

Article

Economic impacts of mangrove ecosystem rehabilitation through an input-output analysis approach

Shella Selvia Putri*, Saharuddin Didu, Umayatu Suiroh Suharto, Rah Adi Fahmi Ginanjar, Togi Haidat Mangara

Department of Development Economics, Faculty of Economics and Business, Universitas Sultan Ageng Tirtayasa, Serang, Indonesia

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Corresponding Author :

Shella Selvia Putri
Department of Development Economics,
Faculty of Economics and Business,
Universitas Sultan Ageng Tirtayasa, Serang,
Indonesia
Email : shellaselviaputri3443@gmail.com

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Keywords : mangrove rehabilitation; input-output analysis; sectoral output; employee compensation; gross operating surplus.

Abstract

Mangrove rehabilitation can support coastal restoration while generating economic activity through public expenditure and interindustry linkages. This study estimates the economic effects of mangrove rehabilitation spending in Indonesia on sectoral output, employee compensation, and gross operating surplus. A quantitative simulation uses the 2020 Indonesian domestic input-output table at basic prices, comprising 185 products. Rehabilitation expenditure is introduced as a final demand shock, and its effects are traced through the Leontief framework and corresponding income coefficients. The reported results indicate positive economic responses across the selected products, with agricultural, forestry, and fisheries services recording the largest changes in all three indicators. Banking services rank second, followed by wood, shrimp and other crustaceans, and fish. These findings suggest that the distribution of spending and existing production linkages shape the economic responses associated with rehabilitation expenditure. Policy should therefore combine ecological restoration priorities with transparent expenditure allocation, stronger local supply chains, and monitoring of income distribution. However, the estimates represent expenditure effects rather than measured ecological recovery or demonstrated improvements in household welfare. Fixed technical coefficients, the use of a historical economic structure, and the absence of spatial and ecological dynamics limit interpretation. Future research should update production relationships and integrate environmental outcomes.

Introduction

Coastal ecosystem degradation creates interconnected environmental and economic challenges for Indonesia. Mangrove loss can weaken coastal protection, reduce habitat quality, and threaten livelihoods dependent on coastal resources. These consequences make mangrove conservation and rehabilitation relevant to both environmental management and economic development. [Menéndez et al. \(2020\)](#) demonstrate the substantial flood protection benefits provided by mangroves, while [Nagelkerken et al. \(2008\)](#) explain their habitat functions for terrestrial and marine fauna. Maintaining these functions is particularly important for communities whose economic activities depend on fisheries and other coastal resources.

Mangroves also play an important role in climate change mitigation through carbon storage in vegetation and soils. [Donato et al. \(2011\)](#) identify mangroves among the most carbon-rich tropical forests, while [Alongi \(2014\)](#) explains the processes supporting carbon cycling and storage within these ecosystems. In Indonesia, [Murdiyarso et al. \(2015\)](#) highlight the mitigation potential of protecting mangrove carbon stocks and preventing emissions associated with ecosystem conversion. These findings establish the importance of mangroves without implying that all mangrove sites store carbon at the same rate or that rehabilitation immediately restores the carbon stocks of intact forests.

Despite these ecological functions, Indonesian mangroves face pressures from land conversion and competing coastal uses. [Murdiyarso et al. \(2015\)](#) identify aquaculture development as an important historical driver of mangrove loss. Such changes can generate economic consequences beyond the converted land itself. [Yamamoto \(2023\)](#), examining the mangrove-fishery relationship in Indonesia, provides evidence connecting ecosystem degradation with adverse fisheries-related welfare outcomes. Mangrove management therefore involves decisions about the distribution of economic benefits and environmental costs across sectors and communities.

Rehabilitation seeks to restore degraded ecosystem conditions and support the recovery of mangrove functions. Indonesia's Manual Pemulihan Ekosistem Mangrove provides guidance for planning and implementing ecosystem recovery activities ([Kementerian Lingkungan Hidup dan Kehutanan, 2023](#)). This institutional source replaces the incomplete author label "Serial" in the original draft. Rehabilitation should also be distinguished from planting alone: improvements in vegetation cover require appropriate site conditions, maintenance, and monitoring before ecological recovery can be established.

To contextualize the need for rehabilitation, Figure 1 presents changes in the recorded area of primary and secondary mangrove forest in Indonesia during 2019–2023. The distinction between these categories provides an initial overview of land-cover dynamics and supports consideration of conservation and rehabilitation needs.

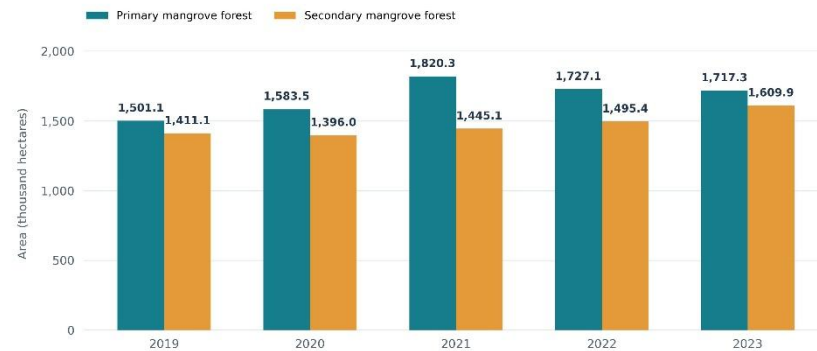


Fig 1.

Primary and Secondary Mangrove Forest Cover in Indonesia, 2019–2023

Source: Badan Pusat Statistik, annual

The series presented in Figure 1 indicates fluctuations in primary mangrove forest cover and an increase in secondary mangrove forest cover over the observation period. These patterns suggest changes in the composition of recorded mangrove cover, but they do not independently establish the success of rehabilitation programmes. An increase in secondary forest area may reflect vegetation recovery, changes in land-cover classification, or transitions between forest categories. Accordingly, interpreting these trends requires information on mapping consistency, ecosystem condition, and the locations of rehabilitation activities. The figure provides descriptive context rather than a direct measure of programme effectiveness.

The rehabilitation literature further emphasizes that ecosystem recovery depends on more than changes in forest area. [Murdiyarto and Ambo-Rappe \(2022\)](#) discuss coastal rehabilitation in relation to climate mitigation and subnational emissions reduction, highlighting the relevance of mangrove management to broader development objectives. [Villarreal-Rosas et al. \(2024\)](#) demonstrate the value of integrating socioeconomic and ecological information into restoration planning. Together, these perspectives suggest that rehabilitation priorities should consider ecological suitability, community conditions, and economic opportunities rather than relying exclusively on planting targets or expenditure totals.

An additional policy question concerns the economic activity generated by rehabilitation spending itself. Government expenditure on rehabilitation creates demand for goods and services, which can stimulate production directly and through purchases from supplying industries. This expenditure channel is analytically distinct from the benefits produced by a recovering ecosystem. Payments for rehabilitation activities may generate output and employee compensation during programme implementation, whereas improvements in fisheries productivity, coastal protection, and carbon storage may emerge over different periods. Distinguishing these channels helps prevent expenditure effects from being interpreted as evidence of ecological recovery or improvements in household welfare.

Input–output analysis provides a framework for examining the expenditure channel. [Leontief \(1986\)](#) describes an economy as a system of interconnected production activities in which the output of one industry supplies inputs to others. Building on this framework, [Miller and Blair \(2022\)](#) explain how changes in final demand can be translated into direct and indirect production requirements. Applied to rehabilitation expenditure, the approach can identify how an initial spending allocation propagates through existing production relationships and generates associated changes in output and income components.

However, input–output estimates describe responses under specified assumptions rather than observed causal outcomes. Fixed technical coefficients imply that production relationships remain unchanged, while the standard demand-driven framework does not explicitly model price

adjustments, resource constraints, or ecological recovery. These limitations are important when applying Indonesia's 2020 input–output structure to a subsequent rehabilitation expenditure scenario. The table published by [Badan Pusat Statistik \(2025\)](#) provides the accounting foundation for the analysis, but the estimated responses remain conditional on the economic structure represented by that table.

The literature discussed above establishes the ecological importance of mangroves, their connections with coastal livelihoods, and the need to integrate socioeconomic considerations into rehabilitation planning. A complementary analytical need is to examine how rehabilitation expenditure is distributed through national production networks and how the resulting economic responses differ across products. In particular, output expansion alone provides an incomplete account of these responses because employee compensation and gross operating surplus represent different components of income generation. Examining all three indicators offers a more informative basis for assessing the economic implications of rehabilitation spending.

Accordingly, this study estimates the effects of mangrove rehabilitation expenditure in Indonesia on sectoral output, employee compensation, and gross operating surplus using the 2020 domestic input–output table at basic prices, comprising 185 products. Particular attention is given to agricultural, forestry, and fisheries services; banking services; wood; shrimp and other crustaceans; and fish. The study contributes an assessment of the production and income responses associated with the expenditure scenario. Its findings are intended to support transparent budget evaluation and coordination between rehabilitation activities and domestic supply chains, while recognizing that ecological effectiveness and local welfare outcomes require separate assessment.

Literature Review

Public Expenditure and the Economic Rationale for Mangrove Rehabilitation. Government intervention in mangrove rehabilitation can be explained through public goods and externality theory. [Samuelson \(1954\)](#) establishes the theoretical foundation for collective consumption goods whose benefits cannot be allocated through ordinary market transactions alone. Mangrove ecosystem services, including coastal protection and climate regulation, exhibit public good characteristics because their benefits extend beyond the individuals or organizations financing conservation. Consequently, private incentives may be insufficient to maintain these services at socially desirable levels.

[Stiglitz and Rosengard \(2015\)](#) explain that public expenditure can address market failures arising from externalities and the inadequate provision of public goods. Applied to mangrove rehabilitation, this perspective provides a rationale for public financing where ecosystem recovery generates benefits that implementing organizations cannot fully capture. However, the justification for intervention does not establish that every rehabilitation project is effective. Its performance depends on ecological suitability, implementation quality, and the relationship between expenditure and intended outcomes.

Mangrove resources also require attention to collective governance. Although coastal protection may have public good characteristics, extractive resources such as fish and wood can be depleted through competing uses. [Ostrom \(1990\)](#) demonstrates the importance of institutions and collective action in managing common-pool resources. This distinction suggests that rehabilitation financing should be accompanied by arrangements governing access, maintenance, and resource use. Public expenditure and community governance therefore represent complementary components of ecosystem management.

Natural Capital and Ecosystem Services. The natural capital perspective treats ecosystems as assets that support economic activity and human well-being. [Dasgupta \(2021\)](#) emphasizes that economic production depends on nature and that conventional measures of economic performance can overlook changes in ecological assets. Mangrove rehabilitation can consequently be understood as an effort to maintain or restore productive natural capital, rather than solely as an expenditure programme.

[Barbier et al. \(2011\)](#) distinguish the ecological functions of coastal ecosystems from the services and benefits derived from them. This distinction is important because restoring vegetation does not automatically produce an immediate or uniform economic return. Benefits depend on ecological processes, connections with adjacent habitats, and the presence of people and businesses able to use the resulting services.

For the present study, natural capital theory establishes the broader rationale for rehabilitation, while input–output analysis addresses a narrower question: how rehabilitation expenditure generates production and income requirements through existing economic relationships. The estimated expenditure effects should therefore be distinguished from the value of recovered

ecosystem services. Carbon storage, avoided flood losses, and changes in fisheries productivity require additional ecological and economic measurements.

Input–Output Analysis and Intersectoral Dependence. Input–output analysis represents an economy as a system of production activities connected through purchases and sales. Each activity uses inputs supplied by other activities and produces goods or services allocated to intermediate use or final demand. Cahyono and Sumargo (2005) explain how input–output tables organize these transactions and provide a framework for analysing intersectoral dependence.

The analytical foundation is the relationship between output, intermediate requirements, and final demand. Leontief (1986) expresses this relationship through a system of linear production equations. In its standard demand-driven form, the model is written as:

$$x = Ax + f$$

where (x) denotes gross output, (A) contains technical input coefficients, and (f) represents final demand. Under the relevant mathematical conditions, the output required to satisfy final demand is:

$$x = (I - A)^{-1}f$$

The Leontief inverse, $((I - A)^{-1})$, captures direct and indirect production requirements. Accordingly, an increase in final demand associated with rehabilitation expenditure generates additional output requirements in the products receiving expenditure and their suppliers.

Akbar et al. (2023) illustrate the application of the Leontief model to calculate sectoral output requirements in Southeast Sulawesi. Their study supports the operational relevance of the framework for tracing production relationships, although it does not provide direct evidence about mangrove rehabilitation. More broadly, ten Raa (2005) situates input–output analysis within the economics of production and intersectoral allocation.

Domestic Transactions and Valuation. The distinction between domestic and total transactions is important when estimating economic effects within Indonesia. A domestic transaction table identifies inputs supplied by domestic producers, allowing the analysis to separate domestic production requirements from imported inputs. Eurostat (2008) explains the construction and interpretation of supply, use, and input–output tables, including the treatment of imports and valuation adjustments.

Basic prices must also be distinguished from purchasers' prices and producers' prices. These valuation concepts differ in their treatment of taxes, subsidies, and distribution margins. The System of National Accounts 2008 provides the accounting framework for these distinctions (European Commission et al., 2009). Consistency between the valuation of expenditure and the input–output table is therefore necessary to avoid attributing taxes, margins, or imported purchases incorrectly to domestic production.

Using Indonesia's domestic transaction table at basic prices enables rehabilitation expenditure to be examined through domestic production relationships. However, expenditure must first be allocated to appropriate product categories and adjusted consistently with the table's accounting conventions. These allocation choices influence the resulting distribution of estimated effects.

Output, Employee Compensation, and Gross Operating Surplus. Gross output measures the value of production generated across activities, including intermediate transactions. It is therefore different from gross domestic product or value added. Summing additional output across products captures production requirements throughout the supply chain, but it does not provide an equivalent measure of additional national income because intermediate production is included.

Employee compensation and gross operating surplus provide complementary information about income generation. Under the national accounting framework, compensation of employees includes remuneration payable by employers in return for work, including relevant employer social contributions. Gross operating surplus represents the operating surplus generated by production before deducting consumption of fixed capital; it is not equivalent to company net profit or cash available for distribution (European Commission et al., 2009).

Miller and Blair (2022) explain how income coefficients can extend an input–output model to estimate income components associated with changes in output. Let (w_i) represent employee compensation per unit of output and (s_i) represent gross operating surplus per unit of output. The corresponding product-level changes can be expressed as:

$$\Delta W_i = w_i \Delta x_i,$$

$$\Delta S_i = s_i \Delta x_i.$$

These relationships show why the product recording the largest output response does not necessarily have the highest compensation or operating surplus per unit of output. Differences in production structure and income coefficients affect how expenditure translates into each indicator. Moreover, employee compensation should not be interpreted as the number of jobs created without additional employment coefficients.

Production Linkages and the Distribution of Expenditure Effects. Backward linkages describe the input requirements generated when an activity expands production. A rehabilitation-related purchase can therefore stimulate suppliers of materials, transport, equipment, and other services. Forward linkages describe the importance of a product as an input into downstream production. These concepts offer complementary perspectives on intersectoral relationships, but they should not be treated as interchangeable.

In the standard demand-driven Leontief model, the expenditure simulation primarily traces production requirements through the input supply chain. Forward linkage indicators may provide additional structural information, but a larger final demand shock does not independently establish that ecological improvements have increased downstream productive capacity. Miller and Blair (2022) emphasize the importance of matching the analytical model to the economic mechanism being investigated.

The distribution of simulated effects depends on both the initial allocation of expenditure and the production structure represented in the table. A product may record a large response because it receives a substantial share of the initial expenditure, because its supply chain is strongly connected to other activities, or both. Consequently, ranking products by the absolute size of their simulated responses does not establish which product has the greatest multiplier or offers the highest return per unit of expenditure.

Model Assumptions and Interpretation. The standard input–output model assumes fixed technical coefficients and proportional relationships between inputs and output. It does not endogenously represent substitution between inputs, changes in relative prices, or capacity constraints. Eurostat (2008) and ten Raa (2005) provide foundations for understanding these production relationships, while Miller and Blair (2022) discuss their implications for applied analysis.

These assumptions make the model useful for transparent expenditure scenarios, but they also limit interpretation. Applying a historical table to a later spending programme assumes that the represented production relationships remain sufficiently relevant. Changes in technology, import dependence, and sourcing patterns may alter the actual response. The model also does not automatically incorporate the ecological processes through which rehabilitated mangroves influence coastal production over time. Accordingly, the present study estimates conditional production and income responses to rehabilitation expenditure. It does not directly test ecological recovery, establish causal improvements in household welfare, or evaluate the full social return on rehabilitation investment.

Analytical Propositions. Because the study uses a deterministic input–output simulation rather than statistical estimation, analytical propositions are more appropriate than hypotheses expressed in terms of statistical significance. Under a productive Leontief system with nonnegative domestic input coefficients, a nonnegative final demand shock generates nonnegative output requirements. Associated compensation and surplus responses depend on the relevant income coefficients.

The analysis is therefore guided by the following propositions:

P1: Mangrove rehabilitation expenditure generates additional domestic output requirements in recipient products and their connected suppliers.

P2: The resulting output changes generate employee compensation according to the compensation coefficients of the affected products.

P3: The resulting output changes generate gross operating surplus according to the operating surplus coefficients of the affected products.

These propositions organize the examination of expenditure transmission across products and income components. Their interpretation remains conditional on the expenditure allocation, accounting consistency, and fixed production relationships used in the simulation.

Methods

Research Design and Data Sources. This study employs a quantitative approach using secondary data to analyse the economic effects of mangrove rehabilitation expenditure in Indonesia. The analysis covers three outcomes: changes in product output, employee compensation, and gross operating surplus.

The data comprise the 2020 Indonesian domestic transaction input–output table at basic prices, covering 185 products and expressed in million Indonesian rupiah, obtained from [Badan Pusat Statistik \(2025\)](#). Realized mangrove rehabilitation expenditure is obtained from the Ministry of Environment and Forestry's 2023 performance report. The expenditure scenario is constructed by accumulating the relevant programme expenditure components identified in that report. Microsoft Excel is used to calculate the technical coefficient matrix, identity matrix, Leontief inverse, and the resulting changes in output, employee compensation, and gross operating surplus.

Input–Output Model. The study applies a demand-driven input–output model to trace the economic responses associated with rehabilitation expenditure. Following Leontief (1986) and Miller and Blair (2022), the relationship between production and final demand is expressed as:

$$X = AX + F$$

where (X) is the output vector, (A) is the technical coefficient matrix, and (F) is the final demand vector. Each technical coefficient is calculated as:

$$a_{ij} = \frac{z_{ij}}{X_j}$$

where (z_{ij}) represents the intermediate input supplied by product (i) to product (j) , and (X_j) denotes the total output of product (j) . Rearranging Equation (1) produces:

$$X = (I - A)^{-1}F$$

where (I) is the identity matrix and $(I - A)^{-1}$ is the Leontief inverse.

Estimation of Economic Responses. Realized mangrove rehabilitation expenditure is introduced as a shock to final demand. The resulting output change is estimated as:

$$\Delta X = (I - A)^{-1}\Delta F$$

where (ΔF) represents the rehabilitation expenditure shock and (ΔX) denotes the corresponding output response. Changes in employee compensation and gross operating surplus are subsequently calculated using their respective coefficient matrices and the estimated output changes.

The results are examined in monetary terms and percentages, with particular attention to agricultural, forestry, and fisheries services; banking services; wood; shrimp and other crustaceans; and fish. These products are compared to identify differences in their estimated output, compensation, and surplus responses. The model assumes fixed technical coefficients and proportional relationships between input requirements and output. Consequently, the estimates describe economic responses under the production structure represented by the 2020 table. They should be interpreted as simulated expenditure effects rather than direct measurements of ecological recovery or observed economic growth.

Result and Discussion

Estimated Changes in Output, Employee Compensation, and Gross Operating Surplus. The input–output simulation estimates the economic responses associated with introducing mangrove rehabilitation expenditure into final demand. The results cover changes in gross output $((\Delta X))$, employee compensation $((\Delta W))$, and gross operating surplus $((\Delta S))$. Table 1 presents the reported monetary responses for the five products examined in detail.

Table 1. Reported Economic Responses to Mangrove Rehabilitation Expenditure

Product code	Product	Output change, ΔX	Employee compensation change, ΔW	Gross operating surplus change, ΔS
30	Agricultural, forestry, and fisheries services	108,370.317	49,417.174	99,928.223
170	Banking services	2,689.833	3,464.951	5,714.247
31	Wood	53.710	29.863	45.838
34	Shrimp and other crustaceans	30.827	8.749	19.953
33	Fish	17.871	6.350	13.764

Source: Authors' calculations, reproduced from the original manuscript.

All five products record positive reported responses across the three indicators. Agricultural, forestry, and fisheries services have the largest values, followed by banking services, wood, shrimp and other crustaceans, and fish. This ordering is consistent across the output, compensation, and surplus columns.

The largest reported output response is IDR 108,370.317 million for agricultural, forestry, and fisheries services, equivalent to approximately IDR 108.370 billion. Banking services record IDR 2,689.833 million, while the remaining three products each record output changes below IDR 54 million. These estimates indicate substantial differences in the scale of the reported production responses among the selected products.

The compensation column follows a similar pattern. Agricultural, forestry, and fisheries services record IDR 49,417.174 million, compared with IDR 3,464.951 million for banking services. Wood, shrimp and other crustaceans, and fish record considerably smaller monetary responses. These figures represent reported changes in compensation rather than employment counts or changes in individual wages. Gross operating surplus is also highest for agricultural, forestry, and fisheries services, at IDR 99,928.223 million, followed by banking services at IDR 5,714.247 million. Fish records the smallest reported response, at IDR 13.764 million. These amounts are simulation outputs and should not be described as budget allocations or observed company profits.

Reported Percentage Distribution. The monetary estimates establish the relative scale of the reported responses. To complement these values, Table 2 consolidates the percentage figures presented separately in the original manuscript. The percentages are retained as reported because their calculation denominator is not specified in the supplied text.

Table 2. Reported Percentages Associated with the Economic Responses

Product code	Product	ΔX (%)	ΔW (%)	ΔS (%)
30	Agricultural, forestry, and fisheries services	76.456	68.172	71.095
170	Banking services	1.898	4.780	4.065
31	Wood	0.038	0.041	0.033
34	Shrimp and other crustaceans	0.022	0.012	0.014
33	Fish	0.013	0.009	0.010

Source: Authors' calculations, reproduced from the original manuscript.

Agricultural, forestry, and fisheries services record the highest percentage in every column: 76.456% for output, 68.172% for compensation, and 71.095% for gross operating surplus. Banking services rank second, with reported percentages of 1.898%, 4.780%, and 4.065%, respectively. Each remaining product records a percentage below 0.05% across all three indicators. The reported results therefore show a consistent concentration in agricultural, forestry, and fisheries services among the products examined. However, this ranking describes the absolute responses generated under the specified expenditure scenario. It does not establish which product has the largest multiplier per unit of expenditure or the highest ecological return. The positive values are interpreted as responses generated by the input–output simulation. They do not constitute statistical hypothesis tests, and no claim of statistical significance is made.

Discussion

Distribution of the Reported Economic Responses. The simulation reports positive output, employee compensation, and gross operating surplus responses across the five selected products. Agricultural, forestry, and fisheries services consistently record the largest responses, followed by banking services, wood, shrimp and other crustaceans, and fish. This pattern suggests that rehabilitation expenditure is transmitted unevenly through the production relationships represented in the input–output table. However, interpretation of the compensation and surplus results remains provisional until their consistency with the output estimates has been verified.

The concentration in agricultural, forestry, and fisheries services is consistent with the operational character of rehabilitation activities. Such activities may require nursery preparation, planting, maintenance, and other supporting services. Nevertheless, the simulation does not independently identify which activities account for the reported response. The size of the estimate reflects the expenditure allocation and production coefficients used in the model, rather than direct evidence that any particular rehabilitation activity generated the largest economic benefit. Leontief (1986) and Miller and Blair (2022) explain that output responses depend on both the initial demand stimulus and the intermediate production requirements associated with it. Consequently, a large

absolute response does not necessarily indicate a large multiplier per unit of expenditure. Establishing that distinction would require comparing the estimated responses with the expenditure initially assigned to each product.

Responses in Banking Services and Wood. Banking services rank second among the selected products. Within an input–output framework, this result indicates a connection between the expenditure scenario and demand for banking services through the production system. It does not establish that banks increased lending to rehabilitation projects, introduced green financial instruments, or expanded credit to coastal businesses. These mechanisms would require additional financial and institutional data.

The distinction matters because the original manuscript interprets the simulated banking response partly through financing activities. Although public expenditure and financial intermediation can support environmental programmes, the current model estimates production requirements rather than changes in credit availability. [Stiglitz and Rosengard \(2015\)](#) provide a broader rationale for government intervention in activities generating social benefits, but the effectiveness of particular financing arrangements cannot be inferred from the banking output estimate alone. The smaller response for wood likewise represents a connection within the expenditure and production system. It should not be interpreted as evidence of increased mangrove harvesting or improved timber yields. The product category does not identify the ecological origin of the wood supplied. Distinguishing materials purchased for rehabilitation from products obtained from restored ecosystems would require more detailed procurement and sourcing information.

Fisheries Responses and Ecological Benefits. Shrimp and other crustaceans and fish record relatively small responses compared with the service products. These estimates should be understood as expenditure-related production responses rather than measurements of the ecological contribution of mangroves to fisheries. A small response in the present simulation does not imply that fisheries receive little benefit from ecosystem rehabilitation. [Nagelkerken et al. \(2008\)](#) describe the habitat functions of mangroves for numerous species, while [Barbier et al. \(2011\)](#) explain how coastal ecosystem functions contribute to economically valuable services. [Yamamoto \(2023\)](#) further demonstrates the relevance of the mangrove–fishery relationship to welfare outcomes in Indonesia. These studies establish the importance of ecological connections that are not explicitly represented in the present expenditure simulation.

Recovering habitat quality may influence fisheries through changes in species abundance, survival, and access to suitable nursery areas. However, the timing and magnitude of these changes depend on local ecological conditions and cannot be derived from fixed monetary input coefficients alone. The fisheries estimates therefore capture a different mechanism from the longer-term productivity benefits discussed in the ecological literature. This distinction also explains why the reported product rankings should not determine rehabilitation priorities by themselves. Products with small expenditure responses may still be associated with substantial ecological or livelihood benefits. [Villarreal-Rosas et al. \(2024\)](#) support integrating socioeconomic and ecological information when selecting restoration priorities, rather than relying on a single economic indicator.

Employee Compensation and Gross Operating Surplus. Examining compensation and gross operating surplus alongside output is conceptually useful because production expansion and income generation describe different outcomes. Under consistent accounting, these indicators help identify how additional production is associated with remuneration to employees and operating income. The national accounting framework distinguishes both components from gross output and from measures of household welfare or corporate net profit ([European Commission et al., 2009](#)).

However, the reported estimates require reconciliation before their distributional implications can be assessed confidently. In particular, the compensation and surplus values for banking services each exceed its reported output change. Several other products also show combined compensation and surplus responses exceeding their output response. These relationships warrant checking the coefficient denominators, matrix operations, product mapping, and monetary units used in the calculations. Accordingly, the current results do not establish improvements in employee productivity, motivation, or household living standards. Nor do they demonstrate increased profitability for individual businesses. Those interpretations would require consistent estimates and additional evidence about employment, wages, costs, and the distribution of income among recipients.

Policy Implications and Analytical Boundaries. The analysis provides a framework for considering rehabilitation expenditure as a source of domestic demand. Its policy value lies in tracing potential production connections and identifying where further examination of income generation is

needed. However, expenditure-related economic activity should complement ecological objectives rather than substitute for evidence of rehabilitation effectiveness.

Samuelson (1954) and Stiglitz and Rosengard (2015) provide a rationale for public financing where environmental benefits are not adequately supplied through markets. Ostrom (1990) adds that resource governance and collective action influence the management of shared resources. Together, these perspectives suggest that budget allocation, implementation arrangements, and community participation should be considered alongside the economic responses estimated by the model. Rehabilitation evaluation should therefore combine expenditure monitoring with indicators of ecological recovery and local benefit distribution. Dasgupta (2021) emphasizes the dependence of economic activity on natural capital, reinforcing the need to assess whether spending maintains or restores ecosystem assets. Output expansion alone cannot establish that this objective has been achieved.

Finally, the estimates remain conditional on the 2020 production structure, the expenditure allocation, and fixed technical coefficients. They do not account explicitly for subsequent changes in prices, technology, sourcing patterns, or ecological conditions. Once the reported calculations have been reconciled, future analysis could strengthen the assessment by updating production relationships, documenting the expenditure allocation transparently, and linking the economic simulation with site-specific ecological and household data.

Conclusion

This study uses Indonesia's 2020 domestic input–output table at basic prices, covering 185 products, to estimate the economic responses associated with mangrove rehabilitation expenditure. The reported simulation indicates positive changes in output, employee compensation, and gross operating surplus across the five selected products, with agricultural, forestry, and fisheries services recording the largest responses and fish the smallest. These findings suggest that rehabilitation spending can generate economic activity through domestic production linkages, although the compensation and surplus estimates require accounting reconciliation before definitive conclusions are drawn. Policy should combine transparent expenditure allocation with ecological suitability, community participation, and monitoring of locally retained benefits. Support for fisheries processing, small business development, and ecosystem-compatible tourism may complement rehabilitation, but product rankings alone should not determine funding priorities or be interpreted as evidence of the largest multipliers. The study is limited by fixed technical coefficients, reliance on the 2020 economic structure, incomplete documentation of expenditure allocation and percentage denominators, and the absence of direct ecological and household welfare measurements. Future research should verify the reported calculations, update the input–output structure using suitable procedures such as RAS where supporting data are available, and integrate local socioeconomic and ecological evidence to assess rehabilitation outcomes more comprehensively.

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