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Size and Resilience of the Blue Economy in Pacific Island Economies

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ABSTRACT: Economic output and livelihoods in Pacific Island economies (PIEs) rely greatly on ocean-related sectors and products, known as the "Blue Economy". Yet, marine ecosystems are under mounting pressure of climate change and human degradation, exposing PIEs to very large risks, while they have only limited technical and financial capacity to mitigate them. This paper aims: first to estimate the size of the Blue Economy in PIEs, based on comprehensive international input-output tables; and second to simulate the impact of selected shocks in PIEs, so as to provide insights on the resilience of the Blue Economy to shocks, including from climate change.

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WORKING PAPERS

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Contents

Glossary

BEA	Bureau of Economic Analysis
COMTRADE	Commodity Trade Statistics Database
EBOPS	Extended Balance of Payment Statistics
EEZ	Exclusive Economic Zone
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GFC	Global Financial Crisis
GST	Goods and Services Tax
GVA	Gross Value Added
HS	Harmonized System
IMF	International Monetary Fund
IO	Input-Output
IUCN	International Union for Conservation of Nature
MRIO	Multi-Regional Input-Output
OECD	Organisation for Economic Cooperation and Development
PIE	Pacific Island Economy
PNG	Papua New Guinea
RCP	Representative Concentration Pathway
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
US	United States
USD	United States Dollar
VAT	Value Added Tax

Introduction

Global oceans and seas play a crucial role in supporting economic development and sustaining livelihoods, especially in developing economies. According to the United Nations (2017), over 3 billion people over the world depend on marine and coastal resources as a means of support for their livelihoods, with a vast majority living in developing countries. Oceans are central to key economic activities for coastal regions, from fishing to sea transport, from beach tourism to offshore resource extraction, and they carry 80 percent of global trade. Oceans and seas provide food, with 112 million tons of fish produced in 2020 from marine capture and marine aquaculture, according to FAO (2022). They also provide jobs. OECD (2016) estimates that over 40 million jobs from ocean-based employment will be achieved by 2030 under a business-as-usual scenario (31 million in 2010), with half in fish production and processing, and more than a fifth in marine and coastal tourism. In addition, developing economies rely more on ocean-based sectors for income and jobs than OECD countries (OECD, 2020b).

Pacific Island economies (PIEs) are particularly dependent on ocean-related activities for their socio-economic development. PIEs sometimes describe themselves as "Great Ocean States". This denomination refers both to the physical prevalence of the sea relative to land areas – the top three countries in the world with record high sea-to-land ratios are all PIEs (Tuvalu, Nauru and Marshall Islands' exclusive economic zones (EEZ) are respectively 25,000, 15,000 and 11,000 times larger than their land areas (Hume et al (2021)) – and to the economic significance of ocean-related activities. Tourism and fishing are two major economic sectors in most PIEs – beaches and marine life are the lynchpin of tourism, and their vast territorial waters contain large populations of sought-after fish, like the yellowfin tuna or the bluefin tuna. In addition, these sectors are often a significant source of fiscal revenue for the government, including from fishing licenses sold to foreign fishing companies, which are then used to finance the delivery of critical public services and infrastructure.

For the purpose of this paper, the Blue Economy is defined as the sum of all marine-related sectors and/or activities. The simple, streamlined definition used in this paper is similar to recent efforts from the European Commission (2022) and the US Bureau of Economic Analysis (BEA) (Nicolls et al., 2020). For the purpose of this paper, we refer to "ocean economy" and "Blue economy" interchangeably and we do not presume whether marine-based activities are sustainable or not to include them in the scope of our study.[1]

Marine ecosystems face acute threats from human degradation and climate change. Oceans, including the Pacific Ocean, have been exposed to multiple sources of man-made pollution in past decades, such as ocean acidification and plastic pollution, with harmful consequences to marine ecosystems. Fish stocks have been depleting, due to the former, as well as overfishing; in the Pacific Ocean, the various species of tuna have seen their populations fall by half to two thirds in sixty years (RAM Legacy Stock Assessment Database, 2023). Climate change is creating additional challenges for the Blue Economy. Rising sea levels, due to an increase in global temperatures, may decrease land areas, displace coastal populations and disrupt coastal activities. The increase in sea temperatures, another consequence of increasing greenhouse gas emissions, is expected to

[1] Earlier definitions of the concept from the United Nations Commission on Trade and Development (UNCTAD) (2014) and from the World Bank (2017) embedded the need for a sustainable approach to the use of marine resources. In Patil et al. (2016), the authors made a distinction between the ocean economy, which is defined as "*the economic activities that take place in the ocean, receive outputs from the ocean, and provide inputs to the ocean*" and the Blue Economy, which is defined as "*a lens by which to view and develop policy agendas that simultaneously enhance ocean health and economic growth, in a manner consistent with principles of social equity and inclusion*."

affect the distribution of fish populations across global oceans, creating uncertainties about commercial fish stocks. Climate change also contributes to an increase in the frequency and severity of weather-related natural disasters such as cyclones, which may result in more extensive damage and socio-economic costs, affecting both short-term production and long-term growth. While awareness about these threats has increased – the conservation and sustainable use of the oceans, seas and marine resources is one of the United Nations' seventeen Sustainable Development Goals – the international community still has a long way to go to durably reverse some of these concerning trends.

These threats put the long-term sustainability and resilience of an ocean-centric economic strategy for PIEs at risk. PIEs are particularly vulnerable to the consequences of human degradation and climate change on the ocean. Rising sea levels is an existential threat for some smaller, low-lying PIEs, given the already limited land area. They have little traction on mitigating these risks, which are largely exogenous for them; and their adaptive capacity is constrained by difficulties in accessing climate finance, by little to no available fiscal space, and by limited skills and expertise on these matters. Climate change in particular creates a new intertemporal policy trade-off for PIE governments. Increasing the share of ocean-related activities in the economy may bring new growth opportunities and additional fiscal revenue in the short- to medium-run, but it may also increase the vulnerability of the economy and of the fiscal position to some of the consequences of climate change down the line; this may require to give consideration to a number of policy options to help mitigate these negative impacts.

This paper aims to estimate the importance of the Blue Economy in PIEs and to assess its resilience to shocks, especially from climate change. After two sections describing the existing literature and the data used for the purpose of this paper, we first propose several metrics to measure the size of the Blue Economy in thirteen PIEs[2] in 2019, making use of an open-source multi-regional input-output database recently compiled by an academic consortium. Then, we apply selected demand and supply shocks, including climate change related, to gauge the vulnerability of the Blue Economy to these shocks, and to assess whether ocean-related activities enhance or dampen the consequences of these shocks for the whole economy.

This paper's main contributions to the literature are three-fold. First, this paper is the first study on the size of the Blue Economy to propose an extensive coverage of the Pacific region, with most countries in the sample having never been tackled in previous literature. Second, this paper makes use of a highly disaggregated multi-regional input-output (MRIO) table to quantify the size of the Blue Economy, allowing for a comprehensive and granular approach not previously applicable, especially in the case of developing economies with little official data; for this approach, we have chosen to adapt the methodology developed for the US by the BEA (Nicolls et al. 2020), which relied on highly granular domestic supply-use tables produced as part of the US national accounts. Third, we leverage useful properties of MRIO tables, applying Leontief/Ghosh matrix modeling to estimate compounded effects of demand and supply shocks on PIEs in the absence of policy changes or substitution effects, and to assess whether the Blue Economy is susceptible to act as a buffer or as an enhancer of shocks for the economy.

[2] The thirteen PIEs are: Cook Islands, Fiji, Kiribati, Marshall Islands, Federated States of Micronesia, Nauru, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu.

Existing literature

The Blue Economy and its importance in the economy have been topics of academic and institutional interest for the past decade, with a relatively wide range of reports and papers covering the world, or focusing on developing economies or on specific regions, like the Caribbean. A number of international, regional and national agencies have developed methodologies to measure the size of the Blue Economy. OECD (2016) assessed that the Blue Economy's direct contribution to the global economy in 2010 was USD 1.5 trillion, corresponding to about 2.5 percent of global gross value added. In its *Blue Economy Report* (2022), the European Commission estimated that the Blue Economy in the European Union represented about 1.5 percent of the regional gross value added in 2019. According to a World Bank study (Patil et al. (2016)), the ocean economy in the Caribbean accounted for 18 percent of the regional GDP in 2012. Some advanced economies have also produced their own methodologies, as part of national accounting, to create and compile satellite accounts on the ocean economy. The ocean economy in the United States (US) was estimated to account for just under 2 percent of GDP in 2018 by the BEA (Nicolls et al. (2020)). Results from these various analytical efforts may not be directly comparable with one another, however, given differences in definition, scope, data sources and vintage.

Despite the particular significance of the topic in PIEs, literature focused on PIEs has been relatively sparse, in part because of data limitations. The few existing cross-PIE studies point to a significant size of the Blue Economy in PIEs, much larger than the OECD (2016) average global estimate of 3 percent of GDP. A study covering 22 Pacific Island countries and territories (Seidel and Lal (2010)) found that sectoral marine-related activities constituted 10.5 percent of regional GDP in 2008; however, these estimates only included the contribution of fisheries (7.2 percent) and tourism (3.3 percent). A more recent study by the Energy and Resources Institute (Juneji et al. (2021)) focusing on 16 countries of the Asia-Pacific region found that the share of the Blue Economy in GDP ranged from 1 percent (Hong Kong) to 87 percent (Timor-Leste) – however, this study only included two PIEs (Papua New Guinea and Solomon Islands). All in all, there has been no recent literature attempt for most PIEs to provide quantified and comprehensive individual estimates of the importance of the Blue Economy.

Granular sectoral data is critical to analyze the importance of the Blue Economy in a given economy. This paper relies on international input-output data as a foundation for its analysis and findings on the size and resilience of the Blue Economy in PIEs. Input-output models were pioneered by Wassily Leontief (1951, 1986) to describe the interdependencies between the inputs and outputs of the sectors and industries in a given economy. In recent decades, there has been extensive literature making use of input-output analysis to analyze the structure of domestic and international production networks and study the propagation of shocks through them. The renewed interest in input-output analysis is closely related to increased data availability, made possible by improved national statistics and enhanced information technologies. The emergence of regional and international input-output tables since the 2000s[3] has enabled the use of input-output analysis for the study of demand shock spillovers through international trade and global value chains. A set of literature has highlighted how sectoral shocks, even at the level of firms, could spill over to other sectors through input-output linkages and lead to aggregate fluctuations of a macroeconomic nature, depending on concentration and sectoral interconnectedness within production networks (e.g. Carvalho (2010), Gabaix (2011), Acemoglu et al.

[3] The IMF has started developing a Multi-Analytical Regional Input-Output (IMF-MARIO) database (Guilhoto et al. 2023), which will cover the years from 1990 to 2022 and 209 economies, including all IMF members.

(2012), Carvalho and Gabaix (2013), Acemoglu et al. (2017)). For example, Acemoglu et al. (2016) evidenced the role of trade linkages in the propagation of shocks across countries. Input-output analysis has also been used in a wide range of IMF working papers, including to analyze the transmission of positive and negative shocks through production networks (for instance Li and Martin (2018), Lee (2019) and Perez-Saiz et al. (2019)) or to measure trade in value added (Aslam et al. (2017)).

In recent years, input-output analysis has also become widely used to assess the sustainability of economic activities. This includes efforts to account for greenhouse gas emissions and trace the carbon footprint across production networks (e.g. Moran et al. (2020), Wu et al. (2021)), as supported by the G20 Data Gaps initiative. This work also includes statistical efforts to analyze Blue Economy activities. The US Bureau of Economic Analysis made use of highly granular input-output statistics compiled as part of the US' national accounts to measure the size of the ocean-based economy in that country (Nicolls et al. (2020)). This paper adapts this methodology to the case of PIEs, and leverages the properties of input-output analysis, as highlighted by literature above, to assess whether the Blue Economy currently acts as a buffer or as an enhancer of shocks for the economy.

Data

In this section, we start by briefly illustrating the general structure of multi-regional input-output (MRIO) tables, before describing the characteristics of the EMERGING database (Huo et al., 2022), which we use as our main data source, and touching upon the data preparation which was carried out for the purpose of this paper.

Multi-regional input-output (MRIO) tables

MRIO tables provide a comprehensive framework to understand the interdependencies between different sectors of the economy within and across countries / territories. These tables offer a systematic and detailed representation of the flows of goods and services among various sectors and industries for a given period of time (typically one year), both domestically and internationally. In the tables, the rows represent the supply sectors, while the columns represent the demand sectors. By capturing the intricate web of relationships between producers and consumers, MRIO tables can help further the understanding of economic structures, trade patterns, and global supply chains.

A typical MRIO table contains three major components. Figure 1 provides a representation of the structure of the MRIO used in this paper, in the case of three countries (A, B and C) and four sectors (a, b, c and d).

- The *intermediate transactions matrix* captures all the transactions between industries of all countries / territories for the purpose of production. In other words, this matrix summarizes the value of all intermediate inputs used for production in each industry, be they purchased domestically or imported. As an illustration, cell (1) should be understood as the value of intermediate inputs from sector b purchased domestically for the production of sector c in country A; and cell (2) should be understood as the value of intermediate inputs from sector c imported from country A for the production of sector d in country B.
- The *final demand matrix* captures the value of goods and services for the purpose of consumption and investment by households, firms and governments. As an illustration, cell (3) is the final household

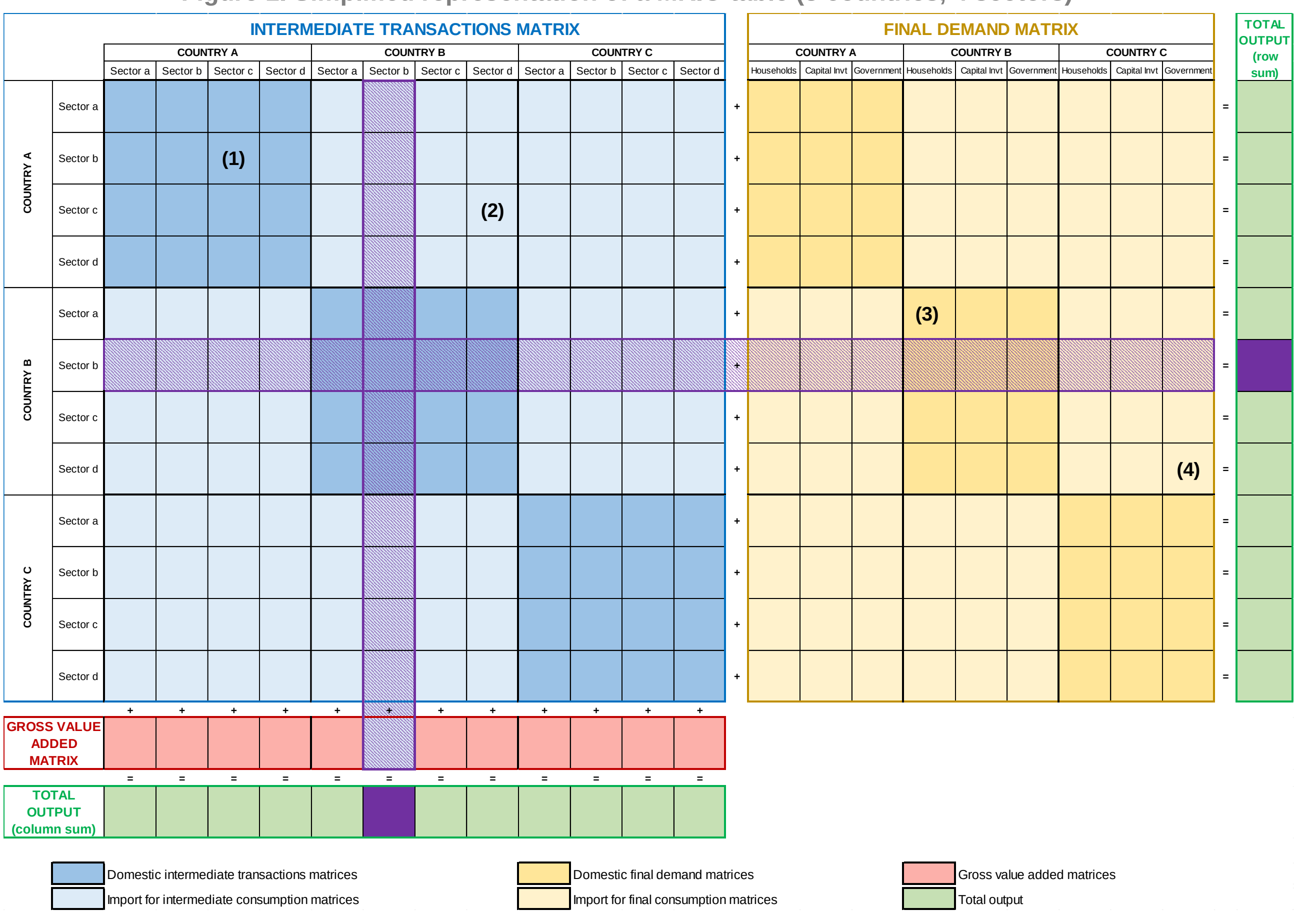
consumption in country B for domestically-produced goods from sector a; cell (4) is the final government demand in country C for imported goods from sector d.

- The *gross value added matrix* captures the gross value added (GVA) stemming from each sector of each country. In some MRIO tables, these numbers can be further broken down into wages and profits.

Total output for each sector in each country can be calculated by computing the sum of all cells within the relevant row or within the relevant column (see example for sector b in country B in purple in Figure 1). On each row, one can read a breakdown of the destination of each sector's supply produced in a given country (domestic intermediate consumption, domestic final demand, export for intermediate consumption abroad, export for final demand abroad). Each column provides a view of the production structure in each sector and each country, and an estimate of the creation of value added (total sectoral output *equals* intermediate inputs (purchased domestically or imported) *plus* gross value added).

While some MRIO tables include them, the version presented here excludes taxes and subsidies on goods and services, as the sectoral breakdown is often difficult to establish, especially for countries and territories with limited data capacity.

Figure 1. Simplified representation of a MRIO table (3 countries, 4 sectors)



Source: authors.

Database

The main data source we use for our paper is the EMERGING database, an open-source and highly disaggregated MRIO table compiled by a consortium of universities (Huo et al. (2022)), covering 245 countries and territories (including the thirteen PIEs which are the focus of this paper) from 2015 to 2019. The EMERGING database provides a disaggregation into 135 sectors, consisting of 105 goods sectors classified according to the UN's Harmonized system 2002 (HS2002) and 30 services sectors classified according to the UN's Extended Balance of Payments Services classification (EBOPS 2010).

To compile the EMERGING database, Huo et al (2022) construct a global high-resolution trade table, making use of bilateral trade data from UN COMTRADE and World Trade Organization. They also compile national input-output (IO) tables for each of the 245 countries or territories, either from existing data in national accounts and international databases, using the structure of existing regional IO tables as proxy. The production of the final MRIO tables relies on a number of algorithms which allow to ensure a harmonized, internally consistent result. The table is ultimately validated through the calculation of gross value-added for each sector in each country or territory, ensuring that sums in rows and columns are equal.

While trade data is generally comprehensive and detailed, domestic sectoral output information and domestic supply-use tables may lack, especially in countries with limited statistical capacity. To reach the desired level of disaggregation, the EMERGING database relies on a number of simplifying assumptions when data is partial or not available, which is the case for most PIEs considered in this study. For example, in the absence of granular sectoral domestic demand, it is assumed that domestic sectoral outputs are proportional to exported sectoral outputs. In addition, in the absence of domestic IO tables, the regional weighted average production structure, based on available IO tables in the region, are used as a proxy. For PIEs, a regional weighted average table for the Pacific region, heavily reflecting the production structure of Australia and New Zealand, has been used as a reference to fill in the gaps in PIEs' domestic production structure.

While there are a few other existing MRIO table compilation efforts available to the public, [4] we choose to work with the EMERGING database, because (i) it is the only database which covers PIEs; (ii) it provides the most detailed sectoral disaggregation, thus allowing to identify marine-related activities in a more granular fashion; (iii) its compilation prioritizes publicly available data from national statistical institutes and other official sources, ensuring better data quality and consistency with cross-country datasets from international organizations, including the IMF; (iv) the EMERGING database is publicly accessible, replicable, and can be extended to recent years given the published methodology.

For any given year, the intermediate transactions matrix in the EMERGING database contains more than one billion cells. Given our focus on PIEs, we condense the MRIO table to 31 countries/territories/regions, including the 13 PIEs of focus, their 13 major trading partners, and 5 regional groupings for the rest of the world, based on geographical locations (Table 1).

[4] Such as EXIOBASE 3rx (compiled by a consortium of research institutes funded by the European Union) and Eora (a private sector initiative).

Table 1. Countries and/or country groupings retained for our study

13 Pacific Island Economies	13 major trading partners	5 regional groupings
Cook Islands, Fiji, Kiribati, Marshall Islands, Federated States of Micronesia, Nauru, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu.	Japan, China, Hong Kong, United States, Australia, New Zealand, Singapore, India, Philippines, Malaysia, Thailand, Korea, European Union.	Africa, Asia-Pacific (Other economies not already covered), Europe (Other economies not already covered),, Middle East and Central Asia, Western Hemisphere (Other economies not already covered).

Source: authors.

Before proceeding to analysis, we checked the robustness and reliability of the MRIO table by comparing total gross value-added in the thirteen PIEs with data compiled from other sources, including WEO and IMF Article IV reports.

Measuring the size of the Blue Economy in PIEs

To measure the size of the Blue Economy in our sample of thirteen PIEs, we adapt the modus operandi developed by the US' BEA (Nicolls et al. 2020), taking into account the specificities of Pacific Islands, and compute a set of descriptive statistics, including the share of marine-related activities in total gross value added. In this section, we first describe the general methodology to assess the size of the Blue Economy, before presenting key results.

Methodology

In 2020, the BEA developed a methodology to produce prototype statistics to measure the ocean's contribution to US GDP, based on supply-use tables which are part of the US' national accounts, with the ultimate aim to build a comprehensive measure of the role of the ocean in the US economy, in the shape of a "satellite account" to the national accounts. This methodology hence goes beyond simpler yet more limitative measures developed by international and regional organizations like World Bank or European Commission, which did not rely on input-output or supply-use tables, and rather focused on aggregating a small number of ocean-related industries, without including sectors which might be partially marine-related.

To develop a comprehensive measure of the Blue Economy for PIEs, we follow a logic similar to BEA's *modus operandi*, but adapting it to the specific case of PIEs and taking into account the much more limited data availability and granularity.

The **first step** is to define the geographical scope of the ocean economy. In its estimates, the BEA only includes activities which take place in the oceans within the US' exclusive economic zone, in its marginal seas (e.g. Gulf of Mexico), in the Great Lakes, and on the shorelines directly along these bodies of water. This allows the BEA to distinguish between three categories of ocean-related production: (i) direct production from the water bodies (e.g. commercial fishing); (ii) production taking place on the shores by necessity (e.g. beach house rentals); (iii) production taking place elsewhere for predominate use on the bodies of water (e.g. ship building). Contrary to the US, all PIEs covered in this paper are small island developing states (United Nations classification), in which any economic activity takes place from a short distance from the ocean. This allows us to simply define the geographical scope of the Blue Economy as the oceans and seas located within the PIEs' exclusive economic zones, as well as the whole land territory of the PIEs.[5]

The **second step** is to identify and define ocean-related activities. The ability to define this with precision hinges on the level of granularity of the input-output tables. US national accounts being very granular, with about 5,000 types of economic outputs accounted for, BEA is able to use a detailed bottom-up approach to identify marine-related activities and create ten major activity groupings for the ocean economy. In the MRIO table used for this paper, production is detailed into 135 goods and services sectors. This is the most detailed level of information at our disposal for the study. As a result, we went through the 135 sectors one by one and identified which ones were marine-related, even partially, based on an analysis of more granular definitions of each sector. Out of 135 sectors, we retained 28 sectors, considered fully or partially marine-related (Table 2).

The **third step** is to compute ocean shares for each of these sectors. For our study, given the lack of further output data granularity beyond the 135 sectoral categories, we have to make assumptions on what share of each output is effectively marine-related. For instance, the "Products of animal origin" sector covers a variety of outputs, some of which are marine-related (like coral or ambergris) and some of which are not (like feathers or mammal bristles). Out of the 28 sectors retained for our study, we assume that seven are fully marine-related (i.e. 100 percent of the output of these sectors is part of the Blue Economy). We put these seven sectors into four categories: fishing ("fish, crustaceans, molluscs, aquatic invertebrates"), ship building ("ships, boats and other floating structures"), transportation ("sea transport") and tourism (composed of "goods (travel)", "local transport services", "accommodation services", and "food-serving services").[6] For the other 21 partially marine-related sectors, we make assumptions on marine shares based on the share of fully marine-related inputs used for production. After completing this step, we are able to produce ***narrow estimates*** of the size of the Blue Economy (in percent of gross value added), which only include the 7 fully marine-related sectors, and ***wide estimates***, which also include the marine-related shares of the 21 other sectors retained for the calculation.

The **last step**, which is specific to our study, is to account for government activities which are funded by marine-related fiscal revenue. PIE governments collect significant revenue from taxes on marine-related goods and services, as well as from fishing licenses sold to foreign fishing companies to grant access to territorial waters; these types of revenue are unaccounted for in the MRIO database we use for our study.[7] Given that this marine-related revenue is used by governments to finance some of their spending, we decide to also include it in our estimates. After completing this step, we are able to produce ***expanded estimates*** of the size of the Blue Economy, which add to the wide estimates the amount of government activities which are financed by marine-related revenue.

[5] While PNG is considered a small island developing state according to the UN, as it does include very small islands, the eastern part of New Guinea island (the western part being part of Indonesia) has an area of 373,000 km^2, and distance to the ocean can reach more than 200 miles. Given that a large part of the island is still very remote and largely undeveloped (except for mining and agricultural activities), and given the inability to access more local data, we consider the whole land territory of PNG in our estimates, as for other PIEs.

[6] Considering that all tourism activities are ocean-related is a simplifying assumption and a likely overestimate. In the larger PIEs, some of the activities captured as tourism might not be ocean- or beach-related, but rather take place inland. In addition, the activities captured as tourism include the output stemming from business travelers, whose main reason for travel may not be ocean-related. Yet, we do not have sufficient data on the reasons for visit to be able to correct for that in a consistent manner across the 13 PIEs.

[7] For each of the 135 sectors, the MRIO table contains an estimate of the gross value added which, by definition, does not include taxes on products such as value-added tax (VAT) or goods and services tax (GST), or fees paid by foreign companies such as fishing licenses. It thus makes sense to also account for the spending financed by this revenue; this would not constitute a case of double-counting. The GVA data however implicitly embeds other types of taxes paid domestically (such as income taxes).

Table 2. List of fully or partially marine-related sectors

Fully marine-related sectors (7)	Partially marine-related sectors (21)
Fish, crustaceans, molluscs, aquatic invertebrates	Products of animal origin
Ships, boats and other floating structures	Oil seed, oleagic fruits, grain, seed, fruit, etc.
Sea transport	Animal, vegetable fats and oils, cleavage products, etc.
Goods (travel)	Meat, fish and seafood food preparations
Local transport services	Residues, wastes of food industry, animal fodder
Accommodation services	Salt, sulphur, earth, stone, plaster, lime and cement
Food-serving services	Essential oils, perfumes, cosmetics, toiletries
	Wadding, felt, nonwovens, yarns, twine, cordage, etc.
	Umbrellas, walking sticks, seat sticks, whips, etc.
	Pearls, precious stones, metals, coins, etc.
	Articles of iron and steel
	Nuclear reactors, boilers, machinery, etc.
	Water collection, purification and distribution
	Maintenance and repair services
	Construction
	Insurance
	Real estate
	Telecommunication services
	Computer services
	Professional and management consulting services
	Recreation and other services

Source: authors.

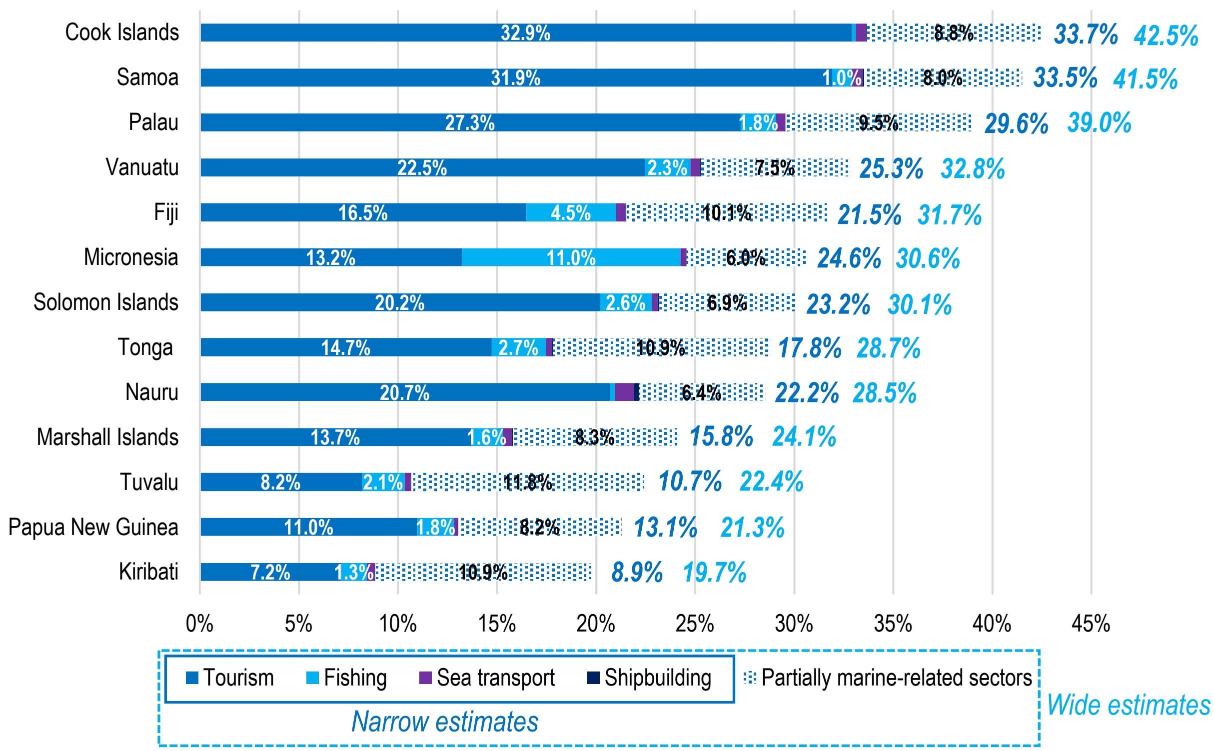
Results

In most PIEs, the Blue Economy represents between a third and a half of gross value added, whichever of our three estimates is considered.

Starting with the ***narrow estimates*** (Figure 2), we see that tourism is the number one Blue Economy sector in all PIEs, with a median weight of 16.5 percent (Fiji), but reaching more than a quarter of total gross value added in Palau, Samoa and Cook Islands. Fishing comes as a distant second in most cases: while the Pacific Ocean is a major fishing area, most of the fishing is carried out by foreign vessels. The domestic fishing sector usually does not represent a large share of gross value added in PIEs, except in Micronesia and in Fiji. Ship building and sea transportation are much smaller sectors, totaling less than 1 percent of gross value added in all 13 PIEs.

Moving on to the ***wide estimates***, we see that the additional Blue Economy activities coming from partially marine-related sectors represent between 6 and 12 percent of total gross value added, mostly from services like construction, real estate and telecommunications.

Figure 2. Narrow and wide estimates of the size of Blue Economy in PIEs
(2019, percent of total gross value added)

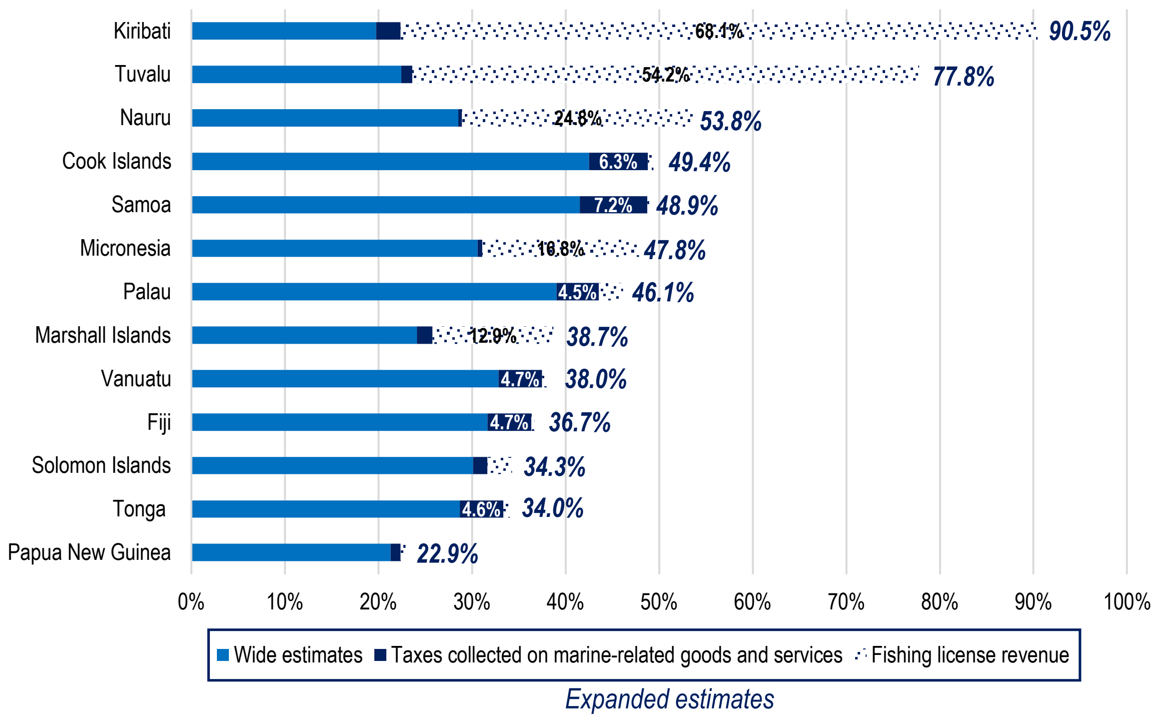


Source: authors based on EMERGING database, IMF GFS database and authorities' data.

When computing the ***expanded estimates*** by also including government activities funded by marine-related revenue (Figure 3), the size of the Blue Economy is moderately increased by about 5 to 7 percent of total gross value added in most cases, for the most part due to taxes applied to marine-related goods and services. However, for five of the PIEs – Kiribati, Tuvalu, Nauru, Micronesia and Marshall Islands – government spending, which carries a large weight in gross value added, is financed in big part by fishing license revenue. This leads to significant reshufflings of the ranking of PIEs. For instance, while Kiribati has the smallest wide estimate of the size of the Blue Economy of our PIE sample, it displays the largest expanded estimate, because of the significance of fishing license revenues in the government budget, and because the government is a major economic agent which produces most of the value added.

The database also allows us to assess for each PIE whether the Blue Economy is more export-oriented than the economy as a whole. This creates opportunities for PIEs, because growth potentialities from external demand are larger than from the much smaller domestic demand. Table 3 compares the share of exports in the GVA of Blue Economy sectors with the share of exports in total GVA. For all but two PIEs (PNG and Solomon Islands), the Blue Economy sectors are more reliant on export than the economy taken as a whole. In half of the PIEs, the Blue Economy is at least 3 times more export-oriented than the economy as a whole.

Figure 3. Expanded estimates of the size of Blue Economy in PIEs
(2019, percent of total gross value added)



Source: authors based on EMERGING database, IMF GFS database and authorities' data.

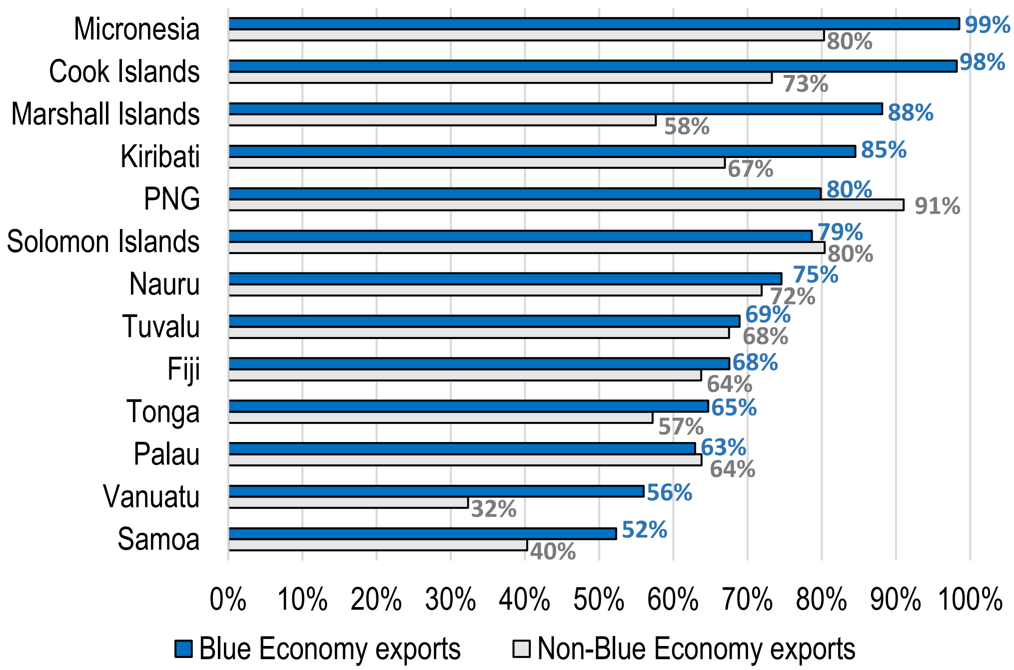
Table 3. Export orientation of the Blue Economy in PIEs
(2019)

	Share of Blue Economy exports in total exports	Ratio of Blue Economy exports to Blue Economy GVA (1)	Ratio of exports to total GVA (2)	Blue Economy export dependence ratio = (1) / (2)
Kiribati	56%	109%	17%	6.3
Marshall Islands	73%	193%	42%	4.6
Tonga	73%	90%	22%	4.1
Micronesia	99%	130%	32%	4.0
Vanuatu	91%	147%	41%	3.6
Tuvalu	35%	70%	22%	3.2
Cook Islands	81%	3%	1%	2.4
Samoa	71%	82%	39%	2.1
Fiji	41%	88%	46%	1.9
Nauru	36%	61%	37%	1.6
Palau	33%	67%	60%	1.1
Papua New Guinea	3%	8%	31%	0.2
Solomon Islands	5%	9%	38%	0.2

Source: authors based on EMERGING database.
Notes: Blue Economy estimates follow the narrow definition. The ratio of exports to GVA can be superior to 100 percent by definition, given its negative components (GVA = consumption + investment + exports – imports – (taxes on products – subsidies on products). A Blue Economy export dependence ratio of 2.0 means that exports represent a share in the Blue Economy GVA that is twice the share of export in total GVA.

A strong export orientation may however create risks too, especially if external demand is volatile and subject to shocks. In particular, concentration of exports to only a few destinations may heighten the exposure to external demand shocks. In the typical PIE, Blue Economy exports tend to be more concentrated on a handful of destinations than non-marine related exports. As shown in Figure 5, in most PIEs, the five main export destinations receive at least two thirds of all Blue Economy exports, a share which is superior (or roughly equal) to that observed in non-Blue Economy sectors in all PIEs but PNG.

Figure 4. Concentration of export destinations in PIEs
(2019, percent of exports)



Source: authors based on EMERGING database.
Note: the concentration rate is defined as the share of exports to the main five trading partners in total exports. Blue Economy estimates follow the narrow definition.

Assessing the resilience to climate change of the Blue Economy in PIEs

In this section, we assess the resilience of the Blue Economy in PIEs to a number of shocks, including climate-related. To do so, we rely on the powerful properties of input-output tables evidenced by economists Leontief and Ghosh, which allow to calculate the compounded effects of either demand or supply shocks applied to one or several sectors, based on their upstream or downstream transmission throughout the domestic and global production networks. After describing the general methodology and several caveats for our shock simulations, we select three main shocks, two of which are climate-related, and assess how they affect the Blue Economy and the economy as a whole in our set of thirteen PIEs:

1. an external demand shock in advanced economies akin to the 2008-09 global financial crisis (GFC), to assess how PIEs would be affected by a large demand shock in major trading partners;
2. a change in fish populations in the Pacific Ocean due to global warming, to assess how a regional shock on fishing activities in PIEs' territorial waters may affect the whole economy;
3. severe tropical cyclones in the Pacific Ocean, to assess how they affect the economy and whether the Blue Economy acts as a shock absorber or shock amplifier.

Methodology

MRIO tables provide detailed snapshots of global, regional and domestic production network structures, through which shocks are susceptible to propagate. To carry out the shock simulations in the following sub-sections, we mainly use a demand-driven input-output model, initially developed by Wassily Leontief, to simulate the transmission of demand shocks in the production network through backward linkages. In one instance, we also use a supply-driven input-output model, developed by Ambica Ghosh as a mirror to Leontief's model, to simulate the transmission of supply shocks in the production network through forward linkages. While these models were developed initially to be applied at a national/domestic level, the emergence of international IO tables in the 2000s has allowed the application of these models to mapping and quantifying potential global spillovers of various demand and supply shocks.

Demand-driven input-output model (à la Leontief)

Leontief's model is based on the idea that sectors respond to exogenous changes in demand by increasing or decreasing their production. When demand in sector S is altered by an exogenous shock, the demand for goods and services used as intermediate inputs in the production of S may also be affected, launching a series of backward linkages rippling through the global production network. For instance, if the demand for restaurant services decreases, this will have an impact of the demand for processed fish purchased by restaurants, which will in turn affect the demand for fish. Leontief's fundamental idea was to consider that IO tables provide very detailed snapshots of sectoral production functions, with information on which inputs are used for the production of any sector, and in which proportion. Given that all the secondary demand effects become weaker and progressively die down, the full backward linkages can be captured in one single matrix, the so-called Leontief inverse matrix.

The starting point is to compute the "technical coefficient matrix" A by dividing each cell in the intermediate transactions matrix (Figure 1) by the total output in each column. Each cell A_{ij} of this matrix can be interpreted as the quantity of input from sector i needed for the production of one unit of good/service from sector j.

In a Leontief model, the demand shock is modelled as a column vector ΔC, describing the direct (first-round) sectoral impacts of the shock. To compute the full impact of the shock (column vector ΔD), including the direct impact and the indirect backward spillovers, one can carry out the following calculation:

$$\Delta D = (I + A + A^2 + A^3 + \ldots).\Delta C$$

Given that all these coefficients in A are comprised between 0 and 1 by definition, the sum of the geometric series above converges, and can be written as:

$$\Delta D = L.\ \Delta C, \textit{ where } L = (I - A)^{-1}, \text{ the Leontief inverse matrix.}$$

In a model à la Leontief, the technical coefficient matrix is basically the equivalent of a fixed production function. In such a production function, inputs are used in a fixed proportion, without any substitution between inputs. This also means that the proportion of value added in the total output of any sector is fixed. In the case of an international IO table, this also implies no substitution between countries from where inputs originate. These assumptions can be considered valid in the short term.

Knowing this, the shock impacts obtained using a Leontief model can be interpreted as the upper-bound and immediate estimates of all direct and indirect sectoral effects from the shock, before any attempt at substitution of suppliers and buyers by firms, and before any change in government policy. While the overall shock impacts should hence be considered with caution, Leontief models provide granular insights on potential sectoral effects and on potential international spillovers in the absence of any reaction from private and public economic agents.

There has been growing literature (reviewed in Carvalho and Tahbaz-Salehi (2019)) aiming at including endogenous changes in the intermediate input shares within the production function. While there is significant potential for future research, in this paper we stick to a traditional Leontief approach for three main reasons: (i) the Leontief model is easy to implement and to replicate so as to test a number of shock scenarios; (ii) introducing endogeneity in the production function may be difficult for PIEs which struggle with data quality and availability, and would likely warrant a PIE-by-PIE approach, given the large differences in economic size and structure across our sample; (iii) in this paper, we are ultimately more interested in *relative* sectoral impacts – e.g. whether the Blue Economy sectors are more vulnerable to shocks than other non-marine sectors – than in *absolute* impacts.

Supply-driven input-output model (à la Ghosh)

Ghosh's approach can be overall qualified as mirroring the Leontief model, this time considering a supply shock and how it would propagate throughout the production network *via* forward linkages. The key idea here is that sectors would respond to exogenous changes in supply of intermediate inputs by increasing or decreasing their own production. Similarly to the Leontief model, all direct and indirect effects from the supply shock can be captured using one single matrix: the Ghosh inverse matrix.

The starting point here is to compute the "technical allocation matrix" B by dividing each cell in the intermediate transactions matrix (Figure 1) by the total output in each <u>row</u> (instead of column in the Leontief approach). Each cell B_{ij} of this matrix can be interpreted as the share of one unit of good/service from sector i that gets supplied to sector j. In a Ghosh model, the supply shock is modelled as a row vector ΔR, describing the direct (first-round) sectoral impacts of the shock. To compute the full impact of the shock (row vector ΔS), including the direct impact and the indirect backward spillovers, one can carry out the following calculation:

$$\Delta S = \Delta R.(I + B + B^2 + B^3 + \ldots)$$

Given that all these coefficients in B are comprised between 0 and 1 by definition, the sum of the geometric series above converges, and can be written as:

$$\Delta S = \Delta R.G, \textit{ where } G = (I - B)^{-1}, \text{ the Ghosh inverse matrix.}$$

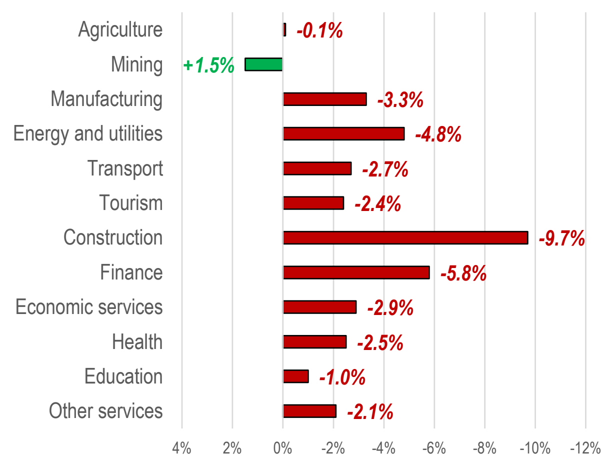
The Ghosh approach can be useful, under certain conditions, to model the forward transmission of price shocks in the cost of production (Escaith and Gonguet, 2011). However, to model real shocks, the Ghosh approach is much more contentious from an economic and theoretical standpoint,[8] and could only be envisaged in certain very specific conditions – for instance to analyze negative supply shocks on highly non-substitutable goods (and services) for which inventories can only be kept relatively low. In this paper, we use the Ghosh approach to simulate (i) the impact of a negative shock on the supply of a single sector (fishing) in PIEs; and (ii) the disruption of supply in several sectors with non-substitutable goods and services due to damage from severe cyclones. Like the Leontief model, it is assumed that there is no substitution between inputs, and no change in government policy; the results can be interpreted as the immediate and upper-bound estimates of all direct and indirect effects from a supply shock.

Shock Analysis

Shock 1. External demand shock in advanced economies

For this shock, we consider a large non-marine-related foreign demand shock in advanced economies, to test how the Blue Economy in PIEs might be affected by a severe dip in foreign demand. We choose to apply a global financial crisis (GFC)-type shock, based on the readily available literature about the first-round effects of the crisis on demand in advanced economies. From the perspective of PIEs, the GFC could affect exports to advanced economies via spillovers throughout the global production network. To calibrate our shock scenario, we rely on the estimates presented in Li and Martin (2018), which studied changes in the transmission of shocks across different sectors of the U.S. economy during the Great Recession and evaluated the cross-sectoral spillovers. The impacts on sectoral demand are considered as first-round effects, which will then propagate through global production networks. The compounded effects of the shock in PIEs can be grasped using the Leontief inverse matrix as explained above. This would however not capture the effect of the GFC on the arrival of foreign visitors in PIEs, which should also be considered in our simulation. According to the World Tourism Organization, international arrivals have decreased globally by 4 percent in 2009 due to the GFC. We estimate, based on statistics from the World Tourism Organization, that the impact of the GFC on tourism in PIEs was sharper than in the rest of the world, with international arrivals about 8 percent lower than what could have been forecast using pre-GFC trends.[9]

Figure 5. First-round impact of the GFC on sectoral demand in advanced economies
(percent of sectoral GVA)



Source: Li and Martin (2018).

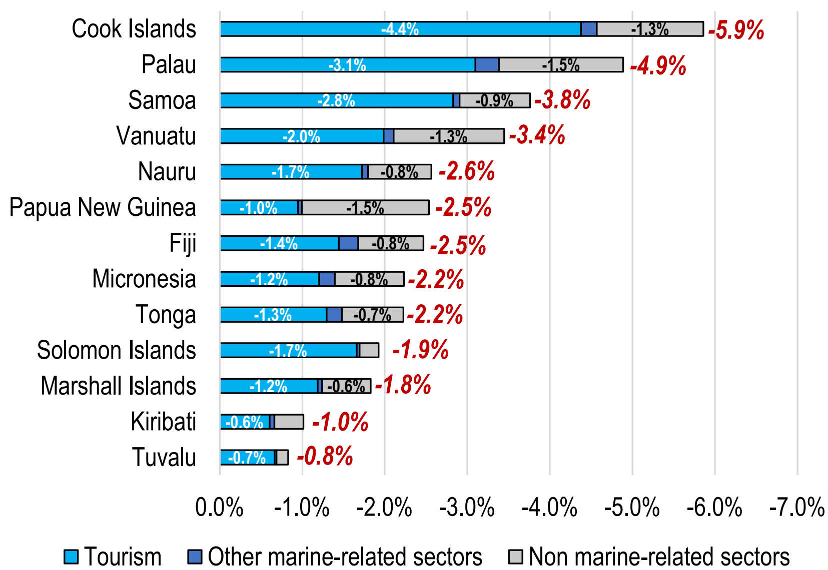
[8] For instance, it cannot be used to describe the impact of a positive real supply shock. In general, the production of a sector is not affected by increases in the supply of inputs.

[9] This estimate covers all PIEs except Nauru, for which data is not available. Total arrivals of international tourists in 2009 staying for at least one night in the PIEs reached 1.18 million, stable relative to 2008 (1.19 million). Over the 2003-2008 period, arrivals grew by 8.0 percent annually on average in the region.

In this simulation, we hence apply the combination of two shocks: (i) a GFC-type demand shock, as calibrated in Figure 5,[10] in six major advanced economies within the PIEs' main trading partners[11] – the effects of this shock will trickle upstream in the global value chain, thus affecting intermediate inputs and final goods and services exported by PIEs; (ii) a simultaneous domestic demand shock in the tourism sector of all 13 PIEs, caused by the decrease in international arrivals. While the effect of the GFC on tourism was different across PIEs, we decide to apply the average regional decrease uniformly to the tourism sector of all PIEs (- 8 percent).

The estimated losses of GVA from this shock are presented in Figure 6. While each economic crisis is different and sectoral impacts in advanced economies may vary from crisis to crisis, this simulation shows that the Blue Economy in most PIEs would be significantly affected by a GFC-type shock in advanced economies, first and foremost *via* induced effects on international travel. The decrease in international arrivals is indeed the main channel through which a GFC-type shock would affect PIEs. In all PIEs except Papua New Guinea, the majority of VA losses occur in tourism, *a fortiori* in marine-related sectors. Economies most affected by the shock are those where tourism is a major economic sector (Cook Islands, Palau, Samoa, Fiji, Vanuatu). While they are smaller, compounded effects in other sectors (mostly non-marine) feeding through the production network, both from the foreign demand shock and from the domestic tourism shock, are far from negligible; they reach above ½ percent of GVA in all but three PIEs, and are superior than 1 percent of GVA in four PIEs (Cook Islands, Palau, Vanuatu, PNG). These compounded effects however account for the majority of GVA losses in PNG, given PNG's larger and more diversified participation in global value chains.

Figure 6. Loss of GVA in PIEs from a GFC-type demand shock in advanced economies
(percent of total GVA)



Source: authors based on EMERGING database; shock calibration based on Li and Martin (2018) and World Tourism Organization statistics. Blue Economy estimates follow the wide definition. The results should be interpreted as upper-bound estimates of the induced impact of the GFC, assuming no substitution effects, no change in prices and no government support.

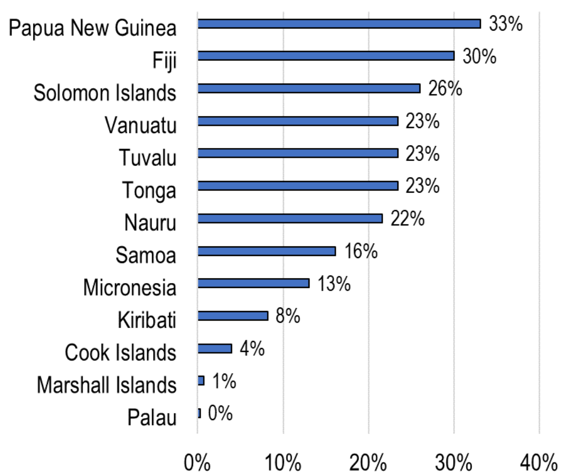
[10] Li and Martin (2018) provides a 12-sector breakdown of the impact of the GFC. For the purpose of our study, which relies on a 135-sector disaggregation level, we make the simplifying assumption that for each of the 12 sectors, the impact is uniform in all relevant subsectors.

[11] United States, Australia, New Zealand, European Union, Japan and Korea.

Yet, this simulation illustrates that while most PIEs are only minor participants in the global production network, a large demand shock akin to the GFC in advanced economies has the potential to severely affect PIEs, most notably those which rely relatively more on international tourism, a major component of the Blue Economy in PIEs. This calls for striking a balance between harnessing the growth potential from tourism and identifying diversification opportunities, including within the tourism sector itself. This could for instance include developing niche tourism which might be less affected by such financial crises (e.g. business/conference tourism, options for digital nomads, medical and scientific tourism, luxury/exclusive tourism).

Shock 2. Redistribution of fish populations in the Pacific Ocean due to climate change

Figure 7. Expected decline in commercial tuna catches by 2050 due to climate change
(percent, RCP 8.5 scenario)



Source: Bell et al. (2021).

For this shock, we consider the impact of climate change on fishing activities in the Pacific Ocean. There is growing literature on the effects of rising sea temperatures and changes in oceanic undercurrents on the distribution of fish populations across global oceans. Barange et al. (2018) estimates that global decreases in maximum fish catch potential could reach 7 to 12 percent by 2050 under a business-as-usual climate change scenario (RCP 8.5), with the biggest decreases expected in the South Pacific region.[12] According to Bell et al. (2021), under RCP 8.5, all PIEs are expected to experience a simultaneous decline in commercial tuna catches, although the magnitude of the decline may significantly vary across PIEs, depending on the location of their territorial waters. This would affect fishing yields for all PIEs' domestic fisheries, but also for foreign fishermen, who purchase fishing licenses from PIEs' governments to access territorial waters.

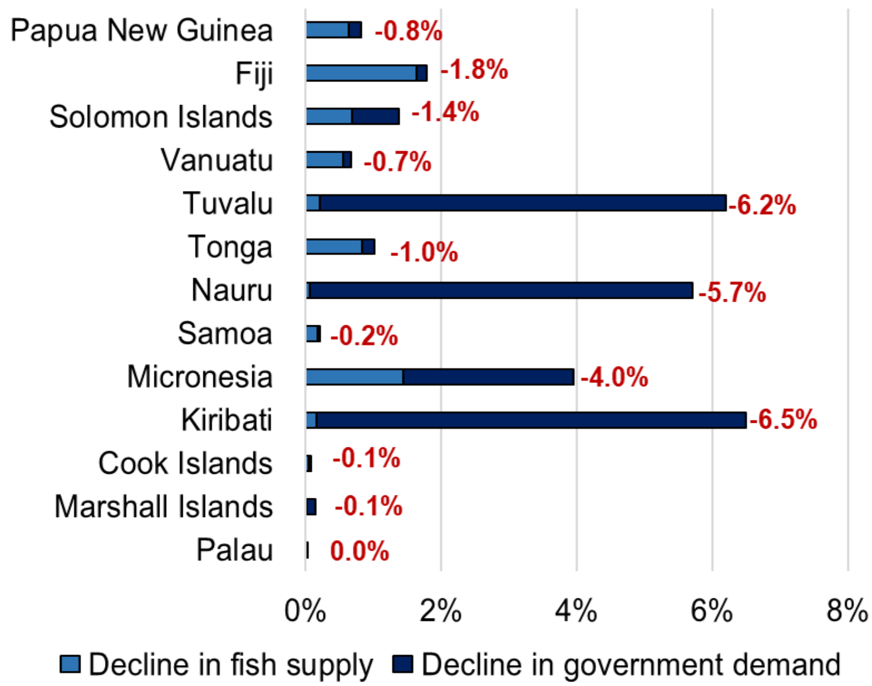
In this simulation, we hence apply, simultaneously in all thirteen PIEs, the combination of two shocks: (i) a supply shock in the domestic fisheries sector, caused by the decrease in fish catches for domestic fishermen; and (ii) a domestic demand shock stemming from a decline in government spending, due to lower collections of fishing license revenues, as foreign fisheries reduce their activities or redirect them to other territorial waters. To compute this shock scenario, we rely on country-level estimates from Bell et al. (2021) on the expected decline in commercial tuna catches by 2050 under the RCP 8.5 scenario (Figure 7), which range from close to zero in Palau to a third in Papua New Guinea. Out of the thirteen PIEs, nine are expected to see their tuna stocks decline by more than 10 percent. These estimates are used in each PIE to calibrate the first-round supply shock in domestic fisheries (e.g. the GVA from the fisheries sector in PNG is reduced by 33 percent)

[12] Representative Concentration Pathways (RCP) are four greenhouse gas concentration trajectories adopted by the UN's Intergovernmental Panel on Climate Change in 2014. RCP 8.5 refers to the concentration of carbon that delivers global warming at an average of 8.5 watts per square meter across the planet. Under that scenario, emissions continue rising throughout the 21st century. It is generally taken as the basis for worst-case climate change scenarios, and often used for predicting mid-century emissions based on current and stated policies.

and the first-round demand shock from reduced government spending (e.g. government GVA in Tuvalu is reduced by an amount corresponding to 23 percent of the fishing license revenue). As a simplifying assumption, we use estimates on the decline of commercial tuna catches as a proxy for all types of fish. While tuna species represent a large share of fish caught in PIEs' territorial waters, both in volume and in value, other fish species may be affected differently by climate change, with some possibly even benefitting from it.

The estimated losses of GVA from this regional shock on fish populations are presented in Figure 8. PIEs most affected by the shock are not necessarily those where fish catches are expected to decline the most. While PNG's fish stocks could decline by a third, its impact on total GVA remains relatively limited, given the smaller size of the domestic fisheries sector relative to the rest of the economy. PIEs most affected are rather those where the fishing sector is relatively large (such as Fiji or Micronesia) and those where governments are most reliant on fishing license revenue (such as Kiribati, Tuvalu, Nauru and Micronesia).

Figure 8. Loss of GVA from a regional negative shock on fish populations due to climate change
(percent of GVA, RCP 8.5 scenario)



Source: authors based on EMERGING database, IMF GFS database and authorities' data; shock calibration based on Bell et al. (2021). The results should be interpreted as upper-bound estimates of the impact of the changes in fish stocks, assuming no substitution effects, no change in prices and no government support.

These results assume no change in fish prices; were fish populations become more rarefied, we could expect to see fish prices increase, thus offsetting some or all of the negative volume effects. Similarly, we assume no changes in fishing license rates – though governments whose fish populations are less affected might choose to increase their rates, while governments most affected might choose to decrease theirs. We also assume that there is no immediately available alternative financing source to compensate the loss in revenue. Given that changes in fish populations are expected to be gradual, production networks, prices and government revenues would be affected as well over time, likely contributing to dampening our estimates.

Nonetheless, this simulation highlights the economic and fiscal challenges associated with exploiting a resource like fish, which can be a finite resource if it is not managed sustainably. Reliance on the fishing sector is a double-edged sword: it can be a sure source of domestic value-added and/or of fiscal revenue in the short-run, but this is only a sustainable strategy if fish remains available. In most PIEs, the loss of GVA from the impact of climate change on fish populations is at or lower than 1 percent, and fiscal consequences are limited. This can be either because the domestic fisheries sector is relatively small, or because fish stocks in their territorial waters would only be moderately affected by an increase in temperatures. However, in four PIEs depending greatly on fishing license revenue for the sustainability of their budgets, the loss is much more significant. For those, the impact of climate change on fish stocks is a major fiscal risk. On top of economic diversification, mitigation strategies include the diversification of domestic revenue sources (Sy et al. 2022), the review of pricing policies for fishing licenses, and possibly saving part of the fishing license revenue in a stabilization fund or in a fund for future generations, as could be recommended for other natural resources.

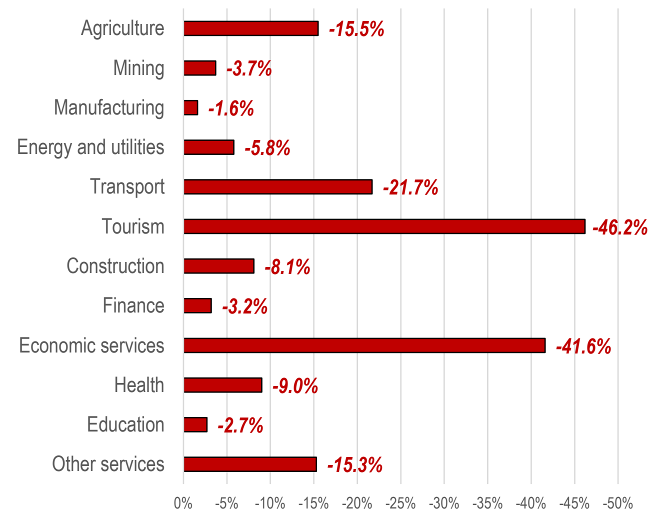
Shock 3. Tropical cyclones in the Pacific region

Despite challenges with the availability and reliability of historical data, literature broadly agrees that climate change is likely increasing the frequency of severe tropical cyclones.[13] Based on a recent literature review of more than 90 papers published over the period 2013-2021 (Knutson et al. 2021), climate change is fueling more severe and destructive cyclones; the proportion of very intense cyclones is likely to increase, compounded with increasing rates of rapid intensification and the slowing of the forward motion of cyclones. Small island states like PIEs are more vulnerable to severe cyclones, given that they are susceptible to hit large portions, if not all, of the land territory, putting human lives, livelihoods and infrastructure at high risk and affecting the economy for several months and even years (Lim and Zhou, forthcoming).

[13] However, the frequency of cyclones overall (severe or not) is likely decreasing. Recent research has shown that climate change in the 20th and early 21st centuries has so far caused a 13 percent decrease in tropical cyclones at a global level (Chand et al. 2022), and a 19 percent decrease in the South Pacific region; and most climate models project a stable or decreasing rate of cyclone occurrence going forward.

For this shock, we consider the impact of major tropical cyclones, simulated in each PIE, on the Blue Economy. The immediate impact of such weather events on sectoral supply and demand in each PIE would also trigger indirect compounded effects *via* the domestic value chain.

Figure 9. First-round sectoral impact of 2018 Gita cyclone in Tonga
(percent of GVA)



Source: authors, calibrated according to Lenzen (2019) and EMERGING database.

To calibrate the shock scenarios, we rely on a methodology proposed by Lenzen et al. (2019), using the MRIO framework to analyze the negative impacts of real-life tropical cyclones, distinguishing between the first-round (direct) effects of the cyclone and the spillover (indirect) effects due to the shock triggered by the cyclones. We apply that methodology to cyclone Gita, a severe tropical cyclone which made landfall in several PIEs in February 2018, with Tonga being the most directly hit.[14] Figure 9 provides the direct (first round) sectoral impact of cyclone Gita on gross value added in Tonga. It was the most intense tropical cyclone to hit Tonga in modern records. While the human toll of the cyclone was limited thanks to thousands of inhabitants seeking refuge in public shelters, infrastructure was severely hit by the cyclone, including the international airport, the Parliament, many schools and hotels. Road and electricity networks were seriously disrupted. Agricultural crops were also largely destroyed. The tourism sector was most affected, due to infrastructure damage and resulting lower tourist arrivals. The impact estimates presented in Figure 9 are consistent with this overview.

For our shock simulation, we assume that the first-round impact in sectors which experienced the most direct damage and destruction from the cyclone – agriculture, energy and utilities, transport, tourism and education – can be modelled primarily as a supply shock; while the first-round impact in the other sectors can be modelled primarily as a demand shock. So, in each PIE taken one by one, we apply simultaneously a supply shock and a demand shock, of a size equivalent to half the first-round impact caused by tropical cyclone Gita, as shown in Figure 9.[15] Figure 10 provides estimates of the added sectoral economic impacts of these shocks, computed using the Leontief and Ghosh inverse matrices. Figure 11 provides a breakdown of the supply-side and demand-side effects of the shock. We also compute shock multiplier effects (Table 4) by normalizing our results with the first-round impacts – hence providing a measure of which sectors are more susceptible to facing indirect spillovers from a tropical cyclone. The higher the shock multiplier effect in a given sector, the more that sector is exposed to spillover effects in the occurrence of a tropical cyclone.

These results show a relatively narrow range of total economic impacts, concentrated between 10 and 15 percent of gross value-added across most of our PIE sample. The size of the impact depends on (i) the relative weight in the economy of the sectors most directly affected by the shock (tourism, services, transport and

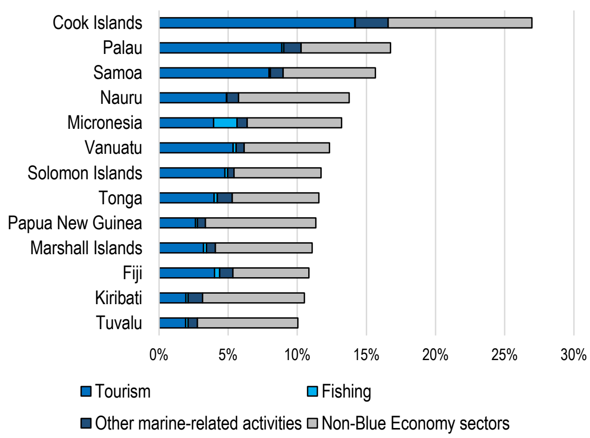
[14] Samoa and Fiji also underwent some, albeit more limited, damage from the cyclone.

[15] We assume that the direct impact of cyclone Gita in Tonga is representative of the typical direct consequences of severe tropical cyclones. Yet, each tropical cyclone is different in intensity and duration. Depending on where it hits and on existing adaptation and disaster management efforts, the direct absolute and relative economic, social and human damages may ultimately be very different from one PIE to another.

agriculture); (ii) the dependence of these sectors on domestic buyers (supply side of the shock); (iii) the reliance of these sectors on domestically-produced inputs in their production process (demand side of the shock).

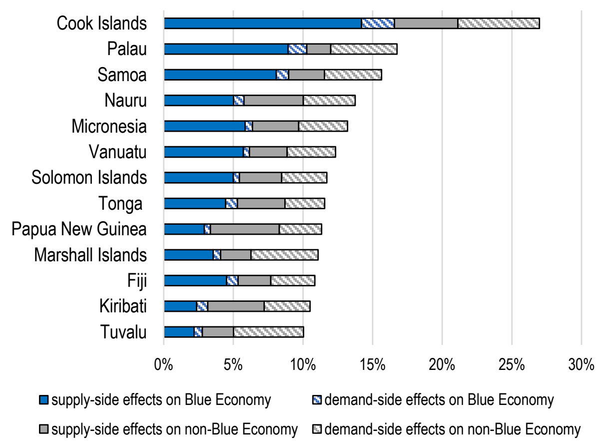
Supply-side effects dominate in all PIEs (except Tuvalu), driven by damage to tourism infrastructure and destruction of crops, and spillover effects to other sectors (Figure 11). Losses in the top three most affected PIEs – Cook Islands, Palau and Samoa – are largely driven by the supply shock in the tourism sector, given that they have the largest tourism sectors in the sample (Figure 2) and given that tourism is the most directly affected sector in the simulation (Figure 9). These are the only three PIEs in our sample where more than 50 percent of the total loss of GVA occurs in Blue sectors. In Cook Islands and Palau, this is combined with relatively large demand-side spillovers in both Blue and non-Blue sectors.

Figure 10. Total loss of GVA caused by a severe tropical cyclone (half of Gita's direct impact) in each PIE
(percent of total GVA)



Source: authors based on EMERGING database; shock calibration based on Lenzen (2019). Blue Economy estimates follow the wide definition. The results should be interpreted as upper-bound estimates of the impact of the severe cyclone, assuming no substitution effects, no change in prices and no government support.

Figure 11. Supply-side and demand-side losses of GVA caused by a severe tropical cyclone (half of Gita's direct impact) in each PIE
(percent of total GVA)



Source: authors based on EMERGING database; shock calibration based on Lenzen (2019). Blue Economy estimates follow the wide definition.

Table 4 shows that shock multiplier effects in Blue Economy sectors are lower (or roughly equal) than multiplier effects in non-Blue Economy sectors, implying that the Blue Economy is less exposed to indirect domestic spillovers from severe cyclones than non-Blue sectors. For example, in Samoa, the shock elasticity in the whole economy is 1.22, meaning that the overall impact of the shock on gross value-added is 1.22 times larger than the first-round effect described in Figure 9; multiplier effects in the Blue Economy are much smaller than in the non-Blue sectors (1.12 against 1.38).

The total economic loss estimates should be interpreted with caution, given that most PIEs are very small economies, and especially given that each future tropical cyclone will carry different impacts from those of Gita depending on where and when it hits. In addition, we are not considering the partial economic rebound which can be driven by reconstruction efforts, and we are not looking into the effects of disaster aid on mitigating the economic and social effects of such cyclones.

Yet, these results show that the most economically vulnerable PIEs to severe tropical cyclones are those with sizeable Blue Economy sectors which are more reliant on domestic suppliers and buyers. Tourism infrastructure is the sector which is most vulnerable to cyclones, via infrastructure damage and lower arrivals, and the economy is all the more vulnerable when the tourism sector also relies relatively more on locally-produced goods and services to operate. Blue Economy sectors however offer additional resilience by being less subject to spillover effects from cyclones than other sectors.

Table 4. Sectoral GVA multiplier effects caused by Gita-like tropical cyclone in each PIE

	Blue Economy	***Incl. Tourism***	**Non-Blue Economy**	**Whole economy**
Cook Islands	1.95	1.86	2.25	2.05
Fiji	1.08	1.05	1.19	1.13
Kiribati	1.26	1.18	1.39	1.35
Marshall Islands	1.08	1.02	1.10	1.09
Micronesia	1.46	1.29	1.50	1.48
Nauru	1.05	1.02	1.51	1.28
Palau	1.43	1.41	1.41	1.42
Papua New Guinea	1.09	1.03	1.58	1.39
Samoa	1.12	1.08	1.38	1.22
Solomon Islands	1.03	1.02	1.16	1.10
Tonga	1.22	1.17	1.44	1.33
Tuvalu	1.05	1.02	1.11	1.09
Vanuatu	1.05	1.03	1.09	1.07

Source: authors based on EMERGING database; shock calibration based on Lenzen (2019). Blue Economy estimates follow the wide definition. Cases where multiplier effects in the Blue Economy are lower than in non-Blue Economy sectors are highlighted in darker blue, while cases where they are slightly lower (gap of 0.2 or less) or roughly equal (+/- 0.05) are highlighted in lighter blue.

In an era when the frequency of severe cyclones is increasing, these results highlight the strategic importance of adaptation efforts to hedge Blue Economy investments from damage and from severe, long-lasting disruptions of activities, as well as all critical economic and social infrastructure and local businesses. Given the potential negative double-digit effects of such cyclones on economic growth, setting up sound and responsive disaster risk management frameworks is particularly important to mitigate the economic and social effects of the cyclone. These results also seem to indicate that an increase in local content in the domestic production structure of either Blue or non-Blue Economy sectors may only be beneficial to economic development if it is associated with adaptation efforts, especially for cyclone resilience and preparedness. Without adaptation, a local content strategy could create an additional source of vulnerability in the event of a cyclone.

Conclusion

By relying on a comprehensive international input-output database, this paper has produced estimates of the size of the Blue Economy in thirteen PIEs, some of which had never been covered in previous literature attempts. Results show that in most PIEs, Blue Economy sectors – tourism and fishing for the most part, and the fiscal revenue drawn from them – represent between a third and half of total value added, making them a critical source of economic and social development for PIEs. The beauty of the Pacific Ocean draws in hundreds of thousands of international tourists every year, making tourism the main Blue Economy sector in all PIEs. The Pacific Ocean also produces highly sought-after fish resources, which can then be sold via fishing licenses or exported to larger countries in the Asia-Pacific region and beyond. The fiscal revenue derived from these activities finances major portions of government expenditure, which then support the whole economy. And there are additional growth and prosperity opportunities to be derived from the ocean, with untapped potential in ocean-based tourism or in fishing (depending on the PIE), and possibilities to diversify sources of external demand for marine-based activities and products.

With these substantial economic benefits and opportunities also come significant risks, which PIEs need to be aware of and actively manage. This paper has illustrated, using input-output models, how a high reliance on the Blue Economy is susceptible to enhance exposure to shocks, including from climate change, especially if the risks are ignored or not taken into account in policymaking and in the decisions of economic agents.

The high dependence of the Blue Economy on foreign demand can be a source of vulnerability. In most cases, Blue Economy exports represent a large share of value added, and they are often concentrated on only a handful of trading partners. Tourism, which represents the number one economic sector in many PIEs, is dependent on international arrivals from high-income countries, which can undergo severe reductions in the event of major economic crises. By modeling a GFC-type shock in major high-income trading partners, this paper has shown that while PIEs are only minor participants in global value chains, they can suffer from large spillover effects caused by reduced international arrivals.

The exposure of the Blue Economy in PIEs to man-made pollution and climate change is another key source of vulnerability. Ocean degradation from overfishing and mass tourism, as well as emerging new activities such as deep-sea mining, could disturb the fragile balance of marine ecosystems, thus reducing the long-run economic and social benefits from the Blue Economy. While PIEs have the ability to mitigate some of the effects of human degradation by adopting environmentally conscious policies, and by finding a sustainable balance between tapping the economic potential of the Blue Economy and preserving its resources in the longer-run, they have however little to no traction on climate change. For PIEs, the consequences of climate change are almost entirely exogenous shocks.

This paper has provided specific insights on how climate change could affect the Blue Economy in PIEs, with consequences for the economy as a whole. On top of negatively affecting domestic fishing, including for local subsistence needs, the expected long-term decrease in fish populations in the Pacific Ocean due to climate change could hit fishing license revenue, thus reducing available fiscal resources for critical investment and social spending. And the likely increase in the frequency of severe tropical cyclones already exposes the tourism sector to extreme disruptions and may undermine strategies aimed at enhancing its local content.

Without consideration for these risks, PIEs might lose part or all of the economic and social benefits and growth opportunities that can be derived from the Blue Economy. Betting on the Blue Economy for longer-term development hence requires a carefully balanced and sustainable approach to managing these risks, with diversification and adaptation at its core.

- Diversification opportunities, including within the Blue Economy itself, can help reduce exposure to risk. This means diversification in terms of products, towards product lines less sensitive to external demand shocks and with an increased value-added content – for example by setting up fish processing plants, attracting outsourced services, or developing niche tourism (higher-end tourism, scientific and medical tourism, eco-tourism). This also means diversification in terms of destinations, by exploring new export markets, diversifying the pool of foreign trading partners and the flags of foreign fishing vessels, expanding flights and doing targeted advertising for tourism in new markets. These policy options all take time and investment, as well as concurrent reforms to create an enabling business environment.

- Adapting to climate change is critical to the sustainability of the Blue Economy, so as to preserve its infrastructure and local content in the event of violent tropical cyclones. Adaptation is a key requirement for successful diversification strategies. Without adaptation, Blue growth strategies will be relentlessly disrupted, due to increasing frequency of severe cyclones and expected impact on sea levels and temperatures. Promoting infrastructure that is both climate-resilient and ocean-friendly is essential. This means ensuring that new and existing investment projects systematically embed cyclone-resilience and ocean protection as part of their design and maintenance.

Several domestic fiscal policy mechanisms could help enhance sustainability and create fiscal space for these priorities, and could be areas for future research – including on (i) designing improved pricing policies for fishing licenses, (ii) ensuring that government budgets effectively contribute to more sustainable marine activities, and (iii) embedding ocean sustainability and adaptation obligations in new infrastructure investment regulation. While fiscal revenue from the Blue Economy is used to cover essential spending in many PIEs, saving some of it for use by future generations could be explored, to help offset the effects of longer-term trends regarding decreasing fish populations and increased frequency of severe tropical cyclones.

Ultimately however, ensuring the sustainability of the Blue Economy will generate very large adaptation costs which PIEs cannot afford on their own. International support and enhanced access to climate finance for both private and government entities will remain critical in that respect. And on a broader scale, regional and international cooperation remain key to prevent human degradation of the ocean and mitigate the consequences of climate change on marine ecosystems.

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Size and resilience of the Blue Economy in Pacific Island economies

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