Hong Kong Research Institute of Humanities and Social Sciences

Journal of Economic Insights

Volume3, Issue1 ISSN 3078-5979 www.wisvora.com

Geographical Forced Agglomeration: A Theoretical Framework for Understanding Marine Industrial Clustering

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Article Info

Accepted: 2026/4/28

Keywords:
Geographical Forced Agglomeration; Marine Economy; Industrial Agglomeration; Location Constraint; First-Nature Geography; Blue Economy; Marine Industrial Policy

JEL Classification:
G31, G32, O16

DOI: 10.70693/jei.v3i1.1933

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Abstract

This paper advances the concept of "geographical forced agglomeration" (GFA) as a distinctive theoretical contribution to understanding marine industrial clustering. Unlike terrestrial industrial agglomeration, which is predominantly driven by voluntary firm choices rooted in labor pooling, shared intermediate inputs, and knowledge spillovers (Marshall, 1890; Krugman, 1991), marine industrial agglomeration exhibits a fundamentally different mechanism: it is primarily constrained and determined by the geographical distribution of marine resources. This distinction maps directly onto Krugman's (1993) first-nature versus second-nature geography framework, with GFA representing the dominance of first-nature forces, natural endowments, over second-nature forces, market-access externalities. The paper argues that the failure to recognize this distinction has generated systematic misapplication of terrestrial agglomeration indices to marine contexts, leading to theoretical confusion and misleading policy prescriptions. By developing the GFA concept, examining its manifestation across marine sectors, and tracing its implications for measurement and policy, this paper provides a critical lens for reexamining existing marine economic research and offers a concrete pathway for theoretical advancement in the field.

1. Introduction

The marine economy has emerged as a significant domain of academic inquiry, particularly following China's implementation of its "maritime power" and "blue economy" development strategies (Wang et al., 2024). These policy initiatives have stimulated a surge of empirical research on marine industrial clusters, marine economic zones, and the spatial concentration of ocean-based industries. Yet, as Shi et al. (2020) observe in their comprehensive review of maritime cluster research, the field remains theoretically underdeveloped. The prevailing approach in much of this

literature is to import and apply frameworks from terrestrial industrial economics, most notably Marshall's (1890) theory of industrial districts and Krugman's (1991) new economic geography, without adequately interrogating whether these frameworks capture the distinctive spatial logic of marine industries.

This paper argues that such uncritical importation is not merely an oversight but a substantive theoretical error, and that correcting it requires introducing a new conceptual category: geographical forced agglomeration (GFA). The central claim is this: the spatial concentration of marine industries is not primarily the product of voluntary firm-level choices aimed at exploiting agglomeration economies, but is instead fundamentally constrained by the immutable geographical distribution of marine resources. In this respect, GFA belongs to what Krugman (1993) terms "first nature", the role of natural endowments in shaping economic geography, rather than to the "second nature" externalities that drive most agglomeration in terrestrial industry.

The theoretical stakes of this distinction are considerable. If marine industrial clustering is primarily resource-determined rather than efficiency-driven, then agglomeration indices developed for terrestrial industries will systematically misrepresent the nature of marine concentration. Policy instruments designed to encourage voluntary agglomeration, enterprise zones, clustering subsidies, innovation parks — may have limited efficacy when applied to industries whose spatial distribution is governed by oceanographic conditions. And research seeking to explain variation in marine economic performance through agglomeration externalities may be misspecifying the causal mechanism.

The remainder of this paper is structured as follows. Section 2 reviews conventional agglomeration theory, with particular attention to the first- versus second-nature distinction. Section 3 develops the GFA concept, provides a formal definition, and examines its manifestation across marine sectors, including the largely overlooked phenomenon of hybrid agglomeration. Section 4 draws out the theoretical and policy implications. Section 5 concludes.

2. Theoretical Background: Conventional Agglomeration Theory and the Nature of Location

Industrial agglomeration theory has a long intellectual lineage. Weber's (1929) classical location theory established that the optimal location of a production facility is determined by the relative weights of three factors: transportation costs, labour costs, and agglomeration economies. Critically, Weber recognised that access to raw materials, a first-nature endowment, could constrain location independently of market forces, a point directly relevant to marine industries. However, the subsequent development of the field, particularly through Marshall (1890) and the new economic geography literature, shifted emphasis decisively toward second-nature forces.

Marshall (1890) identified three primary mechanisms driving voluntary industrial clustering: the pooling of a common labour market that reduces search costs and matching frictions; the development of specialised intermediate input suppliers who achieve economies of scale by serving a concentrated customer base; and knowledge spillovers that enable the exchange of tacit information and accelerate innovation. As elaborated by Krugman (1991) in his influential model of core-periphery dynamics, and subsequently refined by Porter (1998) in his cluster framework, these mechanisms share a fundamental assumption: firms choose to agglomerate because proximity to other firms generate efficiency gains that outweigh the costs of co-location.

Faggio et al. (2017) provide an important empirical qualification to the Marshallian framework.

Using establishment-level coagglomeration data from the United Kingdom, they demonstrate substantial heterogeneity across industries in the relative importance of the three Marshallian mechanisms, labour pooling, input sharing, and knowledge spillovers. This heterogeneity implies that the agglomeration experience of one sector cannot be extrapolated to others. Importantly, however, their analysis concerns variation in the type of voluntary agglomeration mechanism, not variation between voluntary and involuntary agglomeration. The role of natural resource constraints in determining industrial location, what we term GFA, lies outside the scope of their framework.

A critical but insufficiently exploited distinction in the agglomeration literature is Krugman's (1993) separation of "first nature" and "second nature" geography. First-nature advantages are those derived from natural endowments: access to harbors, mineral deposits, fertile land, or fisheries. Second-nature advantages are those created through human economic activity: infrastructure, agglomeration economies, and market access. Krugman's point is that first-nature advantages shaped the initial geography of economic activity, but that over time, as second-nature forces accumulated, economic geography became increasingly self-reinforcing and decreasingly tied to natural endowments. This insight was developed primarily with reference to terrestrial industry, but as we argue below, marine industries represent a class of economic activity in which first-nature forces retain overwhelming explanatory power, and where the transition to second-nature dominance is fundamentally constrained by oceanographic conditions.

The measurement of industrial agglomeration has been formalized through indices such as the location quotient (LQ) and the Ellison-Glaeser (E-G) index (Ellison & Glaeser, 1997). The E-G index is particularly notable because it attempts to identify the component of industrial concentration that exceeds what would arise from random assignment, i.e., it measures the extent to which concentration reflects specific agglomeration forces rather than the natural lumpiness of the industrial size distribution. However, neither the E-G index nor the LQ distinguishes between concentration arising from voluntary agglomeration and concentration imposed by the spatial distribution of natural resources. When applied to marine industries, both measures will register high concentration wherever marine resources are geographically concentrated, which is pervasive — without distinguishing whether this concentration reflects Marshallian externalities or resource geography. This is a fundamental measurement limitation with significant theoretical and empirical implications.

Jofre-Monseny et al. (2011) provide direct evidence on the mechanisms of agglomeration by examining the effect of inter-industry relations on firm location decisions. Their findings demonstrate that labor market pooling and input-output linkages are quantifiable drivers of voluntary co-location in manufacturing. These findings, however, are difficult to extend to marine industries in which the primary location driver is not inter-firm relations but access to a geographically specific natural resource. It is this asymmetry that the GFA framework is designed to capture.

3. The Distinctiveness of Marine Industrial Agglomeration

3.1 Literature Resource Dependency and Location Constraint

Marine industries exhibit a fundamental characteristic that distinguishes them from virtually all terrestrial industries: extreme location dependency on the spatial distribution of natural resources. Unlike manufacturing or service industries that can, in principle, relocate to optimise access to labour markets, capital, or intermediate suppliers, marine industries are physically tethered to the geography of the ocean. This tethering operates through several distinct mechanisms.

First, extractive marine industries, fisheries, offshore oil and gas, seabed mining, are necessarily located at the sites of the resources they exploit. A fishing fleet cannot operate where there are no fish; an offshore platform cannot be positioned independently of geological hydrocarbon structures. The oceanographic and geological processes that determine resource distribution are not responsive to economic incentives and cannot be altered by policy. Zhao et al. (2025) document this phenomenon directly in the context of the Zhoushan Fishing Ground, demonstrating that the spatial patterns of fish community distribution are shaped by oceanographic variables — depth, salinity, temperature regimes, nutrient upwelling, that are independent of human economic organisation.

Second, even marine industries that do not directly extract resources are often constrained by natural conditions. Marine aquaculture facilities must be sited in areas with appropriate water quality, temperature, current regimes, and protection from storm exposure. Port cities, as Jansen and Hein (2023) document in their analysis of port-city symbiosis, owe their origins and continued viability to natural harbour conditions, water depth, coastal geometry, and protection from prevailing weather — that cannot be manufactured or relocated. The spatial distribution of both port cities and aquaculture facilities thus reflects the underlying geography of natural advantages in ways that have no close analogue in terrestrial industrial clusters.

Third, the spatial scale of marine resource distribution is vast and the resource itself is mobile. Fish migrate across oceanographic boundaries following temperature and nutrient gradients; ocean currents redistribute nutrients and temperature regimes seasonally. This introduces a temporal dimension to marine resource geography that has no direct terrestrial parallel: the "location" of the resource is not a fixed point but a distribution over space and time, determined by oceanographic dynamics. The fishing activities in China's coastal waters exhibit seasonal patterns of concentration that correspond systematically to patterns of primary productivity and fish stock distribution (Zhao et al., 2025), illustrating how human economic activity is constrained to track the temporal as well as spatial distribution of natural resources.

3.2 The Concept of Geographical Forced Agglomeration

We define geographical forced agglomeration (GFA) as a form of industrial spatial concentration in which:

> *The location of firms or production units is primarily determined by the immutable or slowly-evolving geographical distribution of natural resources, such that the observed spatial concentration is principally a reflection of resource geography rather than of voluntary, efficiency-seeking firm behaviour.*

This definition has three component elements that merit elaboration. First, GFA is characterised by the primacy of resource geography. This does not require that economic efficiency considerations are entirely absent; it requires that the geographic distribution of resources is the binding constraint on location, such that firms have limited practical choice about where to operate. Second, GFA is characterised by the immutability or slow evolution of the locating force. Natural oceanographic conditions change, but on timescales that far exceed the strategic planning horizon of any firm. This distinguishes resource-constrained marine location from technologically constrained terrestrial location, where infrastructure investments can alter the effective cost of distance over economically relevant timescales. Third, GFA produces concentration as a consequence of constraint, not as a consequence of rational choice in pursuit of agglomeration economies.

Table 1 below presents a systematic comparison of GFA and conventional voluntary agglomeration

along multiple dimensions. The comparison reveals that GFA and voluntary agglomeration differ not merely in degree but in the fundamental causal mechanism and in the appropriate policy response.

Table 1.1. Comparison of Conventional Agglomeration and Geographical Forced Agglomeration

Characteristic	Conventional Agglomeration	Geographical Forced Agglomeration
Primary driver	Economic efficiency (labour pooling, input sharing, knowledge spillovers)	Natural resource distribution (immutable geographic endowment)
Firm decision	Voluntary — firms choose location to maximise returns	Constrained — location dictated by resource geography
Relocatability	High — firms can move as conditions change	Low — viable sites are geographically fixed
Theoretical antecedent	Second nature (Krugman, 1991, 1993)	First nature (Weber, 1929; Krugman, 1993)
Industry examples	Silicon Valley, financial districts, automotive clusters	Marine fisheries, offshore oil extraction, port cities
Temporal stability	Moderate — sensitive to cost, technology, and policy shocks	High — determined by slow-changing oceanographic factors
Policy leverage	Strong — incentives can redirect voluntary location decisions	Limited — resource constraints are not policy-amenable
Measurement challenge	Well-addressed by E-G index, location quotient	Existing indices conflate voluntary and forced concentration

3.3 Evidence from Marine Industries

The GFA phenomenon manifests across all major segments of the marine economy, though with varying degrees of intensity. The following examples illustrate the breadth and pervasiveness of resource-driven spatial concentration:

- Marine Fisheries: The spatial distribution of fishing activities is entirely dictated by the location of fish stocks, which are themselves determined by oceanographic conditions, nutrient availability, and migratory patterns. Zhao et al. (2025) document that the spatial patterns of fish communities in the Zhoushan Fishing Ground — China's largest fishing ground — exhibit strong correspondence with physical oceanographic variables including water depth and salinity regime, rather than with the economic characteristics of fishing enterprises. Fishing fleets congregate at specific coastal locations not because of labour market externalities or knowledge spillovers, but because the fish are there.
- Port Cities: The geographic distribution of major port cities is constrained by natural harbour conditions — water depth, coastal morphology, and shelter from prevailing weather systems. Jansen and Hein (2023) argue that the fundamental nature of port-city symbiosis is shaped by this geographic inheritance: the spatial endowment of natural harbour conditions has created path-dependent development trajectories that cannot be readily replicated elsewhere. The persistence of historically established port city hierarchies over centuries is consistent with the GFA hypothesis: resource geography creates an initial concentration that becomes self-reinforcing, but whose origins

lie in natural endowment rather than voluntary agglomeration.

- Marine Aquaculture: The location of aquaculture facilities is determined by water quality parameters — temperature, salinity, dissolved oxygen, nutrient levels — as well as by coastal geometry that provides protection from wave action. Zhang et al. (2024) demonstrate that marine industrial agglomeration in China's coastal provinces shows significant regional heterogeneity in its effects on high-quality development, a pattern that is consistent with the hypothesis that agglomeration is resource-determined: different coastal regions possess different natural conditions, generating different industrial configurations that are not freely mobile.
- Offshore Oil and Gas: The extreme case of GFA. Exploration and production activities are entirely dictated by the geological distribution of hydrocarbon reserves beneath the seabed. There is no voluntary component to the location of offshore platforms — they are sited where the resources are, or not at all. The spatial concentration of offshore oil and gas activity in specific ocean basins is a direct reflection of geological endowment, with no meaningful contribution from Marshallian agglomeration externalities.

3.4 Hybrid Agglomeration: When GFA Generates Second-Nature Forces

A theoretically important complication is that GFA does not operate in isolation. Once a resource-driven concentration of primary marine industry exists, it may generate secondary agglomeration effects of the conventional voluntary type. A fishing port that develops around a productive fishing ground will attract fish processing facilities, ice suppliers, boat repair yards, and fishing equipment retailers. These downstream and ancillary activities are not constrained by the original resource geography, they could, in principle, relocate, but they choose to agglomerate around the resource-driven core because of the input-output linkages and labour market externalities that Marshall described.

This produces what we term "hybrid agglomeration": a spatial cluster in which resource-driven GFA generates the initial concentration, and voluntary Marshallian agglomeration subsequently amplifies and extends it. The theoretical importance of recognising hybrid agglomeration is that it implies a layered structure in marine clusters: a resource-constrained core of primary industries surrounded by a voluntarily concentrated periphery of secondary and tertiary activities. The Ningbo-Zhoushan port cluster illustrates this structure clearly: the port city owes its existence to a natural deep-water harbour (first-nature GFA), but its development as a logistics and financial hub reflects voluntary agglomeration of secondary marine services around this resource-constrained core.

Distinguishing these two layers is not merely an academic exercise. Policy interventions aimed at strengthening the voluntary agglomeration component of a hybrid cluster may be effective, whereas interventions aimed at displacing or replicating the resource-constrained core will face fundamental physical limits. This distinction has direct relevance for regional marine economic planning.

4. Theoretical Implications

4.1 Critique of Existing Marine Economic Research

The concept of GFA exposes a systematic weakness in existing marine economic research: the uncritical application of terrestrial agglomeration frameworks and measurement tools to marine contexts. This manifests in three specific ways.

First, measurement misspecification. When researchers apply the E-G index or location quotient to marine industries, they are implicitly assuming that the observed concentration is driven by the

same voluntary, efficiency-seeking mechanisms that the E-G index was designed to detect. In GFA contexts, however, the concentration is resource-driven, and the measured index will conflate resource geography with agglomeration economies. This generates inflated estimates of "agglomeration" in primary marine industries that may have no correspondence to the Marshallian forces the index is intended to measure.

Second, causal misattribution. Studies that find a correlation between marine industrial agglomeration (as measured by conventional indices) and marine economic performance may be estimating the effect of resource endowments rather than the effect of agglomeration. If fishing industry concentration in a coastal province reflects the abundance of nearby fish stocks, and if abundant fish stocks also contribute independently to economic performance, then a regression of economic performance on agglomeration will pick up the resource effect through the agglomeration channel, generating biased estimates of the agglomeration-performance relationship. Wang et al. (2024) and Zhang et al. (2024) both identify positive effects of marine industrial agglomeration on high-quality marine economic development, but neither study adequately controls for the possibility that the agglomeration measure is serving as a proxy for underlying resource endowments.

Third, theoretical category errors. Much of the maritime cluster literature, as reviewed by Shi et al. (2020), imports Porter's (1998) cluster framework directly from its terrestrial origins. Porter's framework rests fundamentally on the assumption that clustering is a competitive strategic choice — that firms in a cluster have chosen proximity because of the dynamic competitive advantages it generates. For resource-constrained marine industries operating under GFA, this assumption is violated: firms are at their location because the resource requires it. Applying competitive cluster analysis to GFA contexts risks generating spurious insights about competitive dynamics in industries whose location is primarily a matter of physical constraint.

4.2 A Pathway for Theoretical Contribution

The GFA concept opens several avenues for genuinely novel theoretical and empirical contribution to marine economics and economic geography more broadly:

1. Developing measurement approaches that decompose observed marine industrial concentration into its resource-driven (GFA) and voluntarily agglomerated components. This could build on the logic of the E-G index by incorporating a resource endowment baseline — analogous to the E-G index's correction for the natural lumpiness of the firm size distribution — against which the voluntary component of concentration is assessed.

2. Examining the dynamics of hybrid agglomeration: the conditions under which a GFA core generates secondary voluntary clustering, the scale at which this secondary clustering operates, and the extent to which policy can influence the voluntary component without being able to alter the resource-constrained core.

3. Investigating the policy implications of distinguishing between voluntary and forced agglomeration in the context of marine spatial planning, coastal economic zoning, and blue economy development strategies. GFA implies that the productivity and economic performance benefits of marine agglomeration may have different policy levers than those applicable to terrestrial clusters.

4. Exploring the dynamic evolution of GFA as technological change alters the relationship between resource distribution and firm location. Advances in offshore aquaculture technology, remote sensing for fisheries management, and underwater robotics may reduce the tethering of certain marine activities to specific resource locations, thereby relaxing the constraints that generate GFA.

Understanding the conditions under which technological change transitions an industry from GFA to voluntary agglomeration is a theoretically important question with practical implications for blue economy policy.

5. Addressing the temporal dimension of GFA. Marine resources are not static; fish stocks migrate seasonally, ocean temperature regimes shift with climate change, and oceanographic conditions evolve. Understanding how firms and industries adapt their spatial organisation to the temporal dynamics of marine resource distributions is a question with no direct terrestrial analogue and considerable theoretical novelty.

4.3 Bridging Theory and Practice: The Ningbo–Zhanjiang Puzzle

The GFA framework helps explain a persistent empirical puzzle that conventional agglomeration theory cannot resolve: why does Ningbo, despite being located in a region with comparatively modest natural marine resource endowments, consistently achieve higher composite marine economic competitiveness scores than Zhanjiang, which possesses abundant fisheries resources, deep-water harbour conditions, and well-established port infrastructure?

The GFA framework suggests a direct answer. Zhanjiang's marine economy is disproportionately concentrated in primary industries, fisheries, marine aquaculture, and coastal shipping, whose location is governed by GFA. These industries are productive, but their spatial concentration is resource-determined and their growth is ultimately constrained by the carrying capacity of the marine ecosystem and the congestion effects inherent in fishing grounds. The Marshallian agglomeration economies that drive productivity growth in knowledge-intensive industries, knowledge spillovers, labour market deepening, specialised input markets, are relatively weak in resource-constrained GFA industries, because the location decision is made by geography, not by firms seeking to exploit complementarities.

Ningbo, by contrast, has leveraged its deep-water port infrastructure (itself a GFA asset) to develop a secondary and tertiary marine economy — port logistics, maritime finance, marine equipment manufacturing, and shipping services — in which voluntary Marshallian agglomeration operates more freely. These are hybrid agglomeration industries: they are anchored to Ningbo by the GFA asset of the natural harbour, but their internal structure is governed by voluntary agglomeration dynamics that generate cumulative productivity gains. The implication is not that Ningbo has "more" agglomeration than Zhanjiang, but that its agglomeration is of a qualitatively different type, one in which second-nature forces have been built successfully on a first-nature foundation.

This distinction has direct implications for regional marine economic policy. Efforts to improve Zhanjiang's marine competitiveness through generic cluster promotion policies — modelled on second-nature voluntary agglomeration — are likely to yield limited returns as long as the regional marine economy remains dominated by GFA industries. More promising interventions would focus on developing the hybrid agglomeration potential of Zhanjiang's existing GFA assets: building secondary service industries, logistics capabilities, and knowledge infrastructure around the resource-constrained core.

5. Conclusion

The concept of geographical forced agglomeration represents a meaningful and necessary step toward establishing the theoretical distinctiveness of marine economy as a field of inquiry. By situating GFA within Krugman's (1993) first-nature versus second-nature geography framework, this paper connects a marine economics insight to a well-established body of economic geography

theory, while demonstrating that the existing literature has systematically underweighted the role of first-nature forces in marine industrial location.

The practical implications of the GFA framework can be summarised along four dimensions:

1. A theoretical lens for understanding the unique dynamics of marine industrial clustering, distinguishing resource-determined concentration from efficiency-seeking voluntary agglomeration and introducing the concept of hybrid agglomeration for clusters that combine both.
2. A critique of the uncritical application of terrestrial agglomeration indices — the E-G index, location quotient, and cluster analysis — to marine contexts, with specific identification of the mechanisms through which these measures generate misspecification in GFA settings.
3. A foundation for developing appropriate measurement tools and policy instruments that account for the constrained nature of GFA, with particular attention to the decomposition of observed marine concentration into resource-driven and voluntarily agglomerated components.
4. A pathway for genuine theoretical contribution to the broader field of industrial economics and economic geography, by identifying a class of industries — those subject to GFA — in which the standard assumptions of voluntary agglomeration theory are systematically violated.

Future research should focus on operationalising the GFA concept through modified measurement frameworks, developing empirical tests that distinguish GFA from conventional agglomeration in matched cross-industry datasets, and exploring the conditions under which technological change relaxes resource-based location constraints and enables the transition from GFA to hybrid or voluntary agglomeration. The theoretical advancement of marine economics requires not merely applying existing theories to new empirical settings, but identifying and articulating the fundamental characteristics — of which GFA is a leading example — that distinguish marine economic phenomena from their terrestrial counterparts.

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