



FAERE

French Association
of Environmental and Resource Economists

Working papers

The Study of the Economic Effects for an
Island of a Disruption in Commercial
Links with the Mainland: The Case of the
Island of Yeu

Hugo Emenegger – Clément Cohic – Sophie
Pardo – Agnès Baltzer – Elsa Cariou

WP 2026.03

Suggested citation:

H. Emenegger, C.Cohic , S. Pardo, A.Baltzer and E. Cariou (2026). The Study of the Economic Effects for an Island of a Disruption in Commercial Links with the Mainland: The Case of the Island of Yeu. *FAERE Working Paper, 2026.03*.

ISSN number: 2274-5556

www.faere.fr

Study of the Economic Impact on an Island of a Disruption in Trade Links with the Mainland: The Case of Île d'Yeu

Abstract :

Coastal hazards can trigger large indirect impacts by disrupting supply chains, yet standard monetary assessments often produce aggregate estimates that obscure local inventory constraints and operational thresholds. We develop a volumetric, stock-based approach to characterize short-run economic vulnerability to supply disruption in an insular system, using Île d'Yeu (France) as a case study. Based on freight shipping manifests matched to establishments (SIRENE) and interview-elicited operational thresholds, we quantify time-to-impact metrics (in days) ranging from firm-level stockout to island-wide generalized shortage driven by demand reallocation from downstream firms, such as retailers and food-service establishments, to upstream actors, such as wholesalers and high-volume local suppliers, once downstream inventories are depleted. Results show that food-dependent activities—especially accommodation and food services—have the shortest autonomy (≈ 5 days to stockout), and that vulnerability is strongly seasonal: despite higher summer imports, the sharp increase in population-driven demand reduces the inventory buffer and can push the system toward a near just-in-time regime, making generalized shortage possible within 0–1 day in peak months. Sensitivity analyses on key parameters (employees' consumption, population present, and household consumption) shift estimated threshold values within a range of approximately 3-6 days for the low season depending on the scenario, but preserve the identification of July–August as the most critical period. Because the empirical reconstruction relies on 12 non-continuous weeks of freight records, the results should be interpreted as seasonal orders of magnitude rather than exact day-by-day predictions. The proposed volumetric framework complements monetary evaluations by providing an operational reading of continuity (days before threshold crossings) and by identifying actionable levers for preparedness (buffer inventories, cold chain, prioritization, and logistics coordination).

Authors :

Hugo Emenegger – LETG Nantes - hugo.emenegger@univ-nantes.fr

Clément Cohic – LETG Nantes - clement.cohic@univ-nantes.fr

Sophie Pardo – LEMNA - sophie.pardo@univ-nantes.fr

Agnès Baltzer – LETG Nantes - agnes.baltzer@univ-nantes.fr

Elsa Cariou – OSUNA - elsa.cariou@univ-nantes.fr

Acknowledgments

This article was carried out within the framework of the multidisciplinary research program *ODySéÎles*, which investigates the impacts of climate change on several French islands (Mayotte, Ouvéa, Noirmoutier, and the Île d'Yeu).

This research also relied on close collaboration with several companies on the island, which generously agreed to share essential information regarding their production methods. Their participation was crucial to the implementation of our modeling work.

Finally, we would like to thank the maritime company *Yeu-Continent* for providing valuable documents related to the shipment of goods to the island, which greatly enriched this research.

1. Introduction

Under the effects of climate change, the average frequency and intensity of marine hazards are expected to evolve, while coastal pressures (urbanisation, human activities) continue to intensify, mechanically increasing exposure and potential damage (IPCC, 2023; Neumann et al., 2015). The challenge is therefore not merely to quantify damage, but also to better understand what these disruptions concretely imply for territories and their activities, in order to inform adaptation and crisis management (Merz et al., 2010; Meyer et al., 2012; Lawlor & Cooper, 2024).

Assessments of hazard-related damage rely predominantly on monetary approaches, historically tied to cost-benefit analyses in risk management (Starr, 1969 ; Penning-Rowsell et al., 2014). These frameworks are indispensable for comparing investment scenarios and discussing the exposure of assets in value terms, but they often leave aside central dimensions, for instance regarding the continuity of an isolated system: available stocks, physical constraints, time lags before concrete effects emerge, and degraded modes of operation (Merz et al., 2010; CGDD, 2018). Hallegatte (2009, 2014) reminds us that economic vulnerability depends not only on exposure, but also on the sensitivity of activities to disruption and on structural resilience (the ability to absorb and reconfigure flows). In an island territory, these dimensions relate directly to the capacity to maintain supply and economic activity in a disruption scenario.

While so-called direct damages generally refer to the physical effect of the hazard on exposed assets and their assessment methods are relatively consensual (Penning-Rowsell et al., 2015 ; Brémond et al., 2024), studies focusing on so-called indirect damages and on the propagation of disruptions—often triggered by direct damages—propose various approaches (econometric methods, input–output models, and computable general equilibrium models). However, these methods have well-known limitations, notably difficulties in representing certain substitutions, price effects, or local technical constraints. They also tend to produce aggregated results that make microeconomic and operational mechanisms less visible (Hallegatte, 2008, 2011; Przulski & Hallegatte, 2011; Strobl, 2011; Cavallo et al., 2013; Okuyama et al., 2014; Bosello et al., 2011; Xie et al., 2018; OECD, 2014; Nortes-Martinez et al., 2021). By contrast, the supply-chain literature emphasizes disruption propagation through logistical interdependencies and the role of buffer inventories, with potentially non-proportional effects when supply chains operate under tight conditions (Chopra & Sodhi, 2014; Dolgui & Ivanov, 2021; Ghadge et al., 2022; Brusset et al., 2023).

In what follows, we deliberately use the term « impacts » rather than « damages » when referring to the effects measured by the model. This is because the proposed indicators are not expressed as monetary losses, but as physical volumes, inventory depletion, and days before operational thresholds are crossed. This distinction is consistent with flood-damage and natural-hazard assessment literature, which emphasizes that monetary damage estimates do not fully capture duration, disruption, transfers, degraded modes of operation, or other non-monetary consequences of hazards (Merz et al., 2010; Meyer et al., 2013; CGDD, 2018). The term « damage » is therefore retained mainly when discussing the conventional damage-assessment literature, whereas « impact » refers to the non-monetary continuity effects captured in this article.

Thus, in this article, we propose a volumetric assessment of the indirect impacts of a supply disruption in order to translate logistical dependence into a directly interpretable metric: the time (days) to first operational impact. The central argument is that insular supply security does not depend only on total imported tonnage, but on the capacity of the supply system to adjust flows and inventories to seasonal final demand. We distinguish between two levels of impact. First-order indirect impacts correspond here to the volumes « non-delivered » during the disruption, that is, interrupted inbound flows, consistent with an interpretation in which the effect propagates from the disrupted entity to the economic actors dependent on that entity (Rose, 2004). Second-order indirect impacts refer to the way stock depletion translates into a change in behaviour (local purchases to substitute for imports) and even a degradation in the functioning of establishments (switch to degraded mode, temporary closure), as captured through operational thresholds reported by the actors themselves. Finally, by linking these micro-economic dynamics to the local structure of flows, we define a territorial indicator: the time to generalized shortage,

defined as the moment when the shift in demand toward actors capable of supplying locally collides with the limited quantity of stocks available on the island. In monetary approaches, substitution is often interpreted as a mechanism that reduces losses by reallocating demand toward unaffected actors. In the volumetric perspective developed here, however, substitution may increase pressure on finite local inventories: in an enclosed island system, it reallocates access to existing volumes without creating additional supply.

Empirically, the approach is based on the use of shipping records provided by the freight operator Yeu-Continent, on matching recipients to the SIRENE database, and on a semi-structured survey used to estimate consumption parameters and activity thresholds. The analysis is conducted in volumes and days and does not incorporate price mechanisms, in line with recommendations stressing that certain aspects (duration of disruption, degraded mode, transfers) cannot be properly addressed through a purely monetary approach (CGDD, 2018; Merz et al., 2010). The results should therefore be interpreted as a vulnerability analysis aimed at identifying critical periods and threshold effects. From this perspective, the use of a GIS primarily serves to structure information and connect flows to establishments, in order to make visible the effects that spread beyond the directly affected area (Merz et al., 2010; Nortes-Martinez et al., 2021).

The article therefore addresses the following question: what does a volumetric assessment contribute to the characterization of the economic vulnerability of an isolated territory exposed to coastal hazards? To answer this question, the article is divided into five sections: Section 2 presents the study area and the data sources, their coverage, and their processing; Section 3 describes the model (stock dynamics, impact thresholds, demand shift, and definition of generalized shortage) and the sensitivity analyses; Section 4 presents the results at both the micro and territorial scales, particularly seasonal contrasts and threshold effects; Section 5 discusses the contributions, limitations, conditions of transferability, and operational implications of the approach for preparedness and adaptation; and finally, Section 6 concludes.

2. Study area & data

2.1 Île d'Yeu as a case study of indirect impacts

The island is located in the Vendée department, around forty kilometres off the western coast of France. The island is divided into two clearly distinct areas: to the west, a wild coastline dominated by cliffs; to the east, facing the mainland, a low-lying and highly urbanised area. Year-round, the island has approximately 5,000 inhabitants, while during the summer season this figure can rise to as many as 30,000, reflecting a highly tourism-dependent economy. In terms of food supply, the island is heavily dependent on the mainland. While the fishing economy predominated until the 1980s (Leroy & Trouillet, 2017) — with its fleets as well as its fish-processing plants — almost nothing is now processed locally, except for certain canned products, which are almost entirely exported to the mainland. A small local agricultural production remains, but it represents only around 2% by volume of imports, considering imported food goods alone. The water and energy consumed by island residents come from the mainland and are transmitted through submarine cables.

The port, through which all goods transit, is located in the island's low-lying area (see Fig. 1). Three shipping companies serve the island: one is dedicated exclusively to passenger transport, another carries only construction materials, and the third, Yeu-Continent, handles both passenger and freight transport as well as small parcel delivery. It is therefore clear that, if the port were flooded, the entire island economy would be affected. Indeed, if no vessel can dock on the island, then no goods can reach local businesses, raising the prospect of business disruptions or even a generalized shortage should the situation persist.

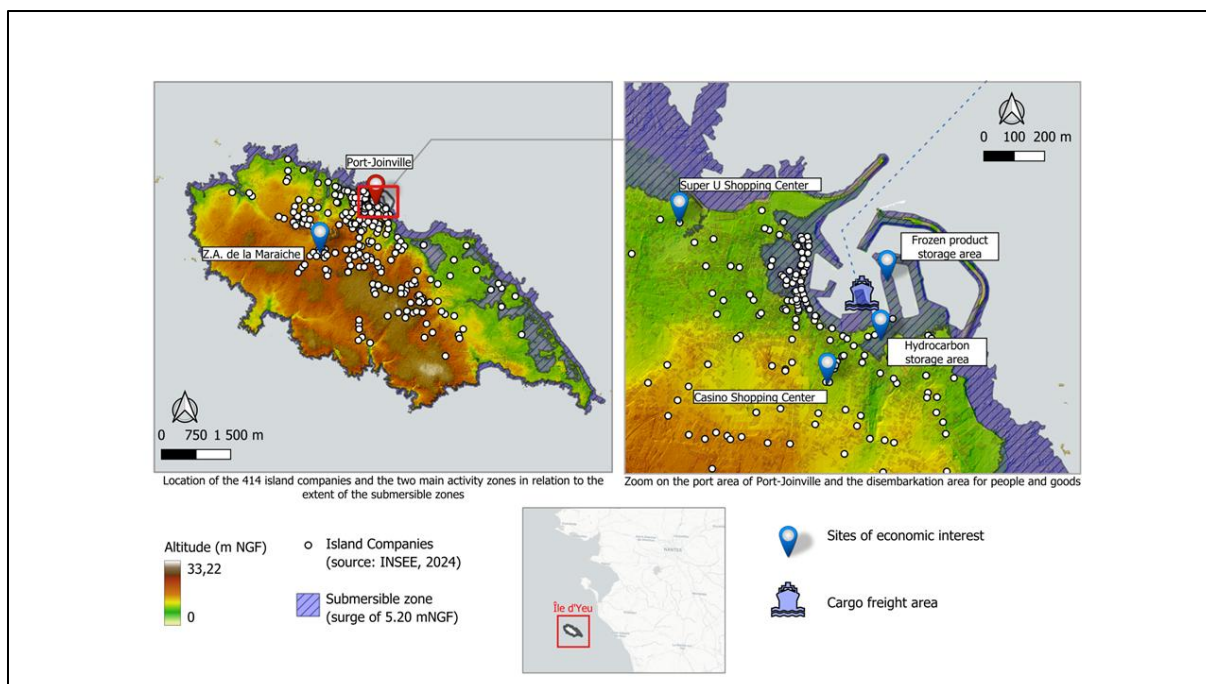


Figure 1 - Location of economic assets and the flood-prone area on Île d'Yeu (source: H. Emenegger & A. Creach)

Only a very limited number of studies have examined indirect impacts in island contexts (ECLAC, 2011). Yet these territories are particularly exposed to sea-level rise and to the intensification of hazards, while also being, in most cases, highly dependent on imports (Hall and Page, 2009). This dependence may constitute an initial aggravating factor for negative indirect impacts. Indeed, if the territory is not supplied for a certain period of time, beyond the risks faced by local economic activities, residents may also have to confront the risk of a generalized shortage. Monetary assessment appears poorly suited to capturing this effect, which strengthens the relevance of a volumetric approach based on available stocks. While value may be generated without goods in certain service-sector activities, many other activities would be disrupted by a supply interruption. A volumetric approach therefore makes it possible to better apprehend indirect impacts in these island territories.

Moreover, unlike continental territories, island territories are fully isolated and relatively constrained in spatial terms. This makes any economic substitution effect far more difficult to achieve (Hallegatte, 2014). Such substitution effects refer to a temporary or lasting reorganisation of demand flows among economic actors in response to a disruption (Hallegatte, 2014). Yet this reorganisation is facilitated by the existence of competitors to the affected firms, which are able to absorb unmet demand and thereby minimise the scale of the indirect impact. Drawing on Hotelling's ideas (1929), one may understand that, in addition to geographical isolation, limited space reduces the scope for economic substitution because it also reduces the number of competitors within each sector of activity, precisely because market size is limited (Briguglio, 2016).

Finally, island economies are supplied with the same diversity of goods as that found on the mainland. They also display a wide range of economic activities and developed inter-firm networks (McElroy and de Albuquerque, 1998; Baldacchino, 2006). On small islands, observing these interconnections is facilitated by the fact that relatively exhaustive fieldwork and survey-based investigation are possible. This is precisely the case of Île d'Yeu. Thus, whereas GIS makes it possible to observe the destination of goods flows originating from the mainland, field surveys then make it possible to understand how these goods are subsequently exchanged locally.

2.2 Data sources used

Our analysis is based on four complementary data sources.

- (i) Yeu-Continent shipping records.

The primary data source consists of the shipping records of the Yeu-Continent company, which document the volumes actually shipped to the island. Each record provides a shipping date, a quantity (mass), a goods category, and a consignee. The goods categories are as follows: A (dry food products), B (fresh food products), C (bread-making flours), D (miscellaneous goods), and E (construction materials). The shipping records processed were available only in paper format, and therefore had to be digitised one by one before the data could be analysed computationally.

These data make it possible to reconstruct a time series of inbound volumes at a weekly level of granularity and to link flows to sectors of activity through the identification of consignees (see Fig. 2).

- (ii) SIRENE database.

The SIRENE database (administered by INSEE) is used to characterise consignees in terms of location and sector of activity, and to group actors according to a typology consistent with the logistical focus of the article. It does not provide information on flows themselves, but it makes it possible to link these flows to local economic entities.

- (iii) Present population variable h (seasonalised variable).

In order to interpret seasonal variations in demand pressure, we use a variable h describing the population present across four periods: low season — October to March — (4,887 inhabitants, INSEE, 2023); spring — April to June — (6,500, estimate provided by the Tourist Office, which reported an increase of one third in the population); July–August (25,583 inhabitants during the 2023 summer period, based on the maximum value observed in Yeu-Continent passenger data); and September (approximately 15,500 inhabitants, estimated from Yeu-Continent information indicating a decline of around 10,000 people present at the end of the summer).

The July–August value should be interpreted as a conservative crisis-planning assumption rather than as an average seasonal population: in a preparedness perspective, the relevant stress case is peak demand, especially because another passenger operator also serves the island during the summer and its passenger counts were unavailable. By contrast, the spring and September population estimates rely on single-source information and should therefore be treated as medium-confidence inputs; their influence is explored through the population sensitivity scenario.

- (iv) Semi-structured interviews.

Finally, 20 semi-structured interviews were conducted with island-based businesses from different sectors of activity (bars, restaurants, construction firms, ready-to-wear retailers, butchers, bakeries, etc.) in order to establish operational benchmarks for impact thresholds (stock depletion, degraded operation, temporary closure). These interviews made it possible both to estimate key variables such as the number of employees — a variable that is poorly represented in the SIRENE database — and to assess firms' capacity to continue operating in the event of a disruption in commercial links with the mainland.

2.3 Data processing and time-series reconstruction

First, the shipping records displayed inconsistencies in the identification of consignees (label variants, abbreviations, changes in business names, etc.). We therefore standardised these entries — by harmonising names and assigning a SIRET number to each entity — in order to enable matching with the SIRENE database. This matching process was intended to associate each consignee with an identified economic unit and a sector of activity, so that flows could be grouped according to a typology relevant to the economic analysis.

Due to time constraints, the available shipping records cover only 12 weeks of observation distributed across the year, in a non-continuous manner (the list of weeks is provided in the Annexes). The selection of these weeks was made in collaboration with the Yeu-Continent company, with two objectives: (i) to capture the periods most representative of the island's economic activity — low season (autumn and winter), pre- and post-peak season (spring and late summer), and peak season (summer) — and (ii) to ensure that the most vulnerable businesses, namely those consuming food products, were all represented. This sampling strategy is therefore purposive rather than random. It improves the coverage of the main seasonal regimes relevant to the island's logistical functioning, but it may under-represent atypical weeks, such as exceptional demand peaks, unusually low-volume periods, or weeks affected by disruptions.

To make these data compatible with a dynamic analysis of logistical continuity (stocks, thresholds, time to shortage), we constructed a continuous weekly time series by estimating non-observed weeks through linear interpolation between two observed weeks. For each interval between two observed weeks, the difference in volume was distributed evenly across the number of weeks separating them, so that volumes gradually increased or decreased from one week to the next.

Two interpretive precautions follow from this procedure. First, the reconstruction is intended primarily to compare seasonal regimes rather than to establish an exact week-by-week chronology. These interpolations therefore necessarily introduce discrepancies between the interpolated logistical flows and those actually observed. Second, some economic entities are absent from our database because they may have been supplied outside the 12 observed weeks (particularly construction firms and ready-to-wear retailers, which are supplied less frequently than businesses dealing with perishable goods).

In line with field observations derived from the semi-structured interviews, flow and stock calculations were conducted on a weekly time step: the firms interviewed reported being supplied on average once or twice per week, leading us to conclude that the weekly scale is appropriate for representing logistical dynamics (restocking, stock pressure, time to stock depletion). However, the seasonality of the island socio-ecosystem is expressed primarily at the monthly scale (seasonal hiring, variations in the present population, intensification of demand, increased productive capacity). To make these contrasts more legible, we introduce M , a grouping variable used to synthesise weekly dynamics into seasonal regimes ($M \in \{\text{January}, \dots, \text{December}\}$). The series is calculated week by week as a function of this temporal index M .

To obtain a weekly consumption value that can be used in the model, these monthly volumes are then converted into an average weekly flow by dividing by 4.33 (= 52 weeks/12 months), which amounts to assuming a uniform distribution of consumption within each month. This intra-monthly smoothing constitutes a simplification: it is not intended to reproduce short-term peaks, but rather to make month-to-month fluctuations comparable. This simplification is particularly important in summer, when short intra-monthly demand peaks may be large relative to average monthly flows. The reconstructed series should therefore be read as a seasonal trend rather than as a representation of daily or weekly logistical stress peaks.

2.4 The scenarios considered

Since the aim of the study is to examine the effects of a supply disruption, we define disruption scenarios affecting the Yeu-Continent link on the basis of plausible causes identified within the territory. In the model, we do not seek to simulate the cause itself (flooding, technical failure, labour unrest), but rather its logistical effect, namely a total interruption of supply (zero inbound flow).

Starting from a shock applied to the inbound flow, we calculate the number of days required for stocks to cross operational thresholds (stock depletion, degraded operation, temporary cessation of activity — see Section 3), thereby providing a direct metric of continuity (« time to first operational impact ») for economic entities and, subsequently, for the territory as a whole.

At the territorial scale, several causes make a supply disruption plausible. First, the island's port is located in a low-lying area, and the freight handling zone lies within a flood-prone area: marine flooding may render the operating area inaccessible, while damage to port infrastructure may extend its unavailability beyond the event itself, for the duration of repair works. During Storm Xynthia (2010), for example, the island's port was flooded by one metre of water, leading to an interruption of the maritime connection. A comparable risk also exists on the mainland side, at the port of Fromentine (Vendée), which likewise constitutes a point of vulnerability in the supply chain. The port of Fromentine has, moreover, been equipped with temporary flood barriers in order to limit potential damage in the event of marine flooding. It is also not uncommon for the vessel to be unable to operate because of rough sea conditions, which occurs several times a year. During Storms Lothar and Martin (1999), testimonies indicated that maritime supply could not be ensured for almost a week. Second, a technical hazard affecting the freight vessel (breakdown, immobilisation at the quay) may interrupt the connection for the duration of maintenance and repair. Finally, organisational disruptions (labour shortages, industrial action within the company) may prevent the normal operation of the route. To these causes may be added accidental events, such as an incident affecting the hydrocarbon storage area located in the immediate vicinity of the freight handling zone, which could temporarily restrict or prohibit access to the facilities.

3. Methodology

In order to characterise what a supply disruption would mean for an island territory that is highly dependent on inbound flows, our methodology develops a continuity metric based on the time required to reach critical thresholds: starting from a shock applied to inbound flows — modelled here as a total interruption of the maritime link — we calculate the number of days required for stocks to cross operational thresholds, first at the level of individual entities (firm-level stock depletion), and then at the territorial scale (generalized shortage).

The approach is structured in four stages (Figure 2). First, we reconstruct a GIS database from the SIRENE register in order to locate the island's different businesses. Second, we reconstruct inbound goods flows and identify their consignees from the shipping records, before matching these consignees to a typology of activities through linkage with the SIRENE database. This makes it possible to describe the local logistics structure and to identify groups of actors differentiated by the volumes they handle — upstream firms, that is, « local suppliers », and downstream firms, that is, « customers of local suppliers » — as well as by their roles in distribution. Third, drawing on semi-structured interviews, we define impact thresholds at the micro level (stock depletion, degraded operating conditions, and temporary business interruption). These thresholds are explicitly grounded in the survey material and are used to calculate an indicator of « time to first operational impact ». Finally, we move to the meso level by modelling the redirection of demand towards local suppliers after stock depletion, thereby making it possible to identify a territorial threshold of generalized shortage.

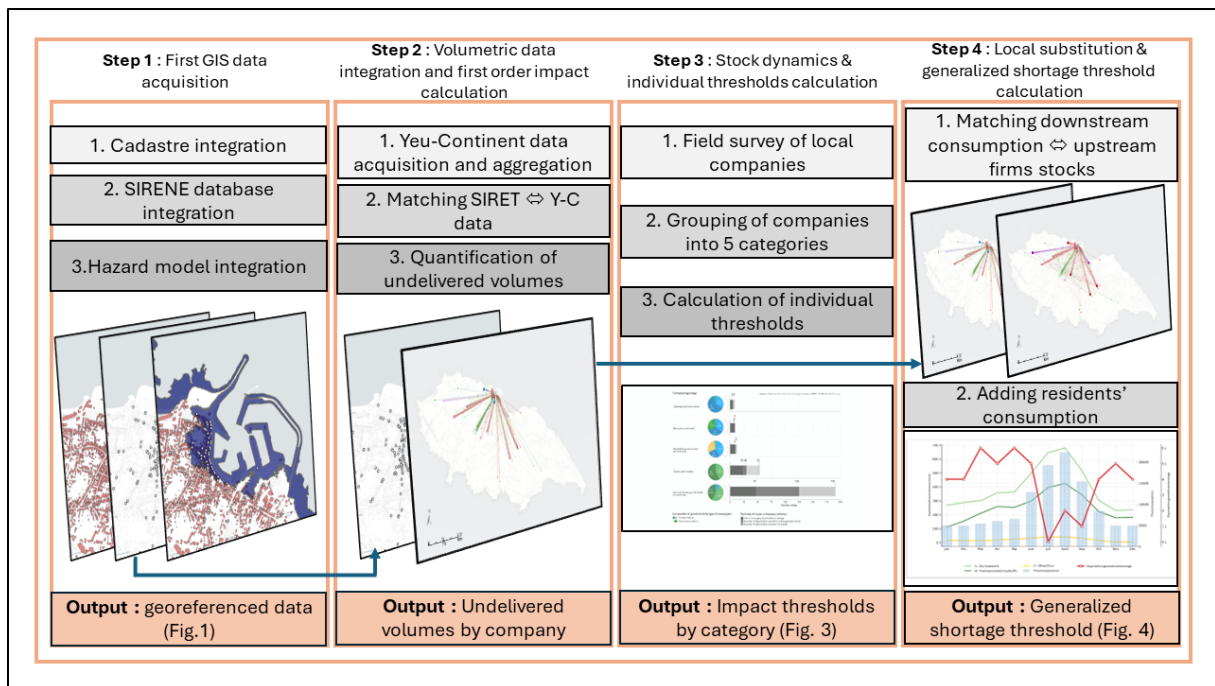


Figure 2 - Methodology diagram: from data to generalized shortage estimation (source: H. Emenegger)

The full formalisation of the model and the complete set of structuring assumptions are presented in the online additional annexes; the main text focuses on the underlying mechanisms, the empirical parameters used, and the indicators produced.

3.1 Reconstruction of inbound flows and quantification of first-order indirect impacts.

The indirect economic impacts considered in this article stem from a single shock: the interruption of the maritime freight link between the island and the mainland, temporarily preventing the delivery of goods. The objective of this first stage is twofold. On the one hand, it seeks to reconstruct inbound flows — who imports what, when, and in what quantity — in order to describe the local logistics structure. On the other hand, it aims to quantify the immediate effect of a disruption of the maritime link in the form of « undelivered » volumes, which here constitute the first-order indirect impact.

Inbound flows are reconstructed from the shipping records provided by the Yeu-Continent company (see Section 2.2). Consignees are then matched to the SIRENE database through their SIRET number, making it possible (i) to geolocate establishments and (ii) to link flows to economic characteristics (activity sector through the NAF code, etc.). This integration is carried out using GIS software in order to connect shipped volumes to recipient establishments. However, the issue is not cartographic per se: rather, the aim is to construct a « flow → establishment → activity typology » table, which is required for aggregation by entity and by activity group. The availability of a cartographic representation nevertheless allows for operational conclusions to be drawn, particularly regarding circulation nodes and areas of concentration of economic activities.

The first-order indirect impact is defined as the volume of goods that should have been delivered during a period of disruption of the maritime link. This definition is consistent with Rose's (2004) approach to first-order indirect losses, in which the directly affected entity — here, the freight handling area — generates cascading effects on the agents dependent on the flows generated by that entity. For a firm i , the volume imported from the mainland over a period T can be written as follows:

$$(Eq. 1) V_{i,T} = \sum_{t=1}^T V_{i,t}$$

Where $V_{i,t}$ denotes the daily volume shipped to i and T the duration of the disruption (daily time step). At the scale of the island, the total volume imported over T can be written as follows:

$$(Eq. 2) V_T = \sum_{i=1}^N \sum_{t=1}^T V_{i,t}$$

Where N denotes the number of recipient establishments. The volume can be disaggregated by firm, by goods category, and by firm typology, thereby providing a detailed description of the territory's economic vulnerability at different scales of analysis.

Finally, we group activities into functional categories that are logistically consistent (supply rotation patterns, commodity tariff scale and perishability, and average imported volume): (1) food-related trades and accommodation–food services, (2) education and health¹, (3) construction, (4) perishable-goods retail, and (5) non-perishable-goods retail. The detailed correspondence between NAF codes and these categories is provided in the Annexes. We also distinguish two broad groups of actors used in the remainder of the method. On the one hand, “downstream” actors (retail, food services, and other services) are characterized by relatively low imported volumes, limited inventories, and the possibility of partial local substitutability during disruptions. On the other hand, “upstream” actors (platforms, wholesalers, high-volume importers), whose redistribution role and large needs make local substitutability impossible. This distinction specifies actors' relative position in the local organization of flows.

This latter distinction is justified because, in our model, substitution is treated as a demand reallocation mechanism: once inventories are depleted, downstream actors' demand shifts toward local suppliers, which makes it possible to examine both the tightening of inventories by activity sector and the conditions under which generalized shortage may occur.

However, in order to simplify the model—and because we do not have sufficient information on each firm's production processes—we assume that downstream actors substitute locally only after their inventories have been fully depleted (H10). The model entails additional assumptions (constant behavior until inventories are depleted (H12): no rationing and no stock-retention behaviors), which are discussed in the limitations section (see Section 5.3).

3.2 Second-order indirect impacts: inventory dynamics and activity thresholds

Second-order indirect impacts correspond to the effects of supply-chain disruption on firms' operations. Unlike first-order impacts (undelivered volumes), they materialize only once the supply interruption leads to inventory depletion and, consequently, to a degradation or temporary halt of activity. The model estimates, in days, the time required to reach several impact thresholds: inventory depletion and generalized shortage.

¹ The “education and health” grouping follows a logistical rationale, limited here to similar food-related collective-catering supply channels. It should not be interpreted as an equivalence in criticality, regulatory continuity requirements, or emergency preparedness between schools and health facilities.

3.2.1 Inventory dynamics under normal conditions

We assume (H1) that firm i 's inventory over period T (daily time step) depends on (i) supply, (ii) consumption in the previous period and (iii) the inventory level from the previous period. The dynamics can be written in general form as follows:

$$(Eq. 3) S_{i,T} = A_{i,T} + S_{i,T-1} - C_{i,T-1}$$

Where $S_{i,T}$ is the inventory at the beginning of period T , $A_{i,T}$ is the supply at the beginning of period T and $S_{i,T-1} - C_{i,T-1}$ is the inventory remainder from the previous period.

At each period, supply $A_{i,T}$ is decomposed into imports and local purchases :

$$(Eq. 4) A_{i,T} = V_{i,T} + L_{i,T}$$

Where $V_{i,T}$ denotes imports from the mainland over the period and $L_{i,T}$ denotes volumes purchased locally on the island from other economic entities. Because the imported share is not directly observable for all firms, it is estimated for each typology k using a self-reported coefficient m_k , computed as the average of interview responses. We assume that the import share remains constant (H2). This coefficient allows us, for a firm i belonging to typology k , to express the imported share and, by extension, the share of local purchases.

Finally, to make supply compatible with seasonal variables expressed at the monthly scale, volumes are aggregated at the month M level and then converted into an average weekly supply by assuming 30 days and 4.33 weeks per month (see Annexes). This operation introduces seasonality (month M) while preserving an inventory dynamic computed at the daily time step.

3.2.2. Inventory depletion and computation of the depletion threshold

Under a disruption of the link, the imported flow becomes zero. To estimate the inventory depletion threshold (first level of effect), we assume that supply becomes null during the disruption, i.e., that firms cannot replenish locally (H6). In this case, $A_{i,T} = 0$, and Eq. 3 shows that each firm's inventory declines solely as a function of its own consumption. This assumption applies only to the computation of the first threshold, namely firm-level inventory depletion. It does not mean that local substitution is absent from the model as a whole. Rather, substitution is introduced in a second step, once downstream inventories have been depleted, in order to model demand reallocation toward upstream local suppliers and the possible emergence of generalized shortage.

The number of days without supply required for $S_{i,T}$ to reach zero then corresponds to the inventory depletion threshold.

3.2.3 Consumption estimation and incorporation of seasonality

We assume (H5) that the consumption associated with a firm's operations can be approximated using employment and the average consumption per employee.

A survey was conducted among island firms (week of 10–15 June 2024) to estimate (i) the number of employees present, (ii) the average consumption per employee for each firm typology, and (iii) the "degraded mode" and temporary cessation-of-activity thresholds (see Section 3.2.4). For each surveyed firm, an average per-employee consumption $c_{i,T}$ is computed by dividing the volume observed during the survey period by the self-reported number of employees:

$$(Eq. 5) c_{i,T} = \frac{S_{i,T}}{n_{i,T}}$$

Where $S_{i,T}$ refers to Eq. 3 and $n_{i,T}$ is the estimated workforce over period T .

These values are then aggregated by typology k to obtain an average consumption per employee \bar{c}_k , which is applied to all firms in typology k .

The number of employees varies with seasonality (month M). For each month, the workforce of each firm i is therefore estimated by dividing the volumes supplying the firm by the average consumption of its typology, while ensuring at least one employee (a principle drawn from CGDD practices). This step provides a daily consumption consistent with seasonal variations in volumes. It should be interpreted as an estimate of production capacity rather than a measurement of actual employment. This estimate is therefore a source of uncertainty. If a firm increases orders to build pre-season inventories rather than to serve a larger workforce or higher current activity, the model may overestimate productive capacity and consumption, thereby shortening estimated inventory lifetimes. This assumption is made explicit in the hypothesis table.

The time to inventory depletion is then computed, for each firm and each month, by dividing the stock volume by the corresponding daily consumption (estimated workforce \times average daily consumption per employee), yielding a duration expressed in days (see online additional annexes).

3.2.4 Post-depletion thresholds: degraded-mode operation and temporary cessation

However, inventory depletion does not necessarily imply an immediate cessation of activity: interviews show that firms will generally seek to maintain part of their activity by sourcing locally when possible. In order to incorporate this reality (and in line with CGDD recommendations regarding business interruption and degraded operation), we consider two additional thresholds: (i) the transition to degraded mode and (ii) the temporary cessation of activity.

These two thresholds are drawn directly from the survey. Two questions were asked to respondents: “In the absence of deliveries, after how many days would you switch to a degraded mode?” and then “After how many days would you temporarily cease operations?”. When respondents asked for clarification of what “degraded mode” meant, we provided a benchmark—intended to make responses comparable—phrased as “corresponding to 75% or less of your usual activity²”. This benchmark was therefore not a normative threshold imposed *a priori*; it was only meant to harmonize respondents’ interpretation of the term so that answers would be more comparable across activities. Responses (in days) were then aggregated by typology k (mean) and applied to establishments in the typology.

In the model, these average thresholds are applied uniformly to all firms within the same typology (H2). Once the inventory depletion threshold is reached, they make it possible to locate in time the concrete degradation of activity (during which the firm can substitute locally according to H8) and then the temporary halt, based on operational thresholds declared by the actors.

3.3 Demand reallocation and local substitution mechanism

The propagation mechanism studied rests on the articulation between final demand and the local organization of supply. On the island, downstream firms consume goods in order to produce goods and services that meet a demand, which varies with the number of people present on the island (permanent residents and seasonal population). This final demand is therefore a central variable for estimating the intensity of goods consumption and, consequently, the time to inventory depletion.

In our model (see Annexes), the disruption of the maritime link is represented as a zero import volume. Downstream actors then draw primarily on their own inventories. Demand reallocation occurs only after downstream inventories reach the depletion threshold (H10): from that point onward, the volumes needed to maintain activity are sought within the territory, i.e., through local purchases from upstream actors

² The 75% threshold is provided for illustrative purposes only. However, it was not challenged by respondents and is not a model parameter

(large retailers and local wholesalers). This sequencing is important: demand reallocation is not an instantaneous mechanism from the outset of the shock, but a response conditioned on the depletion of downstream inventories. If downstream firms started substituting immediately after the shock, pressure on upstream inventories would begin earlier and the generalized shortage threshold would likely be reached sooner. The adopted sequencing is therefore conservative with respect to upstream depletion, because it delays demand reallocation until downstream stocks are exhausted.

This mechanism is directly grounded in the interviews: respondents report that they would try, at least temporarily, to maintain activity by substituting local purchases for imports after depletion, in proportions that vary across typologies. However, this substitution remains constrained by the inventories effectively available on the island.

Finally, incorporating final demand (that of residents) helps explain why the impact of a marginally longer disruption can be non-linear: when the population increases sharply (tourist periods), demand rises while the mobilizable inventory buffer remains limited, which shortens the expected time to depletion and brings the system closer to threshold crossings. Once this depletion threshold is reached, each additional day without deliveries can, through the downstream-to-upstream substitution effect, accelerate the depletion of total inventories available on the island.

3.4 Generalized shortage definition

The generalized shortage model focuses on food products (categories A and B), because they are indispensable for supplying households, public services (health and education), and the core economic activities of a tourism-based economy such as Île d'Yeu (accommodation and food services). This therefore constitutes the main systemic risk associated with a prolonged disruption.

At the territorial scale, the issue is not only when an individual firm crosses a threshold, but when the reallocation of demand flows leads to a shortage affecting the entire island. We define generalized shortage as the situation in which local actors able to absorb the demand shift (i.e., upstream actors) in turn reach the inventory depletion threshold, making the substitution mechanism theoretically impossible within the territory.

Accordingly, in a first stage, downstream actors continue to meet final demand by drawing on their own inventories. In a second stage, once downstream inventories are depleted, demand is reallocated upstream (H10). The date of generalized shortage then corresponds to the moment when upstream inventories reach zero, given (i) seasonal final demand and (ii) the demand shift induced by downstream depletion. In other words, the “downstream inventory depletion” threshold plays a pivotal role: it marks the onset of demand reallocation and the transition to a regime in which upstream inventory depletion becomes decisive for the continuity of overall economic activity (and food security).

In the model, the generalized shortage metric is therefore computed as the number of days between the shock (the moment when imports become zero) and the depletion of local suppliers' inventories. This metric depends directly on the ratio between total inventories on the island and total consumption. If, over a period T , consumption is lower than available inventories, the time to upstream depletion is extended; conversely, a rapid increase in population raises consumption, brings the system closer to thresholds, and sharply reduces the time to generalized shortage.

The time (in days) to generalized shortage $P(M)$ is then expressed as a function of the average time to downstream inventory depletion, $\overline{T_{Sk=1,2,3}}$. Let $V_{AB}(M)$ denote island-wide aggregated inventories of category A and B goods in month M , $d_h(M)$ the residents' demand over the same period, and $\overline{d_e(M)}$ the average daily consumption of downstream firms in that month. We obtain:

$$(Eq. 6) P(M) = \overline{T}_{s_{k=1,2,3}} + \frac{V_{AB}(M) - d_h(M)}{d_e(M)}$$

Result expressed in number of days.

When the expression yields a value below the average downstream depletion threshold, it should not be interpreted as a generalized shortage occurring before firm-level depletion. Rather, it indicates that, once the reallocation mechanism is activated, upstream inventories are already insufficient relative to resident demand and transferred downstream demand.

3.5 Sensitivity analysis

The results presented below rely on a set of assumptions and constructed variables based on (i) the shipping manifests, (ii) a semi-structured survey of local firms, and (iii) a reconstruction of the population present on the island by month.

We therefore conduct sensitivity analyses to assess the stability of the most salient results (seasonal contrasts, times to threshold crossings, and the generalized shortage metric). One parameter is varied at a time, while the others are kept at their baseline values. We examine how these variations affect (i) the average time to inventory depletion and (ii) the time to generalized shortage.

These variations should not be interpreted as statistical confidence intervals or as exhaustive uncertainty bounds. Rather, they are sensitivity scenarios used to examine how strongly the results respond to changes in key parameters and whether the main qualitative findings remain stable under alternative parameter values. The selected ranges were chosen as stress-test values rather than estimated from empirical probability distributions. Given the limited number of surveyed firms per typology, wider uncertainty ranges could be explored in future work.

Three parameters were tested:

1. Per-employee consumption c_k , derived from the survey. Depletion times are computed from an estimate of average consumption per employee by typology, obtained from the survey. Because the respondent sample is limited, we test a $\pm 20\%$ variation in c_k . This test measures how strongly the time-to-depletion depends on the estimated consumption of downstream firms.
2. The population present on the island, $h(M)$, estimated from several data sources. Since final demand varies with population (permanent residents and seasonal visitors), we test a $\pm 10\%$ variation in $h(M)$ to capture variability, as tourist flows can differ from one year to another.
3. Daily consumption per inhabitant. In our model, we use the INCA 3 indicator produced by ANSES (2017), which reports an average consumption of 2.9 kg of food products, including packaging and water. ANSES estimates that beverages account for more than half of this weight. Because the island is supplied with tap water from the mainland via a submarine cable, we first test the effect of a 25% reduction in resident consumption, without explicitly modelling substitution between water and other beverages. Conversely, precautionary or panic buying could increase resident demand during a disruption. We therefore also test a symmetric +25% resident-consumption scenario as an upper stress test.

The purpose of these sensitivity tests is to assess the responsiveness of the model and the stability of the main qualitative findings. The tested variations mechanically shift the absolute values of the thresholds, but the main objective is to verify the stability of the key findings and trends, such as the most critical periods and the most vulnerable business typologies.

4. Results

The results support two complementary levels of analysis: (i) a micro-level reading (by establishment and by typology), focused on the time to reach operational impact thresholds, and (ii) a territorial-level reading, focused on crossing the generalized shortage threshold. The value of the volumetric approach lies in translating logistical dependence on the mainland into an action-oriented metric: the number of days before a concrete effect occurs (stock depletion, activity degradation, or temporary cessation) and the number of days before the island's economy becomes under strain. It is important to recall that these results are expressed in volumes and do not include price mechanisms; they should therefore be interpreted as logistical consequences rather than monetary losses.

At the micro level, the results show that the activities most vulnerable to a disruption of the link are those whose operations depend heavily on food products and, a fortiori, those that rely on a kitchen. This is due to a higher consumption-to-inventory ratio, which mechanically leads to shorter inventory lifetimes. Interviews suggest that this may stem from physical constraints on food preservation and from limited storage space for these typologies.

The interviews thus indicate different average weekly consumption per employee across typologies: an employee in food-related trades and accommodation–food services consumes on average 115 kg of goods, an employee in collective catering (school or hospital) 58 kg, and an employee in perishable-goods retail 321 kg. Consistent with these orders of magnitude and the limited storage capacity for fresh products, food-related trades and accommodation–food services exhibit an average inventory lifetime of about 5 days without supply, education and health about 7 days, and perishable-goods retail about 9 days (see Fig. 3).

By contrast, activities whose inventories are mostly non-perishable (tariff scales D/E) display much longer horizons: about 23 days for construction and 47 days for non-perishable-goods retail.

The results highlight, for certain typologies, a gap between the time to inventory depletion and the post-depletion thresholds (degraded operation and activity cessation). This gap reflects the self-reported ability to maintain activity (at least partially) through local purchases when imports are interrupted. The interviews confirm this point: construction firms and non-perishable-goods retailers report that they can source locally and sustain operations over a prolonged period. By contrast, for accommodation–food services and perishable-goods retailers (bakeries, butcher shops, etc.), local substitution cannot fully maintain activity, so they must shift directly to degraded operation.

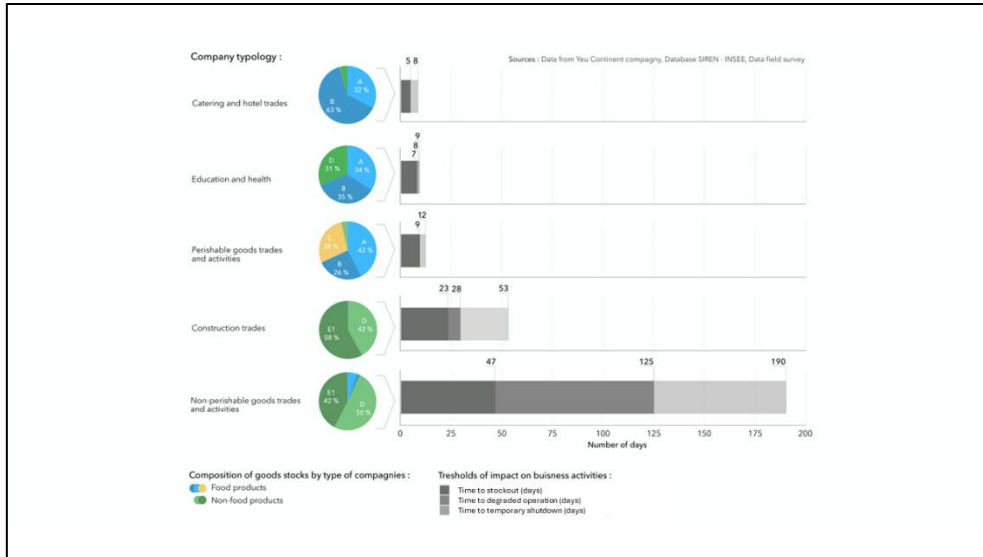


Figure 3 - Types of imported goods and impact thresholds by business typology (source: C. Cohic & H. Emenegger)
 Note: Values are central estimates. Sensitivity tests on per-employee consumption indicate that firm-level depletion thresholds vary within the ranges reported in Appendix 7.5

At the meso level, we observe a marked reduction in the island’s autonomy during the peak season (see Fig. 4). Higher inbound flows are not sufficient to sustain economic activity if demand—driven by the population present—increases faster, which mechanically shortens inventory lifetimes. These results do not imply that households would be immediately deprived of food. The model measures the continuity of the local commercial supply system — inventories held by firms, retailers, and suppliers — rather than domestic food stocks stored in households. Household reserves, rationing, and behavioural adjustments could delay experienced food insecurity. The near-zero value should therefore be interpreted as an indicator of an extremely tight business-based supply system in peak season, not as a prediction of immediate household food deprivation.

During the low season, $P(M)$ (red line) remains around 5 days, while both the population (bars) and imported volumes (green and yellow lines) vary only slightly. From May onward, however, final demand increases due to the progressive rise in the population present on the island (May–June) followed by a sharp jump in July. The pronounced drop in $P(M)$ in July therefore clearly indicates a threshold crossing: despite higher imported volumes, the surge in demand reduces the autonomy buffer to a near just-in-time regime, in which even a brief interruption is sufficient to push the entire supply system closer to a generalized shortage.

Thus, Figure 4 highlights a major seasonal contrast between (i) imported volumes of food products (A and B), (ii) the population present, and (iii) the time to generalized shortage $P(M)$. Two results are particularly salient. First, territorial vulnerability does not track the level of imports: imported volumes reach their maximum (≈ 2) in July–August, yet $P(M)$ reaches its lowest values during the same period. In other words, inbound flows are not sufficient to secure supply when final demand increases faster than imported volumes. The figure suggests that during the peak season, the increase in population (≈ 5) raises daily consumption, reduces the inventory buffer, and places the island’s economy in a near just-in-time regime.

Second, between June and July, despite a marked increase in imported volumes, $P(M)$ drops from about 5 days to an almost zero value ($\approx 0-1$ day). Concretely, over this period and referring to Eq. 6, this means that the difference between imports and residents’ demand ($V_{AB}(M) - d_h(M)$) becomes negative, and that this negatively affects downstream firms’ inventories, which must draw down their stocks more rapidly to meet demand. This sharp decline in $P(M)$ signals a non-linearity because the drop ($\div 5$) is not proportional to the ratio of the population increase to the volume increase ($\div 2.5$). As long as the difference between imported volumes and consumption remains positive, the system retains some autonomy; but once this difference becomes negative, downstream firms’ inventories are depleted faster and their demand

eventually adds to residents' consumption, accelerating the depletion of inventories at the island scale and precipitating generalized shortage.

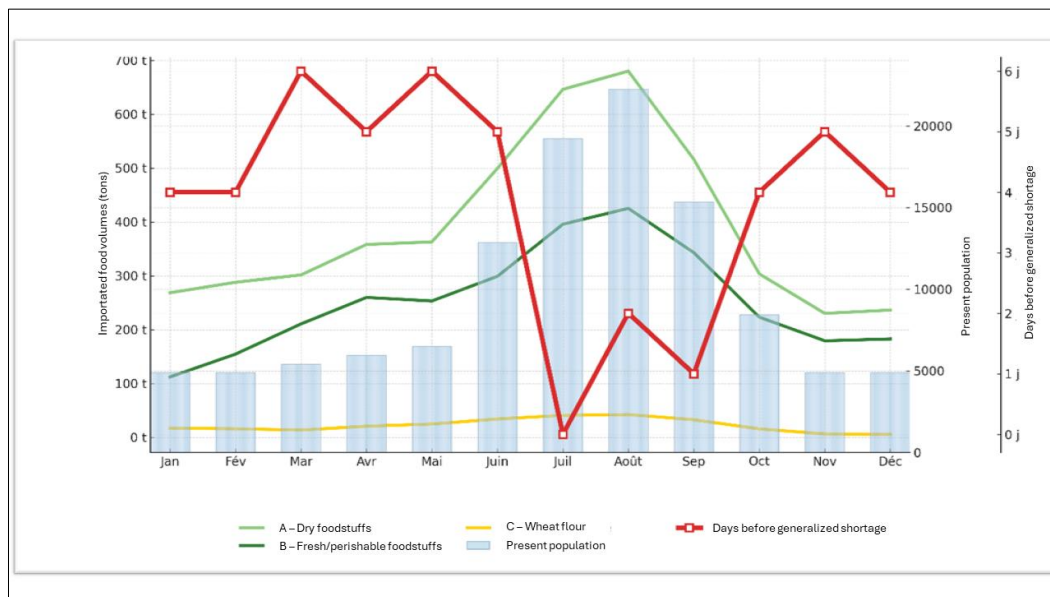


Figure 4 - Smoothed (interpolation-based) trend of the shortage threshold, present population, and imported food goods (source: H. Emenegger)

This figure has two operational implications. First, it identifies a time window during which even a brief interruption of the link may be sufficient to trigger generalized inventory depletion, which argues for preparedness measures specifically tailored to summer conditions (storage capacity, cold chain, distribution organization, prioritization). Second, it shows that slack is highly asymmetric across periods: the same interruption does not have the same effect in the low season (when several days of autonomy remain) as in the peak season (when autonomy is almost null). This means that vulnerability is not determined solely by the shock itself, but also by the initial state of the supply system (inventory levels and demand) at the moment the shock occurs.

These results should nonetheless be interpreted under a “constant behavior” assumption (H12). Household reserves, consumption adjustments, or rationing policies could delay this tipping point. The figure nevertheless indicates the vulnerability of the supply system when seasonal demand increases faster than imported volumes.

Finally, these results lead to interpretations that differ from purely monetary approaches: whereas substitution is often interpreted as a mitigating mechanism (a loss of revenue “compensated” elsewhere by a competitor), the volumetric approach treats it as a mechanism that tightens inventories and, by extension, the local economy. In an enclosed territory, substitution does not create additional volumes; it temporarily reallocates access to finite inventories, which can accelerate their depletion once downstream actors run out of stock.

Regarding the sensitivity analyses (see Section 3.5), before examining the sensitivity of the generalized shortage threshold, we first tested sensitivity at the micro level, in particular the average time to inventory depletion for downstream firms. These tests show that varying \bar{c}_k (consumption per employee) and m_k (dependence on imports) affects the estimated threshold in non-negligible relative terms, with values ranging from approximately 4.4 to 6.1 days depending on the month and scenario (see Annexes). The robustness therefore concerns the qualitative diagnosis — a short-autonomy regime for downstream food-related actors — rather than the exact number of days.

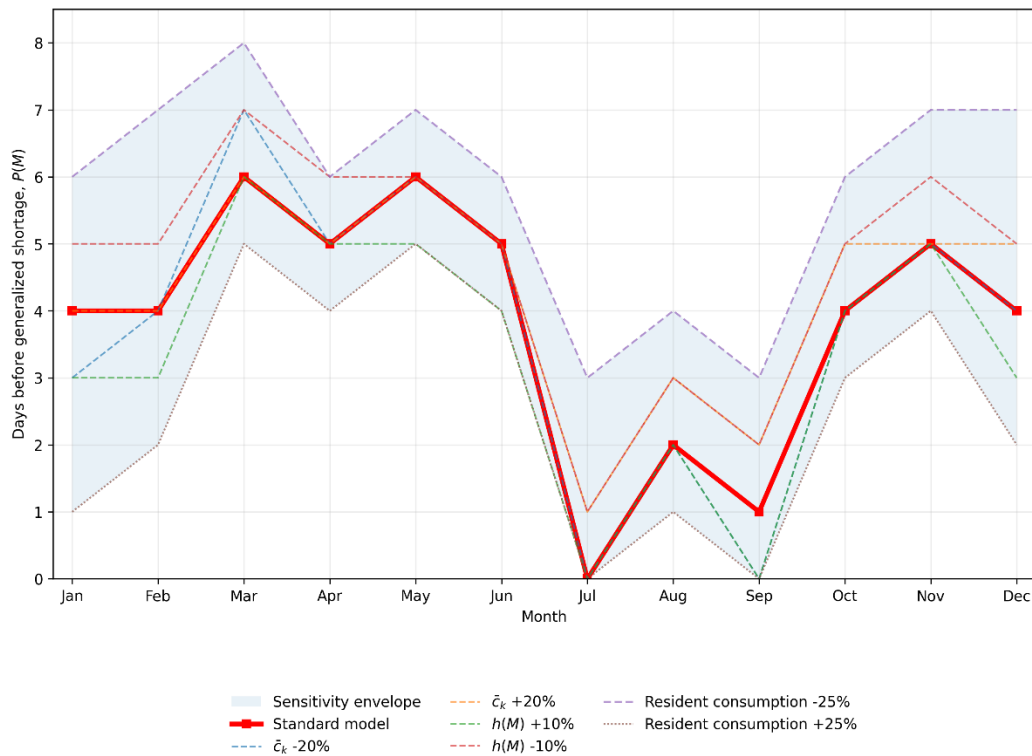


Figure 5 - Sensitivity analysis of the generalized shortage threshold $P(M)$. The standard model is compared with one-at-a-time variations in employees' consumption \bar{c}_k ($\pm 20\%$), population present $h(M)$ ($\pm 10\%$), and resident consumption ($\pm 25\%$) (source : H. Emenegger).

Note : The shaded envelope represents the monthly minimum and maximum values across all tested scenarios. Values are rounded to the nearest day.

At the meso level, the sensitivity scenarios test one-at-a-time variations in \bar{c}_k ($\pm 20\%$), the population present $h(M)$ ($\pm 10\%$), and resident consumption ($\pm 25\%$). Figure 5 reports both the standard model and the individual sensitivity scenarios, while the shaded envelope summarizes the range of values obtained across all tested scenarios. These variations shift the estimated time horizons, sometimes substantially, but they do not alter the main conclusion: July–August remains the period with the shortest time to generalized shortage, even when imported volumes increase. The robustness of the meso-level result should therefore also be understood as qualitative: the seasonal ranking of critical periods remains stable, rather than the exact value of $P(M)$.

Parameter changes shift $P(M)$ in the expected direction, but with different magnitudes. An increase in the population present reduces the time to shortage, whereas a decrease extends it, confirming the central role of $h(M)$ as a determinant of volumetric demand. Likewise, varying employees' consumption affects the timing of downstream inventory depletion and, in turn, the activation of demand reallocation toward upstream suppliers. Finally, resident-consumption scenarios have a direct effect on the generalized shortage threshold: reducing resident consumption increases the time to shortage, whereas a +25% stress scenario — which may represent precautionary or panic buying — shortens it. This confirms that the territorial threshold is highly sensitive to final demand under peak-season conditions.

5. Discussion and limitations

5.1 Contribution of the volumetric approach

Volumetric assessment of impacts enables two levels of analysis that help identify aggravating factors of economic risk in an enclosed territory. First, at the microeconomic level, analyzing impacts on indirectly affected entities makes it possible to identify critical thresholds for each entity. This allows us to identify which activity types are most vulnerable to a no-supply scenario and to characterize this vulnerability in terms of the number of days after which the entity's activity would be affected. This type of analysis and these results would be more complex—if not impossible—to observe with a monetary approach, because the monetary value of damage would dilute information on purchased and sold volumes into an aggregate monetary loss. Moreover, in monetary assessments, indirect damages are expressed as a loss of revenue associated with a disruption duration. The approach presented here instead estimates the duration of disruption before a concrete effect occurs on the activity of indirectly impacted entities—an inverse, though not opposing, perspective.

Second, at the mesoeconomic level (the island scale), volumetric assessment makes it possible—through interconnections between island firms and seasonality—to identify a generalized shortage threshold. This shortage results from volumes that do not reach the island and can be computed from the micro-level analysis of entities. Thus, beyond providing relatively fine-grained detail on impacts borne by indirectly affected entities, the volumetric approach reveals a more global, concrete risk at the scale of the whole territory. Our calculations, through the estimation of a generalized shortage threshold, highlight the economic risks imposed by a tourism-based economy on an insular territory, constraining it to depend on frequent supplies from the mainland.

Our results also show that a volume-based reading directly captures insular supply security, whereas classic monetary approaches express these effects as aggregate financial costs, thereby abstracting from inventory dynamics. This aligns with Hallegatte's (2010, 2015) call to move beyond the sole accounting of direct damages in order to analyze indirect economic mechanisms and macroeconomic resilience (i.e., the capacity to maintain production despite the shock). It also complements IO/CGE models that estimate losses in value but do not account for local inventory constraints (Oosterhaven & Többen, 2017). The volumetric approach also reframes substitution: where a monetary analysis may interpret it as a shock absorber, it appears here as an accelerator of depletion of finite inventories, thereby constraining upstream actors and accelerating the shift toward generalized shortage in peak season. We therefore consider the two approaches (monetary and volumetric) to be complementary: the former is suited to comparing planning scenarios and quantifying losses in value, whereas the latter sheds light on continuity mechanisms, operational thresholds, and inventory constraints that condition propagation.

Hallegatte (2014) recalls that resilience does not refer only to a "return to normal", but to the capacity to maintain essential functions; indirect losses depend on a territory's ability to maintain production and consumption despite the shock, through substitution, reconfiguration, or temporal arbitrage. Our work shows that, in an insular system where nearly everything passes through a port bottleneck, the same shock (a natural disaster, or sailing cancellations due to a strike, for example) can produce non-proportional effects depending on the system's load (i.e., whether it occurs in peak or low season). This is precisely what our monthly series between July and September show: a disruption at the port can rapidly propagate to distributors and points of sale, given the limited slack (inventories too small relative to demand), such that shortage arises quickly. This is consistent with analyses of ripple effects: disruptions propagate along value-chain links and become disproportionate when supply chains are under strain (Dolgui & Ivanov, 2021; Brusset et al., 2023).

Finally, working in volumes rather than prices is not a detail—it is operational. When the problem is feeding a population and maintaining economic activity, identifying flows and estimating inventories speaks directly to port planning (unloading slots, sailing frequency, location of the logistics area, etc.) and to the activities dependent on these flows, because our study defines impact thresholds beyond which local economic entities would be affected. This responds directly to criticisms of monetary approaches in the flood-damage literature: they may inform public policy, but they provide limited guidance for day-to-day management (Merz et al., 2010). Here again, this volume-based perspective complements conventional monetary approaches to damage assessment.

5.2 Specificity of the case study and transferability

As noted in Section 2, an insular territory has a number of intrinsic characteristics (isolation, enclosure, relative dependence on imports, limited space, etc.). These characteristics make it possible, for example, to observe certain phenomena such as the relationships between economic entities—observations that are facilitated by the small size of the territory. They also position the present work apart from part of the literature on indirect damages, which most often focuses on continental or much larger territories (Penning-Rowsell & Johnson, 2015; Merz et al., 2010; Meyer et al., 2013) and/or on specific value chains (Nortes-Martinez et al., 2021).

However, even if this differentiation is scientifically valuable, the question remains whether the method could be reproduced on other territories. We believe it can, provided that we clearly distinguish what pertains to the analytical framework and what pertains to case-specific parameters. The volume-based framework, the simple metric “days before crossing a threshold”, and the propagation logic via demand reallocation are transferable to other insular or quasi-insular territories: peninsulas, enclosed valleys, high-mountain areas, or territories dependent on a single logistics corridor. The key condition for transferability is the existence of a pivot operator (carrier, ferry company, distribution platform, infrastructure manager) and traceable shipment records to reconstruct volumes (at least at the monthly scale). Finally, a survey is necessary to capture the territory’s logistical specificities (supply channels, storage capacities, economic specialization, population seasonality, and institutional organization), which in turn allow operational thresholds (stockout, degraded operation, temporary cessation) to be parameterized.

On larger islands, with multiple ports or several operators sharing flows, the issue is not only that data collection becomes more costly and less centralized. The structure of the model itself would also need to be adapted, because the single-bottleneck assumption would no longer hold. In such contexts, the analysis would have to represent a network of partially substitutable entry points rather than a single logistical node. The external validity of the approach is therefore conditional. What is transferable is the analytical logic: reconstructing inbound flows, estimating inventories, identifying operational thresholds, and expressing vulnerability as a time-to-threshold metric. What is not directly transferable are the parameter values and, in some cases, the network structure itself.

5.3 Limitations and operational implications

We emphasize that our results rely on operational data (shipping manifests, SIRENE database, monthly population) whose quality varies: difficulty in estimating the number of people on the island each month, mixed shipments that may induce differences between net and gross weight, and results based on survey statistics. As noted in Section 2.3, the 12-week coverage of freight records and the interpolation procedure mean that the reconstructed series should be interpreted as a seasonal trend, not as an exact weekly chronology of logistical stress. In addition, because collecting freight data was highly time-consuming, our study focuses only on the year 2023. Working on a longer time series would make it possible to observe whether there are notable changes in the final values (individual thresholds and generalized shortage).

The adopted volumetric stance is that it illuminates logistical autonomy, but not price effects or behavioral responses (rationing, purchase postponement, fine-grained substitutions) that could lengthen or shorten the estimated durations. In this respect, results should be understood as “constant behavior” outcomes that identify orders of magnitude and tipping thresholds, rather than as fine-grained predictions of what would occur with economic adjustments through price dynamics. Note also that the short time horizon treated (about one week) would likely limit the implementation of price-adjustment mechanisms. In small communities, reputational constraints may limit opportunistic pricing, but this remains an untested behavioural assumption in our case and should not be treated as a modelled mechanism.

In our estimation method, we assumed that downstream firms could, after their inventories are depleted, substitute imports with local purchases from upstream actors. This assumption, directly grounded in interviews, remains debatable given the actual availability of products (some specific items may not exist locally), as well as allocation modalities under tension (client priorities, rationing, precautionary behaviors, etc.). This may lead the model to overestimate the fluidity of remaining stocks across actors, since local suppliers may prioritize existing clients, retain precautionary stocks, or be unable to provide specific goods during a crisis. Likewise, we assumed that all firms within a given typology are governed by average consumption and inventory mechanisms. This assumption—necessary for an inter-sectoral reading and for simplifying the model—remains debatable because typologies aggregate heterogeneous NAF codes: the grouping was constructed based on the tariff scales of consumed goods, but it does not exhaust the diversity of internal organization and productive constraints. This limitation is particularly important for the « education and health » category. The grouping is justified only by the logistical treatment of food-related collective catering; it does not capture the specific continuity requirements of health services, such as medicines, sterile equipment, emergency care, or regulatory stock obligations. The model may therefore understate the specific constraints of the health sector.

Finally, our study does not account for external interventions. In our model, the island is “left to itself” and cannot expect exogenous support. Yet in a durable crisis, the State and institutions would likely implement exceptional measures (airlift, requisitions, reorganization of flows). Similarly, we treat agents’ behavior (households, firms, public services) as invariant until the first thresholds, whereas in practice anticipatory and adaptive behaviors would emerge: household stockpiling, precautionary purchases, voluntary consumption reductions, short-time work, etc. These limitations do not invalidate the observed trends, but they bound generalization to comparable logistical contexts and justify complementary analyses (for example, over multiple years, with scenarios of degraded port functioning, or incorporating crisis-management measures). The model also does not represent intersectoral dependencies through labour availability. In a prolonged disruption, food shortages or household constraints could affect workers across sectors, meaning that activities with long material inventories, such as construction, might be interrupted before their own stocks are depleted. Future work could therefore couple inventory-based continuity metrics with labour-continuity or household-autonomy scenarios.

The volume-based analysis also highlights certain planning decisions. Although this observation follows from the studied scenarios (maritime link disruption), it leads us to consider the port area as a critical node of the island’s economic life: if it becomes inaccessible for a certain duration, consequences propagate across all activities. Protecting this node is therefore a strategic priority for maintaining the continuity of economic activity.

Our study also shows that some impacts propagate as soon as inventories are depleted for certain activity types. Increasing inventory capacity within firms could be a lever to reduce vulnerability, but this strategy faces material constraints (space, cold chain, costs). In this perspective, shared arrangements (buffer storage, crisis logistics) or organizational adjustments (delivery planning, pre-season stocking) may be more realistic levers than increasing inventories in each establishment.

Another possible lever is relocating and expanding the refrigerated storage area currently located in the port zone. It could be moved inland, filled ahead of the summer period, and drawn down when a disruption of the maritime link is anticipated. More broadly, results argue for preparedness ahead of the summer period: prioritization of uses (collective catering, health), distribution mechanisms, and coordination with upstream actors able to absorb (at least temporarily) part of the demand reallocation. The levers discussed (targeted buffer stocks, shared arrangements, prioritization) align with the mitigation and contingency strategies commonly discussed in supply disruption risk management (Tomlin, 2006; Chopra & Sodhi, 2014).

The generalized shortage model also highlights the degree of dependence on mainland food imports. Local food production, on the order of 170 t per year, represents only a marginal share of imported volumes (2%). However, the operational conclusion cannot be reduced to a simple call for expanding local production, because this lever faces complex structural trade-offs (competition for land with tourism and housing, operating costs, labor, demand seasonality, production constraints). Local production can contribute to diversification and long-term supply security, but volumetric results above all highlight more immediately actionable levers: targeted strategic inventories, cold-chain arrangements, rationing/prioritization procedures, and continuity plans for the logistics operator.

To conclude, climate change reinforces the relevance of a metric expressed in days: if the frequency, intensity, or duration of disruptions affecting port infrastructure increases, continuity trajectories become a central planning issue. The volumetric approach does not claim to replace monetary approaches, but it provides an operational framing of tipping thresholds and margins of maneuver that is useful for linking prevention, preparedness, and crisis management in insular territories.

6. Conclusion

This article aims to measure concretely the vulnerability of an insular territory to a supply disruption—not in monetary values, but in volumes and days of autonomy. Using shipping data, matching recipients with the SIRENE database, and reconstructing the population present by month, we (i) built, at the microeconomic scale, an indicator to estimate firms' inventory lifetimes and operational consequences for activity under disruption, and (ii) proposed, at the mesoeconomic scale, a metric to estimate the number of days without supply before a generalized shortage materializes at the island scale.

The volumetric approach developed in this article makes it possible to study indirect impacts of climate hazards at the scale of the whole territory, unlike the monetary approaches commonly used (cost–benefit analysis or multi-criteria analysis). Its advantage is to identify the disruption duration (threshold) beyond which concrete effects occur on the territory, and to treat substitution as the signal of an economy becoming under strain in an enclosed territory—thereby aligning more closely with the lived reality of island residents. Identifying these thresholds sheds light on several vulnerability factors: (1) a structural insufficiency of local production relative to demand, (2) storage capacities that are poorly sized for seasonal fluctuations, and (3) dependence on a single logistics bottleneck. These findings invite adaptation levers to be discussed not as a single solution, but as a portfolio: preventive storage and cold-chain arrangements, preparation of prioritization/allocation procedures under tension, and, in the longer term, partial diversification of supply sources, including local production.

Three results emerge from this study. First, firms whose operations depend heavily on perishable goods appear the most exposed, with smaller inventory buffers and faster threshold crossings. Second, autonomy contracts sharply in peak season: our monthly series indicate very low values in July–August–September, despite higher imported volumes. This result underscores that it is not total tonnage that “secures” the island, but the supply system's ability to adjust flows to seasonal final demand. Third,

centralization of freight infrastructure in a single node is a factor of systemic fragility: a disruption at this node rapidly reduces days of autonomy, even if most establishments are not located near the quays.

One particularity of this study is its focus on an insular territory, which raises the question of reproducibility. While numerical values depend strongly on local parameters, the framework (flow reconstruction, formalization of inventory dynamics, metrics in days before threshold crossings) can be transposed to other tourism-based islands, as well as to isolated territories (high mountain areas, enclosed valleys, etc.). Future research would benefit from extending observations over multiple years. A five-year panel of freight manifests, for instance over 2019–2023, would make it possible to capture inter-annual variability in seasonal demand and to test whether the near just-in-time regime observed in July–August is a structural feature of the island supply system or a 2023-specific configuration.

7. Annexes

7.1 Detailed list of observed weeks

2023

January

M	T	W	T	F	S	S
26	27	28	29	30	31	1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31	1	2	3	4	5

February

M	T	W	T	F	S	S
30	31	1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	1	2	3	4	5

March

M	T	W	T	F	S	S
27	28	1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31	1	2

April

M	T	W	T	F	S	S
27	28	29	30	31	1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

May

M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	1	2	3	4

June

M	T	W	T	F	S	S
29	30	31	1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	1	2

July

M	T	W	T	F	S	S
26	27	28	29	30	1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31	1	2	3	4	5	6

August

M	T	W	T	F	S	S
31	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31	1	2	3

September

M	T	W	T	F	S	S
28	29	30	31	1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	1

October

M	T	W	T	F	S	S
25	26	27	28	29	30	1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31	1	2	3	4	5

November

M	T	W	T	F	S	S
30	31	1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	1	2	3

December

M	T	W	T	F	S	S
27	28	29	30	1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

 Collected periods

 Interpolated periods

Note: Observed weeks were selected purposively with Yeu-Continent to cover the main seasonal regimes of the island economy. Non-observed weeks were reconstructed by linear interpolation. The resulting series should therefore be interpreted as a seasonal trend rather than as an exact weekly chronology.

7.2 List of hypothesis

Hypothesis number	Hypothesis formulated	Main implication/limitation
H1 – Stock composition	A company's stock at time t is made up of the remainder from the previous period and the supplies received at the start of the week.	Simplifies inventory dynamics and assumes a regular stock accounting structure.
H2– Imported share and employee consumption	For a typology k , the average imported share m_k and the employee consumption \bar{c}_k are constant and comes from the June 2024 survey.	Intra-typology heterogeneity is not fully represented.
H3 – Reference week	The survey week (June 10-15, 2024), week T , is representative of the operation of the company and the work of the employees; during this week T , the stock can be estimated by the average supply.	Atypical behaviour during the survey week could affect parameter estimates.
H4 – Productive-capacity proxy	Monthly workforce is not observed directly. It is approximated from supplied volumes and average consumption per employee by typology. This variable should be interpreted as a proxy for productive capacity rather than as measured employment.	This is not measured employment, but a proxy for productive capacity.
H5 – Workforce-based consumption	The daily consumption of a company is $C_{i,t} = n_i \cdot \bar{c}$; n_i is the employees of i and the coefficient \bar{c} is constant. The consumption is uniform over 7 days and over the season.	Links stock depletion to estimated workforce and assumes a constant per-employee consumption coefficient over time.
H6 – No local restocking in the event of a stock shortage	When there are no more imports, $L_{i,t} = 0$; no restocking takes place before the total exhaustion of the stocks of client companies.	Stockout is computed before substitution is introduced.
H7 – Import dependency on suppliers	Supplying companies can only replenish their supplies through imports; no local company can meet their demand.	Reinforces the island bottleneck logic.
H8 – Perfect substitutability of goods	Imported goods and those purchased locally (scales A and B) are perfectly substitutable in the model.	May overestimate the fluidity of stocks during crisis conditions.
H9 – Single consumption of residents and businesses	Residents and businesses consume the same categories of food goods (scales A and B).	Product-level differences are not modelled.
H10 – Demand reallocation after stockout	Once its stock reaches zero, a client company transfers its entire request to suppliers until their stocks are exhausted.	Substitution is sequenced rather than immediate.
H11 – Invariance of consumption coefficients	Seasonality M only modifies the number of employees $n_i(M)$ and residents $h(M)$; but the consumption coefficients \bar{c} (companies) and 2.9 kg/h (inhabitants) remain constant.	Behavioural adaptation is not modelled.
H12 – Constant behavior until stocks are depleted	Until inventories are depleted, firms and households are assumed not to ration, hoard, or significantly modify their consumption behaviour.	Results are constant-behaviour estimates, not behavioural forecasts.

7.3 NAF aggregation

Classification name	Classification number	Associated NAF codes	Logistic justification	Associated main commodity categories
Catering & hotel trades	1	NAF starting by 10, 50, 55 & 56	private establishments dependent on a kitchen	A & B
Education & Health	2	NAF starting by 85, 86 & 87	public or semi-public establishments serving group meals	A & B
Perishable goods trades and activities	3	NAF starting by 47	private establishments primarily selling perishable food	A, B & C
Construction trades	4	NAF starting by 41, 42 & 43	Establishment using or selling goods intended for construction	D & E
Nonperishable goods trades and activities	5	NAF starting by 46	Establishment selling non-perishable goods, excluding building materials	E

7.4 Sensitivity of the inventory depletion threshold to changes in employees' average consumption

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Value of $\overline{T}_{sk=1,2,3}$ when $\bar{c}_k - 20\%$	5,42	5,57	5,41	5,66	5,81	5,60	6,00	6,11	5,48	5,3	5,33	5,02
Value of $\overline{T}_{sk=1,2,3}$ when $\bar{c}_k + 20\%$	4,95	5,04	5,06	5,14	5,3	5,17	5,70	5,67	5,12	4,61	4,82	4,39

7.5 Survey questionnaire and expected responses

Questions	Expected responses
Critical goods for the firm's operations	
Which goods are essential for your activity?	Tariff scale corresponding to the type of goods used by Yeu-Continent + details on the specific goods concerned
What is your consumption (in kg) of these goods per day or per week?	X kg/day X kg/week
Do you hold a stock of these goods ?	Yes/No
In volume terms and in number of days ?	Good A : X weeks of stock Good B : X weeks of stock
Suppliers and sourcing	

Who are your main suppliers ?	Supplier1 = X% Supplier 2 = X% Island supplier 1 = X% Island supplier 2 = X%
Do you think there are other suppliers on the island able to provide these goods ?	Island market gardeners (for exemple)
How frequently are you supplied ?	X times/week for good A X times/week for good B
At what volume ?	X kg/week for good A X kg/week for good B
Impacts on activity in the event of a supply disruption	
After how many days without supply would you operate in degraded mode ? (if question "<75% of your usual activity")	From X days
After how many days without supply would you have to cease operations	From X days
In the event of an electricity supply disruption, can you operate?	Activity/No activity
In the event of a water supply disruption, can you operate?	Activity/No activity

8. References

- André, C., Monfort D., Bouzit M. & Vinchon C. 2013. « Contribution of insurance data to cost assessment of coastal flood damage to residential buildings: insights gained from Johanna (2008) and Xynthia (2010) storm events ». *Natural Hazards and Earth System Sciences* 13 (8): 2003-12. <https://doi.org/10.5194/nhess-13-2003-2013>.
- Baldacchino G. 2006. « Innovative Development Strategies from Non-Sovereign Island Jurisdictions? A Global Review of Economic Policy and Governance Practices ». *World Development* 34 (5): 852-67. <https://doi.org/10.1016/j.worlddev.2005.10.004>.
- Bosello F., Nicholls R. J., Richards J., Roson R. & Tol R. S. J. 2012. « Economic Impacts of Climate Change in Europe: Sea-Level Rise ». *Climatic Change* 112 (1): 63-81. <https://doi.org/10.1007/s10584-011-0340-1>.
- Bremond P., Tarrit R., Grelot F., Richert C. Dommages des inondations aux activités économiques. Ministère chargé du développement durable ; Inrae ; Cerema - Centre d'Etudes et d'Expertise sur les Risques, l'Environnement, la Mobilité et l'Aménagement. 2024. 113 p. ⟨hal-04665053⟩
- Briguglio L. P. 2016. « Exposure to External Shocks and Economic Resilience of Countries: Evidence from Global Indicators ». *Journal of Economic Studies* 43 (6): 1057-78. <https://doi.org/10.1108/JES-12-2014-0203>.
- Brusset X., Ivanov D., Jebali A., La Torre D. & Repetto M. 2023. « A Dynamic Approach to Supply Chain Reconfiguration and Ripple Effect Analysis in an Epidemic ». *International Journal of Production Economics* 263 (septembre): 108935. <https://doi.org/10.1016/j.ijpe.2023.108935>.
- Cavallo E., Galiani S., Noy I. & Pantano J. 2013. Catastrophic natural disasters and economic growth. *The Review of Economics and Statistics*, 95(5), 1549–1561. <http://www.jstor.org/stable/43554847>
- Chopra S. & Sodhi M.S. 2014. Reducing the Risk of Supply Chain Disruptions. *MIT Sloan Management Review*, 55, 73-80. <https://sloanreview.mit.edu/article/reducing-the-risk-of-supply-chain-disruptions/>

- Cochrane H. 2004. « Economic Loss: Myth and Measurement ». *Disaster Prevention and Management: An International Journal* 13 (4): 290-96. <https://doi.org/10.1108/09653560410556500>.
- Dolgui A. & Ivanov D. 2021. « Ripple Effect and Supply Chain Disruption Management: New Trends and Research Directions ». *International Journal of Production Research* 59 (1): 102-9. <https://doi.org/10.1080/00207543.2021.1840148>.
- Ghadge A., Er M., Ivanov D. & Chaudhuri A. 2022. « Visualisation of Ripple Effect in Supply Chains under Long-Term, Simultaneous Disruptions: A System Dynamics Approach ». *International Journal of Production Research* 60 (20): 6173-86. <https://doi.org/10.1080/00207543.2021.1987547>.
- Hall C. M. & Page S. J. 2009. « Progress in Tourism Management: From the Geography of Tourism to Geographies of Tourism – A Review ». *Tourism Management* 30 (1): 3-16. <https://doi.org/10.1016/j.tourman.2008.05.014>.
- Hallegatte S. 2009. « Strategies to Adapt to an Uncertain Climate Change ». *Global Environmental Change* 19 (2): 240-47. <https://doi.org/10.1016/j.gloenvcha.2008.12.003>.
- Hallegatte S. 2014a. *Economic Resilience: Definition and Measurement*. Policy Research Working Papers. The World Bank. <https://doi.org/10.1596/1813-9450-6852>.
- Hallegatte S. 2014b. « Modeling the Role of Inventories and Heterogeneity in the Assessment of the Economic Costs of Natural Disasters ». *Risk Analysis* 34 (1): 152-67. <https://doi.org/10.1111/risa.12090>.
- Hallegatte S. & Ghil M. 2008. « Natural Disasters Impacting a Macroeconomic Model with Endogenous Dynamics ». *Ecological Economics* 68 (1-2): 582-92. <https://doi.org/10.1016/j.ecolecon.2008.05.022>.
- Hallegatte S. & Przulski V. 2010. *The Economics of Natural Disasters: Concepts and Methods*. Policy Research Working Papers. The World Bank. <https://doi.org/10.1596/1813-9450-5507>.
- Hallegatte S., Ranger N., Mestre O., Dumas P., Corfee-Morlot J., Herweijer C. & Muir Wood R. 2011. « Assessing Climate Change Impacts, Sea Level Rise and Storm Surge Risk in Port Cities: A Case Study on Copenhagen ». *Climatic Change* 104 (1): 113-37. <https://doi.org/10.1007/s10584-010-9978-3>.
- Hallegatte S. 2015. *The Indirect Cost of Natural Disasters and an Economic Definition of Macroeconomic Resilience*. World Bank, Washington, DC. <https://doi.org/10.1596/1813-9450-7357>.
- Hotelling H. 1929. « Stability in Competition ». *The Economic Journal* 39 (153): 41. <https://doi.org/10.2307/2224214>.
- Lawlor P. J. & Cooper A. 2024. « Mainstreaming Climate Change Considerations for Coastal Areas into Spatial Planning Policies at National and Regional Level; the Example of Ireland ». Preprint. <https://doi.org/10.2139/ssrn.4729469>.
- Leroy Y. & Trouillet B. Les pêches à l'île d'Yeu : évolutions et enjeux. Les Cahiers Nantais, 2017, 2, pp.65-79. <hal-03503728>
- McElroy J. L. & De Albuquerque K. 1998. « Tourism Penetration Index in Small Caribbean Islands ». *Annals of Tourism Research* 25 (1): 145-68. [https://doi.org/10.1016/S0160-7383\(97\)00068-6](https://doi.org/10.1016/S0160-7383(97)00068-6).
- Merz B., Kreibich H., Schwarze R. & Thieken A. 2010. « Review Article ; Assessment of Economic Flood Damage »; *Natural Hazards and Earth System Sciences* 10 (8): 1697-724. <https://doi.org/10.5194/nhess-10-1697-2010>.

- Meyer V., Becker N., Markantonis V. & al. 2013. « Review Article: Assessing the Costs of Natural Hazards – State of the Art and Knowledge Gaps ». *Natural Hazards and Earth System Sciences* 13 (5): 1351-73. <https://doi.org/10.5194/nhess-13-1351-2013>.
- Neumann B., Vafeidis Athanasios T., Zimmermann J. & Nicholls R. J. 2015. « Future Coastal Population Growth and Exposure to Sea-Level Rise and Coastal Flooding - A Global Assessment ». *PLOS ONE* 10 (3): e0118571. <https://doi.org/10.1371/journal.pone.0118571>.
- Nortes Martínez D., Grelot F., Brémond P., Farolfi S. & Rouchier J. 2021. « Are Interactions Important in Estimating Flood Damage to Economic Entities? The Case of Wine-Making in France ». *Natural Hazards and Earth System Sciences* 21 (10): 10. <https://doi.org/10.5194/nhess-21-3057-2021>.
- Okuyama Y. & Joost R. S. 2014. « DISASTER IMPACT AND INPUT–OUTPUT ANALYSIS ». *Economic Systems Research* 26 (1): 1-12. <https://doi.org/10.1080/09535314.2013.871505>.
- Oosterhaven J. & Többen J. 2017. « Wider Economic Impacts of Heavy Flooding in Germany: A Non-Linear Programming Approach ». *Spatial Economic Analysis* 12 (4): 404-28. <https://doi.org/10.1080/17421772.2017.1300680>.
- Penning-Rowsell E. C. & Johnson C. 2015. « The Ebb and Flow of Power: British Flood Risk Management and the Politics of Scale ». *Geoforum* 62 (juin): 131-42. <https://doi.org/10.1016/j.geoforum.2015.03.019>.
- Przyluski V. & Hallegatte S. 2011. Indirect costs of natural hazards. CONHAZ Report WP02_2 (WP2 Final Report, September 2011). SMASH-CIRED
- Rose A. 2004. « Defining and Measuring Economic Resilience to Disasters ». *Disaster Prevention and Management: An International Journal* 13 (4): 307-14. <https://doi.org/10.1108/09653560410556528>.
- Rose A. & Shu-Yi L. 2005. « Modeling Regional Economic Resilience to Disasters: A Computable General Equilibrium Analysis of Water Service Disruptions* ». *Journal of Regional Science* 45 (1): 75-112. <https://doi.org/10.1111/j.0022-4146.2005.00365.x>.
- Starr C. 1969. *Social Benefit versus Technological Risk*. 165.
- Strobl E. 2011. « The economic growth impact of hurricanes : evidence from U.S. coastal counties ». The review of economics and statistics. https://doi.org/10.1162/REST_a_00082
- Tomlin B. 2006. On the Value of Mitigation and Contingency Strategies for Managing Supply Chain Disruption Risks. *Management Science*, 52, 639-657.
- Wei X., Rose A., Li S., He J., Li N. & Ali T. 2018. « Dynamic Economic Resilience and Economic Recovery from Disasters: A Quantitative Assessment ». *Risk Analysis* 38 (6): 1306-18. <https://doi.org/10.1111/risa.12948>.