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Employment and value added created by ports: A case study for Germany with an outlook to 2040

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Abstract

This paper analyzes the economic impacts of German sea and inland ports by estimating the employment and gross value added (GVA) generated by the ports in 2022. We consider both direct effects, arising from the economic activity of port stakeholders, and indirect effects, stemming from the economic activity of suppliers in the upstream value chain. Indirect effects are estimated using an input-output model and the official input-output table for Germany. The results show that ports contribute more than 60,500 jobs and €6.1 billion in GVA to the German economy. Based on the findings for 2022 and the "Transport Forecast 2040" for Germany, we discuss the future development of the economic impacts of ports. Notably, the transition to a carbon-neutral economy is expected to largely eliminate imports of fossil energy carriers such as coal and crude oil, while imports of sustainable energy carriers are unlikely to fully compensate for the resulting decline in cargo volumes. This has substantial consequences for cargo handling at ports and the associated employment and GVA.

Keywords: economic impact assessment; employment; gross value added; input-output analysis; ports; Germany

1. Introduction

In a globalized world, the economic performance of countries depends to a substantial extent on foreign trade. This is especially true for export-oriented economies like Germany. In Germany, the share of employment linked to the production of extra-EU exports amounted to 14.9% in 2022 (Eurostat, 2024a), while the corresponding share of GDP was 16.6% (Eurostat, 2024b; Eurostat, 2025b).

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Most of the intercontinental trade is conducted by sea. For Germany, maritime transport accounts for 47% of extra-EU trade by value and 63% by weight (Eurostat, 2025a). Seaports serve as essential transport hubs, acting as transshipment points that connect domestic transport routes with international shipping lanes. Inland ports play a complementary role by enabling the use of waterways as transport routes in the hinterland of seaports. Together, sea and inland ports provide industries with access to international goods markets for the export of products and the import of intermediate inputs. In doing so, ports support employment and value creation in the economy.

However, ports contribute not only to national employment and GDP by acting as enablers for other industries but also through their own economic activities, referred to as direct effects. In addition, ports purchase intermediate inputs such as energy, which stimulates economic activity in supplying industries, resulting in further indirect effects.

For policy makers and port stakeholders, these direct and indirect effects as well as their future development are of particular interest. A major factor in the future development will be the transition to a carbon-neutral economy. The import of fossil energy carriers, such as coal and crude oil, is expected to disappear almost entirely. Furthermore, automated systems for cargo handling, such as automated cranes and autonomous vehicles, could lead to significant job displacement at ports.

In this paper, we use data from 2022 to estimate the employment and GVA that is directly and indirectly generated by German ports. To estimate the indirect effects in the supply chain, we use an input-output modelling approach and the official input-output table for Germany. Based on our results and the "Transport Forecast 2040" commissioned by the Federal Ministry of Digital and Transport, we discuss the future development of employment and GVA at ports, including the potential consequences of a shift to renewable energy sources.

The remainder of this paper is structured as follows. Section 2 reviews the relevant literature and outlines our contribution. Section 3 describes the methodology and data sources used. Section 4 presents the results of the economic impacts in 2022. Section 5 discusses the potential development of theses economic impacts up to 2040. Finally, Section 6 concludes with implications for port policy and industry stakeholders.

2. Literature Review

Several studies have explored the employment and gross value added (GVA) effects of ports in Germany, with research ranging from analyses of individual ports to broader evaluations of the maritime economy. Studies focusing on specific ports include assessments of the ports of Hamburg (ISL, ETR, Fraunhofer CML, and Ramboll, 2021), Bremen (ISL, 2017), and Kiel (HPC, 2018). These studies primarily address the regional economic effects of these ports.

At a broader level, the European Commission (2021) and the OECD (2010) examine the employment and GVA effects of the maritime economy on a European and global scale, respectively. However, these studies are limited in scope as they focus on the direct effects of maritime industry sectors and do not consider indirect effects of industries in the supply chain.

A more comprehensive analysis of the economic impacts of German ports is provided by ISL et al. (2019) and ISL, ETR, Fraunhofer CML, and DIW Econ (2021). Both studies adopt a national perspective and determine both direct and indirect effects within the supply chain. ISL et al. (2019) specifically focus on the employment effects of German sea and inland ports. In contrast, ISL, ETR, Fraunhofer CML, and DIW Econ (2021) investigate not only the GVA and employment effects of German ports but also of other segments of the maritime economy, including industries such as fishing and offshore wind energy.

This paper contributes to the existing literature in two main ways. First, it provides updated results for 2022 on the direct and indirect economic effects of all German ports, while comparable studies such as ISL et al. (2019) and ISL, ETR, Fraunhofer CML, and DIW Econ (2021) rely on data from 2018 or earlier. Second, this paper identifies key drivers and their direction of impact on the development of employment and GVA up to 2040. In contrast, existing studies report the economic effects at the time of analysis but, to the best of our knowledge, do not address the consequences of potential future developments, such as the transition to a carbon-neutral economy.

3. Methodology and Data

3.1. Direct effects

Direct effects refer to the employment and GVA generated through the activities of the port stakeholders themselves. Data on economic activities at ports are available in official statistics under industry sector 52.22, *"Service activities incidental to water transportation"*, as classified by the European industry classification system NACE. The German industry classification system WZ 2008 further subdivides sector 52.22 into distinct subsectors. Except for economic subsector 52.22.1, *"Operation of waterways"*, all other subsectors can be fully attributed to ports, as shown in Table 1. Another relevant industry sector, which includes activities largely attributable to ports, is sector 52.24, *"Cargo handling"*.

For the year 2022, data on employment and GVA are available for sector 52.22 and 52.24 from the Federal Statistical Office of Germany (Destatis, 2025a). However, for the subsectors of 52.22, such data are only available for 2019 (Destatis, 2025d). To estimate figures for 2022, we use the shares of employment and GVA attributed to these subsectors in 2019.

For industry 52.22.3, *"Pilotage",* the employment data from official statistics appear implausibly low, reporting fewer than 100 ship pilots. According to data from the Federal Chamber of Pilots (Bundeslotsenkammer, 2022), approximately 800 pilots were employed in 2022. We therefore assume that pilots are partially classified under sector 52.22.9, *"Other service activities incidental to water transportation",* and adjust employment and GVA figures accordingly.

Table 1: Classification of industry sectors attributable to ports (according to NACE Rev. 2, WZ2008)

Industry sector	Industry code	Fully attributable to ports?
Operation of ports	52.22.2	✓
Pilotage	52.22.3	✓
Other services activities incidental to water transportation (e.g., berthing, lighterage, and salvage activities)	52.22.9	✓
Cargo handling	52.24	×

Industry sector 52.24, *"Cargo handling",* encompasses not only cargo handling at sea and inland ports but also at rail terminals for combined transport and at airports. The share of employment and GVA attributable specifically to ports is estimated based on the proportional cargo handling (measured in tons) at these transportation nodes. For ports and rail terminals for combined transport, we estimate cargo handling volumes based on the 2010 traffic interconnection matrix for Germany (BVU et al., 2014). Figures on cargo handling at airports are taken from data from the Federal Statistical Office (DLR, DIW, 2023).

3.2. Indirect (supply-chain) effects

3.2.1. Intermediate inputs

Indirect effects refer to the employment and GVA generated by the economic activity of the suppliers of the port stakeholders. These effects are thus the result of the purchase of intermediate inputs by firms in the port industry sectors. To estimate the indirect effects, we first need to determine the amount of intermediate inputs purchased by the port stakeholders. This determination is carried out analogously to the direct effects for the economic sectors 52.22.2, 52.22.3, 52.22.9, and 52.24 for the year 2022.

3.2.2. Input-output table

To model the employment and GVA effects in the supply chain based on the purchase of intermediate inputs, we use an input-output model and data from an input-output table. An input-output table represents the flow of goods and services between different industries within an economy, as well as from industries to end users, such as households. For Germany, we use the national input-output table from the Federal Statistical Office for 2019 (Destatis, 2025c), because the table for 2022 was not yet available at the time of writing and we want to exclude the impacts of the COVID-19 pandemic.

3.2.3. Input-output model

The input-output model, developed by Wassily Leontief, establishes a link between the output of industries and the purchased intermediate inputs by assuming a linear production technology. This implies a proportional relationship between intermediate inputs and production outputs. Under this assumption the necessary amount of inputs from industry i to produce one unit of output of industry j can be described by the technical coefficient

$$a_{ij} = z_{ij}/x_j, \tag{1}$$

where z_{ij} is the amount of purchased intermediate inputs from industry i and x_j is the amount of produced outputs. The relationship between the output of industries and final demand of end users can then be expressed in the Leontief model in matrix notation (for details, see, e.g., Miller and Blair, 2009, pp. 10–21) as

$$\boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{f} = \boldsymbol{L}\boldsymbol{f}, \tag{2}$$

where $\boldsymbol{x} = (\boldsymbol{x_1}, \dots, \boldsymbol{x_n})$ is a vector of outputs of each industry, $\boldsymbol{I}$ is a $n \times n$ identity matrix, $\boldsymbol{A}$ is a $n \times n$ matrix of technical input coefficients, and $\boldsymbol{f} = (\boldsymbol{f_1}, \dots, \boldsymbol{f_n})$ is a vector of final demands. The so-called Leontief matrix is described by $\boldsymbol{L} = (\boldsymbol{I} - \boldsymbol{A})^{-1}$. Each element of this matrix indicates the amount of input that is directly and indirectly required from industry i if final demand for the output of industry j increases by one unit. The matrix $\boldsymbol{L}$ is therefore a measure of the direct and indirect effects.

To determine the impact on employment and GVA, data on these economic indicators is obtained for each industry from the Federal Statistical Office of Germany (Destatis, 2025b). Following Miller and Blair (2009, pp. 250–252), let the vector $\boldsymbol{h_e}$ contain this information for economic indicator $e \in \{gva, emp\}$. Dividing each element of this vector with the corresponding industry output yields ratios relative to output (e.g., GVA per unit of output). Let the vector $\boldsymbol{h_e^c} = (h_{1,e}/x_1, \dots, h_{n,e}/x_n)$ contain these ratios for economic indicator e. Constructing a block diagonal matrix with vector $\boldsymbol{h_e^c}$ on the main diagonal and multiplying it with $\boldsymbol{L}$ yields the impact of one unit of final demand for industry j on industry i, measured in economic indicator e:

$$\boldsymbol{L_e} = \begin{pmatrix} h_{1,e}^c & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & h_{n,e}^c \end{pmatrix} \cdot \boldsymbol{L} \quad \text{for} \quad e \in \{gva, emp\} \tag{3}$$

3.2.4. Indirect effects multipliers

The elements of the matrices $\boldsymbol{L_e}$ describe the direct and indirect impacts on industry i when final demand for industry j increases by one unit. Several steps are required to obtain multipliers indicating the impact of one unit of purchased intermediate inputs on indirect employment and GVA across all industries.

In the first step, we sum the columns of the matrices $\boldsymbol{L_e}$ to obtain multipliers that reflect the overall impact on all industries (Miller and Blair, 2009, p. 246). In the second step, we convert the resulting final-demand multipliers to output multipliers, which indicate the impact of an increase in output instead of an increase in final demand. This is achieved by dividing the final-demand multipliers by the respective element on the main diagonal of the Leontief

matrix (Miller and Blair, 2009, p. 283). In the third step, the resulting values are multiplied by the ratio of total output to total intermediate input. This yields intermediate input multipliers that indicate the combined direct and indirect effect of one unit of purchased inputs. Finally, in the fourth step, the direct effect, measured as the average direct employment and GVA per one unit of purchased intermediate inputs, is subtracted, yielding multipliers that capture only the indirect effects.

The desired indirect effects multipliers for industry j and economic indicator e are therefore given by:

$$m_j^e = \frac{\sum_i l_{ij}^e}{l_{jj}} \cdot \frac{x_j}{\sum_i z_{ij}} - \frac{h_{j,e}}{\sum_i z_{ij}} \quad \text{for} \quad e \in \{gva, emp\} \tag{4}$$

Port activities are all part of the superordinate industry sector 52, *"Warehousing, storage and support activities for transportation"*, according to the NACE industry classification system. As the input-output table does not further disaggregate this sector, we take the multipliers of this sector as a proxy for all port activities. Indirect effects are thus determined by multiplying the purchased intermediate inputs of each port stakeholder with the employment and GVA multipliers for industry sector 52.

4. Results for 2022

4.1. Intermediate Inputs

The purchased intermediate inputs in 2022 are presented in Table 2 for each of the port stakeholders. In total, the purchased intermediate inputs amount to almost €5.9 billion, with nearly half, €2.7 billion, attributed to the "Other port services" sector, which includes activities such as berthing and lighterage. This is followed by the sectors "Cargo handling" and "Port operation", with intermediate inputs amounting to €1.6 billion and €1.5 billion, respectively. Pilotage accounts for by far the smallest share, at €38 million, which is due, firstly, to the comparatively low level of employment in the sector and, secondly, to the low level of purchased inputs per pilot (€47,141).

Table 2: Purchase of intermediate inputs by German port stakeholders in 2022

Port activity	Purchased intermediate inputs	
	Total (million euro)	Per employee (euro)
Port operation	1,482	253,365
Pilotage	38	47,141
Other port services (e.g., berthing, lighterage, and salvage activities)	2,721	245,078
Cargo handling	1,638	140,174
Total	5,878	199,699

4.2. Indirect effects multipliers

The result of the input-output model are the multipliers in Table 3. The employment multiplier of approximately 5.3 indicates that for every million euros spent on intermediate inputs by port stakeholders in a year, 5.3 jobs are created within the supply chain. Similarly, the GVA multiplier of 0.387 suggests that each million euros of purchased intermediate inputs generates €387,000 in GVA at supplying industries.

Table 3: Multipliers for indirect (supply chain) effects of port activities

Indirect economic effect	Multipliers for direct input purchases (million euro)
Employment	5.292
Gross value added (million euro)	0.387

4.3. Total effects

The direct and indirect employment and GVA effects of German ports are illustrated in Figure 1. Direct employment in port-related activities amounts to more than 29,400 jobs, with the largest contributors being cargo handling and other port services. In contrast, port operations and pilotage contribute smaller shares to direct employment. The relatively low share of port operations in total employment of around 20% underlines the prevalence of the landlord model in Germany. Under this model, public authorities typically operate the ports, providing essential port infrastructure such as berths, areas for handling and storage, and access roads. Terminal operators, along with warehousing and logistics companies, lease land and infrastructure from the public port authority and operate the superstructure such as cranes, warehouses and other operational equipment. Indirect employment, driven by the purchase of intermediate inputs along the supply chain, adds about 31,100 jobs, surpassing direct employment. In total, 60,500 people are employed directly and indirectly through port activities.

In terms of GVA, port activities contribute directly €3.8 billion, with the majority, as in employment, coming from cargo handling and other port services. Port operations and pilotage contribute a relatively small share to GVA, similarly to their contribution to employment. Indirect GVA along the supply chain amounts to just under €2.3 billion. In total, this results in a GVA of €6.1 billion generated directly and indirectly by German ports.

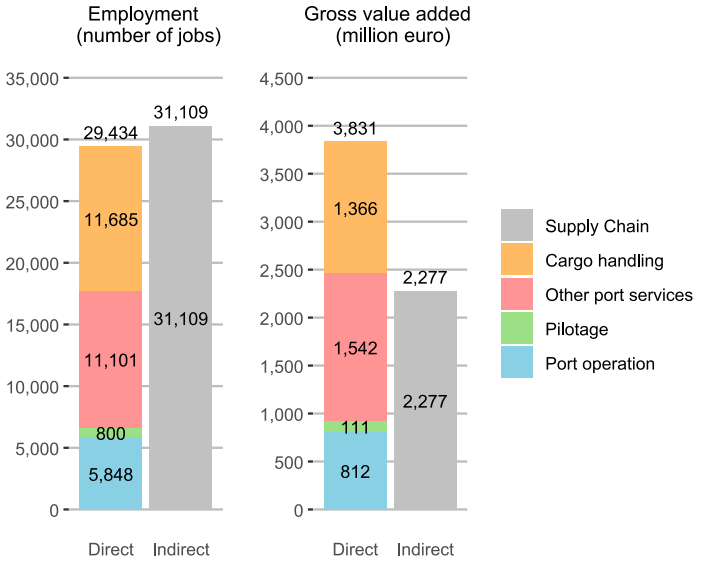

Figure 1: Economic impacts of German ports in 2022

5. Outlook to 2040

Policy makers and industry stakeholders are particularly interested in how employment and GVA at German ports will develop in the future. Based on the predicted changes in transport patterns and volumes in the official "Transport Forecast 2040" for Germany, we qualitatively assess the potential impacts on employment and GVA at German ports (see Table 4). The primary driver of these impacts is the evolution of cargo throughput. The "Transport Forecast 2040" predicts only a slight increase in total cargo volumes at German seaports between 2019 and 2040. Specifically, it is expected that cargo throughput in tons will rise by 2.4% overall, or 0.1% per year, from 305 million metric tons in 2019 to 313 million metric tons in 2040 (Intraplan et al., 2024a).

The main reason for this near-stagnation in throughput volume is the anticipated decline in bulk imports, particularly of fossil fuels such as coal and crude oil. This decrease in cargo volumes is unlikely to be compensated by corresponding imports of natural gas or alternative energy carriers such as hydrogen. For container handling at German seaports, however, the "Transport Forecast 2040" predicts a significant increase in throughput, amounting

to a total growth of 41%, or 1.7% annually, from 14.8 million TEU in 2019 to 20.9 million TEU in 2040 (Intraplan et al., 2024a). As a result, the overall development of throughput volumes is marginally positive.

In contrast, inland ports are projected to experience a decline in cargo throughput in tons by 16.3%, or 0.8% annually, from 237 million metric tons in 2019 to 198 million metric tons in 2040 (Intraplan et al., 2024b). Here too, the expected reduction in the cargo handling of fossil fuels has a negative impact.

While the overall throughput trend does not promise (noteworthy) positive impulses for employment and GVA at German ports, another important factor is the distribution of throughput among different cargo types. Critical here is the required labor input and the GVA associated with the handling of specific types of goods. Generally, the handling of bulk goods such as crude oil and coal requires less labor input and generates lower GVA per ton of cargo than container handling, although this difference has decreased over time (Haezendonck and Moeremans, 2020). Consequently, the declining share of bulk goods and the simultaneous increase in the share of containers are expected to have a positive impact on employment and GVA at ports.

New technologies at ports also affect employment and GVA. The "Transport Forecast 2040" anticipates that by 2040, the automation of handling systems and the control of seagoing vessels will continue to increase (Intraplan et al., 2024c). However, fully autonomous seagoing vessels are not expected to operate in narrow waterways or near ports on a large scale by 2040. Technological progress has two significant effects on employment: First, automation reduces employment by replacing labor and decreasing the labor input required, for instance, per ton of cargo handled. Second, automation lowers costs per ton of cargo handled, which also reduces the prices for handling services. This typically increases demand, thereby positively impacting employment at ports. However, the demand for freight transport is typically price inelastic meaning that a 1% decrease in transport costs will lead to a lower than 1% increase in transport volume. Therefore, the first effect dominates the second and net impact of automation will be negative for port employment.

For GVA, the increase in demand for cargo handling services will be positive. However, automation is likely to be implemented at ports competing for the same hinterland so that competition will decrease the revenue per ton of cargo handled. As a result, the GVA per ton of cargo handled will also decrease, so that the net effect on GVA is uncertain.

Table 4: Forecasted cargo handling developments at German ports and their expected economic impacts

	Forecasted transport changes 2019–2040		Expected economic impacts at ports			
	Seaports	Inland ports	Seaports		Inland ports	
			Employment	GVA	Employment	GVA
Cargo volumes (in tons)	+2.4% (0.1% p.a.)	-16.3% (-0.8% p.a.)	(+)	(+)	–	–
Cargo types	Decrease in the share of bulk cargo (especially fossil fuels) and increase in the share of containerized cargo		+	+	+	+
Cargo handling and ship navigation technology	Increased automatization of cargo handling and navigation of ships		–	+/–	–	+/–
Source	Intraplan et al. (2024a, 2024b, 2024c)		Own analysis			

6. Conclusions

The analysis reveals that sea and inland ports contribute 60,500 jobs and €6.1 billion in 2022 to the German economy. This includes direct economic activity at ports as well as indirect economic activity in the upstream supply chain. The input-output model results indicate that for every €1 million spent by port stakeholders on intermediate inputs in a year, 5.3 jobs are created in the supply chain, along with €387,000 in GVA. Furthermore, the assessment based on the "Transport Forecast 2040" suggests that while total cargo volumes at German seaports are projected to grow marginally, total cargo volumes at German inland ports are anticipated to decline by about 16%. This poses a significant challenge for inland ports and could lead to a reduction in employment and GVA at the affected ports.

Given these finding, policy makers and port stakeholders are required to take proactive measures to ensure long-term employment and GVA at ports, in particular at inland ports facing declining cargo volumes. For inland ports, this could involve diversifying port activities such as strengthening integration with rail and road transport. Many German inland ports are already trimodal terminals with access to the rail, road, and waterways, and the "Transport Forecast 2040" projects significant growth in train and truck cargo volumes. Additionally, both inland and seaports need to continuously enhance operational efficiency, for example by introducing or expanding automated cargo handling systems. Even though these systems may decrease total employment at ports, they are essential for maintaining competitiveness against other ports and land-based transportation alternatives.

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