual total catch and effort of the semi-industrial longliners, deep-water longliners and purse seiners having operated within the Seychelles EEZ during 2004-2017, with a focus on the High Biodiversity Protection Areas (Fig. 1). We split the industrial components of the fleets into national, EU and non-EU vessels accordingly with the types of licensing agreements (Section Licensing fees). We used the number of hooks deployed and fishing sets as effort units for longline and purse seine, respectively, and predicted catch based on different scenarios of effort reallocation in other fishing grounds, using mean catch per unit effort (CPUE) observed during 2012-2017 (Section Scenarios).

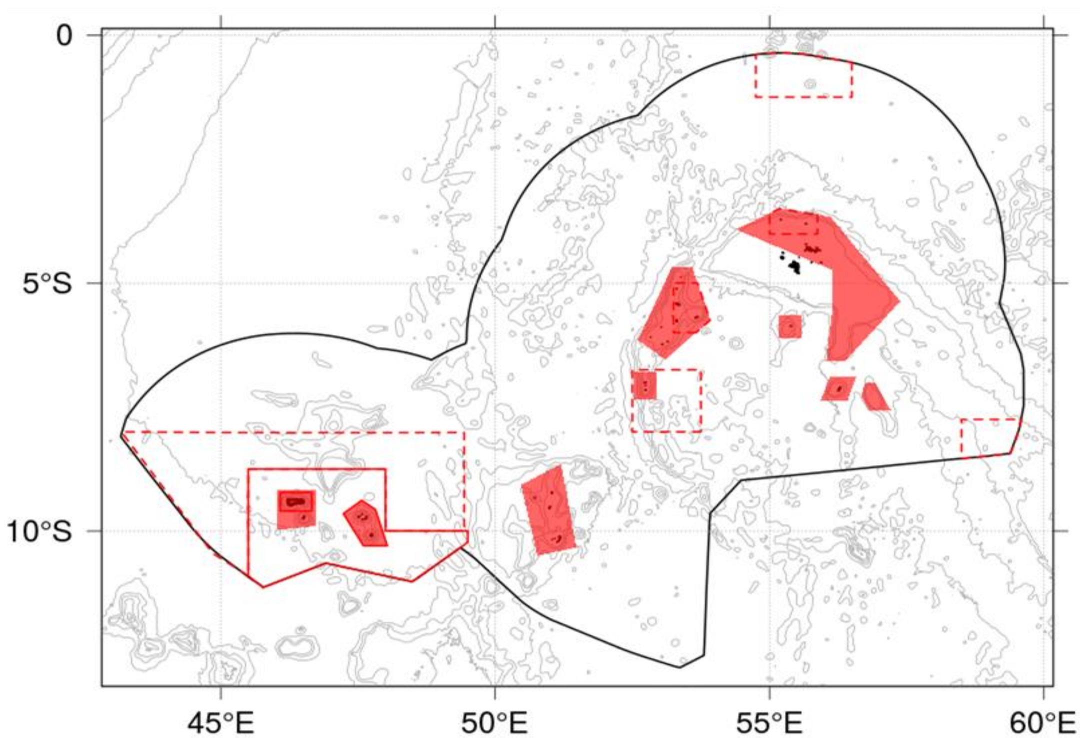

Fig. 1: High Biodiversity protection Areas (red) areas delineated through the Seychelles Marine Spatial Plan (MSP). Solid line indicates Phase 1 gazetted areas and dashed line indicates Phase 2 proposed areas. Zones currently restricted to industrial fishing are indicated in shaded red (Fisheries Act 1982).

Ex-vessel tuna value

We estimated the annual value of tuna catch made for each tuna fishing fleet (i.e. semi-industrial longline, deep-water longline and purse seine) during 2004-2017 based on monthly average prices of tuna imports made available by the Pacific Islands Fisheries Forum Agency (FFA Trade Bulletin). We first estimated the value for the Seychelles tuna fleets and then for all fleets having operated within the Seychelles EEZ. Price data were compiled from longline fresh tuna imported in Oceania (http://www.customs.go.jp/toukei/srch/indexe.htm?M=01&P=1), longline frozen tuna imported in Japan (Nakada San, TIA) and purse-seine frozen tuna imported in Thailand (http://www.customs.go.th) during 2004-2017. Monthly prices of frozen purse seine bigeye were only available from January 2010 and assumed equal to frozen purse seine skipjack over the period 2004-2009. Our approach overestimates the value paid to fishermen as it includes additional costs of international freight and tariff duties (i.e. Cost-Insurance-Freight) as compared to Free-On-Board prices which were not available for the present study. Also, an increasing, but still minor, part of the purse seine catch is now destined to higher-value tuna products such as loins and steaks with the development of deep-freezing storage onboard several purse seiners in recent years. The part of the catch as well as price information for these products remain confidential for competitive reasons.

Fishing vessel expenditures

A large range of information on vessel expenditures is monitored by the economic section of the SFA. Data on port calls are made available by the Seychelles Ports Authority that monitors all activities related to arrivals and departures in Port Victoria. Information was checked against fisheries data and appears to be comprehensive. Records of bunkering operations are routinely provided to the SFA by the Seychelles Petroleum Company Limited (SEYPEC) through monthly reports of bunker uplifts. Data include monthly rates of gasoil (0.05%) expressed in USD per metric ton (t), date of bunkering and the quantity delivered to each vessel in weight (t). Ancillary information made available from SEYPEC on an annual basis suggests that the data managed by SFA might however be incomplete and only covered ~90% of total delivery in 2014. Finally, detailed information on vessel expenditures is made available from the fishing agents and includes stevedoring, port charges (i.e. pilotage exemption fee, port authority fee, port dues, port health fee and transshipment tax) and several expenses considered stable such as agency charges, shipchandling, engineering services, and postage and courier.

We used statistical models to establish relationships between expenditures and vessel activities in order to assess how changes in catch may relate to the main expenditures of fishing companies in Port Victoria. In a first step, we used linear quantile regressions to model the median annual gasoil consumption of purse seiners over 2000-2016 as a function of vessel length overall (m), time at sea (days) and total catch (t) derived from fisheries logbooks. Vessel length was used as a proxy for fuel requirement as it is strongly correlated with engine power and vessel speed. In a second step, median annual expenses in stevedoring during 2003-2016 were modeled with quantile regression as a function of total landings (t) in Port Victoria and landing year to account for potential changes in revenue rate over time. Data however showed some major inconsistencies with almost no stevedoring costs for many landings, suggesting incompleteness of the data collected from the fishing agents. Assuming higher costs in the data may reflect better coverage of the expenditures, we fitted a regression model to the 80% quantile of the data so as to derive an upper estimate of stevedoring costs that would account for missing data. In a third step, median port charges of purse seiners were modeled as a function of annual landings (t) with quantile regression models. Year was included in the model as a factor to account for potential changes in annual ports rates.

Input-output table

An Input-Output Table (IOT) is a widespread approach to evaluate the spillover effects of an external shock onto a national economy (Leontief 1936). The author's original idea was that commodities are produced by means of other commodities, thus creating some backward and forward linkages between an industry (e.g. fishing activities) and the rest of the economy (e.g. fuel, fishing gears, electronic equipment, etc.). The demand for additional inputs by some producers and the supply of their outputs used by others will trigger a chain of cascading effects upstream and downstream of one particular activity. A square and symmetric IOT can be created by crossing the sales (rows) and purchases (columns) of intermediate inputs between the industries of a domestic economy (Table 1). Vertically, the total supply of each industry is obtained by adding up the intermediate consumptions by product, either domestically produced or imported, and the added value. Horizontally, the products of each industry are either sold as intermediate products to other industries or as final goods to the national accounts of households, firms, government, and rest of the world (Table 1). The sum in columns (supply) equals the sum in rows (demand) for each industry. The square matrix of technical (or input) coefficients (i.e. shares of inputs i in total supply of branch j) can be derived from this table by dividing the intermediate consumptions by the total supply value for each industry. More details on the approach are given in Appendix 1.

Table 1: A ***s****implified product by product Input-Output Table (United Nations 2018).*

Products (rows) \ Products (columns)	Products				Final uses			Output
	Agriculture, forestry, etc.	Ores and minerals; etc.	...	Services	Final consumption	Gross capital formation	Exports	
Agriculture, forestry, etc. Ores and minerals; etc. ... Services	Intermediate consumption by product				Final uses by product and by category			Total use by product
Imports	Intermediate consumption of imported products				Final use of imported products			
Value added	Value added by component				(empty cells by definition)			Value added
Input	Total supply				Total final uses by category			

Empty cells by definition

Social Accounting Matrix

A Social Accounting Matrix (SAM) proposes a circular flow diagram of incomes and expenditures by all major macroeconomic agents: households, government, firms, non-profit institutions, and rest of the world (Pyatt & Round 1985, Breisinger et al. 2009). In addition to backward and forward production linkages, the SAM approach is a more comprehensive representation of an economy than an IOT because it considers consumption linkages arising when an expansion of production generates additional incomes for factors (capital and labor) and households who will in turn purchase goods and services, thus creating an income multiplier effect in the economy. The columns of a symmetric SAM can be read as expenditures and the rows as incomes (Table 2). Column-wise, in addition to the commodities purchased by the various activities, the factor market describes how the added value created by industries is split between capital and labor revenues for households, i.e. profits and wages, respectively. Each macroeconomic sector (households, firms, government and rest of the world) is represented by a row to trace the origin of their income and by a column to report their expenditures. For instance, row-wise, the household sector earns income from the labor and capital factor markets driven by activities, from social transfers paid by the government and from foreign remittances received from national expatriates living abroad and sending part of their income back home. Column-wise, this household sector will buy commodities, pay indirect and direct taxes to the government, and save part of the revenue that will be drained to firms for investment. Similar symmetric exercises are conducted for the other national accounts (firms, government, economic relationship with the rest of world), resulting in a fully balanced table. A good example of a SAM used for a Computable General Equilibrium Model and applied to an Indian Ocean island economy (Mauritius) can be found in Cervigni & Scandizzo (2017).

Table 2: Representation of a Social Accounting Matrix (Breisinger et al. 2009).

		Expenditure columns							
		Activities C1	Commodities C2	Factors C3	Households C4	Government C5	Savings and investment C6	Rest of world C7	Total
Income rows	Activities R1		Domestic supply						Activity income
	Commodities R2	Intermediate demand			Consumption spending (C)	Recurrent spending (G)	Investment demand (I)	Export earnings (E)	Total demand
	Factors R3	Value-added							Total factor income
	Households R4			Factor payments to households		Social transfers		Foreign remittances	Total household income
	Government R5		Sales taxes and import tariffs		Direct taxes			Foreign grants and loans	Government income
	Savings and investment R6				Private savings	Fiscal surplus		Current account balance	Total savings
	Rest of world R7		Import payments (M)						Foreign exchange outflow
	Total	Gross output	Total supply	Total factor spending	Total household spending	Government expenditure	Total investment spending	Foreign exchange inflow	

Multiplier effects

IOT and SAM models can be used to simulate the impact of an external shock affecting the final demand for commodities through a multiplier effect approach (Fig. 2). Such external shock can stem from many different drivers affecting the final demand of domestic households, firms, government or rest of world. For instance, the external shock may come from a new project investment for the economy (new plant, major cultural event like a festival, foreign direct investment, etc.), or more negatively from a financial economic crisis affecting the level of government income (e.g. less indirect taxes), a sudden decline of exports due to the rise of customs tariffs, etc.

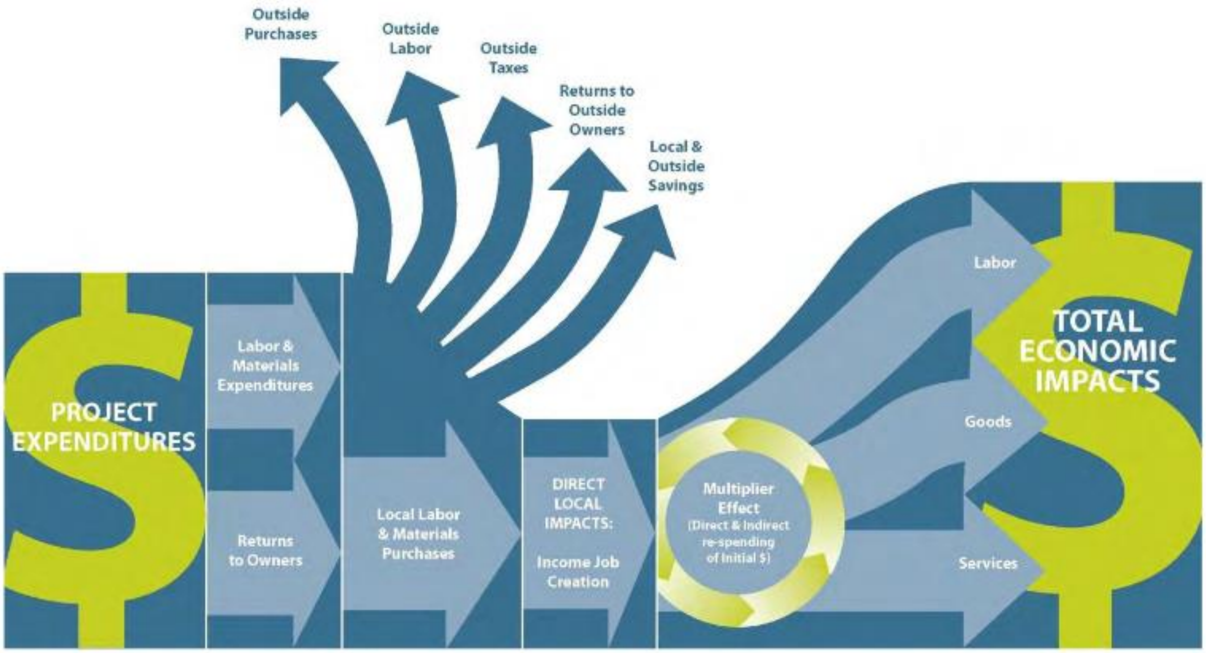

Fig. 2: Multiplier effects in the economy. From an initial expenditure (or external shock), some labor and material expenditures will be injected as inflows into the domestic economy. Part of it will leak out of the system because inputs are partly imported, foreign workers are hired, outside taxes will be paid, part of the profits will be saved, hence not consumed internally, and returns will be directed to foreign owners (Northern Economics 2013).

For the remaining share, it will create spillover effects through the production (backward and forward) and consumption linkages (Fig. 3). It is noteworthy that both IOT and SAM can only describe the monetary transactions passing through the market economy, and not the environmental externalities created by the domestic industrial outputs or by household consumption through imported goods and services. Environmental accounts could be extended to IOT and SAM tables, as long as air, water and soil emissions, waste and residuals data are available, which is currently not the case for Seychelles. In the long-run, it would be interesting for Seychelles to add these environmental data sets into their national accounts as the European Union does with the National Accounting Matrix with Environmental Accounts guided by the international System of Environmental Economic Accounting (United Nations 2014).

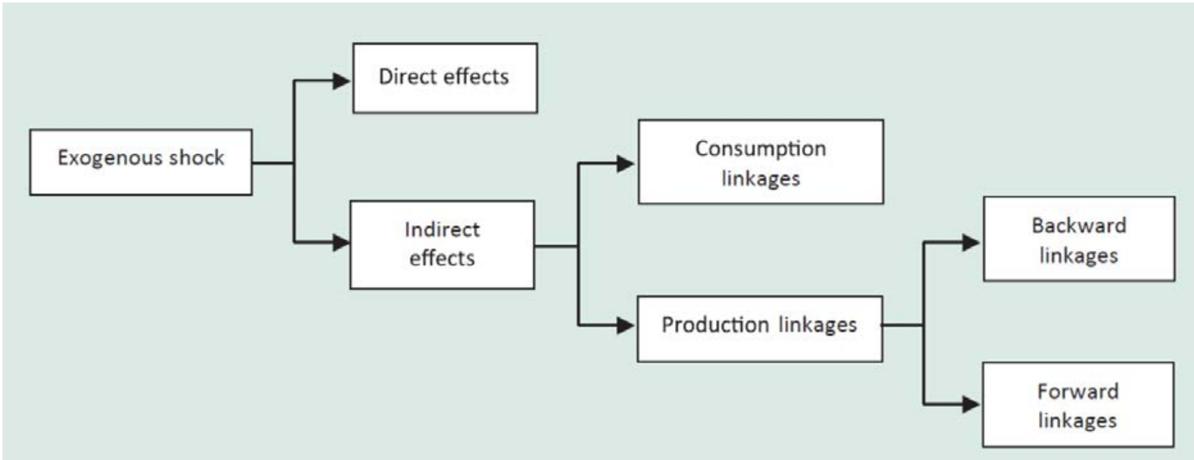

Fig. 3: Direct and indirect effects after an external shock (Breisinger et al. 2009).

The calculation of multipliers is significantly different between the IOT and the SAM approach. In the Input-Output analysis, the input consumption values are divided by the sum of columns, industry by industry, to give the matrix of technical coefficients (A). The vector of output resources X is sold either as intermediate inputs to other industries ($A.X$) or as final goods and services to the end users (E = vector of final demand from households, firms and non-profit institutions, government and rest of the world), as in Equation (1):

$$X = A.X + E \qquad \text{(Eq. 1)}$$

Re-arranging Eq. (1) gives:

$$E = (I - A).X \qquad \text{(Eq. 2)}$$

Where I is the identity matrix. By expressing now output as a function of final demand, we obtain:

$$X = (I - A)^{-1}.E \qquad \text{(Eq. 3)}$$

The Leontief inverse matrix $(I - A)^{-1}$ is the multiplier matrix, and the sum by column gives the output multiplier for each industry. In other words, when using the Leontief inverse Input-Output matrix, we are looking at the effects of exogenous final demand (E) onto the domestic output level (X).

By using the Leontief inverse matrix, we can extend the analysis to many other types of multipliers. For instance, we can use it to calculate the Employment multiplier effects. In that regard, another matrix (L) is constructed by dividing the number of jobs by the output value, industry by industry, on the first diagonal (zero elsewhere). This matrix is multiplied by the right-hand side term of Eq. 3 to give the number of jobs (J) created by unit of final demand:

$$J = L.(I - A)^{-1}.E \qquad \text{(Eq. 4)}$$

The employment effect statistics calculates the impact upon employment throughout the Seychelles economy arising from a change in final demand for industry j's output of SCR 1.

On the basis of matrix calculus, the influence of one specific industry onto the others can be estimated through its output multiplier effects which can be easily interpreted. For instance, for any Seychelles rupee (SCR) created by the fish canning activity through the exports of canned tuna, how many other SCRs are backward created by other industries either directly (first suppliers such as the domestic fleet of frozen tuna) and indirectly (suppliers' suppliers such as SEYPEC for fuel, stevedores and other harbor services, etc.). Other types of multipliers can be evaluated through the Input-Output approach: jobs, income, Gross Domestic Products, tax, environmental impact, etc.

The calculation of multipliers within the SAM approach is somehow more sophisticated because it includes the income effects on the final consumption of commodities, i.e. consumption linkages. We are computing a different matrix (called M) integrating, in addition to the output backward and forward linkages, the distribution of income to households (either capital or labor income) that will be in turn spent by households to buy domestically produced commodities. The meaning of multipliers is therefore different because they reveal the impact of the exogenous final demand (E) onto the total demand (Z) that includes both intermediate and final goods and services:

$$Z = (I - M)^{-1}.E \qquad \text{(Eq. 5)}$$

The mathematical details developed for the SAM approach are available in Appendix 1.

The multipliers of exogenous demand can be estimated for different components of the final demand: the demand for commodities, the demand for factors (= income or GDP multiplier), the demand for investment, the demand for imports, etc. It is also straightforward to decide which component of the final demand can be considered exogenous or endogenous, i.e. what needs to be included in E or Z, respectively. For instance, the household demand can be left on the endogenous (left) side of the equation if what is produced by the domestic economy is partly redistributed as income for households who will spend most of this income in domestic commodities. Similarly, one may decide to leave on the exogenous (right) side, the output vector of one particular industry as long as this industry is constrained by its production capacity. If an exogenous shock increases the final demand (e.g. the foreign demand for exported goods), this specific industry might not be anymore in a position to respond to the shock by increasing its own output level because this would require capacity adjustment (new investments, new plants, hiring new workers, etc.). Moreover, increasing production in some sectors may lead to falling production in others if some resources are scarce (natural resources such as fish stocks, labor or capital). For instance, let's imagine a fishing industry whose production is constrained by a total amount of allowable catch for some species. Consequently, it becomes important to take these constraints into consideration by keeping these industries on the exogenous side. Their final demand becomes endogenous but their production is exogenous. Both unconstrained and unconstrained approaches were considered for computing multipliers from the SAM. More mathematical details about the constrained multipliers are given in Appendix 1.

In order to complement the set of multipliers obtained with IOT and SAM analyses, two indices were calculated to highlight the induced effects of the activities and their ranking order in terms of backward and forward linkages. The Backward Linkage Index (BLI) represents the demand for additional inputs used by producers to supply additional goods or services. Technically, the BLI is computed as the ratio between the mean coefficient of each column of the inverse Leontief matrix and the mean value of coefficients of the whole Leontief inverse matrix. Any index value greater than one means that the industry produces economic effects beyond its own activity. For example, when the Food manufacturing industry (including canned tuna) production expands, it demands intermediate goods like frozen tuna, vegetable oil, salt, machinery, transport services, etc. This demand then stimulates production in other sectors to supply these intermediate goods. The more input-intensive a sector's production technology, the stronger its backward linkages. Forward production linkages account for the increased supply of inputs to upstream industries. For example, when fishing production expands, it can supply more goods to the food-processing sector, which stimulates manufacturing production. So the more important a sector is for upstream industries, the stronger its forward linkages. Technically, the Forward Linkage Index (FLI) is computed as the ratio between the average coefficient of each row of the Leontief inverse matrix and the average value of coefficients of the whole Leontief inverse matrix.

Macro-economic data

We selected 2014 as reference because it was the most recent year with the most complete data for all parameters of the model available from the National Bureau of Statistics, the Central Bank of Seychelles, the Ministry of Finance, and the Seychelles Fishing Authority. Several documents must be compiled to collect all required information from National Accounts: Supply Use Table (SUT), Input-Output Table (IOT), Balance of Payments (BOP) depicting the relationships between the national economy and the rest of the world, government budget, formal employment and earnings, etc. Unfortunately, if most of these documents are available in Seychelles, no SUT and IOT have been constructed yet. Their development is under way by the National Bureau of Statistics and a first version of SUT might become available by the end of 2018.

In the meantime, an intermediate version of SUT inspired by the Mauritius economy (close to Seychelles') was provided by the Seychelles National Bureau of statistics (NBS 2017a) and combined with another version inspired by the Hawaii IOT and applied to the Seychelles economy more than a decade ago (Valenghi 2004). The national accounts are usually described by 23 distinct industries (Appendix 2), but the provisional SUT supplied by NBS includes 44 industries while the study by Valenghi (2004) relied on 16 activities. The more disaggregated the IOT, the more demanding the data collection phase regarding the exchanges of goods and services between the industries at a detailed level. For the present study focusing on fisheries and fish related activities, the whole economy was split into 9 distinct activities (Table 3). This level of disaggregation was deemed a good compromise between a detailed description of the Seychelles economy and the availability of data for all industries in terms of employment, indirect taxes, final demand of households, government and firms, exports, etc. With 9 industries, all information needed is available for fisheries and the fish canning industry. Ideally, the fish (tuna) canning industry would be separated from the other Food manufacturing sectors (e.g. the beer plant Seybrew), but it was not made possible within the project and the risk would be to result in too small sub-sectors within the overall economy. Note that the manufactures of food sector includes the major firm in Seychelles, IOTL, which is strongly related to the fishing sector through its supply of raw materials, the activity ‘Other manufactures’ includes the Seychelles Petroleum Company (SEYPEC) which is a key supplier of all other industries, the Public Utilities Corporation and the Seychelles Port Authority are contained in ‘Public Services’, and the ‘Private services’ sector embodies a great deal of services used by the fishing industry, e.g. stevedoring or shipchandling.

It can be argued that the size of Mauritius is different from Seychelles, but what matters is the structure of the economy represented by the technical coefficients, i.e. tourism and fishing are also the main pillars of the domestic economy of Mauritius. Concerning Hawaii, another island economy close to the Seychelles economic structure, Valenghi’s work was the only available study building a comprehensive IOT for Seychelles. Although ancient, figures appeared to be more consistent and reliable than those of Mauritius. Other small island economies could have been used, such as the Aruba economy, another small island economy, where an Input-Output Table was available (Steenge & Steeg 2010). The study however dates back to 1999, i.e. prior to Valenghi’s work. A sensitivity analysis was carried out to compare the two input-output tables (Mauritius-based and Hawaii-based) and their outcomes (Appendix 3).

Table 3: Selected sectors of the SAM following the International Standard Industrial Classification (ISIC).

9 SAM sector	23 National Account sectors (ISIC)	
Agriculture	A01	**Primary sector**
Fishing	A03	
Manufactures of food	C10	**Secondary secor**
Other manufactures	C11-12, C23, C13-22,24-33	
Construction	F	
Tourism	I	**Tertiary sector**
Transport	H	
Private / other services	G, J, K, L01, L02, M, N, S	
Public services	D, E, O, P, Q, R	

Building the Seychelles SAM

Several steps are required to build a balanced Social Accounting Matrix (Appendix 3). First, some conversions were made in the Supply-Use Table such as the conversion between Cost-Insurance-Freight (CIF) and Free-On-Board (FOB) of the imports. The FOB value is used to avoid the double accounting of imported private services and transport services. Other adjustments were made to obtain annual data from quarterly figures. As new data were collected and introduced in the SAM, some imbalances between incomes and expenditures had to be accounted for to obtain perfect equality. This was done partly by substituting the added value estimated through incomes of the 9 activities for the previous added value estimated by the gross output minus intermediate consumptions (use of the Formal Employment and

Earnings data). The shares of capital (87%) and labor (13%) in the added value were then deducted. Such proportions are quite unusual compared to other economies, presumably because of the informal economy which undermines the importance of labor. Some inconsistencies between the various definitions of the Gross Domestic Product (GDP)[1] were also corrected, resulting in a new breakdown between intermediate inputs (60%) and added value (40%), typical of most economies. Added values per activity looked consistent but most intermediate consumptions were under-estimated, resulting in too low output values. By avoiding to modify the input structure, we kept the vector of technical coefficients and multiplied directly every cell of the input table to the corresponding vector of final demand (consumption, investment, government spending and export) minus some of the supply components (added value, imports and taxes). In the last stage, we adjusted marginally the private savings, the fiscal surplus and the current balance account in rows to match their total in columns. All the differences between column and row values were therefore reduced gradually so as to keep the overall structure of the SAM while reducing the gaps for the various accounts. R scripts for the Input-Output matrix and Social Accounting Matrix models are available in Appendices 4 and 5, respectively.

Marine Spatial Planning Scenarios

The first phase of the MSP resulted in the delineation of a High Biodiversity Protection Area of around 70,000 km^2 (5.3% of the Seychelles EEZ) around the Aldabra atoll which was gazetted in February 2018 as the Aldabra Group Marine National Park (Fig. 1). The second phase of the MSP proposes to extend this area and include some other areas that would cover in total more than 235,000 km^2, 17.4% of the EEZ (Fig. 1). A reference period prior to the start of the MSP (i.e. 2014) should be considered to avoid any effect of the participatory process on the economic activities occurring in the Seychelles. We considered however that the period 2012-2017 was more representative of fishing activities with regard to the major changes having occurred in the fishery in recent years, e.g. increase in number of deep-water longliners and major increase in purse seiner's productivity.

We developed several scenarios to represent the full range of uncertainty associated with the behavioral response of national and foreign fleets to the implementation of High Biodiversity Protection Areas in 2020 (Table 4). The impact of semi-industrial fishing on the whole national economy is negligible and will not be considered here. We assumed that the implementation of the MSP zoning would affect (i) the fisheries production and associated landings through reduction in fishing grounds and (ii) the amount of licensing fees included in the SAM as income for Public services that could be renegotiated in regards to reduction in fishing opportunities. In addition to the fishing industry, it is noteworthy that the EU could play a role in the value of licensing fees through the FPA protocol to be developed for 2020-2025.

Reduction in fisheries production would have direct effects on the expenditures in goods and services at Port Victoria, resulting for Seychelles in less exports of transport, public and private services. We assumed that changes in catch would reduce: (i) port charges that include a transshipment tax proportional to the tonnage of fish unloaded and transshipped at port, (ii) stevedoring activities, and (iii)

[1]Gross output value minus input values; GDP by the expenditure; GDP as the sum of factors' income.

bunkering operations. We used the median regression models derived from expenditure data sets to predict the changes in each of these activities resulting from changes in landings (Section Fishing vessels expenditures). These effects were only considered for the purse seine fleet since deep-water longliners almost never come to Port Victoria for economic reasons and due to the lack of infrastructure for handling and storing frozen longline tuna. The changes in value were subsequently included in the SAM (Section Social Accounting Matrix) as a shock in demand and the four following macro-economic indicators were computed to assess the changes in the economy: total output, Gross Domestic Product, government's budget and imports. Changes in both landings and licensing fees would indeed affect the external current account of Seychelles (e.g. lesser exports means less money received from abroad) and the balance of capital and grant inflows from overseas.

In the base-case scenarios, we assumed that both purse seine and deep-water longline fleets would reallocate all the fishing effort historically exerted in the High Biodiversity Protection Areas in other zones of the Seychelles EEZ. Such effort displacement is consistent with the high mobility of large-scale purse seiners and deep-water longliners. These fisheries have been shown to quickly adapt to time-area closures as observed following the implementation of the Chagos Marine Protected Area in 2010 as well as during the restricted access to Somalia fishing grounds due to piracy threat during 2008-2011 (Chassot et al. 2010, Kaplan et al. 2014, Davies et al. 2014). The assumption of effort displacement limited to the Seychelles waters was made because: (i) longline fisheries data for foreign vessels are only available in the Seychelles EEZ but necessary to compute the catch per unit effort (CPUE) for catch predictions, (ii) the purse seine fleet is described by strong spatio-temporal patterns in the Indian Ocean (Davies et al. 2014) and vessels are then expected to operate in the vicinity of the High Biodiversity Protection Areas at a time when Tanzanian and Comorian waters are not accessible to purse seiners, and (iii) purse seine CPUEs observed in the high seas northwest of the Seychelles EEZ during 2012-2017 were found to be higher than inside the Seychelles. Hence, our results are conservative in a sense that the predicted purse seine catch resulting from effort displacement restricted to the Seychelles waters will be the most negative with regard to fisheries production.

We first considered the area gazetted in February 2018 (Phase 1) and then both areas gazetted and proposed in late 2018 (Phase 2). For each phase, we computed the catch and effort of each deep-water longline component (national, foreigners) and purse seine component (national, EU and non-EU) observed in the High Biodiversity Protection Areas, in the rest of the Seychelles, and outside the Seychelles during 2012-2017. We used CPUE expressed in ton per fishing set for purse seine and in kg per 1000 hooks for longline to predict the expected catch following the MSP implementation. In addition to effort displacement, we considered in scenario 1.3 that licensing fees for both deep-water longliners and purse seiners would be reduced in proportion to the part of EEZ catch made in Zone 1 during 2012-2017 to compensate for reduction in fishing opportunities. For EU purse seine, we assumed that only fishing access and shipowner fees would be reduced through the renegotiation of the FPA protocol and that the sectoral support would not be affected, although some re-balancing would occur as this latter cannot exceed the license fees.

In a second set of scenarios, we assumed that the fishing effort exerted by both deep-water longliners and purse seiners in High Biodiversity Protection Areas during 2012-2017 would not be reallocated but fully removed from the Indian Ocean. This would result in a net reduction of catch equivalent to the average catch observed in Zones 1 delineated during phase 1 (Scenario 2.1) and phase 2 (Scenario 2.2) over the period 2012-2017. As in the base-case scenarios, a third scenario would account for a potential reduction in license fees - by $1.62M - directly perceived from the Government of Seychelles through negotiation (Scenario 2.3).

Table 4. Description of the scenarios considered to assess the potential effects of the implementation of the High Biodiversity Protection Areas on Seychelles economy. EEZ = Exclusive Economic Zone. Base-case scenarios assume reallocation of the fishing effort. Full scenarios assume removal of the fishing effort from the Indian Ocean.

Scenarios	Phase	% EEZ	Definition
Base-case scenarios			
1.1	1	5.3%	Full reallocation
1.2	2	17.4%	Full reallocation
1.3	2	17.4%	Full reallocation and reduction in licensing fees
Full scenarios			
2.1	1	5.3%	No reallocation
2.2	2	17.4%	No reallocation
2.3	2	17.4%	No reallocation and reduction in licensing fees

Results

Licensing revenues

Licensing information available from the Seychelles Fishing Authority indicates that 218 industrial vessels were authorized to operate within the Seychelles waters in 2017 (Table 5). 153 deep-water longliners from China, Taiwan, Korea, and Seychelles were granted 6-month and 12-month licensing periods, amounting to a total of about 3.2 million USD. The licensed purse seine fleet was composed of 13 foreign-owned Seychelles-flagged purse seiners and seven support vessels, 27 EU-flagged purse seiners and 12 support vessels, and four non-EU purse seiners assisted by two support vessels. In 2017, the total purse seine fleet access value was composed of 4.6 million USD of fishing access fees, 1.5 million USD of shipowner fees, and 2.9 million USD provided by the EU agreement in support of the fisheries sector. The total license fees obtained from both national and foreign industrial vessels reached 12.2 million USD in 2017, i.e. about 165.2 million SCR.

Table 5. Annual license fees (USD) for deep-water longline and purse seine fishing within Seychelles national waters in 2017. EU sectoral support and shipowner fees payed through annual advance payment are provided. TTA = Taiwan Deep-sea Tuna Longline Boat Owners and Exporters Association; TFA = Top Fortune Agreement; FPA = Fisheries Partnership Agreement.

Vessel type	Flag	Agreement	Duration (months)	Rate	Quantity	Total
Longliner	China	TFA	6	17,500	25	437,500
	China	TFA	12	24,000	2	48,000
	Seychelles	TTA/TFA	6	17,500	7	122,500
	Seychelles	TTA/TFA	12	24,000	31	744,000
	Taiwan	TTA	6	17,500	33	577,500
	Taiwan	TTA	12	24,000	51	1,224,000
	Korea	Private	12	20,125	4	80,500
Purse seiner	Seychelles		12	90,000	13	1,170,000
	Korea	Private	12	120,000	2	240,000
	Mauritius	SYC-MRU	12	70,000	2	140,000
	EU	FPA	12		27	2,900,000
Support vessel	Seychelles		12	5,000	7	35,000
	EU		12	5,000	12	60,000
	Korea		12	5,000	1	5,000
	Mauritius		12	5,000	1	5,000
Fishing access						7,784,000
Sectoral support	EU	FPA				2,900,000
Shipowner fees (USD/t)	EU	FPA		57,400	27	1,549,800
TOTAL						12,233,800

Fisheries production

The number of tuna fishing vessels operating within the Seychelles EEZ showed high variations over the last 15 years, with a major decline during 2008-2011 due to piracy threat. The total number of active vessels was on average 214 during 2012-2017 (Table 6). The Seychelles domestic longline fleet quickly developed in recent years with the number of active semi-industrial longliners increasing from about seven during 2006-2014 to about 30 in 2016-2017. Activities of both foreign and national deep-water longliners in the Seychelles EEZ also increased in recent years, exceeding 250 in 2016-2017. The number of purse seiners operating within the Seychelles EEZ has been stable at about 45-48 during 2015-2017.

Table 6. Annual number of national and foreign tuna fishing vessels monitored by SFA and having operated within the Seychelles Exclusive Economic Zone during 2004-2017. ELL = semi-industrial longliners, LL = deep-water longliners, PS = purse seiners.

Year	ELL	LL	PS	TOTAL
2004	3	239	47	289
2005	5	267	48	320
2006	6	211	51	268
2007	4	134	51	189
2008	7	97	47	151
2009	8	80	43	131
2010	9	42	35	86
2011	4	46	34	84
2012	7	150	36	193
2013	6	141	38	185
2014	8	125	43	176
2015	11	144	48	203
2016	29	181	47	257
2017	30	193	45	268

In recent years, the national and foreign fleets operating within Seychelles national waters annually caught about 70,000 t of tuna (Table 7). The magnitude of the catch is driven by purse seine which represented about 90% of the total catch taken during 2004-2017 while deep-water longline represented less than 10%. During 2012-2017, purse seiners annually caught about 60,000 t within the EEZ, of which about 20% was caught by the Seychelles vessels (~12,000 t). Seychelles deep-water longliners annually caught about 2,500 t of tuna within the Seychelles EEZ during 2012-2017, representing about 30% of the 8,000 t caught with longline.

Table 7. Mean annual catch (t) taken within the Seychelles EEZ by national and foreign fleets and outside by the Seychelles fleet during 2012-2017. ELL = semi-industrial longline, LL = deep-water longline, PS = purse seine.

Fleet	EEZ	ELL	LL	PS	TOTAL
Foreign	Inside	0	5,457	48,862	54,319
National	Inside	289	2,429	12,180	14,898
National	Outside	6	5,771	69,020	74,797

Purse seiners largely predominate over longliners in the fisheries production of the Seychelles fleets. During 2004-2017, they represented about 90% of the tuna catch of the Seychelles. The purse seine catch varied between a minimum of 50,000 t in 2007 to a maximum of more than 120,000 t in 2017. In recent years, the mean annual purse seine catch exceeded 80,000 t, of which about 15% was taken in the Seychelles EEZ (Table 7). The mean annual catch of tuna by Seychelles deep-water longliners was >8,000 t in recent years, with ~30% coming from the Seychelles national waters. The production of the domestic semi-industrial longline fleet, mainly coming from the EEZ, remained relatively negligible with a maximum of 1% (800 t) of the total tuna catch taken in 2017.

Ex-vessel value of the catch

High-quality tuna caught with longline and destined for the sashimi market worth 4-7 times more than tuna caught with purse seine and destined for canning. Bigeye has the highest value which was very similar between frozen and fresh fish in recent years. The average price for bigeye was about 10.3 USD per kg in 2017 (Figs. 4a-b). For longline-caught yellowfin tuna, the price is higher for fresh than for frozen fish, e.g. 9.5 vs. 8 USD per kg in 2017. Time-series of price show similar temporal trends for tropical tuna (i.e. excluding albacore) caught with purse seine and some high variability with an average price varying between a minimum of 0.6 USD per kg and a maximum of 2.4 USD per kg during 2004-2017 (Fig. 4c).

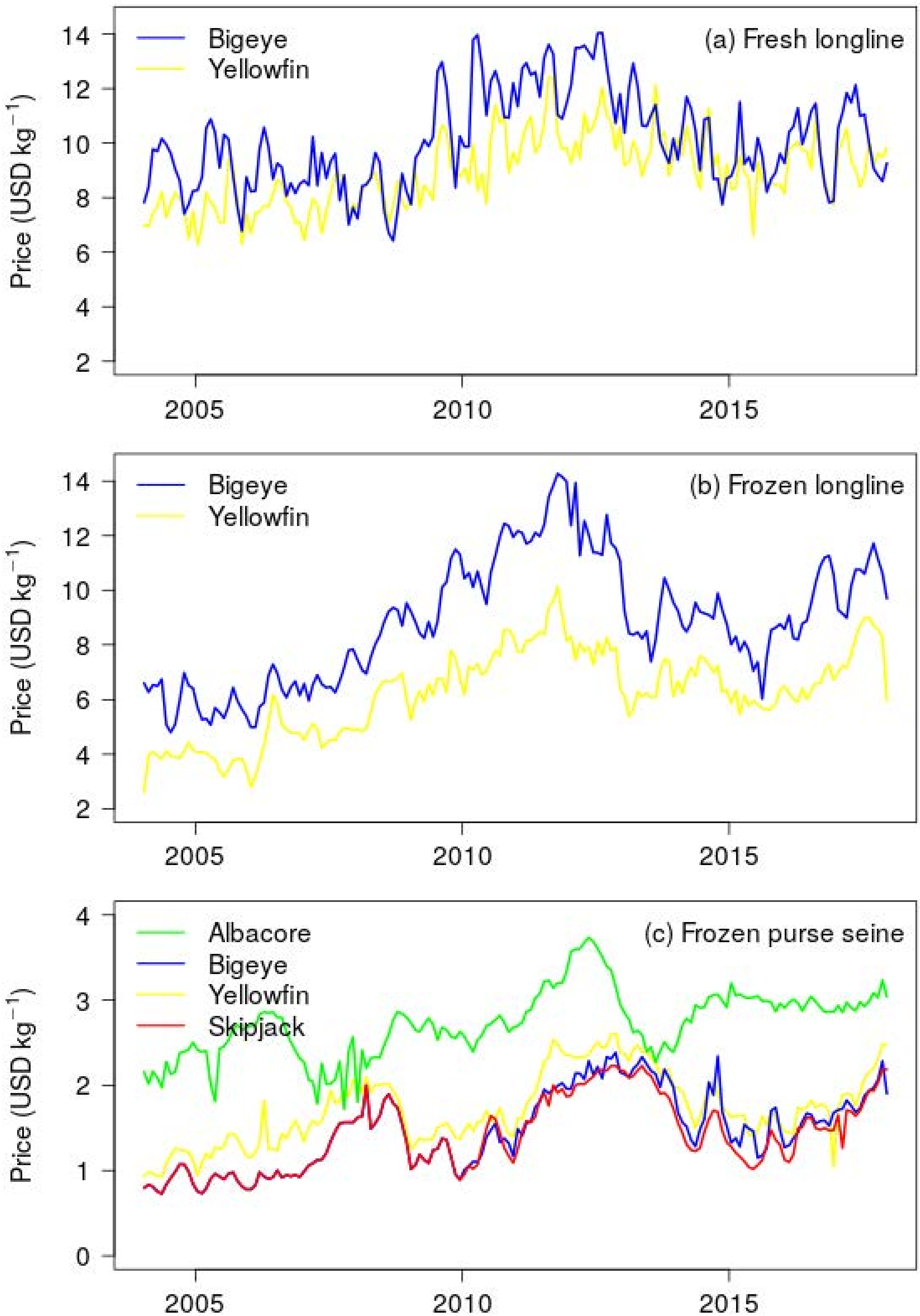

Fig. 4: Monthly time series of tuna price (USD/kg) during 2004-2017. (a) Fresh bigeye and yellowfin tuna caught with longline and imported in Oceania, (b) Frozen bigeye and yellowfin tuna caught with longline and imported in Japan and (c) Frozen bigeye, yellowfin, and skipjack tuna caught with purse seine and imported in Thailand.

The total value of tuna catch in the Seychelles Exclusive Economic Zone varied between a minimum of 56 million USD in 2009 to more than 243 million USD in 2016 (Table 8). Although still predominant, the contribution of purse seine to the total tuna catch significantly decreased when converted from tonnage to value due to the higher market prices of frozen longline. The contribution of each fleet to the value of the tuna catch was about 65% for purse seine and 35% for longline during 2004-2017.

Table 8. Annual value (million USD) of tuna catch taken within the Seychelles Exclusive Economic Zone by each tuna fleet component during 2004-2017, including national and foreign vessels: (a) semi-industrial longliners (ELL), (b) deep-water longliners (LL), and (c) purse seiners (PS). YFT = yellowfin; BET = bigeye; SKJ = skipjack; ALB = albacore.

Year	ELL BET	ELL YFT	LL BET	LL YFT	PS SKJ	PS YFT	PS BET	PS ALB	TOTAL
2004	0	0	37.3	19.6	26.3	50.4	2.8	0.3	133.9
2005	0.5	0.4	40.4	22.4	26.7	47.1	4.1	0.2	137.7
2006	0.4	0.3	27	14.8	23.5	61.1	4.6	3	130.1
2007	0.5	0.5	32.9	10.5	24.9	64.3	7.4	0.5	134.1
2008	0.4	0.3	23.3	6.6	25.8	64.6	8.5	2	123
2009	0.6	0.6	13.6	2.7	18.7	19.8	5	0.3	56.3
2010	0.3	0.5	18	3	29.1	40.4	5.1	0.2	96.6
2011	0.3	0.5	9.8	3.7	39.4	63.1	8.6	0.2	125.6
2012	0.5	0.5	70.5	9.6	30.7	95.4	7.8	0.9	215.9
2013	0.3	0.5	43.8	6.3	28.1	42.9	8	0.4	130.3
2014	0	0.1	48.9	14.6	33.6	52.2	6.9	0.2	156.5
2015	0.3	0.7	43.7	17.5	26.6	38.6	4.9	0.3	132.6
2016	1.1	4.8	65.2	29.5	66.9	69.2	6.6	0.4	243.7
2017	1.1	6.3	49.3	22.9	55.5	69.4	10.6	0.6	215.7

The total value of tuna caught by Seychelles vessels in the Indian Ocean increased from about 130 million USD during 2004-2007 to more than 300 million USD in 2017 (Table 9). Purse seine contributes the most to the total value. The value of the purse seine catch varied between a minimum of about 75 million USD in 2007 to a maximum of about 230 million USD in 2017 (Table 9). Interestingly, the volume of purse seine catch was similar in 2007 and 2012 (~50,000 t) but the value increased from 75 million USD in 2007 to 115 million USD in 2012 (+50%) due to higher prices that were the highest observed during 2004-2017, i.e. >2.2 USD per kg (Fig. 4c). Longline contributes to about 1/3 of the ex-vessel value of the total Seychelles catch (Table 9). The value of the tuna catch of the semi-industrial longline fleet substantially increased from about 750,000 USD prior to 2016 to about 7 million USD during 2016-2017. This excludes the catch of billfish (swordfish and marlins) which represent a major component of the Seychelles ELL fleet.

Table 9. Annual value (million USD) of tuna catch taken by each Seychelles tuna fleet component during 2004-2017: (a) semi-industrial longliners (ELL), (b) deep-water longliners (LL), and (c) purse seiners (PS). YFT = yellowfin; BET = bigeye; SKJ = skipjack; ALB = albacore.

Year	ELL BET	ELL YFT	LL BET	LL YFT	PS SKJ	PS YFT	PS BET	PS ALB	TOTAL
2004	0.1	0.1	33.7	13	29.7	52.2	4.5	0.1	133.4
2005	0.5	0.4	30	28.3	40.4	42.3	4	0.1	146
2006	0.4	0.3	23.7	13.1	45.3	36.8	3.4	0.1	123.1
2007	0.5	0.5	30.9	8.1	41.1	28.6	5.4	0.3	115.4
2008	0.4	0.3	32.6	3.3	54	40.1	9.7	0.2	140.6
2009	0.6	0.6	39.6	2.9	48.1	30.6	8.2	0.1	130.7
2010	0.3	0.5	37.1	3.9	54.1	39.5	8	0	143.4
2011	0.3	0.5	53.1	10.5	56.2	54.2	8.6	0.1	183.5
2012	0.5	0.5	126.8	9.2	40.7	65.7	8.5	0.5	252.4
2013	0.3	0.5	56.3	7.4	52.3	59.6	10.7	0.1	187.2
2014	0	0.1	47.7	10.9	48.7	42.9	8.1	0.1	158.5
2015	0.3	0.8	46	13.5	52.5	61.3	9.9	0.2	184.5
2016	1.1	4.9	50.5	16.8	86.5	65	10.9	0.3	236
2017	1.1	6.5	40.3	25.5	128.1	84.5	18	0.2	304.2

Fishing vessels expenditures

Bunkering services in Port Victoria reported to SFA varied between 65 and more than 140 million USD annually over the last decade. The mean annual value was about 100 million USD during 2012-2016. Purse-seiners account for the large majority of bunkering operations, representing more than 90% of the quantity of gasoil delivered during 2012-2016. In 2014, the SFA expenditure database indicates that more than 130,000 t of gasoil were delivered to 41 purse seiners during 413 bunkering operations, amounting to 134 million USD. Adding the 54 bunkering operations for the supply vessels, the purse seine fleet consumes about 95% of the gasoil delivered by SEYPEC in Port Victoria.

Annual consumption recorded through bunkering operations was found to vary greatly between purse seiners around an annual average of 2,700 t during 2000-2016. The mean annual associated cost was about 1.75 million USD. Some purse seiners consumed more than 6,000 t of fuel in a year. The median regression model explained about 40% of the variability observed in fuel consumption (pseudo-R^2; Koenker & Machado 1999). The annual gasoil consumption by purse seiner was found to significantly increase with the number of days spent at sea (7.8 t per day at sea), vessel size, and total catch to a lesser extent (0.088 t per ton caught) (Fig. 5). Assuming a similar level of catch, the largest purse seiners (length overall larger than 94 m) were found to consume more than twice the volume of gasoil of the smallest ones (length overall smaller than 75 m).

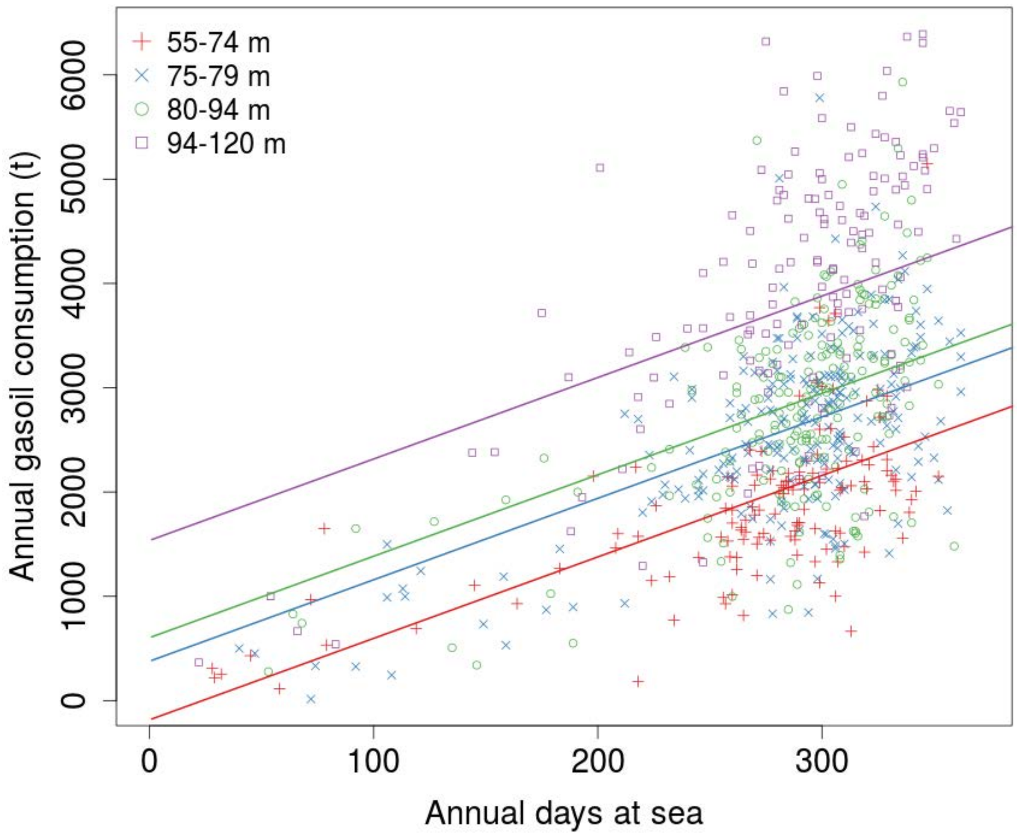

Fig. 5: Relationship between annual gasoil consumption (t) in Port Victoria and annual number of days spent at sea by purse seiners during 2000-2016. Solid lines indicate median predictions for a mean annual catch of 6,722 t for each vessel length class.

Information on expenditures made available from the fishing agents and excluding bunkering indicates an average expense of about 290,000 USD for each purse seiner during 2012-2016 with a large variability between vessels (SD ~180,000 USD). The total expenditures reported to SFA represented an annual value of about 17 million USD spent annually for the purse seine fleet operating in the Western Indian Ocean. These figures might underestimate the total expenditures since the information reported by the agents to the SFA currently lacks some checking procedure and is non-exhaustive. After bunkering, stevedoring represents the principal source of expenditure for the purse seine fleet with a mean annual cost of about 7.4 million USD. During 2012-2016, stevedoring represented more than 40% of the total expenditures, followed by agency charges (16.3%), shipchandling (7.2%), engineering services (4.8%), and port charges (4.4%) (Fig. 6).

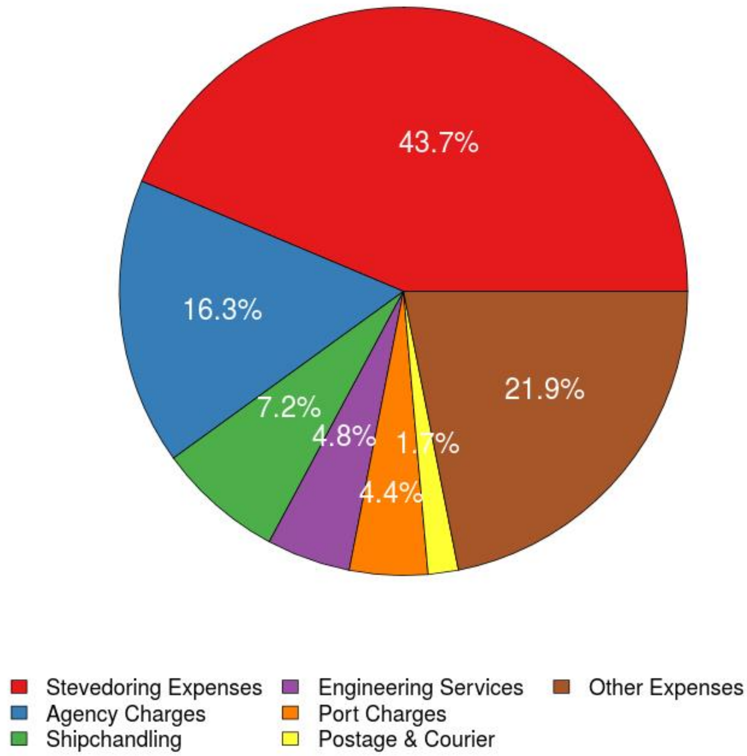

Fig. 6: Percentage composition of purse seiners expenditures (excluding bunkering) in Port Victoria during 2012-2016.

Relating the annual expenditures in stevedoring available from the fishing agents with the annual landings of each purse seiner in Port Victoria shows a large variability in stevedoring costs and some apparent inconsistencies in the data with no cost reported for many landings (Fig. 7). Modeling the median annual expenses in stevedoring as a function of total landings indicates an average cost of about 4 USD per ton unloaded during 2003-2016. Considering a higher quantile (80%) to account for the issue in data coverage, the cost of stevedoring was estimated to be about 7 USD per ton. Data indicate an apparent increase in stevedoring costs between the periods 2004-2010 and 2012-2016 that could be due to improved salaries as well as to the development of tuna storage in dry wells in several purse seiners. This results in a slower process of unloading as compared to brine-freezing wells and generally in higher costs of stevedoring. It is noteworthy that some companies have recently started to hire foreign workers (e.g. from Indonesia) to compensate for the lack of labor force in some cases but also to decrease the stevedoring costs.

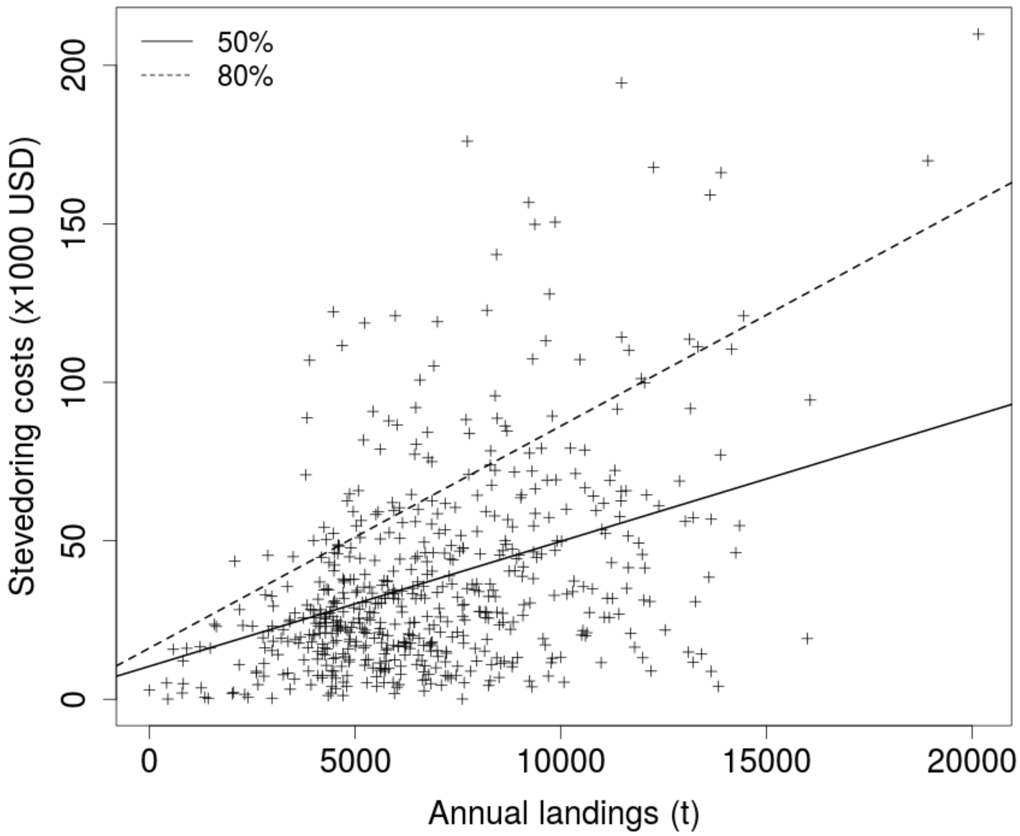

Fig. 7: Relationship between purse seiners annual landings (t) and associated stevedoring costs (x1,000 USD) in Port Victoria during 2003-2016. The solid and dashed lines indicate the 50% and 80% quantile regression models fitted to the data and predicted for an average year effect during 2012-2016, respectively.

Port calls result in direct revenues for the Seychelles government through port and berth dues that vary according to vessel type, gross tonnage and duration of stay. In addition, port charges include transshipment taxes and fixed costs such as pilotage exemption fee, port authority fee and port health fee. Purse seiners represented the large majority of port calls made by fishing vessels during 2012-2016 and made a mean annual number of 445 calls, amounting to about 2,000 cumulative days at port over this period. By contrast, deep-water longliners and support vessels made on average about 70 calls per year and spent in total about 400 days annually in Port Victoria. During 2012-2016, the mean annual port charges by purse seiner was found to be about 26,000 USD (SD = 16,000 USD), amounting to more than 750,000 USD per year for the whole purse seine fleet. Annual port charges significantly increased with landings and years. The median port charges were estimated to be 2.4 USD per metric ton landed in Port Victoria (Fig. 8). The annual fixed charges (i.e. intercept) were shown to increase over time from about 2,400 USD during 2003-2007 to about 12,200 USD during 2012-2016.

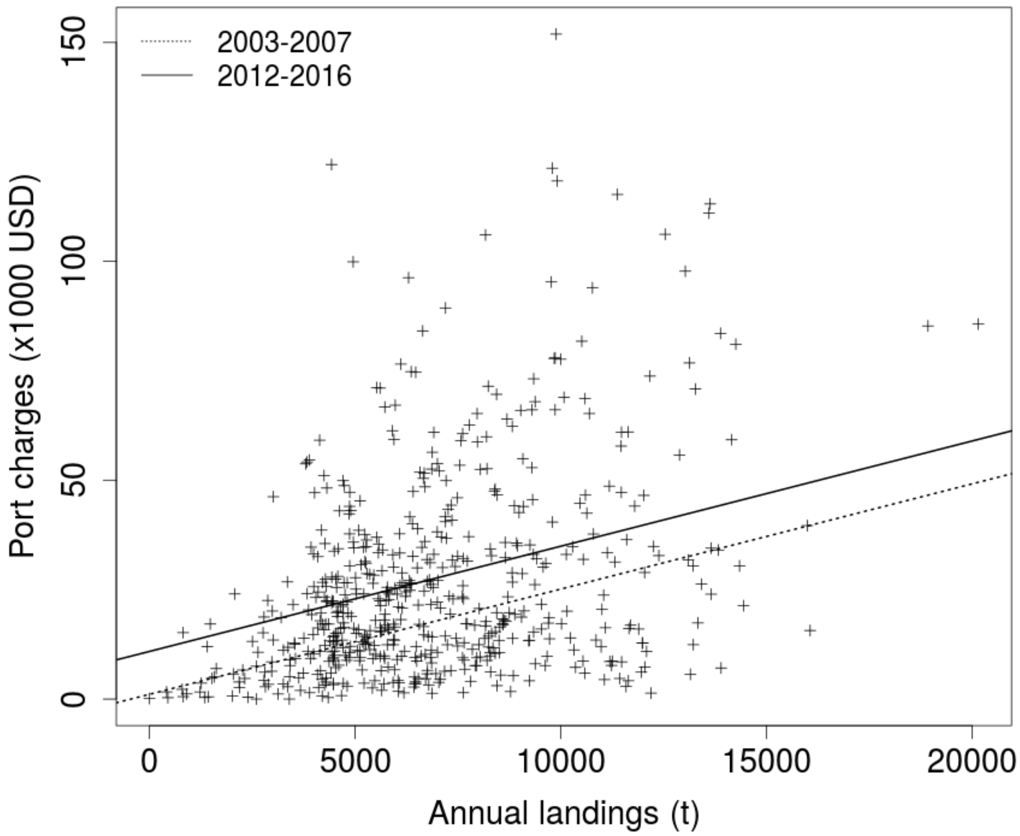

Fig. 8: Relationship between purse seiners annual landings (t) and associated port charges (x1,000 USD) in Port Victoria during 2003-2016. The dashed and solid lines indicate the 50% quantile regression model fitted to the data and predicted for 2003-2007 and 2012-2016, respectively.

The Seychelles' macro-economy

Monetary flows derived from the Social Accounting Matrix built for 2014 show the high dependence of the Seychelles economy on imports (*M*; SCR 19.9 Billion), which exceed the domestic private demand (Household Consumption *C* + Investment *I*; SCR 17 Billion), and the high level of exports (*E*; SCR 17.2 Billion) that drags the whole domestic economy (Fig. 9). The overall import penetration percentage ratio (Import/Total Demand) is high at 34%: 25% for Agricultural goods, 30% for Private services, 46% for Food manufacturing and Transport and 56% for Manufactured goods (Appendix 7). The export intensity (export/gross output) is very high for some activities: 60% for Food manufacturing (with the dominating role of the cannery IOTL), 55% for Tourism and 54% for Transport. The insufficient level of domestic consumption is reinforced by the high level of net remittances from expatriate workers (SCR 541 Million) and the low level of social transfers (SCR 806 Million). The tax rate (16%) and saving rate (13%) are fairly low, explaining the high average propensity to consume the revenue (70%). This results in a significant income multiplier but applied to a low level of domestic consumption, and a strong dependence to foreign products, both representing leakages out of the national economy. With an annual external deficit of about SCR 2.7 Billion (*E*-*M*), the Seychelles economy reveals its dependence to foreign capital inflows. Domestic private savings (SCR 1.9 Billion) and public budget surplus (SCR 1.6

Billion) cannot cover the requirements of the domestic private investment which are therefore funded by capital inflows from foreign direct investment (SCR 3.3 Billion), loans and grants (SCR 89 Million). The two pillars of the Seychelles national economy, tourism and fish canning, are characterized by the cumulative share of their exports which exceeded 50% in 2014, to which the private services (18%) and transports (15%) exported to foreign fleets should be added (Appendix 7).

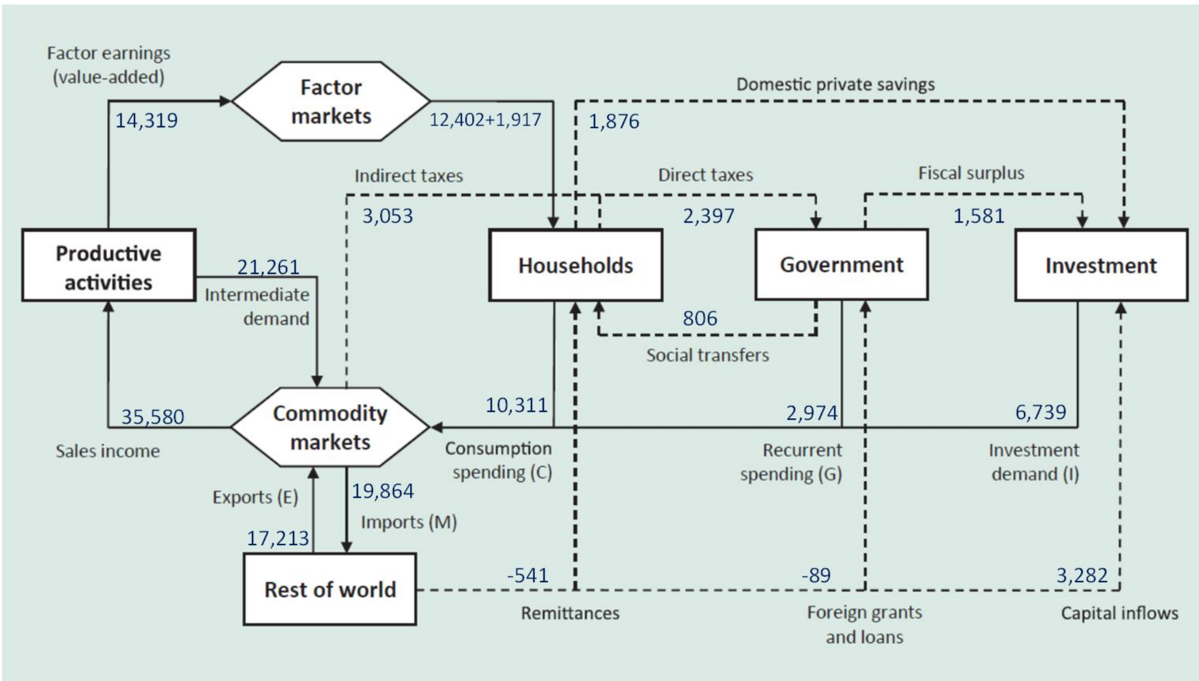

Fig. 9: Circular monetary flows (in Million SCR) derived from the Seychelles Social Accounting Matrix built for 2014.

Economic multipliers

Output and employment multipliers by an input-output approach

The backward effect of fishing goes beyond the mere activity of fishing by influencing upstream industries. For any SCR 1.0 created by the fisheries, the Backward Linkage Index was found to be 1.35 (Table 10). Concerning the forward linkages, a FLI value of 0.68 indicates that if the fishing production increases the availability of fish inputs for other downstream industries (e.g. restaurants, food manufacturing, etc.), it will have less influence on the domestic economy on average than other industries like tourism, other manufactures and private services whose value was found to be greater than one.

Table 10. Backward Linkage Index (BLI), Forward Linkage Index (FLI) and Leontief Output Multiplier (OM) for the nine activities of the Seychelles economy selected in the study.

Activities	BLI	FLI	OM
Fisheries	1.35	0.68	2.30
Agriculture	1.12	0.87	1.90
Tourism	1.10	1.16	1.88
Manufactures of food (incl. IOTL)	1.07	0.95	1.82
Public services	1.05	0.72	1.79
Construction	0.94	0.59	1.61
Other manufactures	0.87	1.78	1.48
Transport	0.76	0.92	1.30
Private / other services	0.74	1.34	1.27

The fishing industry has the highest output multiplier of all Seychelles industries (Table 10). Any SCR spent by final consumers in fishery products would create SCR 2.30 of output value in the rest of the economy. This does not mean that the economic effects of fishing are more important than those of other industries because it depends on the level of final demand. For instance, the final demand for tourism is far more important than the demand for fishery products. The multiplier represents the number or SCR created per unit of final demand while the overall economic effect is equal to the final demand times the multiplier and represents the total value that will be created in the whole economy if the final demand increases by a certain amount.

The number of full-time jobs in the Seychelles fishery production sector was estimated to be 234 in recent years while more than 1,750 persons were employed full time in manufactures of food, mainly by the cannery IOTL (Table 11). The employment multiplier estimated for fishing activities is 0.94, i.e. 1 million SCR of final demand in fishery products creates nearly one new job (Table 11). Other industries such as construction or public services are found to be more job-creating per unit of final demand with multipliers equal to 5.8 and 2.4, respectively. If the national economy was solely stimulated by the demand for Seychelles fishery and food products observed in 2014, the total number of jobs created in the economy would be more than 4,000, with one additional job created for any single job created in both food and fishery sectors, i.e. more than 8% of national employment.

Table 11. Employment and employment effects for the nine activities of the Seychelles economy selected in the study. Total number of jobs expressed in full time equivalent (NBS 2017b). The employment multiplier derived from Input-Output Table corresponds to the number of jobs created for SCR 1 million of final demand. The number of jobs induced by fisheries and manufactures of food corresponds to the number of jobs created in every sector if and only if the national economy was solely stimulated by the demand for fishery and food products.

Activities	Total number of jobs	Employment multiplier	Jobs induced by Fisheries & Man. Food
Agriculture	285	0.80	179
Fisheries	234	0.94	198
Manufactures of food	1 765	0.72	1 439
Other manufactures	3 618	0.58	207
Construction	6 018	5.79	-
Tourism	8 906	1.80	811
Transport	3 342	0.89	247
Private / other services	13 296	1.29	665
Public services	10 488	2.44	271
Total	47 952	1.69	4 015

Output and income multipliers by a SAM approach

In a first step, we considered that all components of the final demand were exogenous and that the domestic supply was unconstrained, i.e. all sectors can increase their supply to meet any additional demand. Results show that the fishing industry has the highest total multiplier value (i.e. output plus income multipliers), mostly because of backward linkage effects. It is noteworthy that income and GDP multipliers are the same in our analysis because the Government expenditure is exogenous in the model and there are no factor taxes in the Seychelles SAM, i.e. all value-added is paid to households. Fishing consumes many intermediate inputs (oil, ice, salt, nets, stevedoring services, etc.) which makes it a stimulating sector for the rest of the economy. In 2014, any SCR of fishery products spent by final consumers (including exports) would create SCR 1.71 of output value in the national economy and SCR 0.41 of GDP or factor income, for a total multiplier effect of 2.13 (Table 12). Tourism comes second in terms of output value per unit of final demand, but is only fourth in terms of GDP (or factor income), behind Construction, Public and Private services which show a greater distribution of income.

Table 12. Output, income and total unconstrained multipliers derived from a Social Accounting Matrix approach for the nine activities of the Seychelles economy selected in the study. GDP = Gross Domestic Product.

	Output	GDP or income	TOTAL
Fisheries	1.71	0.41	2.13
Tourism	1.42	0.54	1.96
Public Services	1.37	0.58	1.95
Construction	1.22	0.61	1.83
Agriculture	1.31	0.40	1.71
Private Services	0.84	0.57	1.42
Food manufacturing	1.06	0.24	1.31
Transport	0.71	0.41	1.11
Other Manufacturing	0.64	0.16	0.81
Average multiplier	1.14	0.44	1.58

Considering the exogenous final demand observed for fishery products in 2014, the Seychelles economy would create directly and indirectly a total output value of SCR 504 Million and contribute to the GDP by an additional amount of SCR 121 Million (0.8% of the GDP), thus generating a cumulative economic effect of SCR 625 Million. Food manufacturing multipliers are found to be smaller than for fishing activities, i.e. 1.06 and 0.24, respectively (Table 12). This industry imports most of its intermediate inputs (frozen fish, tin cans, vegetable oil, etc.), has a lower share of added value in its gross output value and employs many (more than two thirds) expatriates who send part of their wages abroad which appear as remittances in the SAM (Mr. Nichol, Chief Executive Officer of IOTL, *pers. com.*). If the share of EU-flagged vessel in the supply of frozen fish to the canning factory increases in the future, the multiplier effect would also be higher, which could be considered somewhat artificial if shipowners remain foreigners and most crew members are foreigners too, because capital and labor revenues will be spent outside the Seychelles.

The total multiplier obtained for the Food manufacturing sector (incl. Fish processing) is only 1.31 and this sector ranks seventh out of nine activities (Table 12). However, the final demand for manufactured good is far greater than for fishery products, thus having a heavier impact on the Seychelles economy. Stimulated by the mere demand for manufactured food products in 2014 (mainly exports of canned tuna), the Seychelles economy would still create a total output value of SCR 5,558 Million and contribute to the GDP by an additional amount of SCR 1.3 Billion (nearly 9% of the GDP), thus generating a cumulative economic effect of SCR 6.8 Billion. In summary, without any consideration of the MSP, the fishing and fish processing sectors contribute directly or indirectly to nearly 10% of the Seychelles Gross Domestic Product.

In a second step, we computed the output and income (or GDP) multipliers for all Seychelles economic activities under the constraint that the production of fisheries and food manufacturing sectors is exogenous while the final demand is endogenous. In such a case, if the external demand increases, the constrained sector will not be able to respond and the net exports (i.e. the balance) will adjust: the goods that cannot be produced anymore in Seychelles will be imported. In other words, imports will now substitute for fixed domestic supply. For instance, the increased demand for canned fish exports may not lead to increased canned tuna production if IOTL cannot purchase, store or process more frozen tuna for the plant.

Constraining the production of fisheries and food manufacturing provides a different picture of the leading economic sectors in Seychelles. Compared to the unconstrained approach, the total multipliers of Fisheries and Food manufacturing decrease from 2.13 to 1.84 and from 1.31 to 1.02, respectively (Table 13). The output multipliers of Fisheries and Food manufacturing decreased from 1.71 to 1.48 and from 1.06 to 0.83. The impact on GDP (or factors' income) is lower for both sectors (-5%). Multipliers of all other sectors also decreased because of backward and forward linkages, but not to the same extent. Public and private services, construction, transport, agriculture and other manufacturing are less affected than tourism that has greater linkages with the two sectors, e.g. food for restaurants.

Table 13. Output, income, and total multipliers derived from a Social Accounting Matrix approach for the nine activities of the Seychelles economy selected in the study under the constraint of limited supply to Fisheries and Food manufacturing sectors. GDP = Gross Domestic Product.

	Output	GDP or income	TOTAL
Public Services	1.33	0.57	1.90
Fisheries	1.48	0.36	1.84
Construction	1.21	0.61	1.81
Tourism	1.26	0.50	1.77
Agriculture	1.27	0.39	1.67
Private Services	0.83	0.57	1.40
Transport	0.69	0.40	1.09
Food manufacturing	0.83	0.19	1.02
Other Manufacturing	0.62	0.16	0.78
Average multiplier	1.06	0.42	1.48

In the following section, we only present the results for the unconstrained model since the external shocks issued by the socio-economic effects of the Marine Spatial Plan will be mostly negative for the domestic economy and that the domestic production capacity will not be overcome.

The economic impact of High Biodiversity Protection Areas

The High Biodiversity Protection Areas delineated through the MSP process contribute to a small part of the fishing activities of both longline and purse seine fleets. During 2012-2017, no activity from the semi-industrial longline fleet occurred in the Aldabra Group Marine National Park gazetted in February 2018 (Phase 1). This area represented about 3.5% (~800,000 hooks) of the total fishing effort exerted by both national and foreign deep-water longliners in the Seychelles EEZ (Appendix A6.1). This corresponded to a mean annual catch of about 320 t, i.e. about 4% of the total longline catch reported for the EEZ. The catch taken in the area was about 1.5% of the total tuna catch of the Seychelles deep-water longline fleet during 2012-2017. For purse seine, a mean annual catch of about 500 t was taken in the area, representing less than 1% of the catch in the EEZ and less than 0.2% of the total annual catch during that period (Appendix A6.2).

The extension of the High Biodiversity Protection Area from about 70,000 km² to 235,000 km² (Phase 2 proposal) increases the part of effort and catch observed in the past for the three fleet components which remains small. The extended area encompasses about 5.5% (38,000 hooks) of the effort and 4.2% (12 t) of the catch of the domestic semi-industrial longline fleet reported during 2012-2017 (Appendix A6.3). For the deep-water longliners, it includes about 17% (~1,300 t) of the annual catch made by national and foreign fleets within the Seychelles EEZ and contributes to about 4% (~400 t) of the annual 8,200 t of tuna taken by the Seychelles longline fleet in the Indian Ocean (Appendix A6.3). For purse seine, an annual average catch of about 4,500 t was observed during 2012-2017 within the area proposed as High Biodiversity Protection Area, i.e. about 7.4% of the EEZ purse seine catch and 1.5% of the Indian Ocean purse seine catch (Appendix A6.4).

At the macro-economic level, our results show that the implementation of the High Biodiversity Protection Areas will not affect the Seychelles economy. The three base-case scenarios assume that all the effort historically exerted by the tuna fishing fleets in the High Biodiversity Protection Areas will be fully reallocated in the rest of the Seychelles EEZ following the implementation of the Marine Spatial Plan. Predictions of catch based on historical effort and average CPUE for each fleet component show that the displacement of effort in other fishing grounds of the Seychelles EEZ would result in a total decrease of about 35 t and 390 t of tuna catch for longline and purse seine, respectively. Such expected changes in catch are negligible and similar to the level of uncertainty in the statistics available from industrial fisheries. They represent a decrease of less than 0.1% of the tuna catch of the Seychelles deep-water longline fleet and less than 0.05% of the whole purse seine fleet. Based on the relationships linking catch to expenditures (Section Fishing vessels' expenditures), the reduction in purse seine catch would result in a decrease of about 9,000 USD of port charges, 19,000 USD of stevedoring, and 28,500 USD of bunkering. These changes are very small and would not be sufficient to trigger any effect in the Seychelles economy (Table 14). Results for Scenario 1.2 assuming effort displacement show that there would be a decrease of about 130 t for all the deep-water longliners, corresponding to a negligible decrease in catch of about 20 t for the Seychelles component. Besides, the reallocation of purse seine effort would result in an overall increase of about 170 t annually due to higher historical catch rates observed in the rest of the Seychelles EEZ than in the High Biodiversity Protection Areas, i.e. 23.7 vs.

22.6 t per set for the EU fleet component (Appendix A6.4). Consequently, the activities of bunkering, stevedoring and revenues from port calls would benefit from the reallocation of the effort. The impact appears again very limited on the Seychelles economy due to the negligible change in purse seine catch (Table 14). The scenario 1.3 considers an extreme situation whereby the industry would be able to decrease the licensing fees by the percentage of relative decrease in fishing opportunities due to the implementation of the High Biodiversity Protection Areas. Based on information available on licensing fees in 2017, this would correspond to a decrease of revenue of about 1.62 million USD for the Seychelles government. This scenario would decrease the total output and gross domestic product by less than 0.1% and not affect the overall government's budget and imports (Table 14).

Table 14. Macro-economic indicators (Million USD) for the Seychelles economy built for the different scenarios of the Marine Spatial Planning. See scenarios definition in Table 4.

		Effort reallocation			Effort removal		
Variable	Reference	1.1	1.2	1.3	2.1	2.2	2.3
Total output	2,791	2,790	2,791	2,788	2,790	2,790	2,788
Gross Domestic Product	1,123	1,123	1,123	1,122	1,123	1,123	1,122
%Δ GDP / Reference	0	0	0	-0.09	0	0	-0.09
Government's budget	420	420	420	420	420	420	420
Imports	1,558	1,558	1,558	1,557	1,558	1,558	1,557

The three full scenarios represent a more extreme situation whereby the effort exerted by the industrial fishing vessels in the High Biodiversity Protection Areas during 2012-2017 would be removed from the Indian Ocean and the associated catch "lost" for the fishing companies. In phase 1 (Scenario 2.1), this would result in a loss of about 320 t and 510 t for longline and purse seine, respectively (Appendix A6.1-2). According to the median regression models, the reduction in purse seine catch would result in a decrease of about 65,000 USD of expenditures in Port Victoria. In phase 2, the decrease in catch would be about 1,300 t and 4,500 t for longline and purse seine, respectively, resulting in a total purse seine expenditure decrease of about 385,000 USD. Again, these scenarios would have no effect on the macro-economic indicators describing the Seychelles economy (Table 14). The final scenario (2.3) that considers an additional decrease in revenues from licensing would still result in a very limited impact on the Seychelles economy, i.e. a decrease by about 1 million USD of the Gross Domestic Product corresponding to less than 0.1% (Table 14). Overall, all scenarios show a very limited impact of the MSP on the fisheries production and economically-related activities.

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Appendices

Appendix 1. Theoretical framework of the Social Accounting Matrix

To introduce the theoretical background of the Social Accounting Matrix (SAM), we use a matrix with only two sectors and one homogeneous type of households, providing capital and labor to both sectors. We provide the matrix formulas used for estimating SAM multipliers for both constrained and unconstrained models.

1. Unconstrained multiplier model

The model relies on a few simple assumptions. First, prices are assumed to be fixed, i.e. the adjustment after a demand variation must be done on volume of output rather than prices. Second, the adjustments in production volume are unlimited in the unconstrained model, meaning that there is no limited capacity of production. Third, there is no variation neither in consumer's nor in producer's behavior following the demand variation. The production and consumption linkages are therefore stable whatever the change in demand.

Table A1.1: Social Accounting Matrix in monetary flows. X is the total gross output of the activities 1 and 2; Z is the total demand of inputs (commodities); W_k and W_L are the added value (or the factor incomes); Y is the household incomes (or factor incomes in absence of government); G, I and F are respectively the government, investment and foreign (export) demand included in E, the exogenous demand.

2014 (MSCR)		Activity		Commodity		Factor		Final demand			External	Total
		A1	A2	C1	C2	Capital	Labour	Hoh	Government	Investment	Export	
Activity	A1			X_1								X_1
	A2				X_2							X_2
Commodity	C1	Z_{11}	Z_{12}					C_1	G_1	I_1	E_1	Z_1
	C2	Z_{21}	Z_{22}					C_2	G_2	I_2	E_2	Z_2
Factor	Capital	W_{K1}	W_{K2}									W_k
	Labour	W_{L1}	W_{L2}									W_L
Final demand	Hoh					W_K	W_L		R		W_H	Y
	Government			T_1	T_2			T_H			W_G	G
	Saving							S_H	I_G		$-W_E$	I
External	Import			M_1	M_2							F
Total		X_1	X_2	Z_1	Z_2	W_K	W_L	Y	G	I	F	

Table A1.2: Social Accounting Matrix in ratios. Same notations as Table A1.1.

2014 (MSCR)		Activity		Commodity		Factor		Final demand		Total
		A1	A2	C1	C2	Capital	Labour	Household	Exogenous Demand	
Activity	A1			X_1/Z_1						X_1
	A2				X_2/Z_2					X_2
Commodity	C1	Z_{11}/X_1	Z_{12}/X_2					C_1/Y	E_1	Z_1
	C2	Z_{21}/X_1	Z_{22}/X_2					C_2/Y	E_2	Z_2
Factor	Capital	W_{K1}/X_1	W_{K2}/X_2							W_k
	Labour	W_{L1}/X_1	W_{L2}/X_2							W_L
Final demand	Household					1	1			Y
	Exogenous demand							S_H/Y		E
Total		1	1	1	1	1	1	1	1	

Table A1.3. Coefficient matrix of the Social Accounting Matrix. b is the gross output share in total demand; a is the input share in production or commonly known as technical coefficient in Input-Output Tables; w_K and w_L are respectively the income of capital and labor (added value) shares in the gross output; m is the imported commodity share in the total demand (and the indirect tax); c is the household consumption share in its total income; s_H is the household saving share in its total income.

2014 (MSCR)		Activity		Commodity		Factor		Final demand		Total
		A1	A2	C1	C2	Capital	Labour	Household	Exogenous Demand	
Activity	A1			$b_1=X_1/Z_1$						X_1
	A2				$b_2=X_2/Z_2$					X_2
Commodity	C1	$a_{11}=Z_{11}/X_1$	$a_{12}=Z_{12}/X_2$					$c_1=C_1/Y$	E_1	Z_1
	C2	$a_{21}=Z_{21}/X_1$	$a_{22}=Z_{22}/X_2$					$c_2=C_2/Y$	E_2	Z_2
Factor	Capital	$w_{K1}=W_{K1}/X_1$	$w_{K2}=W_{K2}/X_2$							W_k
	Labour	$w_{L1}=W_{L1}/X_1$	$w_{L2}=W_{L2}/X_2$							W_L
Final demand	Household					1	1			Y
	Exogenous demand			$m_1=M_1/Z_1$	$m_2=M_2/Z_2$			$s_H=S_H/Y$		E
Total		1	1	1	1	1	1	1	1	

We use the symbols used in Tables A1.1-A1.3 to express the equations representing the total demand (*Z1* + *Z2*) as the sum of the intermediate demand, household consumption and exogenous demand. The row-wise reading of the SAM is therefore:

$$\begin{cases} Z_1 = a_{11}X_1 + a_{12}X_2 + c_1Y + E_1 \\ Z_2 = a_{21}X_1 + a_{12}X_2 + c_1Y + E_2 \end{cases} \quad \text{(Eq. A1.1)}$$

The gross domestic output can only meet part of the total demand, with a column-wise reading:

$$\begin{cases} X_1 = b_1Z_1 \\ X_2 = b_2Z_2 \end{cases} \quad \text{(Eq. A1.2)}$$

The households' income (Y) is composed by the capital and labor incomes:

$$\begin{cases} Y = (w_{K1} + w_{L2})X_1 + (w_{K2} + w_{L2})X_2 \\ Y = w_1X_1 + w_2X_2 \end{cases} \quad \text{(Eq. A1.3)}$$

With $w_j = w_{Kj} + w_{Lj}$ to simplify the notations.

We put the gross output definition (Eq. A1.2) into the income equation (Eq. A1.3):

$$Y = w_1b_1Z_1 + w_2b_2Z_2 \quad \text{(Eq. A1.4)}$$

Afterwards we can place the output and income equation (Eq. A1.2) and (Eq. A1.4) into the demand equation (Eq. A1.1) and (A1.2):

$$\begin{cases} Z_1 = a_{11}b_1Z_1 + a_{12}b_2Z_2 + c_1(w_1b_1Z_1 + w_2b_2Z_2) + E_1 \\ Z_2 = a_{21}b_1Z_1 + a_{22}b_2Z_2 + c_1(w_1b_1Z_1 + w_2b_2Z_2) + E_2 \end{cases} \quad \text{(Eq. A1.5)}$$

We adjust the equation by moving all the endogenous terms on the left-hand side:

$$\begin{cases} Z_1 - a_{11}b_1Z_1 - a_{12}b_2Z_2 - c_1(w_1b_1Z_1 + w_2b_2Z_2) = E_1 \\ Z_2 - a_{21}b_1Z_1 - a_{22}b_2Z_2 - c_2(w_1b_1Z_1 + w_2b_2Z_2) = E_2 \end{cases} \qquad \text{(Eq. A1.6)}$$

We then factorize the total demand terms (*Z*):

$$\begin{cases} (1 - a_{11}b_1 - c_1w_1b_1)Z_1 + (-a_{12}b_2 - c_1w_2b_2)Z_2 = E_1 \\ (-a_{21}b_1 - c_2w_1b_1)Z_1 + (1 - a_{22}b_2 - c_2w_2b_2)Z_2 = E_2 \end{cases} \qquad \text{(Eq. A1.7)}$$

We rewrite the equation using a matrix format:

$$\begin{pmatrix} 1 - a_{11}b_1 - c_1w_1b_1 & -a_{12}b_2 - c_1w_2b_2 \\ -a_{21}b_1 - c_2w_1b_1 & 1 - a_{22}b_2 - c_2w_2b_2 \end{pmatrix} \begin{pmatrix} Z_1 \\ Z_2 \end{pmatrix} = \begin{pmatrix} E_1 \\ E_2 \end{pmatrix} \qquad \text{(Eq. A1.8)}$$

At this point, we can identify the identity equation minus the coefficient matrix (I-M):

$$\begin{pmatrix} 1 - a_{11}b_1 - c_1w_1b_1 & -a_{12}b_2 - c_1w_2b_2 \\ -a_{21}b_1 - c_2w_1b_1 & 1 - a_{22}b_2 - c_2w_2b_2 \end{pmatrix} = (I - M) \quad \text{(Eq. A1.9)}$$

$$(I - M)Z = E \, \text{(Eq. A1.10)}$$

Finally, we rearrange the terms to obtain the final multiplier matrix:

$$Z = (I - M)^{-1}E \qquad \text{(Eq. A1.11)}$$

2. Constrained multiplier model

In this subsection, we consider that at least one sector is unable to respond to the shock of demand. It can be explained by the limitation of scarce resources or factors; their reallocation takes time during which the supply is unable to respond to the demand. The constrained multipliers are therefore smaller than the unconstrained multipliers. This type of model can be referred to as a mixed (or semi-input) model in the Input-Output literature.

We make a distinction between the two sectors: let the demand Z_2 be supply-constrained. The output of the sector is now fixed and the imports substitute for its production. By doing this, the exogenous demand (E_2) of Sector 2 is now treated as endogenous: net exports (exports minus imports) can change to absorb the shock.

We now replace the new exogenous components (Z_1) on the right-hand side of Equation (A1.7):

$$\begin{cases} (1 - a_{11}b_1 - c_1w_1b_1)Z_1 = E_1 - (-a_{12}b_2 - c_1w_2b_2)Z_2 \\ (-a_{21}b_1 - c_2w_1b_1)Z_1 - E_2 = -(1 - a_{22}b_2 - c_2w_2b_2)Z_2 \end{cases} \qquad \text{(Eq. A1.12)}$$

To make the following adjustment, we need the same equation with a sign modification:

$$\begin{cases} (1 - a_{11}b_1 - c_1w_1b_1)Z_1 = E_1 + (a_{12}b_2 + c_1w_2b_2)Z_2 \\ (-a_{21}b_1 - c_2w_1b_1)Z_1 - E_2 = (-1 + a_{22}b_2 + c_2w_2b_2)Z_2 \end{cases} \qquad \text{(Eq. A1.13)}$$

We can observe a new adjusted coefficient matrix (I-M*) which is a bit different from the (I-M) matrix. Indeed the second matrix column is refined from its coefficients. It means that sector 2, now treated as exogenous, will see its net exports decreasing during the process:

$$\begin{pmatrix} 1 - a_{11}b_1 - c_1w_1b_1 & 0 \\ -a_{21}b_1 - c_2w_1b_1 & -1 \end{pmatrix} = (I - M^*)$$

The first term on the right-hand side of Eq. (A1.13) is a new term that can be abbreviated as B. If none of the sectors is constrained, B will be an identity matrix, showing no economic impact after a shock. Sector 2 being constrained, the second column of B will affect the industrial linkage effects.

$$\begin{pmatrix} 1 & a_{12}b_2 + c_1w_2b_2 \\ 0 & -1 + a_{22}b_2 + c_2w_2b_2 \end{pmatrix} = B \qquad \text{(Eq. A1.14)}$$

If we define Eq. (13) by its matrix abbreviations, we obtain:

$$(I - M^*)\begin{pmatrix} Z_1 \\ E_2 \end{pmatrix} = B\begin{pmatrix} E_1 \\ Z_2 \end{pmatrix} \qquad \text{(Eq. A1.15)}$$

Re-arranging this last equation, we finally obtain the formula to compute the constrained multipliers:

$$\begin{pmatrix} Z_1 \\ E_2 \end{pmatrix} = (I - M^*)^{-1}B\begin{pmatrix} E_1 \\ Z_2 \end{pmatrix} \qquad \text{(Eq. A1.16)}$$

Appendix 2. The 23 industries of the Seychelles National Accounts

Table A2.1. Activities of the Seychelles Industrial Classification. Codes are consistent with the International Standard of Industrial Classification (ISIC).

ISIC	Activity
A01	Agriculture
A03	Fishing
C10	Manufacture of food
C11-12	Manufacture of beverages and tobacco
C23	Manufacture of concrete, rock products, glass etc
C13-22,24-33	Manufacturing, other
D	Electricity, gas, steam and air conditioning supply
E	Water supply, sewerage, waste management and remediation activities
F	Construction
G	Wholesale and retail trade, repair of motor vehicles and motorcycles
H	Transportation and storage
I	Accommodation and food service activities
J	Information and communication
K	Financial and insurance activities
L01	Real estate activities
L02	Owner occupied dwellings
M	Professional, scientific and technical activities
N	Administrative and support service activities
O	Public administration and defense, compulsory social security
P	Education
Q	Human health and social work activities
R	Arts, entertainment and recreation
S	Other service activities

Appendix 3. Building the Seychelles Social Accounting Matrix

Appendix 3.1. Balancing the Social Accounting Matrix

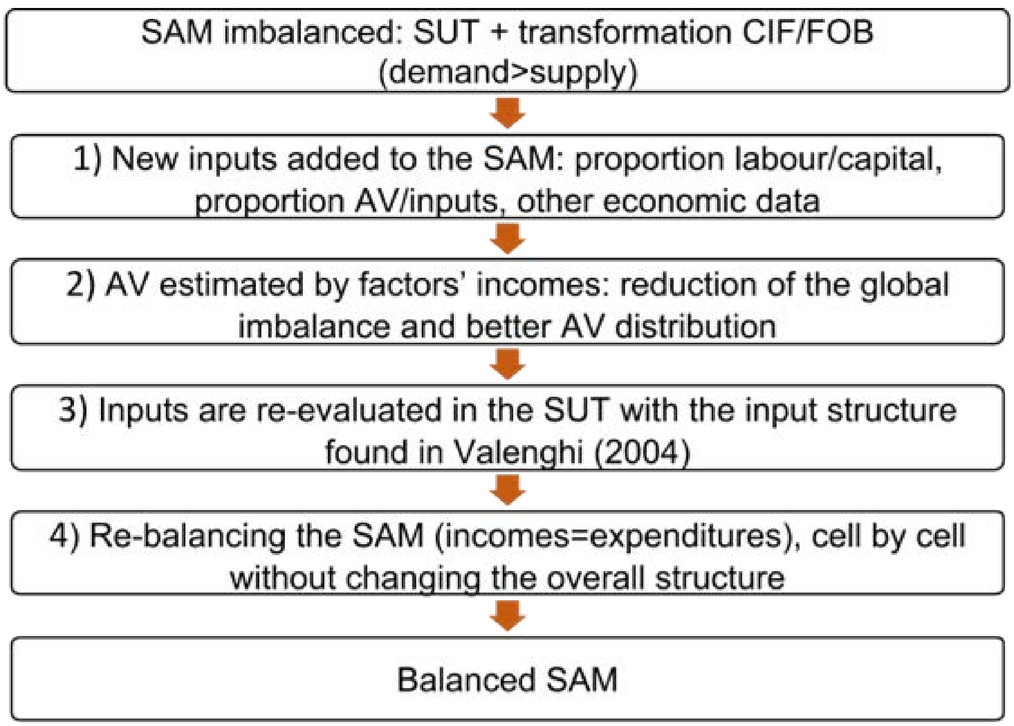

Fig A3.1. Sequential steps for balancing the Seychelles Social Accounting Matrix (SAM). SUT = Supply Use Table; CIF = Cost-Insurance-Freight; FOB = Free-On-Board ; AV = Added Value.

Appendix 3.2. Technical input coefficients

The Input-Output approach is sensitive to the quality of the data. No Supply-Use Table (SUT) is currently available in the national accounts of Seychelles (Bistoquet et al. 2018). The National Bureau of Statistics (NBS) developed a SUT inspired by the example of Mauritius (Table A3.1). Valenghi (2004) built an Input-output Table (IOT) based on the Hawaiian case (Table A3.2). Despite its limitations, we gave preference to Valenghi's approach that looks more consistent than NBS' table that includes for example the same amount of public services for the nine activities, resulting in a coefficient greater than 1 for Agriculture, which is impossible.

Table A3.1 National Bureau of Statistics Supply-Use Table inspired by Mauritius (NBS 2017a). Fish = Fishing industry; ManFood = Food manufactured industries; OthMan = Other manufacturing industries; Constr = Construction; PrivServ = Private Services; PubServ = Public Services.

	Agriculture	Fish	Manfood	OthMan	Constr	Tourism	Transport	PrivServ	PubServ
Agriculture	0.47	-	-	-	-	-	-	-	-
Fish	-	0.93	-	-	-	-	-	-	-
ManFood	-	-	0.88	-	-	-	-	-	-
OthMan	-	-	-	0.34	-	-	-	0.01	0.06
Constr.	-	-	-	-	0.73	-	-	-	-
Tourism	-	-	-	-	-	0.63	-	-	0.01
Transport	-	-	-	-	-	-	0.74	-	0.03
PrivServ	-	-	-	-	-	-	-	0.47	0.10
PubServ	1.90	0.12	0.00	0.03	0.00	0.00	0.00	0.00	0.38

Table A3.2 Supply-Use Table inspired by Hawaii (Valenghi 2004). Fish = Fishing industry; ManFood = Food manufacturing industry; OthMan = Other manufacturing industries; Constr = Construction; PrivServ = Private Services; PubServ = Public Services.

	Agriculture	Fish	Manfood	OthMan	Constr.	Tourism	Transport	PrivServ	PubServ
Agriculture	0.27	0.02	0.19	-	-	0.01	-	-	-
Fish	-	-	0.19	-	-	-	-	-	-
ManFood	0.01	0.19	0.09	0.02	0.00	0.14	0.02	0.00	0.02
OthMan	0.19	0.35	0.12	0.30	0,29	0.07	0.12	0.04	0.39
Constr.	-	-	-	-	-	-	-	-	-
Tourism	0.10	0,15	0.13	0.21	0.07	0.08	0.05	0.05	0.03
Transport	0.05	0.09	0.06	0.09	0.03	0.04	0.11	0.02	0.04
PrivServ	0.07	0.01	0.08	0.21	0.06	0.27	0.08	0.16	0.06
PubServ	0.04	-	0.02	0.06	0.00	0.05	-	0.01	0.01

We performed a sensitivity analysis of the output multipliers to account for the uncertainty in the matrix coefficients by randomly drawing 1,000 values of each technical coefficient in a uniform distribution bounded by the values available from NBS (2017a) and Valenghi (2004). The mean value of the distribution of the output multiplier values for the fishing industry derived from the sensitivity analysis was 1.91 (SD = 0.29) (Fig. A3.2). It significantly departs from the value of 2.30 derived from the input-output table of Valenghi (2004) (Table 10). This value is however comprised within the confidence interval of our sensitivity estimates that are described by a maximum value of 2.90 (Fig. A3.2). Similarly, we estimated a mean value of 1.79 for the output multiplier of Food Manufacturing industry (SD = 0.3) (Fig. A3.3) while the value estimated was 1.82 (Table 10). Such a dispersion around the mean emphasizes the importance of using a reliable SUT-IOT basis for the calculus. This should be improved in the course of time by further industrial surveys conducted by NBS about the purchases and sales of intermediate inputs between industries.

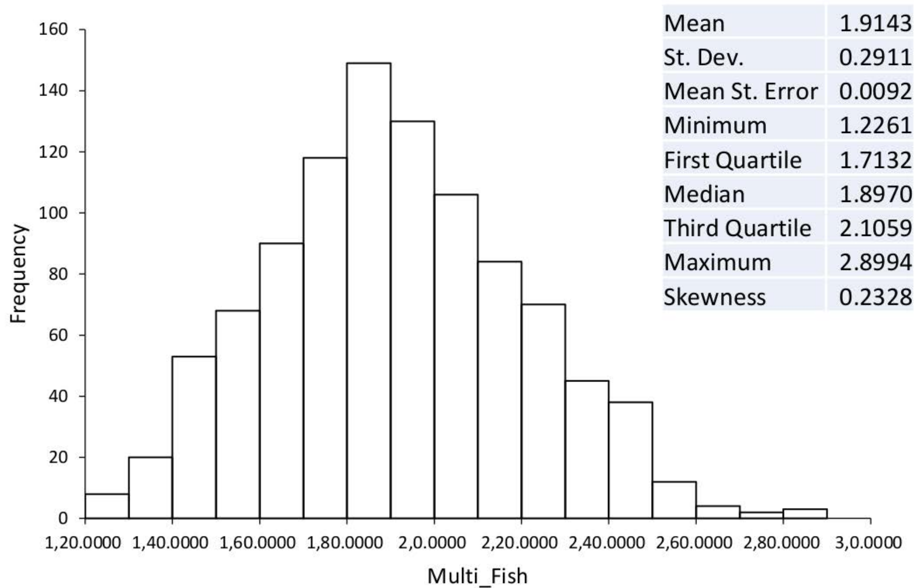

Fig. A3.2 Distribution of output multiplier of the fishing industry (Multi_Fish) derived from sensitivity analysis of input coefficients.

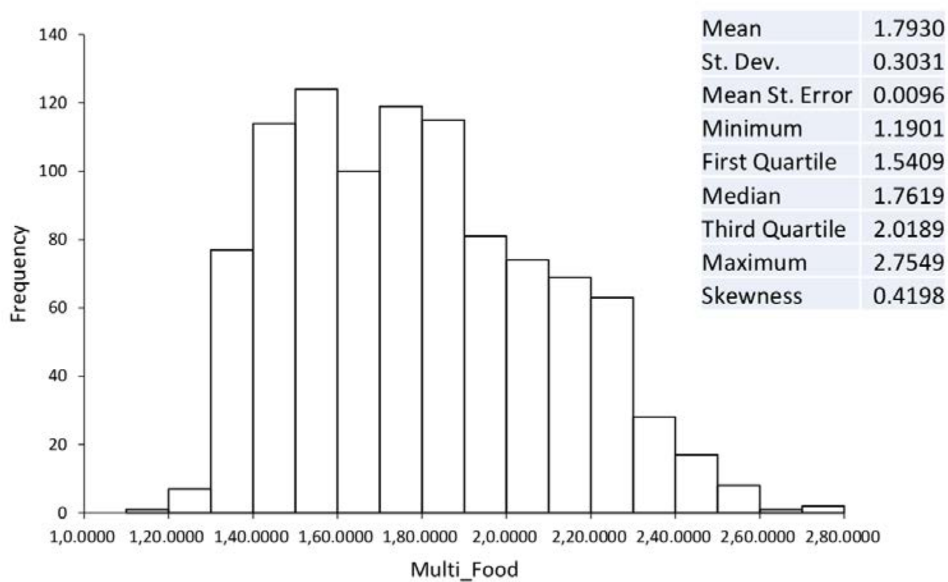

Figure A3.3 Distribution of output multiplier of the food manufacturing industries (Multi_Food) derived from sensitivity analysis of input coefficients.

Appendix 4. R script of the Input-Output model

```
#Import data under csv format
IOT <- read.table("Sey_IOT.csv",sep=";",dec=",",header=TRUE)
FinalUses <-  read.table("Sey_FinalUses.csv",sep=";",dec=",",header=TRUE)

# Bind into input-output table
IOT2 <- cbind(IOT,FinalUses)
# Convert object to data.frame
IOT2 <- as.data.frame(IOT2)

# Name columns of Flowtable (matrix)
Flowtable <- as.matrix.data.frame(IOT)
names( Flowtable ) <-
c("Agriculture","Fisheries","Manufactures_Food","Other_Manufactures","Construction"
,"Tourism","Transport","Private_Other_Services","Public_Services")
# Name columns of IOT table (dataframe)
names(IOT2) <-
c("Agriculture","Fisheries","Manufactures_Food","Other_Manufactures","Construction"
,"Tourism","Transport","Private_Other_Services","Public_Services","Output","FinalDe
mand","HoH_Consumption","Government","Investment","Exports","Jobs","IndTax","Income
")

# Save Final uses vectors as separate objects for later use
Output <- IOT2$Output
FinalDemand <- IOT2$FinalDemand
Consumption <- IOT2$HoH_Consumption
Gov_Expenditure <- IOT2$Government
Investment <- IOT2$Investment
Exports <- IOT2$Exports
Jobs <- IOT2$Jobs
IndTax <- IOT2$IndTax
Income <- IOT2$Income

## Calculate coefficient matrix (the % operator stands for matrix calculus):
z <- (Output)^-1*diag(9)
str(z)
(A <- Flowtable %*% z)
# Identity matrix minus technical coefficient matrix.
IminusA <- diag(9)- A
## Calculate inverse
(L <- solve(IminusA))

## Output multipliers (sum of columns + creation of a Table)
(Outputmultiplier <- apply(L,2,sum))
(TabOM <- matrix(Outputmultiplier,nrow=9))
rownames(TabOM)=c("Agriculture","Fisheries","Manufactures_Food","Other_Manufactures
","Construction","Tourism","Transport","Private_Other_Services","Public_Services")

# Plot output multipliers
par(las=2) # make label text perpendicular to axis
par(mar=c(9,16,2,5)) # increase y-axis margin.
barplot(Outputmultiplier,horiz = TRUE,  xlim = c(00, 2.5), main="Output multipliers
in the Seychelles economy 2014", sub="Source: NBS", cex.sub=1.2, col="blue",
```

```
names.arg=c("Agriculture","Fisheries","Manufactures_Food","Other_Manufactures","Con
struction","Tourism","Transport","Private_Other_Services","Public_Services"),cex.na
mes=1.2)

## Calculate the Demand (direct and indirect) effects on the Seychelles economy
Demandeffects <- L%*%FinalDemand
TabDem <- matrix(Demandeffects,nrow=9)
rownames(TabDem)=c("Agriculture","Fisheries","Manufactures_Food","Other_Manufacture
s","Construction","Tourism","Transport","Private_Other_Services","Public_Services")

#Backward linkage index (means by Column/means Matrix)
BLI <- colMeans(L)/mean(L)
TabBLI <- matrix(BLI,nrow=9)
rownames(TabBLI)=c("Agriculture","Fisheries","Manufactures_Food","Other_Manufacture
s","Construction","Tourism","Transport","Private_Other_Services","Public_Services")
#Forward linkage index (means by Row/means Matrix)
FLI <- rowMeans(L)/mean(L)
TabFLI <- matrix(FLI,nrow=9)
rownames(TabFLI)=c("Agriculture","Fisheries","Manufactures_Food","Other_Manufacture
s","Construction","Tourism","Transport","Private_Other_Services","Public_Services")

#Job multipliers
(LC <- (Jobs)*z)
Emp<-LC%*%L
(Empmult<-apply(Emp,2,sum))
TabEmp <- matrix(Empmult,nrow=63)
rownames(TabEmp)=c("Agriculture","Fisheries","Manufactures_Food","Other_Manufacture
s","Construction","Tourism","Transport","Private_Other_Services","Public_Services")

# Plot employment multipliers
par(las=2) # make label text perpendicular to axis
par(mar=c(9,16,2,5)) # increase y-axis margin.
barplot(Empmult,horiz=TRUE, xlim=c(0.0, 6.0), main="Job multipliers in the
Seychelles economy 2014", sub="Number of jobs per MSCR", cex.sub=1.2, col="red",
names.arg=c("Agriculture","Fisheries","Manufactures_Food","Other_Manufactures","Con
struction","Tourism","Transport","Private_Other_Services","Public_Services"),cex.na
mes=1.2)

#Total effects and Induced effects
# Calculate first wages per unit of output and multiply by the Marginal Propensity
to Consume and by the Leontief inverse matrix to obtain the V Matrix = L*B*C
# Calculate Total effects (Direct+Indirect+Induced)(I-Z)^-1=(I-A)^-1*(I-V)^-1 and
subtract (I-A)^-1 from (I-Z)^-1 to obtain the Induced effects.
B <- (Income)*z
MPC <- cbind(rep(0.73, 9)) # Create a Column vector replicating the Marginal
Propensity to Consume 0.73 in 9 rows
MPC <- as.vector(MPC)
C <- (MPC)*diag(9) # To obtain the MPC matrix by multiplying the Identity matrix(9)
by 0.73) Assumption of MPC=73% in every branch

## Other and more direct way of diagonalising a vector: MPC <- diag(MPC)
V <- L%*%B%*%C #Obtain Matrix V
IminusV <- diag( 9 ) - V
W <- solve(IminusV ) ## Calculate inverse of IminusV
Z <- (L)%*%(W) ## Calculus of Total effects (I-Z)^-1
Induc <- Z-L
InducedEffects <- apply(Induc,2,sum)
TabInduced <- matrix(InducedEffects)
```

```
rownames(TabInduced)=c("Agriculture","Fisheries","Manufactures_Food","Other_Manufac
tures","Construction","Tourism","Transport","Private_Other_Services","Public_Servic
es")

#Indirect Tax multipliers
T <- (IndTax)*z
Tax<-T%*%L
(Taxmult<-apply(Tax,2,sum))
TabTax <- matrix(Empmult,nrow=9)
rownames(TabTax)=c("Agriculture","Fisheries","Manufactures_Food","Other_Manufacture
s","Construction","Tourism","Transport","Private_Other_Services","Public_Services")

# Plot tax multipliers
par(las=2) # make label text perpendicular to axis
par(mar=c(9,16,2,1)) # increase y-axis margin.
barplot(Taxmult,horiz=TRUE, main="Indirect Tax multipliers in the Seychelles
economy 2014", sub="Source: MoF", cex.sub=1.2, col="green",
names.arg=c("Agriculture","Fisheries","Manufactures_Food","Other_Manufactures","Con
struction","Tourism","Transport","Private_Other_Services","Public_Services"),cex.na
mes=1.2)
```

Appendix 5. R script of the Social Accounting Matrix unconstrained model

```
#Import a database under format csv from R version 3.5.1
SAM <- read.table("SeySAM.csv",sep=";",dec=",",header=TRUE)
SAM_Matrix <- as.matrix(SAM)
FinalDemand <- read.table("SeySAM_FinalDemand.csv",sep=";",dec=",",header=TRUE)
# Bind into a single SAM data frame
SAM_FULL <- as.data.frame(cbind(SAM,FinalDemand))

# Name columns of SAM_FULL table (dataframe)
names(SAM_FULL) <-
c("AAgri","AFish","AFood","AOthMan","Aconstruc","ATourism","ATransport",
"APrivServ","APubServ","CAgri","CFish","CFood","COthMan","Cconstruc","CTourism","CT
ransport","CPrivServ","CPubServ","CapIncome","LabourIncome","Household","Government
","SavInvest","External", "TotalOutput","TotalDemand")
names(SAM_Matrix) <-
c("AAgri","AFish","AFood","AOthMan","Aconstruc","ATourism","ATransport",
"APrivServ","APubServ","CAgri","CFish","CFood","COthMan","Cconstruc","CTourism","CT
ransport","CPrivServ","CPubServ","CapIncome","LabourIncome",
"Household","Government","SavInvest","External")
# Save Final uses vectors as separate objects for later use
Output <- SAM_FULL$TotalOutput
TotalDemand <- SAM_FULL$TotalDemand
Household <- SAM_FULL$Household
Government <- SAM_FULL$Government
Investment <- SAM_FULL$SavInvest
External <- SAM_FULL$External

## Calculate coefficient matrix (the % operator stands for a matrix calculus):
z <- (Output)^-1*diag(24)
(M <- SAM_Matrix %*% z)
# Identity matrix minus technical coefficient matrix.
(IminusM <- diag(24) - M)
## Calculate the inverse Matrix of IminusM
L <- solve(IminusM)

## Create Matrix E (External shock) of order(24*9)
E1 <- matrix(0,nrow=9,ncol=9)
E2 <- diag(9)
E3 <- matrix(0,nrow=6,ncol=9)
E <- as.matrix(rbind(E1,E2,E3))

## SAM Multipliers (sum of columns + creation of a Table)
SAM_multipliers <- L %*% E
TabSAM_Mult <- matrix(SAM_multipliers,nrow=24)
rownames(TabSAM_Mult)=c("AAgri","AFish","AFood","AOthMan","Aconstruc","ATourism","A
Transport","APrivServ","APubServ","CAgri","CFish","CFood","COthMan","Cconstruc","CT
ourism","CTransport","CPrivServ","CPubServ","CapIncome","LabourIncome","Household",
"Government","SavInvest","External")
colnames(TabSAM_Mult)=c("AAgri","AFish","AFood","AOthMan","Aconstruc","ATourism","A
Transport","APrivServ","APubServ")
TabMulti <- as.data.frame(SAM_multipliers)
rownames(TabMulti)=c("AAgri","AFish","AFood","AOthMan","Aconstruc","ATourism","ATra
nsport","APrivServ","APubServ","CAgri","CFish","CFood","COthMan","Cconstruc","CTour
ism","CTransport","CPrivServ","CPubServ","CapIncome","LabourIncome","Household","Go
vernment","SavInvest","External")
```

```
colnames(TabMulti)=c("AAgri","AFish","AFood","AOthMan","Aconstruc","ATourism","ATra
nsport","APrivServ","APubServ")
Output_multi <- apply(TabMulti[10:18,],2,sum)   ##Sum in column (2=col, 1=ligne)
des lignes 10 à 18
GDP_multi <- apply(TabMulti[19:20,],2,sum)
Tax_multi <- TabMulti[22,]

# Plot output and GDP multipliers
par(las=2,mar=c(9,16,2,5)) # make label text perpendicular to axis and increase y-
axis margin
barplot(Output_multi,horiz = TRUE,  xlim = c(00, 2.5), main="Output multipliers in
the Seychelles economy 2014", sub="Source: own calculation from NBS data",
cex.sub=1.2, col="blue",
names.arg=c("Agriculture","Fisheries","Manufactures_Food","Other_Manufactures","Con
struction","Tourism","Transport","Private_Other_Services","Public_Services"),cex.na
mes=1.2)
barplot(GDP_multi,horiz = TRUE,  xlim = c(00, 0.7), main="GDP multipliers in the
Seychelles economy 2014", sub="Source: own calculation from NBS data", cex.sub=1.2,
col="green",
names.arg=c("Agriculture","Fisheries","Manufactures_Food","Other_Manufactures","Con
struction","Tourism","Transport","Private_Other_Services","Public_Services"),cex.na
mes=1.2)

## Calculate the Demand (direct and indirect) effects on the Seychelles economy
# First, by checking the Final Demand effects using the product of L=(I-M)^-1 of
order (24x24) and the Total Demand vector (24 x 1)
DemandEffects <- L %*% TotalDemand
TabDem <- matrix(DemandEffects,nrow=24)
rownames(TabDem)=c("AAgri","AFish","AFood","AOthMan","Aconstruc","ATourism","ATrans
port","APrivServ","APubServ","CAgri","CFish","CFood","COthMan","Cconstruc","CTouris
m","CTransport","CPrivServ","CPubServ","CapIncome","LabourIncome","Household","Gove
rnment","SavInvest","External")

## To obtain the distributed effects of the demand shock, we need first to
diagonalise the TotalDemand vector
DemandMatrix <- E*TotalDemand
DistribDemandEffects <- L %*% DemandMatrix
TabDistDemand <- matrix(DistribDemandEffects,nrow=24,ncol=9)
rownames(TabDistDemand)=c("AAgri","AFish","AFood","AOthMan","Aconstruc","ATourism",
"ATransport","APrivServ","APubServ","CAgri","CFish","CFood","COthMan","Cconstruc","
CTourism","CTransport","CPrivServ","CPubServ","CapIncome","LabourIncome","Household
","Government","SavInvest","External")
colnames(TabDistDemand)=c("AAgri","AFish","AFood","AOthMan","Aconstruc","ATourism",
"ATransport","APrivServ","APubServ")
DistribEffectsOnOutput <- apply(TabDistDemand[1:9,],2,sum)   ##Sum in columns
(2=col, 1=ligne) of rows 1 to 9
DistDistribEffectsOnGDP <- apply(TabDistDemand[19:20,],2,sum)   ## Sum in columns
of rows 19 and 20
## Calculate the effects of a Demand shock on Output, GDP, factors' income, tax and
imports (direct and indirect) effects on the Seychelles economy

# Another Demand vector has to be created. Example:
NewDemand <- c(rep(0,9), 157.52, 242.77, 5219.31, 11279.47,
1111.12,4688.31,2253.92,6261.56,4104.41,0.00,0.00,264.56,2307.57,6410.48,0.00)
DemandShock <- L %*% NewDemand
TabDemShock <- matrix(DemandShock,nrow=24)
rownames(TabDemShock)=c("AAgri","AFish","AFood","AOthMan","Aconstruc","ATourism","A
Transport","APrivServ","APubServ","CAgri","CFish","CFood","COthMan","Cconstruc","CT
```

```
ourism","CTransport","CPrivServ","CPubServ","CapIncome","LabourIncome","Household",
"Government","SavInvest","External")
(ShockOnGDP <- TabDemShock[21,] - 14583)
```

Appendix 6. Fishing effort and catch in the Seychelles waters

Table A6.1. Summary statistics of the activities of the semi-industrial and industrial longline fleets in Phase 1 during 2012-2017. Effort is expressed in number of fishing sets and number of hooks (x1,000) deployed. Catch is expressed in metric tons. Zone 1 = High Biodiversity Protection Area gazetted in February 2018. Statistics were computed from annual values. Avg = average; Sd = standard deviation; Min = minimum; Max = maximum.

	Flag	AvgSets	AvgHooks	AvgCatch	SdCatch	MinCatch	MaxCatch	CPUE (t/set)	CPUE (kg/1000 hooks)
Semi-industrial longline									
Zone 1	Seychelles	0	0	0	-	0	0	-	-
Rest of Seychelles EEZ	Seychelles	837	654	289	337	20	784	0.35	442
Outside Seychelles EEZ	Seychelles	20	17	6	8	0	19	0.32	376
Deep-water longline									
Zone 1	Foreign	168	505	198	127	29	352	1.18	392
Zone 1	Seychelles	96	301	123	80	16	212	1.28	409
Rest of Seychelles EEZ	Foreign	5360	15816	5259	1419	3210	7623	0.98	333
Rest of Seychelles EEZ	Seychelles	1977	5923	2306	459	1547	2975	1.17	389
Outside Seychelles EEZ	Seychelles	6069	19333	5771	2272	4379	10352	0.95	299

Table A6.2. Summary statistics of the activities of the purse seine fleet in Phase 1 during 2012-2017. Effort is expressed in number of fishing sets and fishing days. Catch is expressed in metric tons. Zone 1 = High Biodiversity Protection Area gazetted in February 2018. Statistics were computed from annual values. Avg = average; Sd = standard deviation; Min = minimum; Max = maximum.

	Flag	AvgSets	AvgFishingDays	AvgCatch	SdCatch	MinCatch	MaxCatch	CPUE (t/set)	CPUE (t/day)
Zone 1	EU	16	25	412	508	25	1334	25.8	6
Zone 1	Non-EU	0	2	0	0	0	0	-	0
Zone 1	Seychelles	4	6	101	140	6	377	25.3	16.8
Rest of Seychelles EEZ	Non-EU	286	338	5268	4233	396	11354	18.4	15.6
Rest of Seychelles EEZ	EU	1833	2098	43182	11315	28491	59413	23.6	20.6
Rest of Seychelles EEZ	Seychelles	522	597	12079	5377	6595	20886	23.1	20.2
Outside Seychelles EEZ	EU	5321	4974	154051	18759	130484	184500	29.0	31.0
Outside Seychelles EEZ	Non-EU	696	704	14898	8504	2329	23436	21.4	21.2
Outside Seychelles EEZ	Seychelles	2204	1963	69020	25134	40678	105801	31.3	35.2

Table A6.3. Summary statistics of the activities of the semi-industrial and industrial longline fleets in Phase 2 during 2012-2017. Effort is expressed in number of fishing sets and number of hooks (x1,000) deployed. Catch is expressed in metric tons. Zone 1 = High Biodiversity Protection Area gazetted in February 2018 and proposed in November 2018. Statistics were computed from annual values. Avg = average; Sd = standard deviation; Min = minimum; Max = maximum.

	Flag	AvgSets	AvgHooks	AvgCatch	SdCatch	MinCatch	MaxCatch	CPUE (t/set)	CPUE (kg/1000 hooks)
Semi-industrial longline									
Zone 1	Seychelles	51	38	12	16	2	45	0.24	324
Rest of Seychelles EEZ	Seychelles	786	616	277	324	18	740	0.35	449
Outside Seychelles EEZ	Seychelles	20	17	6	8	0	19	0.32	376
Deep-water longline									
Zone 1	Foreign	824	2449	911	342	297	1205	1.11	372
Zone 1	Seychelles	337	1032	422	213	109	644	1.25	409
Rest of Seychelles EEZ	Foreign	4705	13873	4547	1252	2941	6730	0.97	328
Rest of Seychelles EEZ	Seychelles	1737	5192	2008	422	1456	2748	1.16	387
Outside Seychelles EEZ	Seychelles	6069	19333	5771	2272	4379	10352	0.95	299

Table A6.4. Summary statistics of the activities of the purse seine fleet in Phase 2 during 2012-2017. Effort is expressed in number of fishing sets and fishing days. Catch is expressed in metric tons. Zone 1 = High Biodiversity Protection Area gazetted in February 2018 and proposed in November 2018. Statistics were computed from annual values. Avg = average; Sd = standard deviation; Min = minimum; Max = maximum.

	Flag	AvgSets	AvgFishingDays	AvgCatch	SdCatch	MinCatch	MaxCatch	CPUE (t/set)	CPUE (t/day)
Zone 1	EU	141	173	3188	1837	1506	5649	22.6	18.4
Zone 1	Non-EU	16	20	303	409	10	1072	18.9	15.2
Zone 1	Seychelles	46	55	1040	937	324	2779	22.6	18.9
Rest of Seychelles EEZ	EU	1708	1951	40420	10684	26049	55371	23.7	20.7
Rest of Seychelles EEZ	Non-EU	271	318	4966	3907	386	10282	18.3	15.6
Rest of Seychelles EEZ	Seychelles	480	548	11140	4840	5931	18484	23.2	20.3
Outside Seychelles EEZ	EU	5321	4974	154051	18759	130484	184500	29.0	31.0
Outside Seychelles EEZ	Non-EU	696	704	14898	8504	2329	23436	21.4	21.2
Outside Seychelles EEZ	Seychelles	2204	1963	69020	25134	40678	105801	31.3	35.2

Appendix 7. The Seychelles Social Accounting Matrix

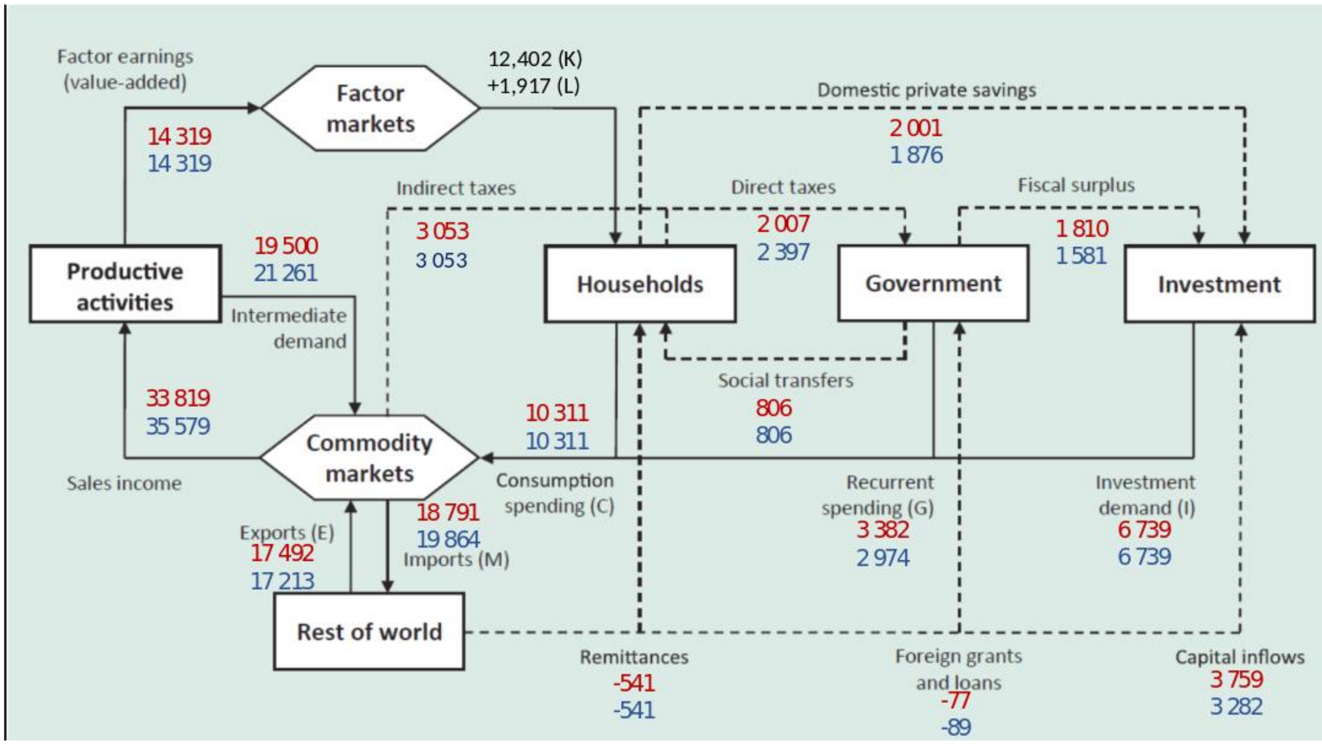

Figure A7.1. Monetary flows (Million SCR) included in the Seychelles Social Accounting Matrix representing the year 2014. Unbalanced accounts are indicated in red and balanced accounts in blue.

Table A7.1. The comprehensive Social Accounting Matrix of Seychelles with nine industries (in Million SCR).

2014 (MSCR)		Activity									Commodity									Factor		Final demand			External	Total
		Agriculture	Fishing	Manufactures of food	Other manufactures	Construction	Tourism	Transport	Private services	Public services	Agriculture	Fishing	Manufactures of food	Other manufactures	Construction	Tourism	Transport	Private services	Public services	Capital	Labour	Hoh	Gov	Sav/Inv	External	
Activity	Agriculture										839,04															839,04
	Fishing											996,46														996,46
	Manufactures of food												3 646,45													3 646,45
	Other manufactures													6 091,26												6 091,26
	Construction														994,49											994,49
	Tourism															6 898,50										6 898,50
	Transport																2 613,43									2 613,43
	Private / other services																	8 447,56								8 447,56
	Public services																		5 052,19							5 052,19
Commodity	Agriculture	226,37	21,76	676,71	23,01	-	35,88	0,31	0,32	-												150,75	-	-	6,77	1 142,07
	Fishing	-	-	688,06	0,48	-	33,57	0,05	0,08	-												123,90	-	-	169,81	1 015,95
	Manufactures of food	9,17	190,60	313,12	116,17	-	989,39	45,64	40,57	125,35												984,41	-	-	4 234,91	7 049,32
	Other manufactures	160,82	348,09	442,23	1 800,67	283,72	516,87	324,42	309,30	1 977,50												3 039,56	-	5 627,58	2 612,33	17 443,08
	Construction	-	-	-	-	-	-	-	-	-												-	-	1 111,12	-	1 111,12
	Tourism	80,71	153,23	479,41	1 305,04	72,90	565,78	140,14	428,03	128,10												247,84	-	-	4 440,47	8 041,66
	Transport	44,64	89,39	204,50	547,06	79,03	266,89	280,26	194,81	189,15												405,28	-	-	2 640,91	4 891,93
	Private services	62,49	9,93	306,93	1 295,20	60,22	1 882,56	207,08	1 318,81	296,31												4 194,10	172,22	-	2 827,05	12 633,33
	Public services	11,85	0,47	69,99	356,14	4,81	330,56	10,73	74,82	42,37												1 444,97	2 801,64	-	0,00	5 168,36
Factor	Capital	216,80	178,07	406,42	565,32	357,94	1 924,43	1 457,97	5 548,60	1 746,62																12 402,16
	Labour	6,00	4,93	59,08	82,18	185,86	352,57	146,83	532,20	546,78																1 916,44
Final demand	Hoh																			12 402,16	1 916,44		806,00		541,44	14 583,16
	Gov										18,93	15,56	146,40	1 598,30	-	668,08	50,90	438,68	116,14			2 117,00			191,00	5 360,99
	Sav/Inv																					1 075,70	1 580,70		3 282,30	6 738,71
External	Ext										284,10	3,92	3 256,46	9 753,53	116,64	475,08	2 227,61	3 747,09	0,03							19 864,45
Total		839,04	996,46	3 646,45	6 091,26	994,49	6 898,50	2 613,43	8 447,56	5 052,19	1 142,07	1 015,95	7 049,32	17 443,08	1 111,12	8 041,65	4 891,93	12 633,33	5 168,35	12 402,16	1 916,44	14 583,50	5 360,56	6 738,71	19 864,55	154 942,11

Table A7.2. Breakdown of the Social Accounting Matrix multipliers. Output, Factors' income, Gross Domestic Product, government budget and external.

		Agriculture	Fishing	Manufactures of food	Other manufactures	Construction	Tourism	Transport	Private services	Public services
Output multipliers	Agriculture	0,92	0,04	0,10	0,00	0,00	0,02	0,00	0,00	0,00
	Fishing	0,00	1,00	0,10	0,00	0,00	0,02	0,00	0,00	0,00
	Manufactures of food	0,02	0,12	0,56	0,01	0,01	0,08	0,01	0,01	0,02
	Other manufactures	0,08	0,16	0,06	0,40	0,11	0,05	0,03	0,01	0,16
	Construction					0,90				
	Tourism	0,11	0,20	0,11	0,09	0,09	0,96	0,04	0,04	0,06
	Transport	0,04	0,07	0,03	0,02	0,02	0,03	0,57	0,01	0,03
	Private services	0,09	0,09	0,08	0,08	0,08	0,21	0,05	0,76	0,09
	Public services	0,05	0,02	0,02	0,03	0,02	0,05	0,01	0,01	1,00
Leontief multipliers	Agriculture	1,25	0,06	0,13	0,01	0,00	0,03	0,00	0,00	0,01
	Fishing	0,00	1,02	0,11	0,00	0,00	0,02	0,00	0,00	0,00
	Manufactures of food	0,03	0,24	1,09	0,02	0,02	0,15	0,02	0,01	0,04
	Other manufactures	0,24	0,46	0,16	1,15	0,31	0,14	0,09	0,04	0,45
	Construction					1,00				
	Tourism	0,13	0,23	0,13	0,10	0,10	1,12	0,04	0,05	0,07
	Transport	0,07	0,13	0,06	0,05	0,04	0,06	1,07	0,02	0,06
	Private services	0,14	0,13	0,11	0,13	0,12	0,32	0,07	1,13	0,13
	Public services	0,05	0,02	0,02	0,03	0,02	0,05	0,01	0,01	1,02
GDP multipliers	Capital	0,37	0,38	0,22	0,14	0,43	0,46	0,37	0,52	0,46
	Labour	0,03	0,03	0,03	0,02	0,18	0,07	0,04	0,05	0,12
Income multipliers	Household	0,40	0,41	0,24	0,16	0,61	0,54	0,41	0,57	0,58
Gov. spending mutipliers	Government	0,06	0,09	0,06	0,12	0,04	0,12	0,03	0,05	0,08
Imports multipliers	External	0,54	0,50	0,70	0,72	0,35	0,34	0,57	0,38	0,35