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MSc in Economic Geography: Regional Competitiveness and Trade

Master's Thesis in Economic Geography

The Strait of Messina Bridge: Some geographical evaluations of the most controversial Italian infrastructural project

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To my Family, my beloved Girlfriend and my Land.

Abstract

The development of transportation infrastructure is of fundamental relevance in the spatial allocation of economic activity. The paper shows how the development of the Strait of Messina Bridge would impact on the geographical distribution of economic activity within Italy. The simulations which are based on the New Economic Geography (NEG) Model developed by Paul Krugman in 1991, have been conducted through MATLAB 2021b, a programming software for economic database analysis, and the results were visualized using ArcGIS Pro.

Our research aimed to deepen our understanding of the geographic economic implications of such a significant infrastructure endeavor. By examining the potential effects on spatial distribution of manufacturing industry, we sought to find a pattern on the expected outcomes of the Strait of Messina Bridge.

The results show that the development of such infrastructure would encourage the phenomenon of intra-regional migration: manufacturing workers would relocate from peripheral areas in Sicily/Calabria to the main provinces of these two regions, increasing the geographical polarization of economic activities in the Southern Italy. On the other hand, no significant relocation would be expected in the North and Central regions of the country.

This study contributes to understanding the potential consequences of huge infrastructure projects on national/(sub-)regional economies. Our research can help policymakers and stakeholders involved in regional development and infrastructure planning, offering valuable considerations for decision-making processes.

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Introduction

Italy is characterized by a significant economic and social fragmentation between the North and the South: while the Northern regions are economically in line with advanced Europe, the South, commonly referred to as the "Mezzogiorno" in Italian, experiences comparatively lower economic development and slower growth.
Starting from the late 50s, huge investments in infrastructures significantly improved the connectivity between the North and the South. As a result, the two longest motorways in Italy were inaugurated: the "Autostrada del Sole" connecting Milan and Naples in 1958, and the "Autostrada Adriatica" starting from Bologna and extending to Taranto in 1965. However, the investments in large infrastructure failed to decrease the economic gap between the North and the South. According to Cosci & Mirra (2018), the investments intended for the Southern regions were not large enough to fill the gap with the North. Back in our days, infrastructural polarization is still ongoing and it's not only related to transport infrastructures but also to social ones such as hospitals and waste disposal facilities, as Bucci et al. (2021) highlight.
In such a context, the Strait of Messina Bridge may be intended as a large infrastructural project, leading to a decrease in the economic development between the North and the South.
Since the 1960s several Italian cabinets have tried to realize a permanent link between the cities of Messina and Reggio Calabria in order to directly connect Sicily with the mainland. The project was never realized due to the unstable political scenario which always characterized the Peninsula.
In 1992, the Ponte sullo Stretto S.p.A. published the first preliminary project for the bridge which was approved by the Italian High Council of Public Works. This study had: technical feedback, a study on the environmental feasibility, some geological, hydrological, and archeological analysis, planimetry, some preliminary insights on the safety plan, and a cost-benefit analysis.
In 2003 a reworked proposal based on the 1992 preliminary project was finally presented. In 2006, the project was formalized in an executive contract. However, during the same year, the Cabinet fell and the project was blocked by the Italian parliament. Two years later, the realization plan was reinstated by the new government as part of the 2011 plans for the Trans-European Transport Corridors (TEN-T). In this view, the Strait of Messina Bridge would have completed the direct corridor between Berlin and Palermo. The project was indefinitely suspended in 2013 during the Euro crisis which heavily hit Italy.
In 2016, Italian Prime Minister Matteo Renzi revived the idea of a permanent link between Messina and Reggio Calabria. However, he failed to attract any significant public and political support.
The Strait of Messina Bridge was back in the spotlight at the end of April 2021, when the Minister of Infrastructures and Sustainable Mobility published a technical dossier to assess some alternative solutions (one-span bridge, multi-span bridge, underwater tunnel...) to create a stable connection in the Messina strait.
The Strait of Messina Bridge also failed to positively attract the local civil society in toto. According to Sacco & Scotti (2013), the social conflict between the Public Administration and the local community aroused from an inability of the Public Administration to directly involve all the external stakeholders (associations or initiatives that operate at the local level and are actively engaged in promoting and addressing the needs of their community) in the process. This becomes of fundamental relevance since the construction of large public infrastructure such as a bridge bears functional, symbolic, historic, and cultural meanings, as Chang & Choo (2009) suggest. In particular, the social value of a bridge is related to its role as a tool to spread both the living space and the culture. Therefore, involving external stakeholders in the bridge's development process would promote inclusivity and increase support for the project.

Although the historical framework emphasizes that the discussion regarding the viability of this work has shifted to the political arena to garner consensus during electoral campaigns, the underlying reasons for this long-standing debate are diverse and (partly) unrelated to one another.
First of all, the Strait of Messina is a high-risk geological area due to a fault-length along with the seafloor in its tectonic structure (Barreca et al., 2021). On December 28, 1908, Messina and Reggio Calabria experienced a devastating earthquake with a moment magnitude of 7.1, resulting in complete destruction and the loss of over 80,000 lives.
While modern bridges have the capability to withstand significant earthquakes, geological considerations remain central to the ongoing debate, primarily due to their connection with another critical aspect: the physical structure of the bridge or tunnel. Over the years, besides the bridge, other types of stable connection between Sicily and the mainland were taken into account. As mentioned above, the 2021 technical dossier published by the cabinet, shows different solutions to establish a stable connection between Messina and Reggio Calabria. However, both the multi-span bridge and the different types of underwater tunnels would lead to huge problems related to the high abundance of marine life in the Strait. Consequently, the one-span bridge appears to be the only feasible option for achieving a stable connection. Nevertheless, constructing a one-span bridge of such length (3.2 km) is unprecedented worldwide, and coupled with the geological configuration of the area, these factors have generated considerable doubts within the public debate.
Another aspect that considerably slowed down the development of a stable connection in the Strait was the fear of Mafia infiltration in the work. In 2005, the DIA (=Anti-Mafia Investigation Division) highlighted a significant interest in the development of the bridge by the local Mafia clans.
Also, the construction of a bridge/tunnel would revolutionize the economic identity of the two cities. In the Medieval Age, Messina was an important free port in the middle of the Mediterranean Sea and one of the most important centres of production and trade of silk. Nowadays, the city relies mainly on an economy centred around serving as a transportation hub for agricultural goods produced on the island. Unlike from the rest of the country, the transportation of agricultural goods from/to Sicily is predominantly conducted by road: while on a national level the airplane transport of goods has increased from 1.5 to 2.1 million of ton in the last decade, the transport from and to Sicily has witnessed a significant decrease from 11,000 tons to 6,000 tons from/to Sicily (Antonelli et al., 2021). This is mainly due to the fact that the two largest airports in Sicily, Catania Fontanarossa and Palermo Punta Raisi, are currently characterized by the heavy presence of low-cost airlines, which do not offer freight services (Antonelli et al., 2021). Therefore, today Messina serves as the primary location where trucks and trains stop and wait to be boarded onto ferries or other means of transportation. Accordingly, much of the urban economy revolves around this activity, involving port workers and local entrepreneurs who provide tertiary services. In this light, it’s easy to affirm that the construction of the bridge/tunnel would completely distort this type of economy, making Messina no longer a mere stopover but a crossroads between the mainland and Sicily. In this sense, the development of a stable connection between the Island and the Mainland raises many doubts among the local society which is worried about losing its “status quo”.
Although these technical and social issues could be resolved with a strong commitment from both institutions and technicians, they have generated a sense of apprehension among the public. This apprehension, coupled with the persistent fear of the unknown, has resulted in a state of immobilism that has hindered any progress in constructing the bridge.
As explained above, this widespread mentality both locally and nationally has never been opposed by the institutions, which always failed to inform and involve stakeholders in the process. Therefore, whenever a cabinet tried to revive the idea, or even launch the project of a bridge/tunnel in the Strait of Messina, this eventually mired and stalled.

Besides the social and political controversial history, in academic literature, the development of the Strait of Messina Bridge has always been a topic of engineering and geological studies. However, the latter lacks economic simulations that study the morphological transformations of urban agglomerates after the construction of the bridge. Only recently, Altafini et al. (2022) utilized a quantitative method, namely Space Syntax, to simulate how the urban configuration of Strait cities, i.e., Messina and Reggio Calabria, would react to the cross-strait connection. Altafini et al. (2022) findings reveal that, with a stable connection of the Strait, a new hierarchical relationship would emerge between Messina and Reggio Calabria. In this regard, Messina would assume the role of the logistic core of the Strait, whereas Reggio Calabria would become its periphery.

In such academic literature, our Paper studies how the development of the Strait of Messina Bridge would change the geographical distribution of manufacturing activity within the country. In this light, the Paper may confirm or deny the results of Altafini et al. (2022). Our study, indeed, gives a significant contribution to the academic literature in two ways: firstly, it enriches the existing body of knowledge on economic geography, specifically in relation to real models of geographical economics. Secondly, and perhaps more importantly, it sheds light on a complex reality that has been explored from various perspectives but remains underdeveloped in terms of economic and geographical analysis.

To this end, we conduct some simulations based on the New Economic Geography (NEG) model developed by Paul Krugman in 1991. The NEG model analyzes the core-periphery patterns by studying the spatial interdependencies between two regions.

By dividing the economy into two sectors (manufacturing and food), the NEG model starts with analyzing the two regions' demand, supply, and general equilibrium. Then, to allow for the spatial interdependencies, Paul Krugman introduced the concept of "transport costs" which shows how geography has an impact on the behavior of individuals (both consumers and producers) and how this behavior affects the spatial distribution of economic activity. The idea behind it is that economic geography matters since moving goods/people over space implies a cost (Brakman et al., 2020).

In the NEG model, the Strait of Messina bridge can be conceived as a decrease in travel time between the provinces of Messina and Reggio Calabria.

These simulations are of fundamental relevance to explain the possible economic consequences of a large infrastructure project from a geographical perspective:

- Does the construction of the Strait of Messina Bridge change the geographical distribution of economic activity at a (sub-)national level?
- Does the Strait of Messina Bridge spread economic activity all over the country in the long run? Or does it agglomerate the whole manufacturing industry within a single province/region?

To answer these questions, we provide an overall detailed framework of what would happen to the spatial distribution of economic activity if a cross-strait stable connection would exist. In this light, the Paper becomes of fundamental importance to assess whether the Strait of Messina Bridge is able to (partly) reduce the economic disparities between the North and the South.

From a technical point of view, the simulations are conducted through two different software: MATLAB R2021b and ArcGIS Pro. In particular, we use the MATLAB GEAM (=Geographic Economic Agglomeration Model) program, which provides the NEG model written in MATLAB code. While with MATLAB GEAM, we run the simulations themselves, with ArcGIS Pro, we visualize the results over a map.

The paper is structured into 4 parts. Chapter 1 shows the main characteristics of the New Economic Geographic Model and its implications. This section entirely follows Chapter 7 of Brakman et al. (2020). In Chapter 2, the systematic approach that guides the research process and the collection and interpretation of data is presented. This Chapter is divided into three subsections: the first part introduces the two software programs utilized in the study, highlighting their significance for

conducting the research. The second section outlines the process of gathering the necessary statistics, while the third one elaborates on the crucial data processing steps essential for ensuring the validity of the study's findings.
Then, Chapter 3 shows the main results of the simulations and their implications. This chapter is split into two sections: on one hand, the first part shows the simulations with some parameters that try to closely adhere to reality. This indicates an effort to ensure the simulations are as realistic as possible; on the other, in the second section, the simulations are conducted with different values of some parameters in order to study the model’s sensitivity. This suggests an investigation into how changes in these parameters affect the outcomes of the simulations.
In Chapter 4, the main insights and limitations of the study are presented. This final chapter provides a comprehensive summary of the study and tries to address future research in the field.

1. The Core Model of Geographical Economics: the main structure and its implications

Differently from urban economics, geographical economics allows for spatial interdependencies between different locations. In this way, agglomeration economies are influenced not only by the characteristics of their geographical locations but also by their proximity to other economic locations (Brakman et al., 2020). Therefore, geographical economics studies how different geographic entities (cities, regions, etc.) react to inputs within an interconnected system. In 1991, Paul Krugman developed the core model of geographical economics, also known as the New Economic Geography (NEG) model. In this chapter, we will show the structure of the core model and its main implications, following chapter 7 of Brakman et al. (2020).

By dividing the economy into two sectors (manufacturing and food), the core model starts with analyzing the demand (1.1), supply (1.2), and general equilibrium of two bordering regions (1.5). To allow for the spatial interdependencies, Paul Krugman introduced the concept of "transportation costs" which shows how geography has an impact on the behavior of individuals (both consumers and producers) and how this behavior affects the spatial distribution of economic activity (1.3). The idea behind it is economic geography matters since moving both goods and people over space implies a cost. As we will see later, transportation costs, which are of fundamental relevance in geographical economics, are an extremely abstract concept, and it's very tricky to get them into practice.

1.1 Demand Side

To decide how to allocate their income (Y) between manufactures (M) and food (F), consumers follow a Cobb-Douglas function:

$$U = F^{(1-\delta)}M^{(\delta)} \qquad \text{with } 0 < \delta < 1 \tag{1. 1}$$

Where δ is the share of income spent on manufacturing. Obviously, the choice is subject to the budget constraint:

$$F + I * M = Y \tag{1. 2}$$

Where I is the price of manufactures. Note that the price of food is equal to one: therefore, income Y is then measured in terms of food to avoid the money illusion, as Brakman et al. (2020) suggested. Given the budget constraint, the maximization of the utility function is then:

$$F = (1 - \delta)Y \text{ and } I * M = \delta * Y \tag{1. 3}$$

The core model follows the Dixit-Stiglitz model to understand how the manufacturing spending δ is distributed among the different products. The latter, which shows that product differentiation can cause different market imperfections like monopolistic competition, is based on the Constant-Elasticity-of-Substitution (CES) function:

$$M = \left(\sum_{i=1}^{N} c_i^{\rho}\right)^{1/\rho} \qquad \text{with } 0 < \rho < 1 \tag{1. 4}$$

Where c_i is the level of consumption of a specific product i, ρ is the substitution parameter and N represents the total number of different varieties.

Assuming that p_i is the price of variety i for i = 1,2,…,N, the equation 1.2 becomes now:

$$\sum_{i=1}^{N} p_i c_i = \delta Y$$

(1. 5)

Again, given the new formula of budget constraint, the maximization of the utility function is then:

$$C_j = P_j^{-\varepsilon}(I^{\varepsilon-1}\delta Y) \qquad I \equiv \left(\sum_{i=1}^{N} p_i^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}} \qquad \text{with } j = 1,\ldots,N$$

(1. 6)

Where $\varepsilon \equiv \frac{1}{1-\rho}$ measures the elasticity of substitution between two different varieties.
Furthermore,

$$M = \frac{\delta Y}{I}$$

(1. 7)

This implies that utility from manufacturing goods increases if, and only if, manufacturing expenditures grow faster than the price index.
From equation 1.6, three insights can be drawn:

a. The more the individual spends on manufacturing goods (δY ↑), the more he/she will spend on good j (C_j ↑).
b. As the elasticity of substitution increases (ε ↑), a small increase in price (p_j ↑) results in a greater decrease in demand for a particular product (C_j ↓).
c. As the manufacturing price index increases (I ↑), individuals start to consume more of product j (C_j ↑), since ε > 1.

1.2 Supply Side

Turning to the supply side, we first assume that workers in food production cannot be relocated. Note that in the following chapter, we will refer to food production as one of the "bounded sectors". As a matter of fact, differently from the footloose sectors, these industries need to be very close to the raw materials and require specific resources, inputs, or infrastructure. That's why workers in food production are considered to be immobile (Brakman et al., 2020).
After this small digression (we will delve deeper into this topic in chapter…), we now assume that food production equals employment in the food industry:

$$F = (1-\gamma)L$$

(1. 8)

Where γ is the share of workers employed in the manufacturing sector and L is the total labor force.
On the other hand, manufacturing production shows internal economies of scale. This means that firms experience cost savings by increasing their production output within their existing facilities. Obviously, with internal economies of scale, large firms face a significant advantage over smaller firms: larger firms can achieve lower costs simply due to their size and specialization, which allows them to set the price of their products lower than smaller firms. This can make it difficult for smaller firms to

compete and survive in the market. Furthermore, internal economies of scale can also lead to barriers to entry into the market, making it difficult for new firms to enter the industry and compete with established firms. In this situation of imperfect competition, each firm specializes in a different variety of products:

$$l_i = \alpha + \beta x_i \tag{1.9}$$

Where l_i is the amount of labor required to produce x_i units of variety i, α represents the fixed labor input, and β is the marginal labor input. Equation 1.9 depicts the internal economies of scale: with the presence of fixed labor input (α), when the production increases, the average labor required to produce a certain amount of x_i decreases.

Assumed that labor is the only factor of production in the NEG model, the cost of producing a variety i will be:

$$W \times l_i = W \times (\alpha + \beta x_i) \tag{1.10}$$

Where W represents the wages.
Given these conditions, equation 1.11 shows the profit π for a manufacturing company:

$$\pi = px - W \times (\alpha + \beta x_i) \tag{1.11}$$

Assuming a constant price elasticity of demand ε, maximizing profits, we obtain the so-called "mark-up pricing" (see chapter 7 of Brakman et al. 2020 for the appendix):

$$p\left(1 - \frac{1}{\varepsilon}\right) = \beta W \; ; \; p = \frac{\beta W}{\rho} \tag{1.12}$$

The mark-up pricing refers to the amount added to the cost of a product in order to determine its selling price (The Economic Times, 2023). In our model, the mark-up price is given by the ratio between the cost of producing an extra unit of product (c'= βW) and the substitution parameter (ρ). According to Brakman et al. (2020), the difference between the selling price and the marginal cost depends on the price elasticity: with inelastic demand, the mark-up price will be higher than the one with elastic demand. This reflects the view that when demand is inelastic, firms can set a higher price because consumers will continue to buy the product regardless of the price change. On the other hand, when demand is elastic, consumers are more sensitive to changes in price and will buy less of a product if the price is too high.

According to the economic theory, in monopolistic competition, equilibrium is reached when the profits (π) are equal to 0. Therefore:

$$x = \frac{\alpha(\varepsilon - 1)}{\beta} \qquad l_i = \alpha\varepsilon \qquad N = \frac{\gamma}{\alpha\varepsilon} L \tag{1.13}$$

Equation 1.13 shows that the output per firm is fixed in equilibrium, as Brakman et al. (2020) suggests. The manufacturing sector, therefore, grows/shrinks only by producing more/less varieties. This means, for instance, that a phenomenon such as immigration leads to a larger market only in terms of the diversity of available options.

Before turning on the price equilibrium section, explaining transport costs' role and relevance to the NEG model is important.

1.3 Transportation Costs

To allow for spatial interdependences, the NEG model takes into account the transport costs. As explained at the chapter's beginning, the idea behind it is that moving goods and people over space implies a cost that determines the choice of each individual where to live/work. In this light, the behavior of individuals, both as consumers and producers, is influenced by geography.

In theory, there are several ways to measure transport costs. For instance, some measurements are based on the accessibility of goods, services, and activities for individuals and companies (Litman, 2003). On the other hand, the transport costs can also be represented by the annual income people use to spend on the transportation system. However, these methods do not suit efficiently with the NEG model. In this light, Brakman et al. (2020) uses the "iceberg" transport costs developed by Samuelson (1952). Theoretically, the concept of "iceberg" transport costs is straightforward: since only a fraction of manufacturing good will arrive at the destination, the "iceberg" transport costs (T) measure how many units of manufacturing good will have to be shipped from the city A to city B in order to have one unit of that good in city B. The transport costs values go from 1 to 2: if T is equal to 1, this means that there are no transport costs. On the other hand, if T is equal to 2, the transport costs will be the highest since only 50% of the manufacturing good will arrive at the destination. Obviously, this way of computing transport costs is purely theoretical; it is very difficult to describe the real situation with the iceberg transport costs since they are based on a subjective choice. However, as we will see in the next chapter, it is interesting to see how the spatial distribution of economic activity would change with either increasing or decreasing the transport cost parameter.

Therefore, the transport costs can be represented as:

$$T_{ab} = T^{D_{ab}}$$

(1. 14)

Where D_{ab} is the distance between city A and city B. In this light, $T_{ab} = T_{ba}$ and $T_{aa} = T^0 = 1$. In this way, we can distinguish whether a change in the transport costs stems from a reduced distance in time between city A and B (for example, a tunnel/bridge or a high-speed railway which leads to substantial improvement in the connection) or a general improvement/deterioration applied to all the cities, as Brakman et al. (2020) explain.

1.4 Two Regions Framework in the NEG Model

To start with analyzing the spatial interdependencies between two regions (1 and 2), we first have to determine where the workers are initially located.

Given that the total number of workers is L, the number of workers in the manufacturing sector will be γL. Consequently, the fraction of people employed in the food sector will be $(1 - \gamma)L$. With a two-region framework, the number of food sector workers in regions 1 and 2 will be $\phi_1(1 - \gamma)L$ and $\phi_2(1-\gamma)L$, respectively. Likewise, the number of people employed in the manufacturing sector in region 1 and 2 will be $\lambda_1\gamma L$ and $\lambda_2\gamma L$, respectively.

After having defined the initial allocation of workers, we now focus on region 1: the main goal is to analyze the implications of both demand and supply in the spatial interdependencies between regions

1 and 2. As Brakman et al. (2020) suggests, we assume that workers will migrate from region 1 to region 2 if the real wages in region 1 (W_1) are lower than the ones in region 2 (W_2).

Given that food production is equal to employment in the food sector, equation 1.8 becomes $F= ø_1(1 – γ)L$. The latter also represents both the income from the food sector and the farmers' wages in region 1.

On the other hand, the wages of manufacturing employees in region 1 (W_1) are different from the ones in region 2, because of the transport costs. In this light, the mark-up price (equation 1.12) and the number of firms in region 1 are equal to $p = \frac{\beta W_1}{\rho}$ and $N = \frac{\gamma}{\alpha\varepsilon}\lambda_1 L$, respectively. The mark-up price, $p = \frac{\beta W_1}{\rho}$, represents the price that a firm located in region 1 will set within its region. Due to the transport costs, this price will be T times higher in region 2. Therefore, the price of manufacturing goods depends on the location of both firms and consumers, as Brakman et al. (2020) highlights. Given all the above considerations, the price index in region 1 (equation 1.6) becomes now:

$$I_1 = \left(\frac{\beta}{\rho}\right)\left(\frac{\gamma L}{\alpha\varepsilon}\right)^{\frac{1}{1-\varepsilon}}\left(\lambda_1 {W_1}^{1-\varepsilon} + \lambda_2 T^{1-\varepsilon} {W_2}^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}$$

(1. 15)

Equation 1.15 shows that the price index in region 1 is the weighted average price between domestically produced goods and imported ones.

1.5 Equilibrium in the NEG model

Having previously presented the demand, supply, and location analysis of the two regions, now we will calculate the equilibrium within the framework of the NEG model. In doing so, we will split the analysis into short-run and long-run equilibria. The short-run equilibrium merely depicts a given spatial distribution of economic activity that is exogenous to the model, as Brakman et al. (2020) defines. In our paper, therefore, the short-run equilibrium is only intended to reflect the initial allocation of workers according to the current Italian framework. On the other hand, the long-run equilibrium represents the final allocation of workers. As explained in section 1.4, workers are going to relocate from region 1 to region 2 (and vice versa) due to the different levels of wages between the two regions. In the long run, a state of equilibrium is reached in which the real wages in both regions are equal ($w_1 = w_2$), meaning that workers no longer have the incentive to relocate. On the other hand, the short-run equilibrium is characterized by different level of real wages between the regions ($w_1 \neq w_2$). This gives the workers a reason to move towards the region with the highest real wages. In this respect, it is necessary to consider real wages instead of the wage rate to ensure accuracy. As a matter of fact, real wages take into account the price index, reflecting the actual purchasing power of the wages.

All workers are employed in either the food or manufacturing industry and profits are always 0 in both sectors (due to the entry/exit in manufacturing and perfect competition in food). Thus, disposable income comes solely from consumers' wages. Therefore:

$$Y_1 = (\lambda_1 \gamma L)W_1 + ø_1(1 - \gamma)L$$

(1. 16)

In equations 1.15 and 1.16, only W_1 and W_2 are unknown: We will compare demand and supply to derive the wages. Aggregate demand in region 1 is composed of the total demand for goods produced and consumed in region 1 and the total demand for goods exported from region 1 in region 2. In this light, we obtain aggregate demand for goods produced and consumed in region 1 simply by substituting markup price (equation 1.12), price index I_1 (equation 1.15), and aggregate income Y_1 (equation 1.16) into the maximized utility function C_j (equation 1.6). Thus:

$$x_{1;1} = (\delta\beta^{-\varepsilon}\rho^{\varepsilon})Y_1 W_1^{-\varepsilon} I_1^{\varepsilon-1}$$

(1. 17)

The total demand for goods exported from region 1 to region 2 is derived in the same way. However, some transport costs are charged on the markup price, as already explained in section 1.4. Thus, the total demand will be:

$$x_{1;2} = (\delta\beta^{-\varepsilon}\rho^{\varepsilon})Y_2 W_1^{-\varepsilon} T^{-\varepsilon} I_1^{\varepsilon-1}$$

(1. 18)

Intuitively, the demand for goods imported into region 2 declines as transport costs increase.
The total demand for goods produced in region 1 will be therefore:

$$X = x_{1;1} + x_{1;2} = (\delta\beta^{-\varepsilon}\rho^{\varepsilon})\,(Y_1 W_1^{-\varepsilon} I_1^{\varepsilon-1} + Y_2 W_1^{-\varepsilon} T^{-\varepsilon} I_1^{\varepsilon-1})$$

(1. 19)

On the other hand, the supply of goods produced in region 1 is $x = \frac{\alpha(\varepsilon-1)}{\beta}$ (equation 1.13). Hence, the equilibrium equation will be:

$$\frac{\alpha(\varepsilon-1)}{\beta} = (\delta\beta^{-\varepsilon}\rho^{\varepsilon})\,(Y_1 W_1^{-\varepsilon} I_1^{\varepsilon-1} + Y_2 W_1^{-\varepsilon} T^{-\varepsilon} I_1^{\varepsilon-1})$$

(1. 20)

From equation 1.20, the wage rate W_1 can be inferred:

$$W_1 = (\rho\beta^{-\rho})\left(\frac{\delta}{(\varepsilon-1)\alpha}\right)^{\frac{1}{\varepsilon}} (Y_1 I_1^{\varepsilon-1} + Y_2 T^{1-\varepsilon} I_1^{\varepsilon-1})^{\frac{1}{\varepsilon}}$$

(1. 21)

Firstly, Brakman et al. (2020) underlines that this equation shows that the attractiveness of a region (W_1) is determined by the purchasing power of the region itself, as well as the purchasing power of all the bordering regions, weighted by transport costs (recall the importance of the location within the space).
Also, this formula suggests that proximity to large markets and the level of competition in a region are two factors that significantly impact wages in that region.
As a matter of fact, W_1 is higher when region 1 is close to large markets (Y_1 and Y_2), as Brakman et al. (2020) highlights. When a region is located close to large markets, it can provide firms with greater access to potential customers, which can help to increase their revenues and profitability. This, in turn, may allow these firms to offer higher wages to attract and retain workers, as they have more resources available to invest in their labor force.
On the other hand, the higher the wage rate, the lower the level of competition that firms will face within the region. As a matter of fact, since the elasticity of substitution is positive ($\varepsilon > 1$), the demand for a specific variety is going to increase as the average price of the other competing products rises.

Brakman et al. (2020) suggest using normalization to derive the short-run equilibrium equations. In this respect, the parameters of normalization are: $\gamma = \delta$; $\beta = \rho$; $L = 1$; $\alpha = \gamma L/\varepsilon$. Accordingly, the number of parameters is reduced to 3: δ, ε, and T. Hence, the short-run equations are:

$$Y_1 = \lambda_1 \delta W_1 + \frac{(1-\delta)}{2} \qquad Y_2 = \lambda_2 \delta W_2 + \frac{(1-\delta)}{2}$$

(1. 22)

$$I_1 = \left(\lambda_1 {W_1}^{1-\varepsilon} + \lambda_2 T^{1-\varepsilon} {W_2}^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}} \qquad I_2 = \left(\lambda_1 T^{1-\varepsilon} {W_1}^{1-\varepsilon} + \lambda_2 {W_2}^{1-\varepsilon}\right)^{\frac{1}{1-\varepsilon}}$$

(1. 23)

$$W_1 = (Y_1 I_1^{\varepsilon-1} + Y_2 T^{1-\varepsilon} I_2^{\varepsilon-1})^{\frac{1}{\varepsilon}} \qquad W_2 = (Y_1 T^{1-\varepsilon} I_1^{\varepsilon-1} + Y_2 I_2^{\varepsilon-1})^{\frac{1}{\varepsilon}}$$

(1. 24)

$$w_1 = W_1 I_1^{-\delta} \qquad w_2 = W_2 I_2^{-\delta}$$

(1. 25)

These equations convey the idea that the two regions are equivalent in all their aspects apart from the share of manufacturing employment (λ), which is the only relevant variable. In this respect, Brakman et al. (2020) focuses on three particular cases to analyze the long-run equilibrium: (I) spreading equilibrium ($\lambda_1=\lambda_2$), (II) complete agglomeration in region 1 ($\lambda_1=1$; $\lambda_2=0$), and (III) complete agglomeration in region 2 ($\lambda_1=0$; $\lambda_2=1$).

(I) Firstly, we look at a situation where the manufacturing activity is equally spread between the two regions ($\lambda_1=\lambda_2=0.5$). Instead of solving all the above equations that would make the calculations needlessly complex and lengthy, Brakman et al. (2020) starts with a specific example in order to derive the mathematical rule. As a matter of fact, the authors assume that the two wages are equal to 1 ($W_1=W_2=1$). In this light, I_1 and I_2 are both equal to $(0.5 + 0.5\,T^{1-\varepsilon})^{\frac{1}{1-\varepsilon}}$, and Y_1 and Y_2 to $\frac{1}{2}$. Substituting them into equation 1.25, we can observe that w_1 and w_2 equalize. Obviously, the real wages are equal and, consequently, people do not have any incentive to relocate since the two regions are completely identical (even in their initial distribution of manufacturing employment). Therefore, a spreading framework ($\lambda_1=\lambda_2=0.5$) is always a long-run equilibrium, as Brakman et al. (2020) conclude.

(II) We now assume that region 1 is the exclusive hub of all manufacturing activity ($\lambda_1=1$; $\lambda_2=0$). Again, Brakman et al. (2020) sets W_1 equal to 1 as a starting point. Accordingly, I_1, w_1, and Y_1 are equal to 1, 1 and $\frac{(1+\delta)}{2}$, respectively. Differently from tase (I), W_2 is undefined due to the absence of manufacturing workers in region 2. If a firm relocates to region 2, the wage rate would become $W_2 = \left[\left(\frac{(1+\delta)}{2}\right) T^{1-\varepsilon-\varepsilon\delta} + \left(\frac{(1-\delta)}{2}\right) T^{\varepsilon-1}\right]^{\frac{1}{\varepsilon}}$. Consequently, $w_2 = \left[\left(\frac{(1+\delta)}{2}\right) T^{1-\varepsilon-\varepsilon\delta} + \left(\frac{(1-\delta)}{2}\right) T^{\varepsilon-1-\varepsilon\delta}\right]$. When there are no transport costs (T=1), the real wages in region 2 are equal to 1. Therefore, in this particular case, w_1 and w_2 equalize. Hence, complete agglomeration in region 1 is considered to be a long-run equilibrium.

(III) When all manufacturing activity is centralized solely in region 2, the same results of case (II) are applied to region 2.

Spreading and complete agglomeration represent two completely different long-term equilibria. Even in terms of trade flows, they have two different consequences: when the manufacturing activity is evenly distributed over two regions, the trade between them will be characterized by an exchange of manufacturing goods, i.e., intra-industry trade. On the other hand, if the manufacturing activity is centered only in region 1 (or vice versa), the latter will trade manufacturing goods for non-manufacturing goods from the other region, resulting in inter-industry trade.

After analyzing the most extreme cases of the NEG model, it is of fundamental relevance to study the main economic forces behind the model to understand its dynamics.

1.6 The Economic Effects behind the NEG Model

To assess whether a worker moves to the other region, three economic forces come into play: (a) the price index effect, (b) the home market effect, and (c) the extent-of-competition effect.

a. The price index effect (agglomeration force) increases the attractiveness of larger regions as smaller shares of varieties have to be imported at high transportation costs (Brakman et al., 2020).
b. The home market effect (agglomeration force) states that when a region shows a high demand for a specific good, then there will be a more than proportionate increase in the production of that good within the region (Brakman et al., 2020).
c. The competition effect (spreading force) illustrates the fact that when the price index in larger markets decreases, the individual firm will experience a decrease in demand due to a poorer competition position (Brakman et al., 2020).

Whether it is beneficial for a worker/firm to relocate or not depends on the interplay of these three effects. The stability of the initial equilibrium depends on whether after the initial reallocation of a firm, a chain reaction is triggered, with other companies subsequently moving to the same region. When such a chain reaction occurs, the equilibrium is unstable; otherwise, it is stable. This process is known as cumulative causation. Below, the picture by Neary (2000) depicts how the home market effect (1), the price index effect (2), and the extent-of-competition effect (3) work in the monopolistic competition framework.

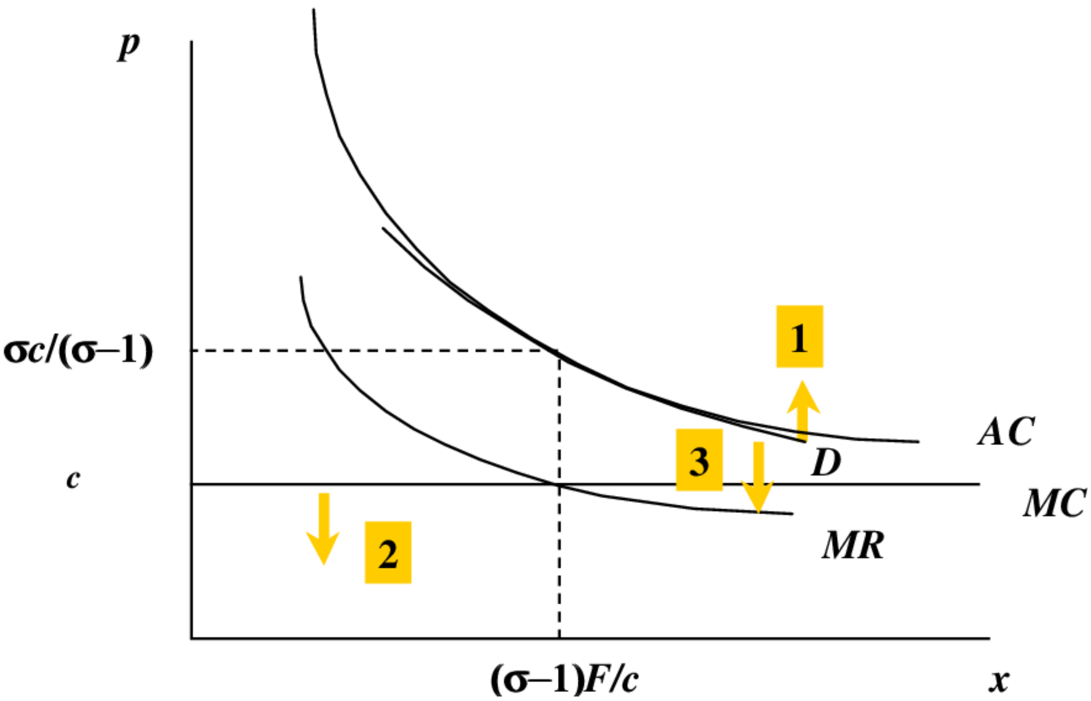


Figure 1 Chamberlin-Dixit-Stiglitz Equilibrium by Neary (2000)

Note that $\sigma = \varepsilon$ and $c = \beta W$.

We assume that the initial manufacturing activity is evenly spread over two regions. In this light, we analyze the particular case in which a firm decides to relocate from region 1 to region 2. Contextually, the three economic forces (graphically described by the three yellow arrows) arise:

(I) The first arrow shows the home market effect. The effect can be explained by the fact that the new firm creates more jobs, leading to an increase in labor demand and, subsequently, wages in region 2. As a result, the demand curve (D) shifts upward. That is why the home market effect is considered to be an agglomeration force.

(II) The second arrow depicts the price index effect. Once a firm in region 1 moves to region 2, the cost of living in region 2 decreases due to an increase in the number of varieties supplied. Accordingly, the average and marginal cost curves drop. In this sense, the price index effect fosters agglomeration.

(III) The third arrow represents the extent-of-competition effect. The latter lowers both the demand and marginal revenue curves. As a matter of fact, an expansion in the manufacturing activity of region 2 weakens the price index in that area. Consequently, the demand for an individual firm decreases as its competitive position declines. Therefore, the extent-of-competition effect works in the opposite direction to the other two forces, supporting a spreading equilibrium.

When the home market effect balances out the extent-of-competition effect (and vice versa), the price index effect becomes of fundamental relevance to understanding an increase in agglomeration. The cumulative causation process will stop as the real wages in region 1 (w_1) will be equal to the real wages in region 2 (w_2).

1.7 Computer Simulations

To entirely describe the NEG model, Brakman et al. (2020) also implements some computer simulations to understand the behavior of the model with different parameters.

Figure 2 shows the flows of short-run equilibrium (depicted by the blue arrows) as the manufacturing workforce in region 1 varies. According to the graph, five possible long-run equilibria exist: partial (B and D) and complete agglomeration (A and E) in one of the two regions, and spreading of the manufacturing activity over the area (C). Furthermore, the picture split the equilibria into stable and unstable: on one hand, the orange dots represent stable equilibria; on the other, the white dots show the unstable ones.

Let's analyze a situation where the starting point is F. Here, the initial share of the manufacturing workforce in region 1 is less than 0.5 and the relative real wage (w_1/w_2) is more than 1. According to the arrows, workers start to migrate from region 2 to region 1 till the relative real wage is equal to 1, i.e. point C, where the long-run equilibrium stabilizes.

Let's assume now that point F would be between points A and B: the share of manufacturing employment would be less than 0.5 and the relative real wage would be less than 1. In this case, even the remaining manufacturing workers in region 1 would relocate to region 2 and the complete agglomeration in region 2 would be the only stable scenario in the long run. The same considerations can also be done on the right-hand side of the graph (with points B and E).

It is therefore important to underline that points B and D are unstable long-run equilibria in the sense that they are the watershed in the direction of short-run equilibrium. In the following section, we will define B and D as the "break" and "sustain" points.

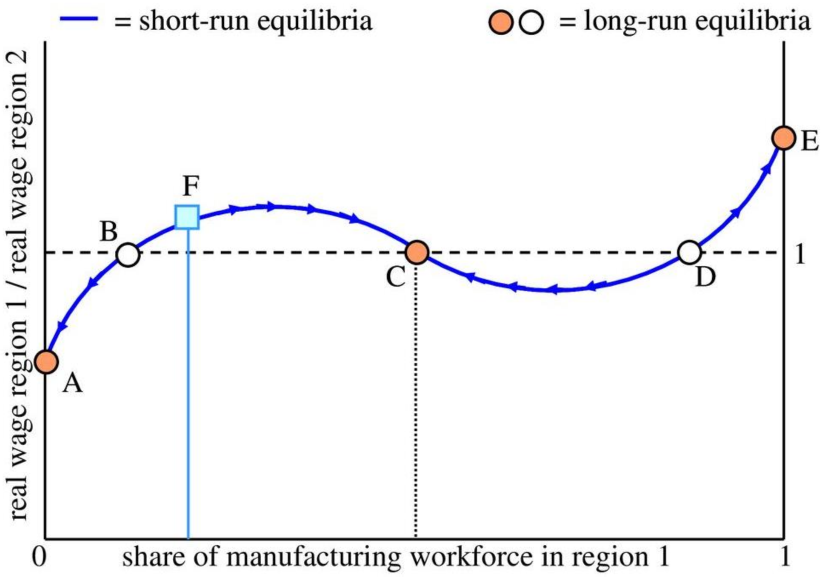


Figure 2 Relative real wage by Brakman et al. (2020)

The picture below shows the evolution of the short-run equilibrium according to three different values of transport costs: T = 1.3, T= 1.7, and T = 2.1.

With few transport costs (T = 1.3), complete agglomeration in one of the two regions is the only stable long-run equilibrium. The reason behind it is that the manufacturing market can be remotely supplied since transportation has few costs. In this light, manufacturing firms locate in one region to fully exploit the benefits of agglomeration.

On the other hand, when transport costs are very high (T = 2.1), the manufacturing activity is evenly spread over the two regions. As a matter of fact, manufacturing goods are locally provided since high costs in transportation weaken inter-regional trade.

T = 1.7 shows a short-run equilibrium flow very similar to the one described in figure 2. Briefly, five long-run equilibria are possible: complete agglomeration (stable equilibrium) in either region, spreading equilibrium (stable equilibrium), and partial equilibrium in either region (unstable equilibrium). The final allocation of workers mostly depends on both the initial relative wage rate and manufacturing employment share, as explained before.

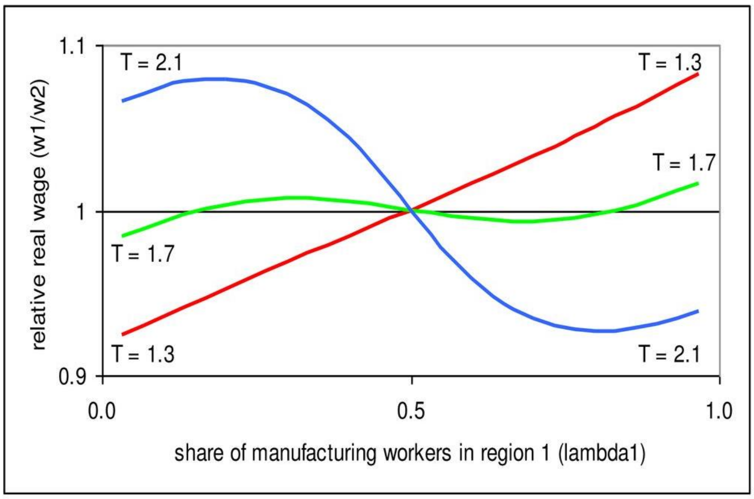


Figure 3 The evolution of short-run equilibria according to different values of T by Brakman et al. (2020)

1.8 The Sustain and Break Analysis

Brakman et al. (2020) makes also use of the "Sustain and Break Analysis" to study for which values of T, complete agglomeration and spreading could be "sustained" and "broken", respectively.

To identify the sustain point, we first assume that all the manufacturing workforce is located in region 1 (λ_1=1; λ_2=0). In this view, the long-run equilibrium is characterized by both W_1 and w_1 equal to 1. Since there is no manufacturing employment in region 2, we are not able to define the exact value of W_2 and w_2, consequently. However, manufacturing workers will start to migrate from region 1 to region 2 when $w_2 > w_1 > 1$. If this condition is met, complete agglomeration in region 1 will no longer be sustainable (Brakman et al., 2020). Solving equation 1.26 in terms of T, Brakman et al. (2020) suggests using w_2^{ε} rather than w_2 to simplify the analysis) gives us the so-called 'sustain point,' which represents the threshold at which the system can be sustained.

$$w_2^{\varepsilon} \equiv f(T) \equiv \left[\left(\frac{(1+\delta)}{2}\right)T^{1-\varepsilon-\varepsilon\delta} + \left(\frac{(1-\delta)}{2}\right)T^{\varepsilon-1-\varepsilon\delta}\right] = \left[\left(\frac{(1+\delta)}{2}\right)T^{-(\rho+\delta)\varepsilon} + \left(\frac{(1-\delta)}{2}\right)T^{(\rho-\delta)\varepsilon}\right] = 1$$

(1. 26)

Hence: $w_2^{\varepsilon} = f(1) = 1$. The result provides us with a clear understanding of the framework: if the transport costs do not exist, the complete agglomeration is always in equilibrium in the long run. Furthermore, f(1)' < 0. This means that the slope of the tangent line of f(T) at T = 1 is negative, and the function is decreasing as T increases from 1. Accordingly, for low values of T, f(T) is less than 1, and w_2 < 1, consequently. Therefore, when transport costs are sufficiently low, complete agglomeration becomes a sustainable equilibrium (Brakman et al., 2020). When the transport costs start to grow significantly, the result is different: looking at equation 1.26, the first term proportionally decreases; on the other hand, however, if (and only if) $\rho > \delta$, the second term goes up. In this sense, when transport costs are sufficiently large and $\rho > \delta$, complete agglomeration is no more a sustainable equilibrium. In particular, Brakman et al. (2020) recalls Fujita, Krugman, and Venables (1999, p. 58) by defining $\rho > \delta$ as the "no-black-hole" condition. As a matter of fact, if $\rho < \delta$, then complete agglomeration would always happen regardless of the level of transport costs.

To analyze the "break point", we now turn to a situation where the manufacturing activity is equally distributed over the two regions (λ_1= λ_2=0.5). The process is similar to the "sustain point" method, where we aim to determine whether relocating a few workers from region 1 to region 2 would increase real wages in region 2, leading to a significant migration of workers to that region. Obviously, if further migration follows, the spreading equilibrium was unstable; otherwise, stable. In this respect, the point at which the spreading equilibrium changes from stable to unstable is called the "break point". Rather than going into a detailed explanation of how to calculate the break point mathematically, only the final expression has been reported below:

$$g(T) \equiv \frac{1-\ T^{1-\varepsilon}}{1+\ T^{1-\varepsilon}} + \left(1 - \frac{\delta(1+\rho)}{\delta^2+\rho}\right) < 1$$

(1. 27)

If this inequality is satisfied, then the spreading equilibrium is unstable. It is important to underline that the first term of the inequality ($\frac{1-T^{1-\varepsilon}}{1+T^{1-\varepsilon}} \equiv Z$) is known as an index of trade costs. Without transportation costs (T=1), this parameter is null (Z=0); on the other hand, as the transport costs become high, this trade costs index comes infinitely close to 1 (Z → 1).

Turning back to inequality 1.27, $\left(1 - \frac{\delta(1+\rho)}{\delta^2+\rho}\right)$ is always positive since ρ > δ, i.e., the no-black-hole condition is met (if ρ > δ, then $\delta^2 + \rho > \delta(1 + \rho)$). Therefore, inequality 1.27 holds for sufficiently low values of T; otherwise, g(T) > 1. In this light, Fujita, Krugman, and Venables (1999) explains that with ρ > δ, full agglomeration occurs with a sufficiently low level of transportation costs, whereas the spreading of economic activity is the only stable equilibrium in the long run when the transportation costs are very high. The threshold level of T is the so-called break point.

Below, the so-called "Tomahawk diagram" by Brakman et al. (2020) represents the break and sustain points graphically.

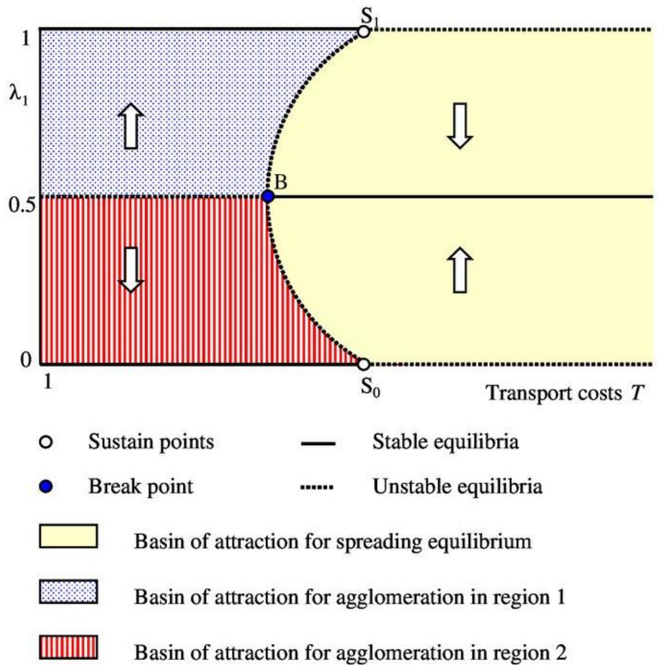


Figure 4 The Tomahawk Diagram by Brakman et al. (2020)

The Tomahawk diagram resembles the structure of a cartesian plan in which the transport costs (T) are on the x-axis and the share of manufacturing employment in region 1 (λ_1) is on the y-axis. The direction of the model is depicted by the 4 white arrows. The stable long-run equilibria are represented by the continuous line, whereas the unstable ones by the dashed line.

Assuming an initial situation in which the manufacturing activity is evenly distributed between two regions and transport costs are very low (e.g., T = 1.2), a small migration of workers from region 1 (2) to region 2 (1) will result in a massive migration of manufacturing activity to region 2 (1) in the long run. In this light, Brakman et al. (2020) identifies two basins of attraction: for agglomeration in region 1 (purple area), and for agglomeration in region 2 (red area). These basins illustrate that when T is smaller than B, the largest region will attract all the manufacturing industry. In this respect, the initial spreading equilibrium is considered to be unstable, whereas the full agglomeration is the only stable equilibrium in the long run.

On the other hand, starting from a full agglomeration framework, a sufficiently high value of transport costs (e.g., T = 2 > B) will lead to a spreading of economic activity over the two regions. Brakman et al. (2020) identifies, thus, the basin of attraction for spreading equilibrium (yellow area).

Interestingly, when B < T < S_0 (S_1), there is an unstable long-run equilibrium represented by the dashed line which connects S_0, B, and S_1. In this case, the geographical distribution of economic activity will depend on the level of T: the unstable equilibrium will come close to the symmetric equilibrium, as T decreases and vice versa (Brakman et al. 2020).

The core model of Economic Geography has been entirely discussed throughout the chapter. The following section will present the Congestion model, which is an extension of the NEG model developed by Brakman et al. (2020).

1.9 The Congestion Extension

To develop the congestion model, Brakman et al. (2020) starts from the idea that agglomeration which is driven by location-specific economies of scale, can also lead to the rise of diseconomies of scale. For example, firms could experience some difficulties to attract and retain workers, as the demand for goods and services increased in agglomerated areas resulting in a higher cost of living. External diseconomies of scale stem also from all the costs related to an increase in traffic and demand for resources as more and more people start to cluster together. Likewise, environmental pollution and commuting costs are other reasons why diseconomies of scale may occur. The nature of these diseconomies, however, will be further discussed in the next chapter. Now, we will focus on the general concept and refer to them as "congestion costs".

According to Brakman et al. (2020), the NEG model has an unbalanced of economic forces that mostly fosters agglomeration. As a result, this model often leads to a scenario in which a single large region (city) attracts all the manufacturing workers. In this light, congestion works as a spreading force that favors balance between agglomeration and spreading forces. Hence, the city's externalities are labeled as:

$$l_{ir} = N_r^{\frac{\tau}{1-\tau}}(\alpha + \beta x_i) \qquad \text{with } -1 < \tau < 1$$

(1. 28)

Equation 1.28 shows the quantity of labor (l) in region r needed to produce a certain number of units x of a particular product variety i. As a region expands/shrinks, there are different costs of production. In this respect, τ is called the "congestion parameter":

- $-1 < \tau < 0$ → city's expansion leads to positive location-specific externalities
- $\tau = 0$ → there are no externalities (the core model without extension)
- $0 < \tau < 1$ → city's expansion leads to negative location-specific externalities

To counterbalance spreading and agglomeration forces, Brakman et al. (2020) focuses on the case in which $0 < \tau < 1$. Here, when a new firm moves to region r, every firm in the region experiences an increase in the production costs.

With congestion, the short-run equilibrium equations become:

$$Y_r = \lambda_r \delta W_r + (1 - \delta)\phi_r$$

(1. 29)

$$I_r = \left(\sum_{s=1}^{R} \lambda_s^{1-\tau\varepsilon} T_{rs}^{1-\varepsilon} {W_s}^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}$$

(1. 30)

$$W_r = \lambda_r^{-\tau}\left(\sum_{s=1}^{r} Y_s T_{sr}^{1-\varepsilon} I_s^{\varepsilon-1}\right)^{\frac{1}{\varepsilon}}$$

(1. 31)

As highlighted by equation 1.31, the wage rate and the congestion parameter are inversely proportional: the wage in region r reduces, as the congestion in the region starts to increase. On the other hand, equation 1.30 shows that the increase of congestion in region r leads to a decrease in the price index of other regions. These two effects foster the spreading of economic activity over the regions.

Brakman et al. (2020) conducts some simulations on the two-city congestion model to assess the long-run equilibrium at nine different rates of transport costs (from 1.01 to 1.9). The congestion parameter was set at 0.01. The main results are reported below:

a. $1.01 \leq T \leq 1.03$: spreading of economic activity over the regions is the only possible equilibrium in the long-run
b. $T = 1.05$: even if the level of transport costs is still low, congestion allows for some partial agglomeration in either region as a stable equilibrium in the long run.
c. $1.07 \leq T \leq 1.4$: with intermediate values of T, the simulations show that complete agglomeration is the only possible equilibrium in the long run.
d. $T = 1.6$: as T continues to grow, spreading equilibrium becomes stable in the long run. It is important to note that also some partial agglomeration equilibria are stable in the long run.
e. $1.61 \leq T \leq 1.9$: full agglomeration of economic activity in one region is the only possible equilibrium in the long run.

Therefore, through these simulations, Brakman et al. (2020) finds that the possible scenarios in the long run are wider with congestion rather than without it. Moreover, the partial agglomeration framework allows for the coexistence of larger and smaller regions in a stable long-run equilibrium.

1.10 Critical Discussion on the NEG model

To study the impact of new infrastructures, researchers usually conduct some What-If analysis based on a difference-in-differences framework (Hoogendoorn et al., 2019). For instance, Gibbons & Machin (2004) compared the changes in house prices in South East London between areas that were affected by the construction of new underground stations and those that were not affected. Also, Ghani et al. (2013) used the diff-diff approach to study how the development of the Golden Quadrilateral highway impacted the manufacturing industry in India.

In evaluating the impact of infrastructures, the diff-diff method is highly reliable mainly due to its causal inference: by comparing treated and control groups both before and after the development of infrastructure, it is able to isolate the impact of the infrastructure itself and evaluate it. In this light, the statistical method is particularly efficient when researchers can gather empirical data both pre-and post-intervention, enhancing the accuracy and effectiveness of the analysis.

However, evaluating the economic impact of infrastructure before being developed cannot be done through a difference-in-differences statistical method due to the unavailability of post-development empirical data.

In this light, we opted for the NEG model, which allowed us to simulate the behavior of different economic agents (firms and workers) and their interactions within a spatial framework, making use of mathematical and computational techniques. Using the NEG model provided us with a particular advantage in many respects: first of all, the Krugman's model provides a theoretical and scientific explanation to the dynamics of spatial economies. This is of fundamental relevance for researchers, who manage to analyse complex interactions among economic agents, understand the formation of agglomerations, and explore how different factors influence economic outcomes. Then, the NEG model simulations offer flexibility in examining various scenarios and assumptions. In this light, we could edit the values of different parameters, introduce the time-saving impact of the Strait of Messina bridge, and observe the resulting changes in the spatial distribution of economic activity. This flexibility allowed us to evaluate even the sensitivity of the analysis by playing with the values of the parameters and deeply exploring the infrastructural policy and its potential impact.

On the other hand, by full describing the NEG model, we identified some weaknesses. Firstly, our simulations are based on some simplifying assumptions which make the analysis more suitable. These assumptions, however, could not capture the complexity of real-world economic dynamics and interactions in toto. For instance, the model could not take into account specific industry characteristics, or underrate unique regional factors (natural characteristics, political administration…). These simplifications can limit the model's ability to capture the range of impacts that the Strait of Messina bridge may have on the actual spatial redistribution of economic activity.

Furthermore, the NEG model heavily relies on both the data collected and their elaboration. Therefore, the results coming from the NEG model simulations are strictly sensitive to the parameter values chosen and the interpretation of collected data. Small changes in elaboration of data or values of parameters can lead to significant differences in the outcomes. Acquiring and processing such data can be challenging and may introduce uncertainties and limitations. To address this weakness, we dedicated a significant amount of time to collecting the appropriate data and addressing any related issues through meticulous elaboration (see the next chapter on methodology).

Differently from the Diff-Diff methods, the main weakness of the NEG model is the lack of a counterfactual analysis. As a matter of fact, simulations based on the NEG model typically analyze the impact of infrastructure under specific scenarios or changes. While simulations based on the NEG model are able to compare different infrastructure configurations, they may not explicitly provide a counterfactual analysis that manages to isolate the effects of Strait of Messina bridge from other internal/external factors. In this way, it is hard to assess the specific impact of the infrastructural project on the broader economic trends.

These are all the strengths and weaknesses that we identified by fully analysing the theoretical structure of the model. Additionally, after presenting the results, we included a paragraph in conclusions addressing further considerations that emerged from running the model and studying its outcomes.

Stelder (2005) is the first approach to implement the NEG model into the reality. In this study, the Professor Dirk Stelder defined space as a grid consisting of n locations on a two-dimensional surface. To calculate the distance between different locations, the shortest path was computed, with the assumption that the distance between horizontal and vertical neighbors was equal to 1, and the distance between diagonal neighbors was equal to √2. In this way, all the natural barriers such as mountains and seas were not taken into account in the simulations, increasing the reliability of the results. To this end, He run some simulations to study the geographical distribution of economic activity within Europe starting from some defined parameters. This study was of significant relevance as it bridged the gap between the NEG model and real-world scenarios. Following Stelder (2005), Bosker, Buringh & Van Zanden (2013) and Bosker & Buringh (2017) also adopted the grid approach to run simulations on the NEG model.

In our study, as detailed in the following chapter, we calculated distances between locations using an external Excel file and the Google Maps API. In this sense, the study is completely based on the current state of the railways and railroads which makes the simulations as closest the reality as possible. By using this method, we were able to adapt a theoretical model to the complex geographical scenario of the Italian peninsula. Computing distances based on actual driver routes enabled us to exclude potential errors caused by the presence of the sea between Sicily and the mainland.

The main structure and the extension of the core model of Geographical Economics have been widely discussed in the chapter. In the next chapter, the paper will present both the collection and elaboration of data needed to conduct our study.

2. Methodology

In this chapter, we explain the main approach and methods used to conduct the study, analyze the data, and draw conclusions/limitations. The chapter has been divided into 3 sections: the first section presents the two software programs used in the study and why they were of fundamental importance to conducting the research (2.1). The second one outlines the processes of gathering the statistics needed for the study (2.2) and the third one shows the process to elaborate particular data which are essential for the validity of the study's findings (2.3).

2.1 Matlab 2021b and ArcGIS Pro

To conduct the simulations, we made use of two different software programs: Matlab R2021b and ArcGIS Pro. On one hand, Matlab R2021b allowed us to process the data and run the new economic geography model; on the other, we used ArcGIS Pro to visually display the spatial results. By combining these two programs, an advanced spatial data analysis on the Italian distribution of manufacturing activity was performed.

Matlab R2021b is a version of the numeric computing software developed by Mathworks corporation. The program can adapt or be adapted to many different functions or activities. In geographical terms, it can be used to model geographic phenomena or to analyze geospatial data, for example. In this light, the Mapping Toolbox, which is a free extension of Matlab, delivers tools for georeferencing data and performing spatial analysis. In our research, Matlab R2021b was the main tool in processing the data and mathematically running the core model. As a matter of fact, the Geographic Economic Agglomeration Model (=GEAM) was originally written in Matlab code by Professor Dirk Stelder in 1995. The University of Groningen (RUG) provided us with the latest version of this GEAM code. Below, the GEAM configuration file used in our research is reported:

```
%------------------------------------------------------------------------------------------------------
%                             Geographic Economic Agglomeration Model
%                                     GEAM configuration file
%             use this settings by copying this file to 'geam_config.m' in the main directory
%------------------------------------------------------------------------------------------------------

%------------------------------------------------------------------------------------------------------
%                        startup commands; DO NOT EDIT THE FOLLOWING TWO LINES
home;
clear;
%------------------------------------------------------------------------------------------------------

%--------------------------------general program options-----------------------------------------------
run_name='runs/italy_run_1';   % .xls output file name (no extension, must start with a letter)
nrit=10000;                     % number of iterations
tol=0.0001;                     % iteration tolerance
showit=0;                      % if showit=1 show graph of each iteration (if showit=0 only last picture is shown)
showbar=1;                     % if showbar=1 show initial and final distributon in a barchart
%-------------------------------------------------------------------------------------------------------

%------------------------------model options------------------------------------------------------------
gamma=0.41;                     % share manufacturing
epsilon=4.7;                     % demand elasticity (=1/1-rho)
t=1.583;                         % iceberg transport cost (units to be shipped over one distance unit)
model_option=2;                % 1=core model;2=congestion model;3=footloose entrepreneur model
tau=0.065;                         % congestion parameter for congestion model (if model_option=2)
iceberg_option=2;              % options for transport cost parameter t; 1=standard; 2=log-adjusted
history_option=1;              % 0=no history; overrules history from from external model
%-------------------------------------------------------------------------------------------------------

%-----------------------------geography options---------------------------------------------------------
space_option=2;                % 1=internal xy coordinates of grid in 2D space; 2=external xy coordinates from model_in
%-----------------------------if space_option=1:--------------------------------------------------------
i=371;                         % number of x-axis pixels of grid in 2D space
j=1;                           % number of y-axis pixels of grid in 2D space
circle=107;                      % number of locations on a circle space; if > 1 overrules i and j and xy-coordinates from external file
%-----------------------------if space_option=2:--------------------------------------------------------
model_in='models/italy_copy.xls';    % external model file (must be .xls or .shp extension)
%-------------------------------------------------------------------------------------------------------

%-----------------------------distance options----------------------------------------------------------
distance_option=3;             % 1=calculate xy distance;2=calculate LL distance;3=load from distance_in
distance_in='models/italybridge5';     % external .mat file with distance matrix (no extension) when distance_option=3
                               % note: internal variable name must be 'distance'
%-------------------------------------------------------------------------------------------------------

% start program
load version;
geam;
```

From the picture above, the initial options chosen for running the simulations are visible. From line 21 to line 24, it was possible to edit the initial values of T, γ, ε, and τ (see chapter 1). Further discussion on these values will follow in section 3.

Running the GEAM model, we obtained the percentage change and the final distribution of manufacturing activity in each Italian province in the long run with/without the bridge. To visualize these results, ArcGIS Pro was used.

ArcGIS Pro is a GIS (=Geographical Information Systems) software developed by ESRI company in 2015. Thanks to ArcGIS pro, spatial data can first be related to non-spatial data and then visualized on a map in order to make some inferences in a spatial dimension. Like Matlab, also ArcGIS Pro is a versatile tool that nowadays both institutions and researchers use in a wide range of studies that involve spatial data. In our case, ArcGIS was of fundamental relevance to geographically displaying the results obtained through Matlab. In this respect, all the maps in the paper have been made using ArcGIS Pro. To work with this program, we converted all the Matlab results into the shapefile format, a geospatial Esri vector data layout (arcgis.com).

2.2 Collection of Italian statistics

To conduct the study, we first had to define the appropriate unit of analysis. This passage was of fundamental relevance because making an appropriate choice would have led to potential implications. In this respect, setting the 21 Italian regions as the unit of measure would not have indicated the real impact on individual cities. On the other hand, considering only the Italian cities would have left out the economic activity in the Italian countryside, resulting in a biased final distribution. Therefore, we opted to set the 107 Italian provinces as the unit of analysis. This setting was extremely useful: on one side, in fact, the whole Italian territory was taken into account in the simulations; on the other, we had a more precise indication of the impact on the different Italian cities. In this way, after getting the first results, we could also assess whether the development of the Strait of Messina Bridge would have been either a regional or a national impact on the geographical distribution of economic activity.

Defined the unit of analysis, we had to create an excel database with some statistics related to the Italian provinces. In particular, we had to identify how many workers were employed either in footloose or bounded sectors in each province. The core model theory required this categorization (see chapter 1). As a matter of fact, assuming that some economic sectors are more easily relocated than others, the NEG model splits the economy into two big categories: food and manufacturing. Likewise, we needed to distinguish between footloose and bounded sectors to accurately represent the potential impact of the Strait of Messina Bridge on different economic sectors and provinces. The footloose sectors are more mobile and can easily relocate, while the bounded sectors are less mobile and tied to a specific geographic location. By categorizing the sectors in this way, we could simulate the potential relocation of economic activity from one province to another and assess the impact on the overall distribution of economic activity across the Italian provinces. This process was crucial to ensure the accuracy and reliability of our simulations and to draw meaningful conclusions about the potential effects of the bridge development project.

All the data on the Italian labor market were collected through the National Institute of Italian Statistics (istat.it). The different economic activities were, then, clustered according to the NACE classification (=Statistical Classification of Economic Activities in the European Community):

- Agriculture, Forestry, and Fishing (column A)

- Manufacturing (column B)
- Mining and Quarrying; Electricity, Gas, Steam, and Air Conditioning Supply; Water Supply, Sewerage, Waste Management, and Remediation Activities (column C)
- Construction (column D)
- Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles; Transportation and Storage; Accommodation and Food Service Activities (column E)
- Information and Communication (column F)
- Financial and Insurance Activities (column G)
- Real Estate Activities (column H)
- Professional, Scientific and Technical Activities; Administrative and Support Service Activities (column I)
- Public Administration and Defence; Compulsory Social Security; Education; Human Health and Social Work Activities (column L)
- Arts, Entertainment, and Recreation; Other Service Activities (column M)

The selected period was 2018.
Below, the Italian labor market database is reported:

Table 1. Italian Labor Market by Province

Province	A	B	C	D	E	F	G	H	I	L	M	Total	F sect	B sect
Agrigento	159	62	35	66	314	8	23	3	79	335	140	1224	241	983
Alessandria	54	333	19	114	457	19	38	11	164	302	170	1681	679	1002
Ancona	47	493	23	105	497	51	53	17	247	458	211	2202	966	1236
Aosta	23	48	10	51	175	14	13	5	65	155	56	615	196	419
Arezzo	77	407	15	109	328	23	32	9	165	230	151	1546	745	801
Ascoli Piceno	34	154	11	56	231	15	21	4	97	148	89	860	347	513
Asti	60	164	9	66	192	8	22	5	86	139	87	838	351	487
Avellino	79	224	24	110	354	20	25	6	155	307	168	1472	540	932
Bari	299	540	67	326	1335	111	98	24	597	942	430	4769	1696	3073
Barletta	152	187	16	74	353	10	20	5	100	229	103	1249	396	853
Belluno	20	273	8	58	229	7	17	5	98	172	67	954	458	496
Benevento	90	100	15	71	201	10	16	3	86	212	86	890	286	604
Bergamo	61	1383	48	423	1136	73	120	32	568	700	435	4979	2599	2380
Biella	11	172	7	42	161	7	31	4	83	142	66	726	339	387
Bologna	77	1011	51	263	1331	192	162	44	798	975	490	5394	2470	2924
Bolzano	205	367	29	221	972	48	61	21	254	643	227	3048	972	2076
Brescia	147	1526	80	402	1360	86	133	38	736	875	391	5774	2921	2853
Brindisi	167	136	21	89	364	10	19	4	113	285	107	1315	371	944
Cagliari	40	105	45	109	521	55	35	14	284	486	324	2018	602	1416
Caltanissetta	72	46	13	48	168	6	13	2	80	189	67	704	195	509
Campobasso	70	102	7	58	189	13	15	4	76	186	69	789	268	521
Caserta	136	284	37	212	770	23	41	17	255	648	269	2692	832	1860
Catania	188	258	54	202	1020	45	68	12	380	822	408	3457	965	2492
Catanzaro	118	63	21	85	305	17	21	4	142	320	133	1229	332	897
Chieti	90	343	22	107	378	14	29	6	173	299	141	1602	672	930
Como	24	559	18	151	585	39	47	20	313	391	233	2380	1129	1251
Cosenza	274	110	44	134	558	38	38	5	232	505	228	2166	557	1609
Cremona	71	360	12	79	309	21	33	10	165	269	106	1435	668	767
Crotone	80	34	18	35	135	3	7	2	48	123	50	535	129	406
Cuneo	214	617	28	206	640	35	66	15	293	429	220	2763	1232	1531

Enna	38	30	8	27	101	4	7	2	39	138	53	447	109	338
Fermo	22	255	6	36	161	7	15	5	54	103	58	722	372	350
Ferrara	92	226	24	69	353	18	27	9	140	265	141	1364	489	875
Firenze	72	932	50	259	1338	114	139	44	727	953	618	5246	2215	3031
Foggia	290	169	38	129	570	11	38	7	157	462	132	2003	511	1492
Forlì	104	375	23	116	525	28	43	15	194	300	146	1869	771	1098
Frosinone	49	313	27	151	432	15	29	8	174	318	226	1742	690	1052
Genova	17	354	51	257	1323	82	108	32	476	737	482	3919	1309	2610
Gorizia	17	126	6	32	137	6	12	4	51	123	48	562	231	331
Grosseto	106	62	16	57	278	12	19	10	86	171	108	925	246	679
Imperia	42	37	11	60	273	8	16	8	65	152	87	759	194	565
Isernia	16	37	5	30	73	3	5	1	30	73	24	297	106	191
La Spezia	11	99	14	53	269	12	19	6	103	244	99	929	292	637
L'Aquila	53	118	23	120	272	14	20	8	134	271	100	1133	414	719
Latina	215	254	29	142	593	28	39	14	205	370	215	2104	682	1422
Lecce	172	275	38	214	714	34	50	10	279	514	264	2564	862	1702
Lecco	12	439	11	89	292	18	30	10	171	207	115	1394	757	637
Livorno	28	140	23	76	464	14	29	15	141	270	144	1344	415	929
Lodi	24	165	7	50	199	24	18	9	95	135	79	805	361	444
Lucca	27	299	23	118	458	23	38	17	169	261	155	1588	664	924
Macerata	54	333	19	91	345	20	27	7	130	215	121	1362	608	754
Mantova	108	508	19	104	406	24	40	11	221	271	171	1883	908	975
Massa-Carrara	12	92	21	52	214	9	16	7	76	148	80	727	252	475
Matera	103	68	37	51	170	7	10	2	74	142	51	715	212	503
Messina	113	129	26	122	557	20	36	8	191	550	238	1990	506	1484
Milano	66	2276	235	908	5249	1176	878	213	4042	2718	2427	20188	9493	10695
Modena	89	978	31	202	805	69	89	27	414	490	288	3482	1779	1703
Monza Brianza	8	826	25	223	858	94	83	34	448	519	306	3424	1708	1716
Napoli	143	1100	133	633	3158	221	196	53	1201	2051	1027	9916	3404	6512
Novara	21	364	16	101	372	26	36	9	174	272	136	1527	710	817
Nuoro	91	54	16	46	179	6	11	2	57	187	89	738	176	562
Oristano	62	30	9	30	142	5	8	2	40	127	87	542	115	427
Padova	106	990	38	261	1172	136	100	38	602	743	402	4588	2127	2461
Palermo	141	181	76	174	950	71	80	24	458	1116	468	3739	988	2751
Parma	65	538	28	148	536	48	54	14	306	352	243	2332	1108	1224
Pavia	58	336	22	126	457	28	44	14	231	424	205	1945	779	1166
Perugia	117	485	33	173	731	42	57	19	311	518	338	2824	1087	1737
Pesaro Urbino	43	403	16	94	380	22	33	14	162	255	153	1575	728	847
Pescara	31	142	15	84	340	26	30	6	180	242	131	1227	468	759
Piacenza	48	252	14	69	395	20	28	7	150	222	137	1342	526	816
Pisa	39	323	33	119	465	52	41	13	232	385	189	1891	780	1111
Pistoia	49	207	8	78	305	14	30	13	117	197	124	1142	459	683
Pordenone	52	408	19	74	275	19	31	10	149	275	112	1424	691	733
Potenza	107	212	28	97	298	20	21	3	145	298	104	1333	498	835
Prato	5	462	14	64	298	19	23	13	128	159	98	1283	709	574
Ragusa	242	82	17	70	290	12	16	3	81	221	108	1142	264	878
Ravenna	92	303	18	100	509	28	37	14	195	286	190	1772	677	1095
Reggio Calabria	281	82	20	104	458	12	32	3	144	461	148	1745	377	1368
Reggio Emilia	67	747	23	147	552	36	65	16	299	372	185	2509	1310	1199
Rieti	29	39	5	37	117	6	10	2	48	121	93	507	142	365

Rimini	29	205	14	87	589	28	33	22	161	252	141	1561	536	1025
Roma	164	893	269	1086	5390	1181	670	189	3773	4804	3361	21780	7792	13988
Rovigo	66	204	13	71	229	9	18	5	89	166	91	961	396	565
Salerno	254	392	69	250	1172	42	77	12	377	729	372	3746	1150	2596
Sassari	96	106	29	125	530	19	34	13	186	417	248	1803	483	1320
Savona	34	113	17	91	365	12	24	14	109	204	133	1116	363	753
Siena	101	189	14	76	312	20	55	9	156	229	128	1289	505	784
Siracusa	105	95	30	87	299	12	19	4	103	324	118	1196	320	876
Sondrio	25	127	12	58	221	9	27	4	67	143	102	795	292	503
Sud Sardegna	98	84	20	63	264	6	14	2	68	229	127	975	237	738
Taranto	188	280	24	92	443	35	30	5	179	490	154	1920	621	1299
Teramo	52	277	16	112	305	13	23	8	129	194	126	1255	562	693
Terni	33	117	16	63	220	23	18	5	96	175	123	889	322	567
Torino	105	1856	130	528	2330	471	388	82	1489	1803	978	10160	4814	5346
Trapani	131	90	21	68	340	10	23	6	93	325	139	1246	290	956
Trento	122	343	35	183	697	77	58	18	322	638	188	2681	1001	1680
Treviso	154	1165	40	272	909	64	125	44	459	554	314	4100	2129	1971
Trieste	6	105	16	49	259	35	51	9	137	285	126	1078	386	692
Udine	79	466	31	135	576	34	53	15	280	475	239	2383	983	1400
Varese	16	931	29	187	895	59	72	44	418	601	352	3604	1711	1893
Venezia	75	546	62	250	1259	70	75	40	454	639	346	3816	1435	2381
Verbano	7	89	11	45	178	7	13	4	53	113	75	595	211	384
Vercelli	22	162	12	49	165	7	16	3	69	130	72	707	306	401
Verona	193	825	45	263	1323	97	107	35	478	719	394	4479	1805	2674
Vibo Valentia	85	31	4	29	133	4	7	2	36	120	39	490	109	381
Vicenza	76	1425	31	220	904	59	75	34	414	565	296	4099	2227	1872
Viterbo	86	88	16	80	282	14	23	8	102	225	161	1085	315	770

Note that the names of two Italian provinces have been cut to fit in the first column of the table: Barletta-Andria-Trani, and Verbano-Cusio-Ossola. Due to the limited space, we also had to divide the number of workers by 100 in each cell of the table. Therefore, the number of workers employed in agriculture, forestry, and fishing in the province of Agrigento (Sicily) is 15.900 (=159x100), for example. The subdivision of economic activities into footloose and bounded sectors is quite arbitrary. We adopted the main criterion of the footloose industry, which is the independence from any location-specific resource (physical and abstract). The column labeled 'F sect' displays the number of workers employed in the footloose industry (sum of all the green columns), while the 'B sect' column shows the number of workers employed in the bounded sectors (sum of all the white/blue columns).

From table 1, it is also possible to compute the F-share, i.e., the ratio between the number of workers in the footloose industry and the total number of workers employed in each province. This index reflects the rate of economic mobility of each Italian province: higher F-shares may indicate higher economic mobility, and, consequently, higher potential for geographical relocation, while lower F-shares may suggest a more stagnant economy. In this light, the province of Prato (Tuscany) shows the highest F-share rate (0.55) whereas the province of Agrigento (Sicily) shows the lowest one (0.19). Another interesting point here is the significant difference between the north and the south of Italy: while the provinces of northern regions (Aosta Valley, Liguria, Lombardy, Piedmont, Emilia-Romagna, Friuli-Venezia-Giulia, Trentino-South Tirol, and Veneto) have an F-share of 0.42 on average, the provinces in the South (Abruzzo, Apulia, Basilicata, Calabria, Campania, Molise, Sardinia, and Sicily) show an F-share of 0.29 on average. In the center of Italy (Lazio, Marche, Tuscany, and Umbria) the workers employed in the footloose industry are 39% of the total workforce, alleviating, therefore, the geographical polarization of Italian footloose sectors. Based on these estimations, the construction of a big infrastructure such as a bridge seems to have a greater impact in terms of job relocation in the north.

In the GEAM model, the spatial dimension is defined by the x and y coordinates of the locations and the distance between them. Therefore, having elaborated on the Italian labor market database, we computed the distance between each province. The latter could be either automatically calculated by Matlab R2021b or loaded from an external excel file. We opted for the second option due to a practical reason: Matlab R2021b computes the distances based on x/y coordinates without taking into account natural barriers; therefore, it would not have reported the effective travel distance by car/truck/train since Italy is a boot-shaped peninsula that extends into the Mediterranean Sea. In this way, we generated a 107x107 distance matrix in excel, making use of a Google Maps API. To create it, we followed step by step a process published on syntaxbytetutorials.com. The code is reported below:

```
Function TRAVELTIME(origin, destination, apikey)

    Dim strUrl As String
    strUrl = "https://maps.googleapis.com/maps/api/directions/json?origin=" & origin & "&destination=" & destination & "&key=" & apikey

    Set httpReq = CreateObject("MSXML2.XMLHTTP")
    With httpReq
         .Open "GET", strUrl, False
         .Send
    End With

    Dim response As String
    response = httpReq.ResponseText

    Dim parsed As Dictionary
    Set parsed = JsonConverter.ParseJson(response)
    Dim seconds As Integer

    Dim leg As Dictionary

    For Each leg In parsed("routes")(1)("legs")
        seconds = seconds + leg("duration")("value")
    Next leg


    TRAVELTIME = seconds

End Function
```

```
Function TRAVELDISTANCE(origin, destination, apikey)

    Dim strUrl As String
    strUrl = "https://maps.googleapis.com/maps/api/directions/json?origin=" & origin & "&destination=" & destination & "&key=" & apikey

    Set httpReq = CreateObject("MSXML2.XMLHTTP")
    With httpReq
         .Open "GET", strUrl, False
         .Send
    End With

    Dim response As String
    response = httpReq.ResponseText

    Dim parsed As Dictionary
    Set parsed = JsonConverter.ParseJson(response)
    Dim meters As Integer

    Dim leg As Dictionary


    For Each leg In parsed("routes")(1)("legs")
        meters = meters + leg("distance")("value")
    Next leg


    TRAVELDISTANCE = meters

End Function
```

The square matrix reported the distance in terms of time (minutes) between all the 107 Italian provinces. In this light, developing a bridge between Messina and Reggio Di Calabria would decrease the travel time between the two cities. Therefore, generating a second distance matrix with a reduced travel time for this route was necessary to compute the potential impact of the bridge on the spatial distribution of economic activity. Obviously, this was not possible through Google Maps API since it takes into account only the existing roads. Hence, the matrix containing travel times between cities after the construction of the bridge was calculated manually. First, we assumed that with the Strait of Messina bridge, the travel time between Messina and Reggio di Calabria would reduce by 35 minutes

(Antonelli et al., 2021). Then, based on the first distance matrix, we only edited the travel times from each province (except for Sardinia) to all provinces in Sicily and vice versa (since the Strait of Messina bridge would be the only ground vehicles' gateway for Sicily). Obviously, the distances between non-Sicilian provinces were not modified, nor were those between Sicilian provinces.

Generated these two distance matrices, all the data needed to conduct the simulations were collected and elaborated. However, before running the simulations, we also had to set the initial values of T, γ, ε, and τ (see chapter 1). This passage was of fundamental relevance so that the simulations could work with parameters that represented the Italian framework as closely as possible. In this light, setting the actual values is essential for the validity of the study's findings.

2.3 The initial values of T, γ, ε, and τ

In the configuration file of the GEAM model, there was the possibility to manually set the values of 4 parameters: the share of manufacturing employment (γ), the elasticity of price demand (ε), the iceberg transport costs, and the congestion parameter (τ).
As explained in the chapter on theory, these parameters are significant in elaborating the results. Therefore, to ensure the validity of the simulations, their initial values should reflect the actual values. In the core model theory, the share of manufacturing employment (γ) represents the share of workers who are able to relocate (see chapter 1). Therefore, in the GEAM model, γ is equivalent to the share of workers employed in the Italian footloose sectors, i.e., the F-share. According to the collected data, the workers in Italy are about 25.364.500, around 40% (10.073.400) of them are employed in the footloose industry. Therefore, we set 0.40 as the initial value of γ in the GEAM configuration file.
The elasticity of substitution (ε) was computed as the average price elasticity across many different manufacturing varieties. To this end, we collected the price elasticities of import demand in the destination markets of Italian exports from Felettigh & Federico, 2010.

Figure 5. Sectoral decomposition for the time average (1994-2008) of the overall export elasticities by exporting country (Felettigh & Federico, 2010)

	Sectoral elasticity (A)				Percentage share on total exports (B)				Percentage contribution to the overall export elasticity η_i ($A \cdot B / \eta_i$)			
	FRA	GER	ITA	SPA	FRA	GER	ITA	SPA	FRA	GER	ITA	SPA
Agricultural, food, beverages and tobacco products	5.2	5.5	4.7	5.5	10.8	5.1	7.3	15.4	8.6	3.7	6.2	11.4
Minerals and mineral products	5.3	7.9	5.8	6.6	3.1	1.6	2.4	2.9	2.6	1.7	2.5	2.6
Textiles	5.7	6.1	5.6	5.1	1.9	1.9	4.7	2.4	1.6	1.5	4.8	1.6
Wearing apparel	3.8	3.4	4.0	3.5	1.8	1.5	5.6	2.1	1.1	0.7	4.0	1.0
Leather and footwear	4.4	5.0	6.5	4.6	1.2	0.6	5.3	2.4	0.8	0.4	6.2	1.5
Wood and products of wood (except furniture)	3.9	4.3	3.8	4.3	0.6	0.7	0.5	0.8	0.4	0.4	0.4	0.5
Paper and paper products, printing	3.7	4.2	4.2	4.4	2.3	2.8	2.2	2.8	1.3	1.6	1.7	1.7
Chemical and pharmaceutical products	4.1	4.4	4.7	4.6	12.0	9.3	7.3	8.4	7.5	5.4	6.3	5.2
Rubber and plastic products	4.8	4.4	4.2	4.7	4.6	4.9	5.0	5.3	3.4	2.8	3.9	3.4
Non-metallic mineral products	3.5	4.2	3.9	3.4	1.4	1.2	3.2	2.8	0.8	0.7	2.3	1.3
Metals and metal products	4.7	5.1	4.8	4.8	7.0	8.4	9.4	8.7	5.1	5.6	8.1	5.6
Computer, electronic and optical products	4.2	3.7	4.2	3.9	3.0	4.2	2.1	1.0	1.9	2.0	1.6	0.5
Electrical equipment	4.2	4.2	4.0	4.2	9.6	11.1	6.6	7.0	6.2	6.3	4.8	3.9
Machinery and equipment	4.0	4.4	4.6	5.1	14.0	19.7	20.7	9.1	8.7	11.6	17.2	6.3
Motor vehicles, trailers and semi-trailers	15.1	16.2	12.5	14.5	12.5	21.4	8.8	23.7	29.0	46.1	20.1	46.1
Other transport equipment	10.5	18.3	10.3	14.8	12.0	3.2	2.3	2.8	19.3	7.7	4.2	5.6
Furniture and other manufacturing	5.4	5.3	5.1	5.3	2.2	2.5	6.3	2.5	1.8	1.8	5.7	1.8
TOTAL[1]	**6.5**	**7.5**	**5.5**	**7.4**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

The picture above shows the export elasticity of 4 exporting countries (France, Germany, Italy, and Spain) between 1994 and 2008 according to the sector of production. Focusing on the Italy column, it is possible to compute an average elasticity of substitution across sectors. To do it, we considered only the footloose sectors since ε measures the elasticity of substitution between two different manufacturing varieties (see chapter 1). Therefore, the following sectors were taken into account:

- Textiles
- Wearing Apparel
- Leather and footwear
- Paper and paper products
- Chemical and pharmaceutical products
- Rubber and plastic products
- Computer, electronic and optical products
- Electrical equipment
- Machinery and equipment
- Furniture and other manufacturing

As mentioned earlier, the attribution of footloose sectors is quite arbitrary and, thus, needs a brief explanation. Theoretically, the textiles, wearing apparel, and leather/footwear industries require access to raw materials. However, nowadays the costs for shipping these materials are very low, making it easier and more affordable to relocate these industries anywhere. As a result, these industries can be considered relatively footloose. The same applies to paper, chemical, pharmaceutical, rubber, and plastic products. On the other hand, electronic, electrical, and machinery equipment sectors do not depend on location-specific resources, and, thus, are completely footloose. Furniture and other manufacturing sectors are a too vague categorization. However, we took it into account since furniture can be carried out almost everywhere without a strong dependence on the location's resources. With these considerations, we computed the elasticity of substitution (ε) as:

$$Average\ \varepsilon = \frac{5.6 + 4.0 + 6.5 + 4.2 + 4.7 + 4.2 + 4.2 + 4.0 + 4.6 + (5.1)}{10} = 4.71$$

Therefore, we set 4.7 (4.66 without furniture's elasticity of substitution) as the initial value of ε in the GEAM configuration file.

As explained in chapter 1, the iceberg transport costs (T) are a purely theoretical parameter. As a matter of fact, Deardorffs' Glossary of International Economics resumes the iceberg transport costs as "a cost of transporting a good that uses up some fraction of the good itself, rather than other resources. By analogy with floating an iceberg, costless except for the part of the iceberg that melts. Far from realistic, but a tractable way of modeling transport costs since it impacts no other market". Therefore, adapting this parameter to a real situation like the Italian framework could be misleading and debatable. In this light, we set 1.58 (an intermediate value) as the initial transport costs (T) in the GEAM configuration file. Then, as we will see in the next chapter, we played with the value of this parameter to study the change of the distribution of Italian economic activity.

As for the transport costs (T), also the congestion parameter has only been theorized (τ). However, unlike the cost of transportation, the definition of this parameter (τ) is quite general, allowing for various interpretations. As discussed in chapter 1, the congestion index, which ranges from 0 to 1, refers to all the costs related to the diseconomies of scale that arise from agglomeration. Therefore, we tried to put the congestion parameter into practice, adapting it to the Italian framework. To do it, we first defined all the factors that contribute to congestion and, second, gathered data on them. Once the sample was created, we theorized a formula to calculate this parameter for our unit of analysis.

To ensure accuracy, we had to collect all the congestion data from the Italian provinces. However, this type of statistic was not available *in toto* at the NUTS 3 level. Therefore, we opted to compute the congestion index by comparing the Italian performances with the ones of the other 26 European countries. In doing so, we identified 11 different negative factors which arise from agglomerations and lead to inefficiency. All of the data were collected through Eurostat and numbeo.com:

1. *Size of housing* (Eurostat) shows the average number of rooms per person. Having too few rooms per person can lead to the so-called "household crowding" which is "a condition where the number of occupants exceeds the capacity of the dwelling space available, whether measured as rooms, bedrooms or floor area, resulting in adverse physical and mental health outcomes" (World Health Organization, 2018). This also leads to a lack of privacy, which can reduce the quality of life of the inhabitants, as well.
2. *Rent Prices* index (Eurostat) shows the average rent (€) per month of a 1-bedroom flat in each European capital. The data were collected from the "2021 CURRENT MARKET RENTS" document published by Eurostat. As the population expands and, consequently, demand for housing increases, landlords may start to charge higher rent prices, leading to higher housing costs for both individuals and firms. Higher rent prices, which arise from agglomeration, may thus lead to diseconomies of scale.
3. *Housing Costs overburden* (Eurostat) index measures the percentage of households that live in apartments where the total housing costs are more than 40% of their total disposable income. As for the rent prices, also the general housing costs increase with agglomeration. As a matter of fact, an increase in the demand for a limited number of houses not only increases the rent prices but also the overall costs related to housing.
4. *Housing Deprivation* (Eurostat) is a further statistic on household overcrowding. In particular, it shows the percentage of people living in overcrowded dwellings which lack basic amenities like lighting, adequate toilet services (no indoor toilet, no bath/shower), and, a leaking-free roof. Agglomeration can lead to housing deprivation due to an increase in the demand for limited housing resources such as land, construction materials, and financial capital. This can result in overcrowding, and, consequently, in poor living conditions and inadequate access to basic amenities. As cities rapidly grow, low-income families may be forced to live in deprived dwellings due to the lack of affordable options. Therefore, if an increase in agglomeration is faster than the conditions that make this phenomenon sustainable, agglomeration can exacerbate existing housing shortages and lead to further inequities in access to adequate housing.
5. *Air pollutants and greenhouse gases* (Eurostat) calculate the 2019 average concentration (micrograms per cubic meter) of particulate matter, PM10 and PM2.5, at urban background stations in highly populated areas, weighted on population. PM10 and PM2.5 are two inhalable particulate matters which emerge from the combustion of fuel and industrial operations (ca.gov, 2022). If constantly inhaled, these particulates have deleterious health consequences on the human body in the long term.
6. *Cost of Living* (numbeo.com) index compares the price of consumer goods such as groceries, transportation, and other utilities (excluding accommodation), with those of New York City, which is set, as the benchmark, at 100. In this light, if a country has a cost-of-living value of 60, this means that the consumer goods are, on average, 40% cheaper than those of New York.
7. *Traffic Index* (numbeo.com) takes into account several factors related to road traffic, including commuting time, traffic dissatisfaction, CO_2 consumption in traffic, and other traffic system

inefficiencies. The mathematical formula to compute some of these parameters is shown on numbeo.com. As the population expands, there also is an increase in traffic and congestion which lead to higher commuting costs and longer delivery times. Furthermore, people reduce productivity since they get stuck in traffic for more and more time.

8. *Inefficiency (in traffic) index* (numbeo.com) measures how inefficiently traffic is moving. A high/low index means that the traffic system is very inefficient/efficient. Numbeo.com explains that high inefficiencies often stem from the fact that people choose their personal vehicle instead of public transport to move around the city. This index is strictly correlated to the previous one and has the same consequences.
9. *Passenger cars* index (Eurostat) reports the number of personal cars per 1000 inhabitants. The main idea behind considering this index to measure diseconomies of scale is that an increase in personal vehicles leads to more traffic and, consequently, to traffic inefficiency. This is basically because personal vehicles take up physical space on the road and contribute to congestion, which can lead to longer commute times, increased fuel consumption (higher living costs), and higher CO_2 emissions (higher pollution).
10. *Crime Index* (Eurostat) shows the number of recorded offenses of robbery, burglary, serious assault, theft, homicide, and sexual violence by country. The idea that agglomeration leads to an increase in crime is quite debatable but well supported by the academic literature: while Harries (2006) documents a moderate correlation between some crimes and population density, Glaeser & Sacerdote (1999) shows that, in relative terms, there are more crimes in bigger cities than in small ones. In this light, we included it in computing the congestion parameter.

Based on these considerations, we gathered all these data in the following table:

EU Country	Housing	Air pollution	Cost of Living	Rent Prices	Traffic Index	Inefficiency index	Crime Index	Housing Deprivation	Housing Costs overburden	Passenger cars
Belgium	2.2	11.1	72.6	880	146.2	187.8	3359.55	5.2	14.6	511
Bulgaria	1.2	19.6	38.4	390	99.4	89.1	695.54	7.7	16.1	396
Czech Republic	1.6	14.4	48.2	760	90.6	71.7	833.78	3.2	12.9	540
Denmark	2.1	10	84.1	1500	87.5	119.1	4271.73	4.9	21.2	447
Germany	2	10.9	65.6	1150	105.1	124.4	1961.03	3.8	17.6	567
Estonia	1.7	4.8	53.7	560	84	95.2	605.25	2.6	4.6	563
Ireland	2.4	8.8	76.1	1600	149.5	172.5	1876.85	1.7	4.5	445
Greece	1.3	14.1	56.2	860	133.1	144.1	972.33	6.5	43.9	493
Spain	2	11.8	53.9	810	105.2	125.1	877.78	1.7	10	513
France	2	10.4	74.1	1250	128.8	143.6	2341.06	4	6.3	569
Croatia	1.1	16	48.9	680	96.1	98	597.04	6.5	4.2	409
Italy	1.4	15.1	66.5	890	130.1	155.6	1822.64	6.4	11.7	652
Cyprus	2.1	13.4	59	570	105.2	141.5	256.19	0.3	3.1	629
Latvia	1.2	12.1	48.5	600	107.9	118.7	1059.78	14.6	6.9	369
Lithuania	1.6	11.1	45.6	620	89.6	75.5	574.57	5.7	4.1	512
Luxembourg	2.2	10.2	80.5	1750	108.9	117.1	2536.35	4	18	676
Hungary	1.6	14.4	40.7	610	126	131.1	669.95	7.3	11.3	373
Malta	2.3	:	67.8	710	98.6	109.9	1729.86	1.3	1.7	608
Netherlands	1.9	10.4	75.7	1050	89.4	149	1831.8	1.6	12.1	494
Austria	1.8	12	71	1050	79.1	79.6	2131.48	7.7	11.6	562
Poland	1.1	19.3	39	470	114.4	109.7	487.11	7.6	8.3	617
Portugal	1.7	9.1	47.9	1050	110.9	118.3	1205.61	5.4	6	514
Romania	1.1	16.4	35.2	510	123.9	130.1	698.46	4.9	7	332
Slovenia	1.6	15.3	53.9	640	99.2	137.6	1459.78	5.4	7.6	549
Slovakia	1.2	13.8	44.7	640	100.9	164.1	451.34	1.6	5.6	426
Finland	2	5.1	73.2	1100	82.6	72.8	2412.05	1	5.4	629
Sweden	1.9	5.8	71.7	1650	98.2	132.7	4396.48	3.5	10.1	476

All these indicators have different units of measure. To combine them into a general congestion index, we had to set all the indicators within the same scale. To achieve this, we opted to use the normalization tool that was well-suited for our case. This enabled us to compare ratings across different items in a meaningful way. Before doing it, we excluded the outliers (red cells) of each index to better perform the normalization. The exclusion of outliers was based on a 95% confidence interval:

- $Inferior\ Threshold\ = mean\ -\ 2\ \times standard\ deviation$
- $Superior\ Threshold\ = mean\ +\ 2\ \times standard\ deviation$

Then, each index was normalized to a scale of 0 to 1 using the following formula:

$$Normalization = \frac{Italy\ value - Min\ value}{Max\ Value - Italy\ Value}$$

(2. 1)

Normalized Indexes	Italy value
Housing size	0.23
Air pollution	0.70
Cost of Living	0.64
Rent Prices	0.40
Traffic Index	0.94
Inefficiency index	0.83
Crime Index	0.50
Housing Deprivation	0.82
Housing Costs overburden	0.51
Passenger cars	0.93

After normalization, we computed the average of each normalized parameter to obtain the congestion index, which represents the overall level of congestion. Hence:

$$Congestion\ (\tau) = \frac{0.23 \times 0.70 \times 0.64 \times 0.40 \times 0.94 \times 0.83 \times 0.50 \times 0.82 \times 0.51 \times 0.93}{10} = 0.65$$

Therefore, in the GEAM configuration file, we set 1.58, 0.41, 4.7, and 0.65 as the initial values of T, γ, ε, and τ, respectively.
The chapter on methodology ends here. First, we presented the two software programs that we used to conduct the study. Second, we showed how the data were both collected and analysed. Then, we focused on explaining how we set the initial values of some fundamental parameters. In the next chapter, we will show the main results of the study and their implications.

3. Results

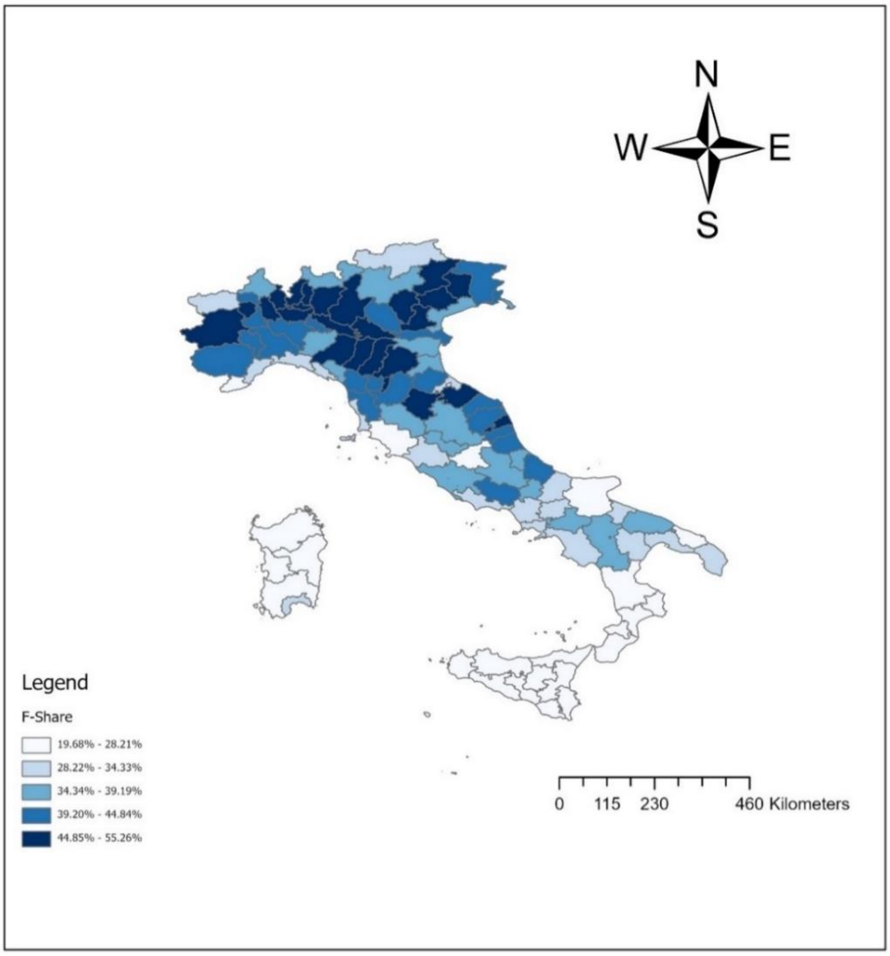
The chapter shows the main results of the simulations and provides a clear understanding of their implications. It is divided as follows: section 3.1 deals with the baseline model, which reproduces the initial and final spread of manufacturing activity in Italy with/without the bridge. Then, section 3.2 shows several simulations with different values of γ, ε, T, and τ to study the impact of these parameters on the geographical distribution of economic activity in Italy.

3.1 Economic activity in Italy in the short/long-term

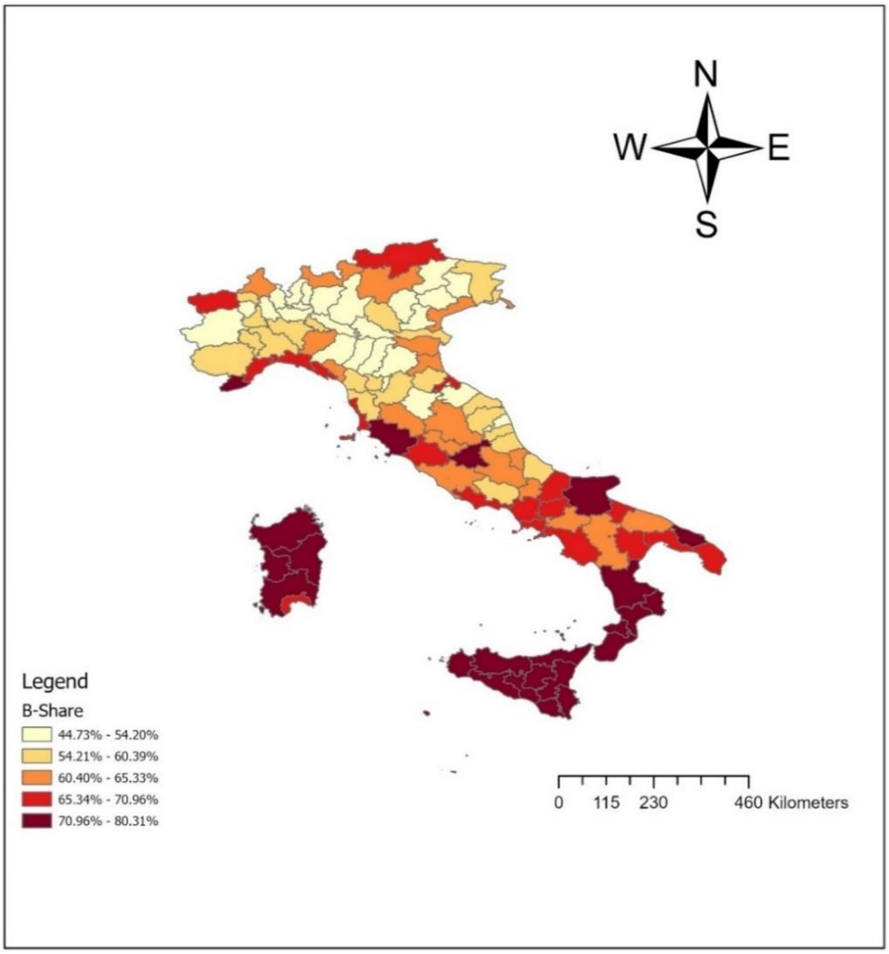
Section 3.1 starts by providing a clear overview of the current Italian manufacturing activity in geographical terms. In this light, we created two maps: on one hand, Map 1 shows the initial share of workers employed in footloose sectors relative to the total workforce by province; on the other, Map 2 shows the initial share of workers employed in bounded sectors relative to the total workforce by province.

From these maps, it is visible a clear geographical distinction: while the share of footloose sectors is significantly higher in the North of Italy, the bounded industries such as agriculture and fishing are more prominent in the South: the top (bottom) 5 provinces in terms of F-share (B-share) are Prato, Vicenza, Reggio Emilia, Lecco, and Bergamo, whereas bottom (top) 5 are Agrigento, Oristano, Reggio Calabria, Vibo Valentia, and Ragusa.

Map 1. Footloose sectors share by province in Italy



Map 2. Bounded sectors share by province in Italy



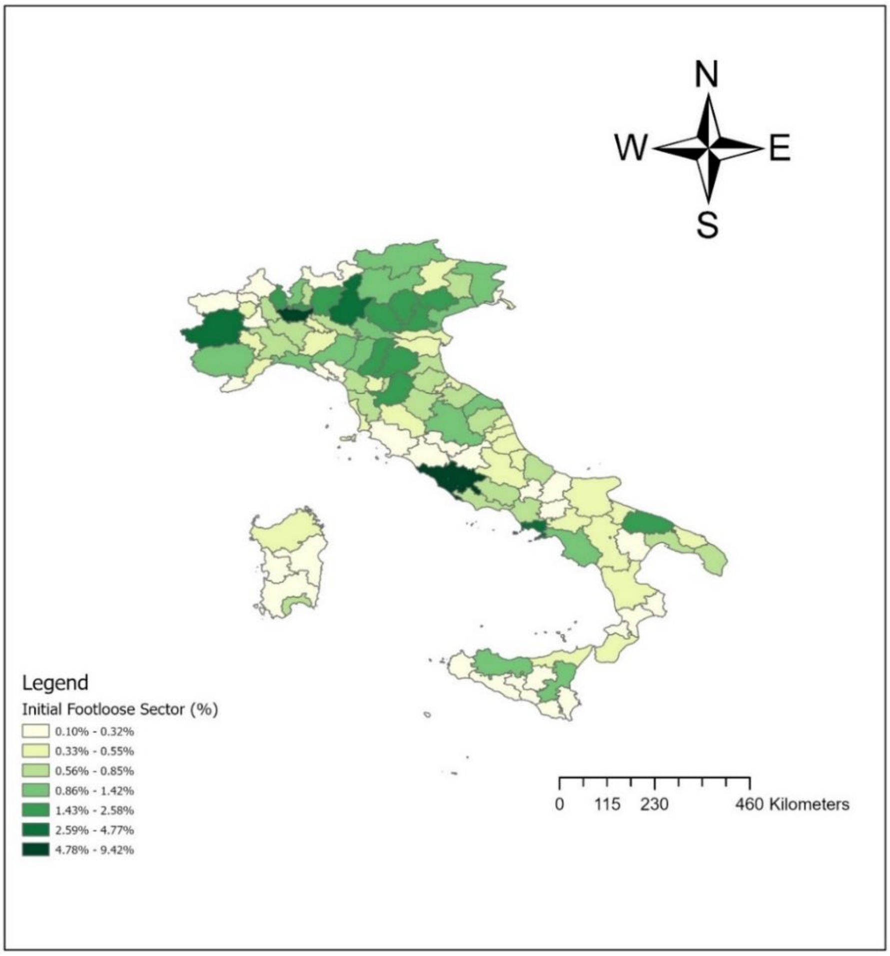
Footloose and bounded industries are strictly related to the concept of geographic mobility in the economy. While footloose sectors are not tied to any particular location, bounded industries are located close to the primary resources and cannot easily move their operations to different places. This geographical polarization of footloose and bounded sectors has significant economic and social consequences. In regions with limited geographic mobility, such as Southern Italy, job opportunities may be scarce, leading individuals to migrate to areas with better prospects and higher wages. In contrast, in regions with higher levels of geographic mobility, such as the North, there may be more competition among regions to attract footloose industries and create jobs. Furthermore, a geographically immobile economy can significantly reduce the exchange of ideas, hinder new businesses, and limit the creation of new industries. This can lead to a lack of innovation and entrepreneurship, which can shrink economic growth. Therefore, this geographic polarization of footloose/bounded industries may lead to some regional disparities between the North and the South of Italy.

As mentioned in Chapter 2, in terms of job relocation, a big infrastructure that significantly decreases transportation costs, such as a bridge, may impact more if constructed in the North rather than in the South.

Having illustrated the current allocation of manufacturing activity in Italy, now we will show the simulation results and give them an interpretation. To this end, we created three maps: while the first map shows the initial allocation of footloose workers in Italy, the second and the third ones depict the final distribution of manufacturing activity with and without the bridge, respectively. This allows us to make some comparisons between the final geographical allocation of the manufacturing industry with and without the bridge and assess the impact of this big infrastructure in terms of geographical economics.

Map 3 reproduces the initial province-based shares of the footloose industry in absolute terms ($\frac{footloose\ workers\ of\ province\ A}{total\ footloose\ workers\ in\ Italy}$). The map itself should not be informative since it is not relative to the size of the population: larger (smaller) provinces in terms of workers are expected to have a higher (lower) percentage of footloose sectors. As a matter of fact, the five provinces with the highest initial percentage of footloose workers are Milan (9.42%), Rome (7.74%), Turin (4.78%), Naples (3.38%), and Brescia[1] (2.90%). On the other hand, the bottom five provinces in terms of footloose sectors are Crotone (0.13%), Oristano (0.11%), Enna (0.11%), Vibo Valentia (0.11%), and Isernia (0.11%).

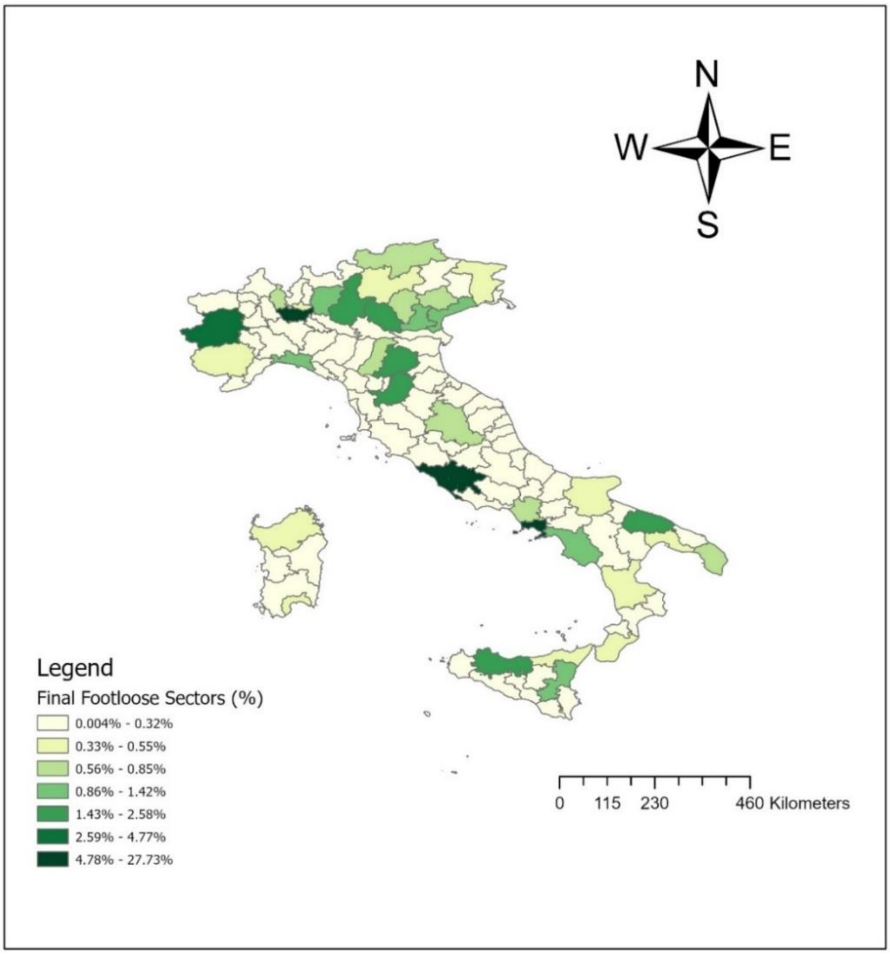
Map 3. Initial distribution of footloose sectors (%) by province



Map 4 shows the final distribution of Italian manufacturing activity in the long run. Together with Map 3, the main goal of these two representations is to visualize the change in manufacturing presence by province.

[1] Even if Brescia is the 16th most populated city in Italy (196,670.00 inhabitants), its province is actually the 5th most populated in Italy with 1,254,322.00 inhabitants (Istat, 2020).

Map 4. Final distribution of footloose sectors (%) by province



Nine provinces only experience an increase in their manufacturing employment in the long run: Genoa +0.78% (from 1.29% to 1.30%), Reggio Calabria +10.30% (from 0.37% to 0.41%), Bari +12.18% (from 1.68% to 1.88%), Salerno +14.36% (from 1.14% to 1.30%), Catania +39.11% (from 0.95% to 1.33%), Palermo +53.16% (from 0.98% to 1.50%), Naples +94.82% (from 3.37% to 6.58%), Milan +194.16% (from 9.42% to 27.72%), and Rome +243.14% (from 7.73% to 26.54%). Note that Rome, Milan, and Naples, which experience the highest increase, are also the biggest Italian provinces in population and initial footloose sectors.

In contrast, all the provinces which border Milan sharply decrease in their manufacturing shares: Lodi -92.90% (from 0.35% to 0.02%), Novara -89.85% (from 0.70% to 0.07%), Cremona -88.76% (from 0.66% to 0.07%), Pavia -78.22% (from 0.77% to 0.16%), Monza -75.22% (from 1.69% to 0.42%), Varese -67.02% (from 1.69% to 0.56%), Bergamo -61.14% (from 2.58% to 1.00%).

The same applies to the provinces bordering Rome: Rieti -90.84% (from 0.14% to 0.01%), L'Aquila -86.84% (from 0.41% to 0.05%), Frosinone -81.37% (from 0.68% to 0.12%), Viterbo -79.68% (from 0.31% to 0.06%), and Latina -59.48% (from 0.67% to 0.27%).

This trend suggests that shifting activities from less populated areas to larger cities is more effective, despite the potential drawbacks of congestion arising from diseconomies of scale. As a result, these smaller provinces lose their market potential since the transportation costs outweigh the benefits of reduced congestion. Note that the market potential of a particular location (A) depends on the income levels of other locations, adjusted for the distance between location A and those other locations (Brakman et al., 2020).

The situation in Naples and its neighboring provinces is partly different. Although Naples nearly doubles its manufacturing share over the long run (+94.82%), the neighboring province of Salerno also expands its manufacturing activity (+14.36%). This suggests that the market potential of Salerno does not decrease over time due to its proximity to Naples, which makes it an attractive location for manufacturing activities in Southern Italy. As a result, a sort of interconnection of manufacturing activities between Salerno and Naples is created, which is not observed in the bordering provinces of Milan and Rome.

Particular attention is given to the changes in the distribution of manufacturing activity in both the Sicilian provinces and Reggio Calabria. Despite being considered semi-peripheral areas, the provinces of Catania and Palermo experience a significant increase in their manufacturing employment (+39.11% and +53.16%, respectively), attracting the manufacturing workforce from the nearby provinces (Trapani, Agrigento, Siracusa, Ragusa, Enna, and Caltanissetta) in the long run. In contrast, the pattern is different at the gateway of Sicily where, in absolute values, Messina remains bigger than Reggio Calabria (from 0.502% to 0.501% and from 0.37% to 0.41%, respectively) over time.

However, while the Sicilian province slightly decreases (-0.10%) its manufacturing activity in the long term, the Calabrian one observes a significant growth (+10.30%) in its manufacturing employment. The reason behind it may be that, without the bridge, Sicilian firms are going to relocate to the mainland where the market potential is higher.

Overall, we observe a partial agglomeration of footloose sectors in a few cities as a stable equilibrium in the long run. In the north, most of the manufacturing workers, especially from the North-West, migrate to Milan, which remains the biggest footloose hub in Italy. Here, a considerable decline is in the province of Turin, the initially 4th largest province, where the spreading force of congestion combined with a limited market potential from geographical isolation reduces the city's long-run manufacturing employment share by 5.2%.

In the center of Italy, we observe a full agglomeration around Rome, making all the other provinces nearly free of footloose sectors.

In the South, the long-run equilibrium is characterized by a more heterogeneous distribution of footloose activity. In this light, it is interesting to underline that Calabria (Reggio Calabria +10.3%), Campania (Naples and Salerno +94.82% and +14.36%, respectively), Sicily (Catania and Palermo +39.11% and +53.16%, respectively), and Apulia (Bari +12.18%) have at least one province that increases its manufacturing employment in the long term.

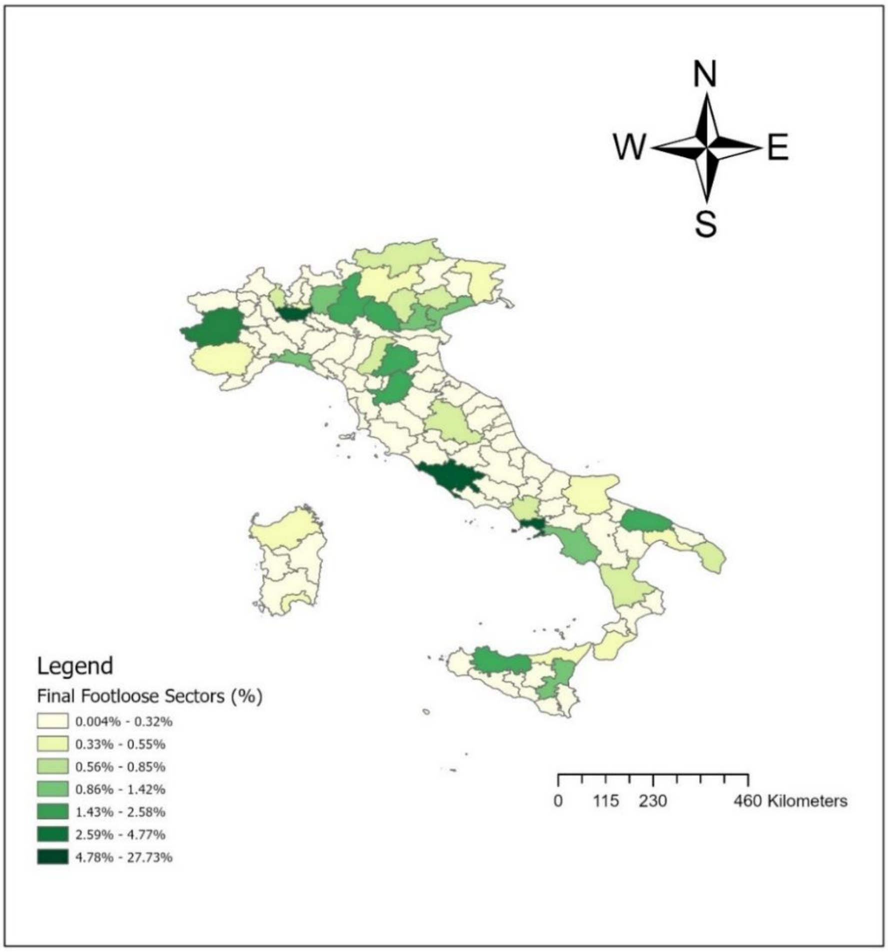
In this context, it is interesting to understand whether the construction of a bridge between Messina and Reggio Calabria has an impact on the distribution of footloose sectors in the long run. In particular, we would focus on two main points:

1. What would be the magnitude of the bridge development in terms of changes in the geographical reallocation of economic activity within the country
2. Whether the economic geography consequences of this bridge are either on a national or a regional scale.

According to the theory, after the development of a stable connection between the island and the mainland, some companies should relocate to the South, especially to Sicily, increasing the competition in the South (price index effect) and lowering the prices there. This will give an incentive to individuals to migrate to Sicily from other peripherical areas of the country. As a result, the market of the firms located in the South will further increase and, consequently, the prices charged by them will be lower. This process will stop when the real wages of the core and periphery will be equalized, reaching, thus, a long-run equilibrium.

Back to our context, Map 5 shows the final geographical distribution of the Italian footloose industry if the Strait of Messina Bridge would exist.

Map 5. Final distribution of footloose sectors (%) by province with the Strait of Messina Bridge



By comparing Map 4 and Map 5, only a few changes are visible. First, the province of Caserta in the South lost manufacturing to other provinces, as well as Perugia, located in the center of Italy. On the other hand, the provinces of Lecce and Cosenza moved up one category. In relative values, however, the construction of the Strait of Messina bridge does not significantly change the (%) final allocation of footloose sectors among the Italian provinces: the initial biggest (smallest) provinces in terms of manufacturing industries remained the biggest (smallest) ones.

In this light, it could be more interesting to compare the long-run changes (%) in the distribution of manufacturing activity both without the bridge and with the bridge. To this end, Table 1 provides a clearer overview of the bridge's impact on each province by allowing a comparison between the long-run change in the actual geographical distribution of footloose sectors and the hypothetical change if the Strait of Messina bridge existed.

Table 2. Long-run changes in the geographical allocation of the footloose industry by province

Province	% change without the bridge	% change with the bridge	% Difference
Agrigento	-10.65	-12.74	-2.09
Alessandria	-81.17	-81.16	0.01
Ancona	-72.24	-72.25	-0.01
Arezzo	-88.83	-88.83	0.00
Ascoli Piceno	-91.72	-91.72	0.00
Asti	-93.14	-93.14	0.00
Avellino	-78.71	-78.71	0.00
Bari	12.18	12.23	0.04
Barletta-Andria-Trani	-72.83	-72.85	-0.02
Belluno	-94.20	-94.20	0.00
Benevento	-85.77	-85.77	0.00
Bergamo	-61.14	-61.12	0.02
Biella	-95.82	-95.82	0.00
Bologna	-17.61	-17.61	0.00
Bolzano	-12.79	-12.79	0.00
Brescia	-42.58	-42.56	0.02
Brindisi	-57.78	-57.83	-0.05
Cagliari	-16.97	-17.01	-0.04
Caltanissetta	-80.25	-80.74	-0.49
Campobasso	-89.40	-89.40	0.00
Caserta	-27.75	-27.76	-0.01
Catania	39.11	44.89	5.78
Catanzaro	-56.71	-56.74	-0.03
Chieti	-82.21	-82.22	-0.01
Como	-82.62	-82.61	0.01
Cosenza	-0.59	-0.48	0.11
Cremona	-88.76	-88.76	0.00
Crotone	-86.45	-86.45	0.00
Cuneo	-67.53	-67.52	0.01
Enna	-88.31	-88.47	-0.17
Fermo	-96.36	-96.37	0.00
Ferrara	-76.57	-76.57	0.00
Firenze	-11.34	-11.35	-0.01
Foggia	-14.69	-14.74	-0.04
Forlì-Cesena	-73.76	-73.76	0.00
Frosinone	-81.37	-81.37	0.00
Genova	0.79	0.80	0.02
Gorizia	-95.30	-95.30	0.00
Grosseto	-78.87	-78.88	-0.01
Imperia	-83.62	-83.62	0.00
Isernia	-96.05	-96.04	0.00
L'Aquila	-86.85	-86.86	-0.01
La Spezia	-83.36	-83.36	0.00
Latina	-59.48	-59.50	-0.02
Lecce	-26.48	-26.52	-0.04

Lecco	-94.41	-94.41	0.00
Livorno	-69.44	-69.45	0.00
Lodi	-92.90	-92.91	0.00
Lucca	-80.81	-80.82	0.00
Macerata	-87.90	-87.91	-0.01
Mantova	-84.24	-84.24	0.00
Massa-Carrara	-90.11	-90.11	0.00
Matera	-86.36	-86.36	0.00
Messina	-0.10	0.51	0.61
Milano	194.16	193.38	-0.78
Modena	-67.32	-67.31	0.01
Monza e della Brianza	-75.23	-75.21	0.02
Napoli	94.83	95.06	0.23
Novara	-89.85	-89.85	0.00
Nuoro	-69.70	-69.73	-0.03
Oristano	-77.60	-77.63	-0.03
Padova	-37.11	-37.11	0.00
Palermo	53.17	53.38	0.21
Parma	-78.15	-78.15	0.01
Pavia	-78.22	-78.21	0.02
Perugia	-48.44	-48.45	-0.02
Pesaro e Urbino	-86.53	-86.54	-0.01
Pescara	-84.46	-84.47	-0.01
Piacenza	-84.13	-84.13	0.00
Pisa	-73.95	-73.96	0.00
Pistoia	-86.02	-86.02	0.00
Pordenone	-89.47	-89.48	0.00
Potenza	-80.06	-80.07	-0.01
Prato	-93.82	-93.82	0.00
Ragusa	-38.33	-38.44	-0.11
Ravenna	-70.64	-70.64	0.00
Reggio Calabria	10.31	11.57	1.26
Reggio nell'Emilia	-81.96	-81.95	0.00
Rieti	-90.85	-90.85	0.00
Rimini	-68.57	-68.58	-0.01
Roma	243.14	243.36	0.22
Rovigo	-89.23	-89.23	0.00
Salerno	14.37	14.43	0.06
Sassari	-12.74	-12.77	-0.04
Savona	-82.00	-82.00	0.00
Siena	-84.32	-84.33	0.00
Siracusa	-51.05	-53.43	-2.38
Sondrio	-92.33	-92.33	0.00
Sud Sardegna	-51.78	-51.82	-0.04
Taranto	-44.74	-44.77	-0.04
Teramo	-90.05	-90.06	-0.01
Terni	-89.76	-89.76	0.00
Torino	-5.30	-5.31	-0.01

Trapani	-28.96	-30.57	-1.61
Trento	-46.90	-46.89	0.01
Treviso	-61.63	-61.63	0.00
Trieste	-84.30	-84.31	0.00
Udine	-62.43	-62.43	0.00
Valle d'Aosta	-92.46	-92.46	0.00
Varese	-67.03	-67.00	0.03
Venezia	-13.01	-13.01	0.00
Verbano-Cusio-Ossola	-94.11	-94.11	0.00
Vercelli	-94.36	-94.37	0.00
Verona	-12.27	-12.26	0.01
Vibo Valentia	-85.83	-85.70	0.14
Vicenza	-67.75	-67.74	0.00
Viterbo	-79.69	-79.70	-0.01

From column 4 in Table 1, it is visible that the gate has an impact on 57 Italian provinces, of which 32 of them are located in the South, 15 in the North, and the remaining 10 in the Centre. To establish whether the bridge has either a positive or a negative impact on each of the three macro-regions (North, Centre, and South), we sum the values of column 4: while the South and the Centre increase by 1.16% and 0.14%, respectively, the North decreases by 0.60%.

However, although the Strait of Messina Bridge seems to have an impact on a national scale, the magnitude of this impact is completely different among these macro-regions. By summing the absolute values of column 4, we found that the magnitudes in the North, Centre, and South provinces are equal to 0.98%, 0.31%, and 15.72%, respectively. Therefore, we can conclude that the construction of the Strait of Messina Bridge would have a (macro-)regional effect from a geographical economics point of view.

By focusing on the Southern regions, we found that the province which would benefit more from a stable connection between Sicily and the mainland is Catania (+5.78%). On the other hand, the province of Syracuse would be the biggest “loser” of manufacturing activity in the long term if the Strait of Messina bridge existed (-2.38%). As for Syracuse, also the other already “losers” provinces such as Agrigento, Caltanissetta, Enna, and Trapani further diminish their footloose employment over the long period. It is striking that the province of Messina would inverse its long-run trend from -0.10% to +0.51% with the bridge's construction. In this light, the Strait of Messina Bridge would enhance Messina in terms of manufacturing activity.

The gate would have a positive impact also on the opposite side of the strait, where Reggio Calabria would increase its manufacturing activity by 1.26% more than without the bridge. In addition to Reggio Calabria, also other Calabrian provinces such as Cosenza and Vibo Valentia, would benefit from the development of a bridge in the Messina Strait (+0.11% and +0.14%). However, this would not stop their strong decline in manufacturing activity over time.

We can conclude that the construction of the Strait of Messina Bridge would not significantly contribute to reducing the inter-macroregional inequalities within the peninsula. As a matter of fact, the reduced travel time between Reggio Calabria and Messina would positively affect only the already “big” agglomerations like Messina, Catania, and Palermo, by attracting manufacturing activities from the other remote Sicilian provinces such as Syracuse, Agrigento, and Caltanissetta. Essentially, the market potential of Catania, Messina, and Palermo promotes the clustering of manufacturing in these provinces fostering intra-regional inequality. In that sense, according to our simulations, the Strait of Messina bridge is detrimental to the Sicilian peripheral areas and beneficial to the biggest Sicilian provinces, especially for Messina which reverses its trend.

As far as what concerns the Calabrian provinces' pattern, the bridge would only alleviate a negative trend that is going to push the footloose workers away from this region in the future. The only exception is made by Reggio Calabria which will increase its manufacturing employment mainly thanks to its position as the gateway to Sicily.

3.2 Changing the values of key parameters: τ, γ, ε, and T

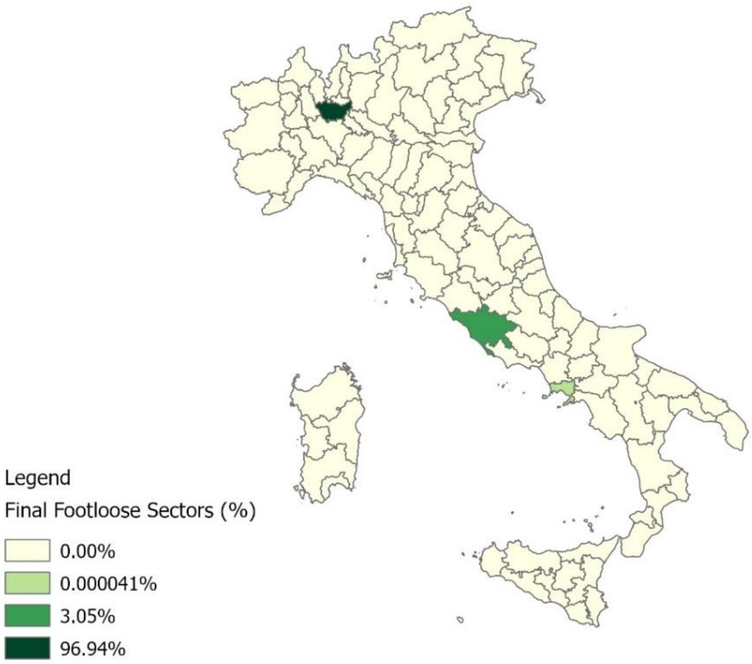
In section 3.2, we run several simulations with different values of γ, ε, T, and τ in order to understand their impact on the distribution of footloose activity in Italy. All the new long-run equilibria will be explained through the lens of the three economic forces behind the Krugman model: home market, price index, and extent-to-competition effect. Note that the simulations are conducted through the Excel distance file adjusted for the Strait of Messina Bridge.

3.2.1 The congestion parameter: τ

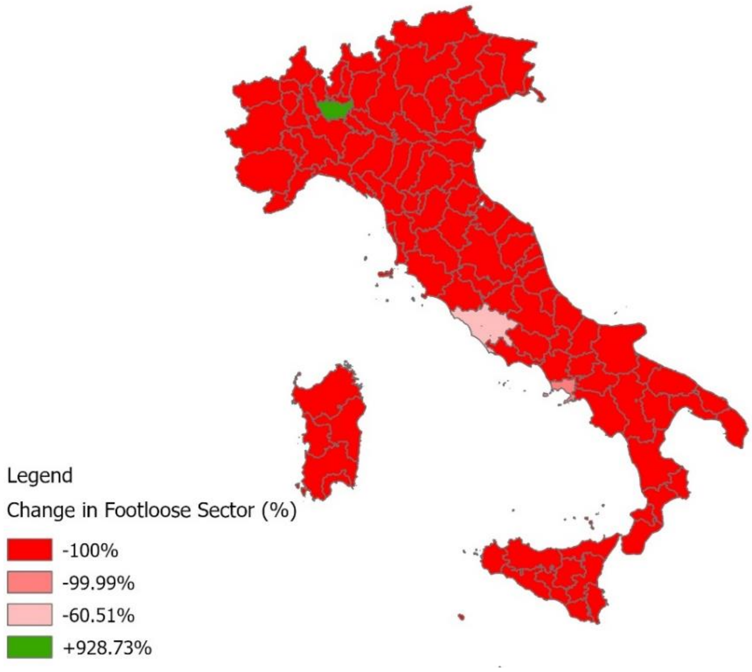
The first parameter we took into consideration is the congestion index. In the standard simulations, τ was set at a value of 0.65. To understand how the geographical allocation of the industries changes as the congestion value varies, we run two different simulations with τ equal to 0 and 1.

When the congestion index does not exist (τ=0), Map 6 shows that all the footloose workers are going to relocate to Milan in the long run. In particular, the province increases its footloose employment by +927%, leaving almost all the other provinces without any type of manufacturing activity, as depicted in Map 7. The only exceptions are made by the provinces of Rome and Naples, which their share of footloose workers is equal to 3.05% and 0.000041%, respectively. Hence, without diseconomies of scale, a fairly extreme situation is expected. However, this geographical framework is quite unthinkable and impossible to occur in the future. In that sense, the model's extension developed by Brakman et al. (2020) allows to better fit Krugman's model into reality.

Map 6. Final distribution of footloose sectors (%) by province with τ=0



Map 7. Change (%) of footloose sectors by province with τ=0



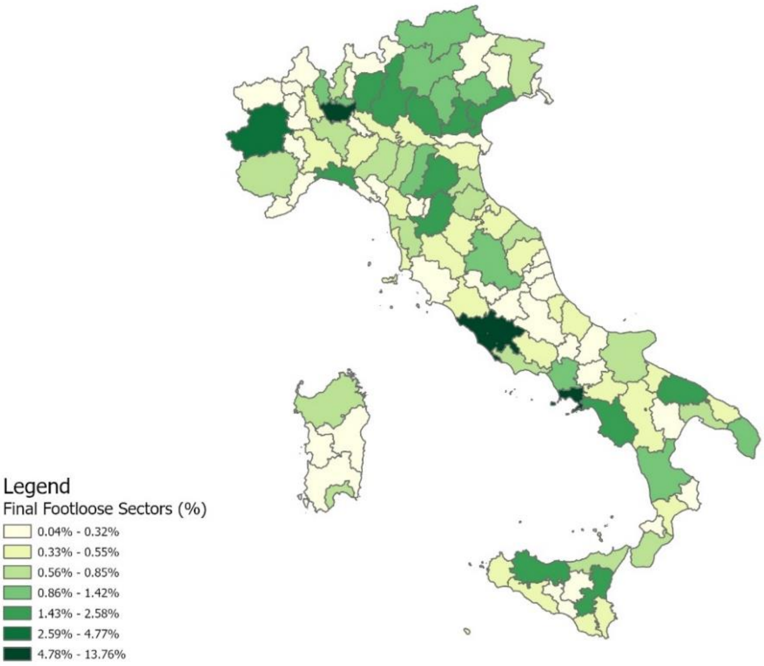
The results presented here are supported by the home market effect. According to Brakman et al. (2020), this effect explains that when a region is characterized by a high demand for a specific good, the production of that good and, consequently, its exports, will increase more than proportionally (see Chapter 1).

Similarly, the price index effect comes into play as the cost of living in Milan decreases due to an increase in the number of varieties supplied. As a result, more and more footloose workers relocate from all the Italian provinces to Milan.

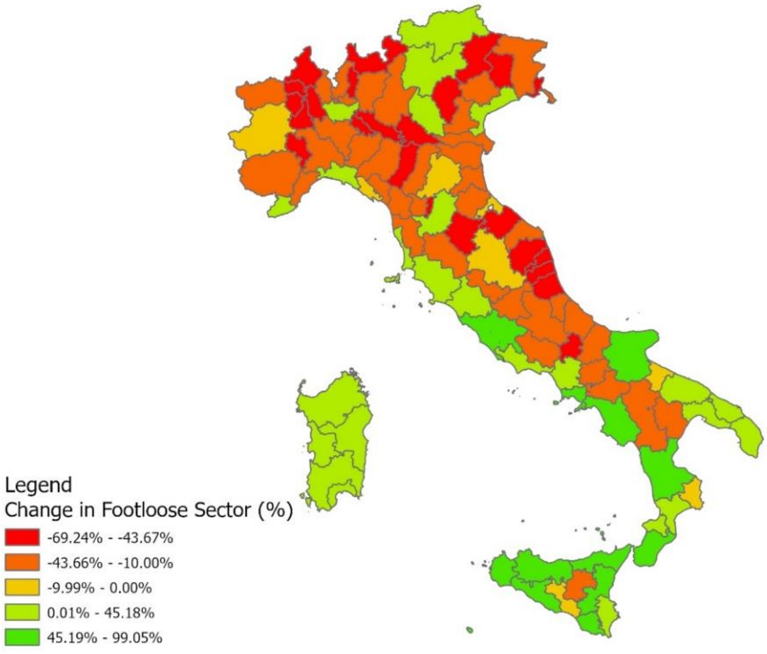
On the other hand, many firms located in Milan could decrease the price index in that province, potentially weakening the competitive position of each individual firm, as described by the extent-of-competition effect. Nevertheless, the magnitude of the home market and the price index effects definitely outweigh the extent-of-competition effect, leading to full agglomeration of footloose activity within the province of Milan.

When the congestion index is at its peak (τ=1), we observed a completely opposite situation: Map 8 shows that the footloose industry is more equally spread over the entire Italian peninsula. At first glance, by comparing Map 3 and Map 8, we can confirm that many Southern provinces significantly increase their footloose employment in the long run, leading to a more homogeneous geographical distribution of the manufacturing industry. Map 9 confirms the trend: when congestion is very high, firms start relocating from the North to the South, especially to the Islands.

Map 8. Final distribution of footloose sectors (%) by province with τ=1



Map 9. Change (%) of footloose sectors by province with τ=1



Also, Map 9 shows that most of the provinces which increase their manufacturing employment in the long run, partly border with the sea. Few exceptions are represented by the provinces of Milan, Bolzano, Trento, Verona, and Florence. On the other hand, it is interesting to note that most of the central provinces in a north-south direction yield a negative long-run equilibrium outcome. In other words, in the long period, the central provinces, namely the “backbone” of Italy, decrease their manufacturing industry in favor of some provinces located at the edge of the peninsula.

When the congestion is very high, the interplay between the home market, the price index, and the extent-of-competition effects produces the opposite outcome: as a matter of fact, the evidence suggests that the impact of the extent-of-competition effect in promoting dispersion is stronger than the combined effects of the home market and price index factors.

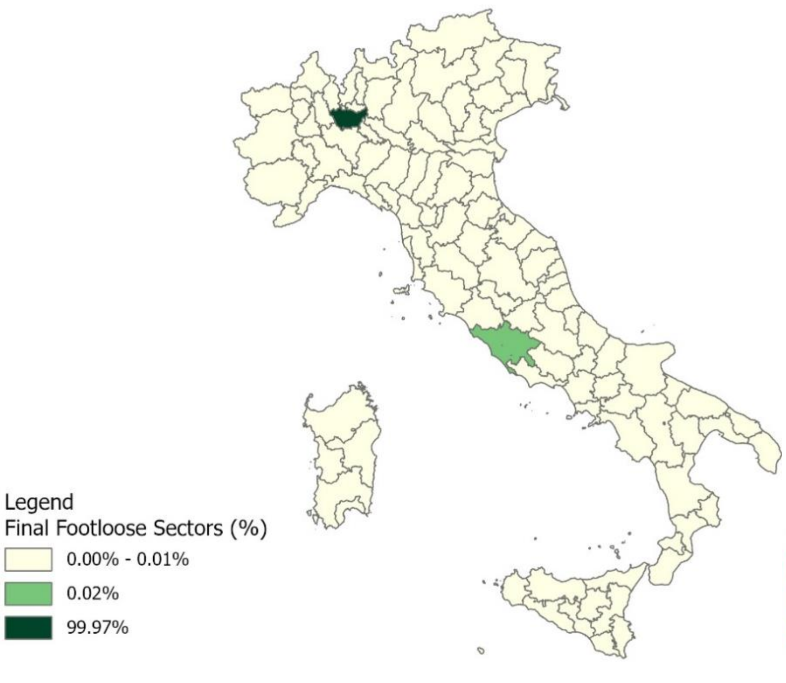
3.2.2 The share of manufacturing employment: γ

Manipulating the value of the manufacturing employment share revealed an issue within the model, as changing γ in the GEAM configuration file did not result in any significant impact on the overall outcome of the model. Accordingly, we found that the γ implicitly computed through the external Excel file superseded any value of γ in the GEAM configuration file.

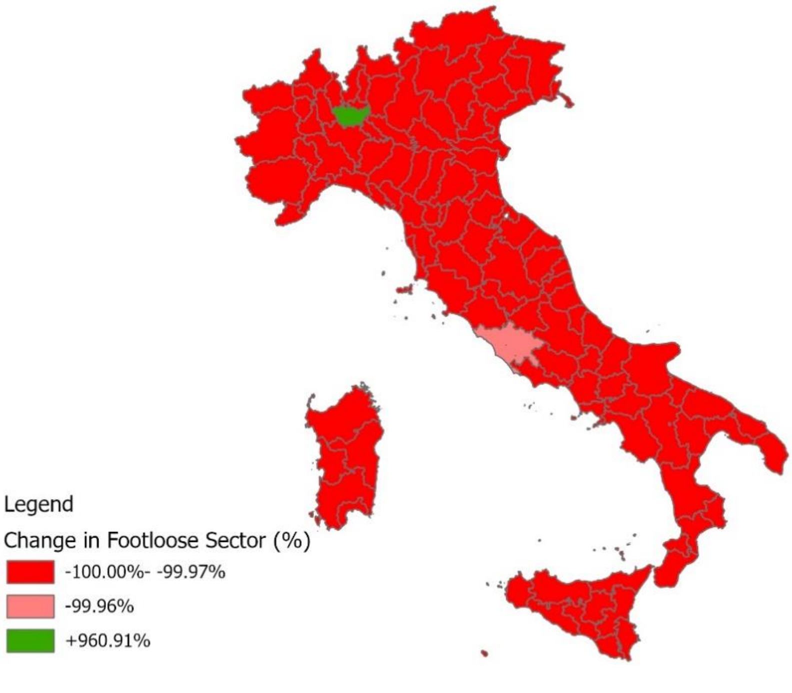
To provide a solution, we decided to manually change the values of both the initial footloose and bounded sectors in the external Excel file. To this end, we first calculated the share of both the total footloose and bounded employment of each province. Then, setting 0.8 as the new γ, we computed firstly the new footloose and bounded shares of total employment and, secondly, by how much they deviated from the original shares. Essentially, the latter represents how many workers must move from one sector to the other, keeping constant the sum of total employment. This delta has then been divided between the provinces according to their shares of total footloose and bounded employment. In conclusion, we added this amount for all the provinces to the initial employment values. In this light, we obtained the new spread of employment for γ across the Italian provinces. The new external Excel file has been saved and loaded on the GEAM configuration file. The same procedure has been taken for γ=0.2.

After explaining the issue in the model's processing of data, we now present the results for γ=0.8. On the left, Map 10 shows the long-run distribution of footloose activity within the peninsula. On the right, Map 11 represents the change in the presence of the footloose industry in the long term by province.

Map 10. Final Distribution of Footloose sectors (%) by province with γ=0.8



Map 11. Change (%) of footloose sectors by province with γ=0.8



The two maps make explicit the fact that with a very high level of initial footloose employment, i.e., 80% of the total workforce in Italy, full agglomeration occurs within the province of Milan in the long period. The result is even more marked than the one found with τ=0: while in case of no congestion, nearly 97% of the total Italian footloose activity would be centered in Milan, with an initial workforce mostly based on footloose activities, the 99.9% of the total footloose employment would be allocated in the province of Milan in the long-run.

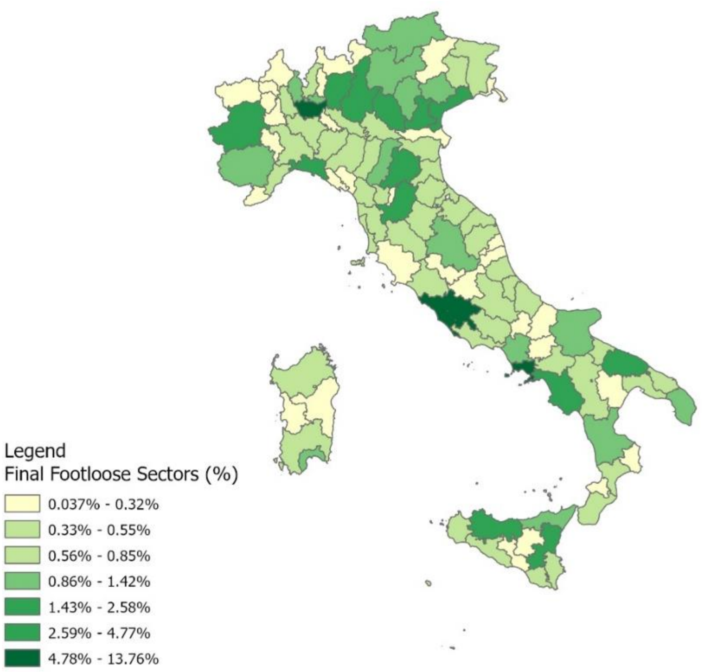
The economic mechanism behind it is the same as described in the case of τ=0: when full agglomeration in a province occurs, the combined impact of price index and home-market effects prevail over the extent-of-competition effect. According to the home market effect, indeed, the increase in the footloose presence is more than proportionate in those provinces that already have a consistent footloose industry. In the Italian framework, the province of Milan has the highest initial percentage of footloose activity (9.42%). Therefore, increasing γ from 0.41 to 0.8 (=the number of workers who are able to relocate), makes the actual long-run results (see section 3.1) even more oriented towards a complete agglomeration around Milan.

The same logic applies to the price index effect: individuals are more attracted to move to larger regions since a smaller share of varieties has to be imported and, consequently, there are fewer transportation costs (Brakman et al., 2020). On the other hand, when some firms start to allocate in the same region, the demand for each company's product decreases due to a decline in the price index, leading to a possible migration of firms towards less competitive areas (extent-of-competition effect). However, the latter is completely offset by the previous two economic forces.

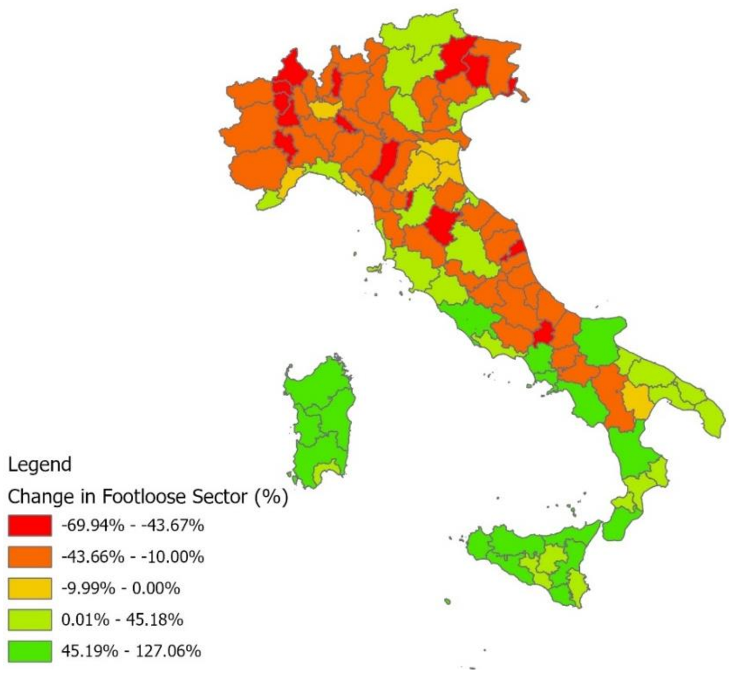
As explained above, the simulations in section 3.2 take already into account the existence of the Strait of Messina bridge. Therefore, in this section, we cannot estimate the impact of the bridge on the geographical distribution of footloose activity. However, these results allow us to confirm that with these initial conditions, the Strait of Messina Bridge would have no significant impact on the final distribution of footloose activity.

Running the model with γ equal to 0.2 implies a completely different scenario: Map 12 illustrates the distribution of the Italian footloose industry in the long term, while Map 13 displays the change in the number of footloose firms by province over time.

Map 12. Final Distribution of Footloose Sectors (%) by province with γ=0.2



Map 13. Change of Footloose sectors (%) by province with γ=0.2



At first glance, when γ is equal to 0.2, mobile economic activity appears to be much more spread over the country. What is striking here is that the province of Milan experiences a reduction in its footloose employment (-0.21%) in the long run. Furthermore, as for Map 8, also Map 13 shows that most of the provinces that gain footloose workers over time, partly border with the sea.

In such a framework, the Southern regions, except for Basilicata, Molise, and two of Campania's provinces (Avellino and Benevento), positively change their manufacturing workforce over time. In particular, the Messina and Reggio Calabria provinces record an increase of 83.15% and 120.97% in their footloose workers.

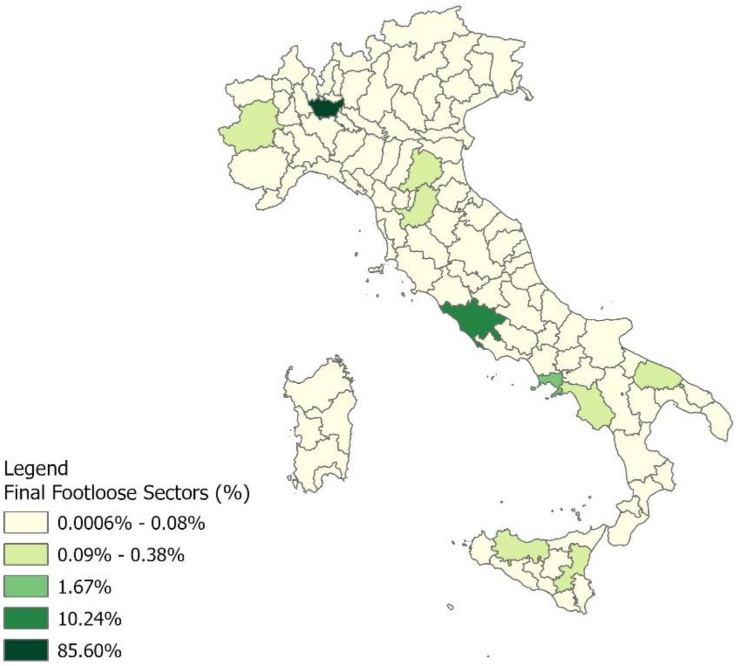
In this case, as the number of mobile workers reduces, both the home market and the price index effect have a weaker impact on the geographical distribution of economic activity. On the other hand, the extent-of-competition effect plays a significant role in determining the allocation of footloose workers within the peninsula.

3.2.3 The elasticity of substitution: ε

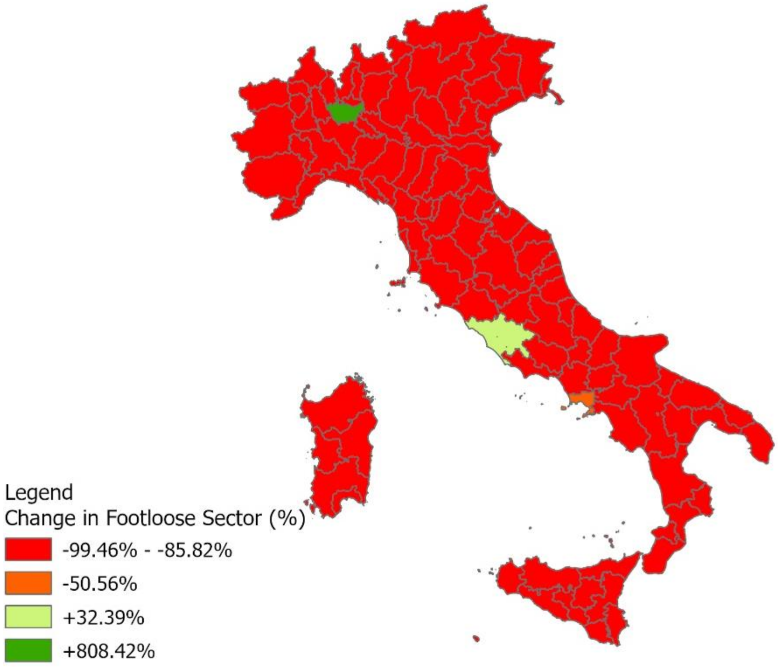
Besides the congestion parameter (τ) and the manufacturing share of employment (γ), even the elasticity of substitution (ε) is of fundamental relevance in determining the geographical allocation of footloose sectors. To study the impact of ε as part of the model's sensitivity, we run the model with ε equal to 4 and 6.5. The latter are respectively the lowest and the highest value used to compute the real elasticity of substitution in section 2.3.

Starting from ε=4, on one hand, map 14 shows the long-run representation of Italy in terms of the footloose sector's share. On the other, map 15 allows us to visualize the change in the presence of manufacturing activity by province in the long run.

Map 14. Final Distribution of Footloose Sectors (%) by province with ε=4



Map 15. Change of Footloose sectors (%) by province with ε=4



When ε decreases from 4.7 to 4, the long-run equilibrium is oriented towards a scenario of almost full agglomeration in Milan (85.60%). This province experiences an increase of 808.42% in its manufacturing activity over time. A limited presence of footloose workers is then recorded also around the Capital (10.24%) and Naples (1.67%), which undergo a +32.39% and a -50.56% in their footloose workforce, respectively. The remaining 2.49% of manufacturing employment is distributed among the other 104 provinces.

As for the case of γ=0.8, we can confirm that with a low value of ε, the Strait of Messina bridge would not have any significant impact on the geographical allocation of economic activity in Italy.

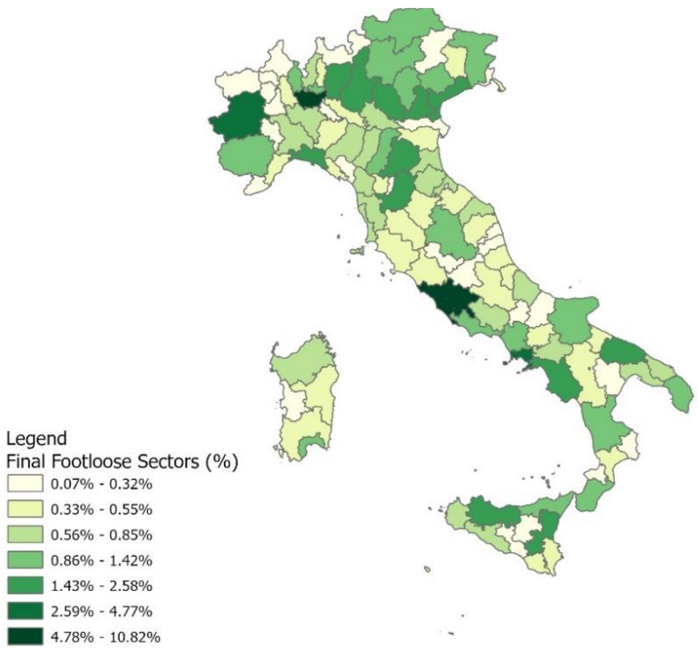
From a theoretical standpoint, when the elasticity of substitution reduces, consumers are less likely to switch the manufacturing goods that they buy, as their prices go up. In this sense, firms increase their market power, since they are able to charge higher prices without being undercut by competitors. As a result, firms are going to relocate to the same geographical area, where they benefit more from other advantages such as spill-over effects.

In other words, as the elasticity of substitution shrinks, the home market and the price index effects strengthen their impact, at the expense of the extent-of-competition effect. In particular, a decline in the elasticity of substitution (ε) leads to an increase in the price index (I). However, since customers are less inclined to buy less of that product, the firm may be able to maintain its competitive force despite raising prices. In this light, the price index effect increases its magnitude, whereas the extent-of-competition effect is almost phased out.

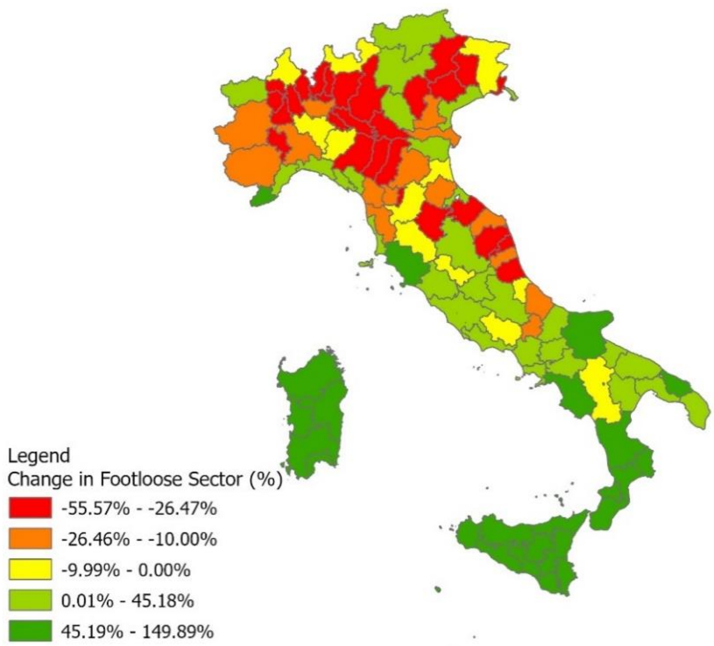
Increasing ε from 4.71 to 6.5, a completely opposite framework is observed: Map 16 shows that in the long term, the footloose sectors are evenly spread over the Italian peninsula. According to Map 17, a significant decline (-12.81%) in manufacturing employment is recorded in the province of Milan, whereas the islands and Calabria report a huge increase in the footloose workforce in the long run. In particular, the provinces of Messina and Reggio Calabria increase their manufacturing workers by 86.83% and 129.33%.

Although the province of Rome shows a positive increase in footloose activity over time (+39.78%), it is worth noting that this increase is smaller than the one observed with ε=4.71 (+243%). In this light, by increasing ε from 4.71 to 6.5, Milan and Rome would lose around 206% and 204% of the "potential" long-run footloose workforce, respectively.

Map 16. Final Distribution of Footloose Sectors (%) by province with ε=6.5



Map 17. Change of Footloose sectors (%) by province with ε=6.5



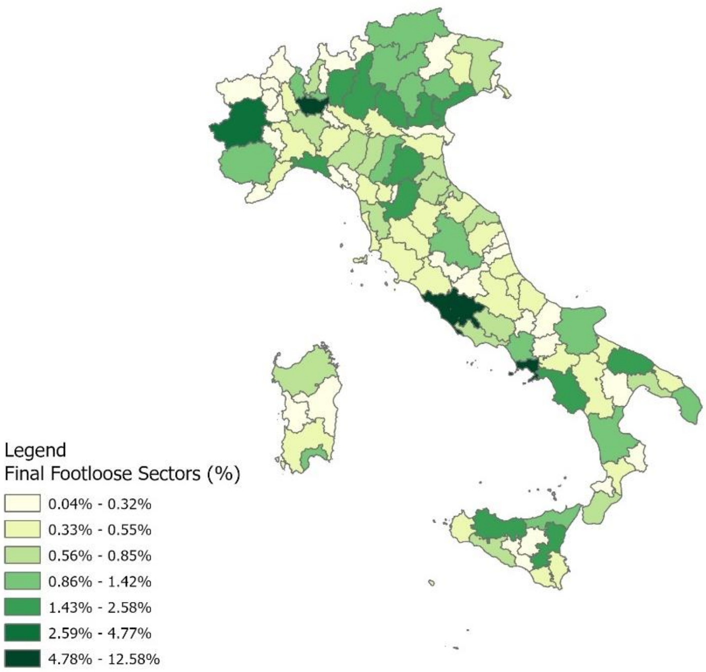
The cumulative effect of the three economic forces supports the spreading of economic activity throughout the country. The home market effect diminishes due to the high elasticity of substitution, which causes a decrease in demand for a range of goods. Accordingly, the agglomeration force weakens. Furthermore, an increase in the elasticity of substitution (ε) leads to a reduction in the price index (I): since the firm charges a higher price for a manufacturing product, on average the prices of manufacturing varieties competing with that specific good decline. According to the extent-of-competition effect, the competitive position of the firm weakens, leading it to consider relocating away from the agglomerated areas.

3.2.4 The Transportation Costs: T

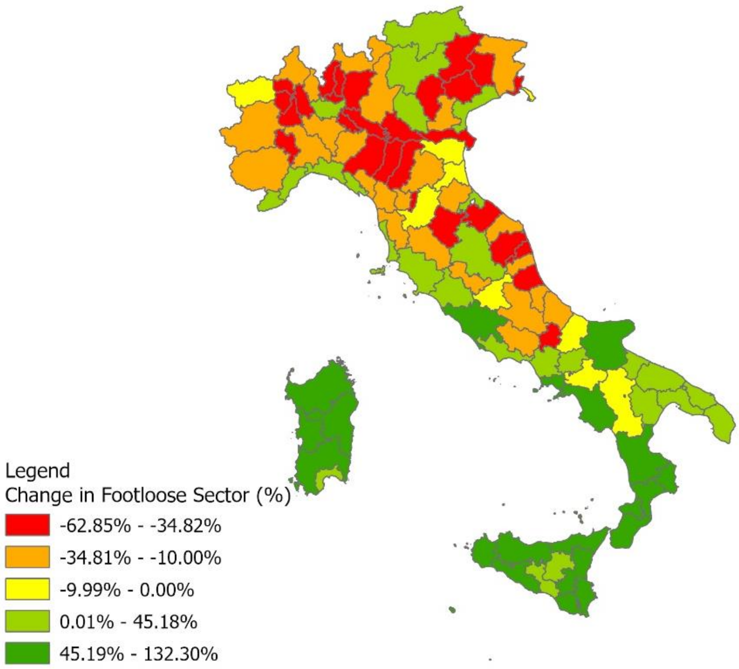
The last parameter we take into account is the transportation costs (T). As explained in the theory chapter, the (iceberg) transportation costs range goes from 1 (no costs) to 2 (highest T). In this respect, we run the model with T=2 and T=1.10 but didn't consider T=1 because it wouldn't yield significant results without transportation costs. As Brakman et al. (2020) write: "Only if it is costly to move products and people over space does geography makes sense in the model".

According to theory, with the highest level of transportation costs, says T=2, we expected the spreading of economic activity as the only possible stable long-run equilibrium. As a matter of fact, the simulations partly confirm the expectations: on the left, Map 18 displays the final allocation of footloose workers in Italy over time, while, on the right, Map 19 depicts the long-run percentage change of manufacturing activity by province.

Map 18. Final Distribution of Footloose Sectors (%) by province with T=2



Map 19. Change of Footloose sectors (%) by province with T=2



Although the long-run footloose activities are almost evenly distributed throughout the Peninsula, the biggest Italian provinces in terms of the manufacturing workforce, namely, Milan, Naples, and Rome, report a positive change in the footloose presence over time. Specifically, the changes in percentage for each of these provinces are given as +0.62%, +51.64%, and +62.55%, respectively. Note that these % changes are much lower than the ones observed with T=1.58 (see Table 1, column 3), but they are still positive. This implies that the three provinces with the biggest presence of initial manufacturing activities increase their footloose workforce over time, despite the very high costs of transporting people and goods.

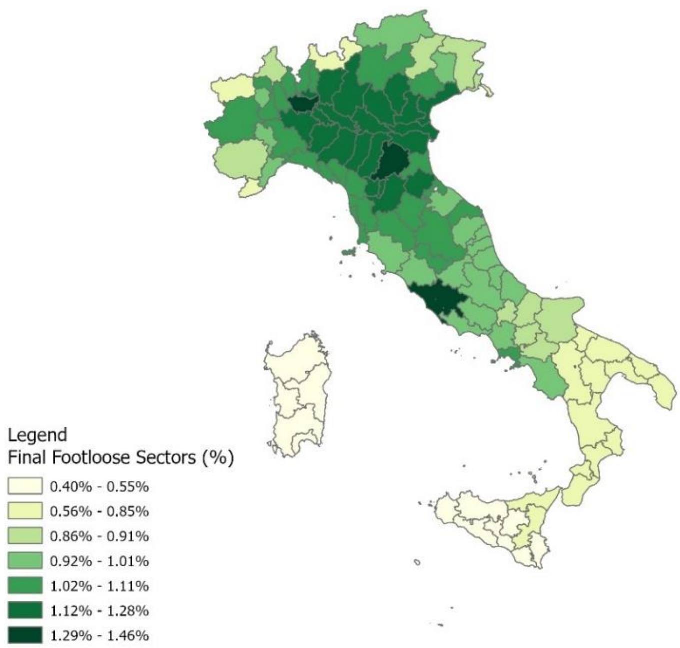
When the transport costs are at their peak, the Strait of Messina provinces significantly expand their manufacturing employment in the long term: while the footloose presence in Messina changes by +79.83%, the one in Reggio Calabria by +118.71%. Overall, these rank respectively as the 7th and the 3rd most significant provincial manufacturing expansions.

According to Brakman et al. (2020), the price index effect supports the idea that larger regions become more attractive since they require fewer imports of different varieties, which can be expensive due to transportation costs. In this sense, increasing the (iceberg) transportation costs, people and firms have more incentives to move to larger agglomerations. Furthermore, manufacturing firms, which are closer to the home market, have more demand for products at lower transportation costs (=home market effect). This works as an agglomerating force that pushes firms and manufacturing workers toward the big cities.

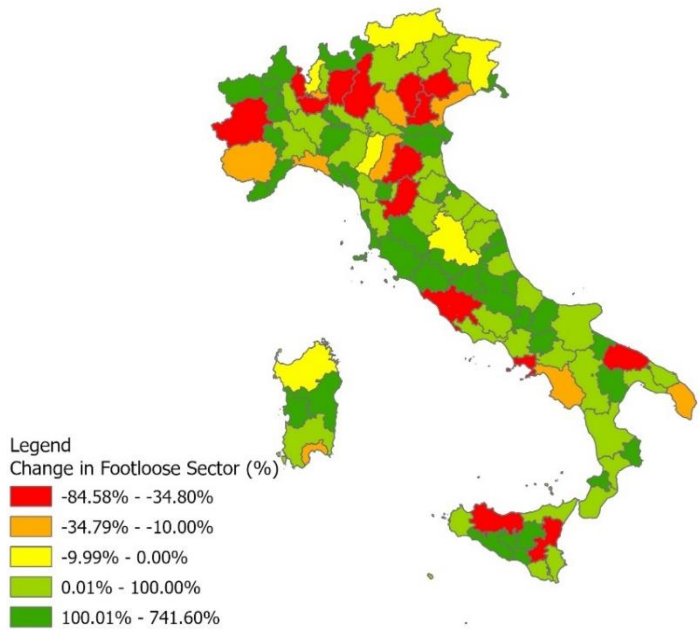
On the other hand, footloose firms weaken their competitiveness, as the price index in larger agglomeration declines. In this light, firms are more attracted to relocate to less agglomerated areas where they consolidate their competitive force. Overall, we can state that with T=2, the extent-of-competition effect exceeds the other two agglomeration forces, namely the price index effect and the home market effect.

Lowering the transportation costs to 1.10, the final geographic distribution of footloose activity is highly polarized: Map 20 shows that there is a decreasing concentration of manufacturing presence, as we move southward. However, this geographical polarization is not determined by an increase of a footloose workforce in the North, at the expense of the South: all the top 15 Italian provinces in terms of manufacturing activity lose a significant share of their footloose workers in the long run, as Map 21 suggests. As a result, the peripheral areas in the north, center, and south gain manufacturing employment. At a very low level of transportation costs, therefore, firms prefer to relocate throughout the entire territory in order to not suffer from competition (extent-of-competition effect).

Map 20. Final Distribution of Footloose Sectors (%) by province with T=1.10



Map 21. Change of Footloose sectors (%) by province with T=1.10



Before concluding the chapter, some overall considerations would be important to understand the main scope of this section. In this respect, Table 2 shows the final allocations of the footloose sector (%) by macro-region, region, and province for each simulation run.

Firstly, the two parameters that allow a more equal distribution of economic activity throughout Italy are ε=6.5 and T=2. In these simulations, Italy's economic activity is geographically divided as follows: North = 47%, Center=23%, and South 30%. Compared to the initial footloose allocation, the North loses around 11%, whereas the Center and South gain about 2% and 9%, respectively.

An equal allocation of economic activity can help to promote balanced regional development by reducing inequalities between (macro-)regions. Furthermore, if firms were equally spread over the entire territory, then job opportunities would be more accessible in every region, without leaving behind any geographical area. This would not only have positive implications in terms of the labor market but also for internal migration: nowadays youth generations tend to move to the North/abroad, increasing the average age in the Center/South regions.

On the other hand, both γ=0.8 and τ=0 led to a framework where Milan collects nearly 100% of the manufacturing employment, coming from all the other parts of Italy. Complete agglomeration in only one province could lead to several economic and social issues such as income inequality, reduced economic growth, and social exclusion.

Table 3. Final Footloose Sectors (%) by macro-region, region, and province

Geographic Area	τ=0	τ=1	γ=0.2	γ=0.8	ε=4	ε=6.5	T=1.10	T=2
North	**96.95%**	**48.53%**	**48.07%**	**99.98%**	**87.00%**	**47.16%**	**50.15%**	**47.17%**
Emilia Romagna	**0.00%**	**7.33%**	**7.56%**	**0.00%**	**0.23%**	**7.54%**	**10.60%**	**7.21%**
Bologna	0.00%	2.31%	2.25%	0.00%	0.11%	2.00%	1.29%	2.05%
Ferrara	0.00%	0.43%	0.46%	0.00%	0.01%	0.51%	1.15%	0.46%
Forlì-Cesena	0.00%	0.59%	0.63%	0.00%	0.01%	0.67%	1.13%	0.62%
Modena	0.00%	1.11%	1.15%	0.00%	0.03%	1.10%	1.24%	1.07%
Parma	0.00%	0.71%	0.74%	0.00%	0.02%	0.76%	1.22%	0.71%
Piacenza	0.00%	0.40%	0.41%	0.00%	0.01%	0.47%	1.19%	0.42%
Ravenna	0.00%	0.58%	0.63%	0.00%	0.01%	0.67%	1.10%	0.62%
Reggio nell'Emilia	0.00%	0.68%	0.72%	0.00%	0.02%	0.74%	1.21%	0.69%
Rimini	0.00%	0.52%	0.57%	0.00%	0.01%	0.62%	1.07%	0.57%

Friuli Venezia Giulia	**0.00%**	**1.44%**	**1.61%**	**0.00%**	**0.02%**	**1.87%**	**3.50%**	**1.70%**
Gorizia	0.00%	0.10%	0.10%	0.00%	0.00%	0.17%	0.85%	0.13%
Pordenone	0.00%	0.31%	0.35%	0.00%	0.01%	0.42%	0.95%	0.38%
Trieste	0.00%	0.27%	0.32%	0.00%	0.00%	0.40%	0.81%	0.36%
Udine	0.00%	0.76%	0.85%	0.00%	0.01%	0.88%	0.88%	0.84%
Liguria	**0.00%**	**2.59%**	**2.73%**	**0.00%**	**0.07%**	**2.86%**	**3.89%**	**2.74%**
Genova	0.00%	1.82%	1.86%	0.00%	0.06%	1.75%	1.05%	1.77%
Imperia	0.00%	0.20%	0.23%	0.00%	0.00%	0.32%	0.83%	0.27%
La Spezia	0.00%	0.26%	0.28%	0.00%	0.01%	0.36%	1.05%	0.31%
Savona	0.00%	0.32%	0.36%	0.00%	0.01%	0.44%	0.96%	0.39%
Lombardia	**96.95%**	**19.69%**	**18.50%**	**99.98%**	**85.89%**	**17.41%**	**13.72%**	**18.29%**
Bergamo	0.00%	1.67%	1.69%	0.00%	0.05%	1.58%	1.17%	1.58%
Brescia	0.00%	2.16%	2.13%	0.00%	0.08%	1.94%	1.21%	1.97%
Como	0.00%	0.67%	0.72%	0.00%	0.02%	0.77%	1.07%	0.72%
Cremona	0.00%	0.36%	0.37%	0.00%	0.01%	0.44%	1.18%	0.38%
Lecco	0.00%	0.26%	0.27%	0.00%	0.01%	0.35%	1.06%	0.30%
Lodi	0.00%	0.18%	0.16%	0.00%	0.01%	0.22%	1.19%	0.16%
Mantova	0.00%	0.51%	0.53%	0.00%	0.01%	0.58%	1.17%	0.53%
Milano	96.95%	10.83%	9.40%	99.98%	85.61%	8.22%	1.45%	9.48%
Monza Brianza	0.00%	1.07%	1.12%	0.00%	0.03%	1.10%	1.16%	1.06%
Pavia	0.00%	0.62%	0.67%	0.00%	0.02%	0.71%	1.13%	0.66%
Sondrio	0.00%	0.16%	0.19%	0.00%	0.00%	0.27%	0.84%	0.23%
Varese	0.00%	1.20%	1.26%	0.00%	0.03%	1.23%	1.09%	1.20%
Piemonte	**0.00%**	**6.67%**	**6.61%**	**0.00%**	**0.44%**	**6.71%**	**7.97%**	**6.65%**
Alessandria	0.00%	0.50%	0.54%	0.00%	0.01%	0.60%	1.09%	0.55%
Asti	0.00%	0.18%	0.18%	0.00%	0.00%	0.26%	1.01%	0.21%

Biella	0.00%	0.12%	0.12%	0.00%	0.00%	0.19%	0.96%	0.15%
Cuneo	0.00%	0.84%	0.93%	0.00%	0.01%	0.97%	0.87%	0.93%
Novara	0.00%	0.37%	0.40%	0.00%	0.01%	0.47%	1.08%	0.42%
Torino	0.00%	4.40%	4.18%	0.00%	0.38%	3.82%	1.06%	4.09%
Verbano-Cusio-Ossola	0.00%	0.11%	0.12%	0.00%	0.00%	0.20%	0.87%	0.16%
Vercelli	0.00%	0.14%	0.13%	0.00%	0.01%	0.20%	1.04%	0.15%
Trentino Alto Adige	**0.00%**	**2.30%**	**2.45%**	**0.00%**	**0.06%**	**2.43%**	**1.92%**	**2.38%**
Bolzano/Bozen	0.00%	1.30%	1.37%	0.00%	0.03%	1.36%	0.91%	1.34%
Trento	0.00%	1.00%	1.07%	0.00%	0.02%	1.07%	1.01%	1.04%
Valle d'Aosta	**0.00%**	**0.13%**	**0.14%**	**0.00%**	**0.00%**	**0.22%**	**0.84%**	**0.18%**
Valle d'Aosta	0.00%	0.13%	0.14%	0.00%	0.00%	0.22%	0.84%	0.18%
Veneto	**0.00%**	**8.37%**	**8.48%**	**0.00%**	**0.28%**	**8.12%**	**7.70%**	**8.01%**
Belluno	0.00%	0.17%	0.19%	0.00%	0.00%	0.27%	0.89%	0.23%
Padova	0.00%	1.76%	1.77%	0.00%	0.06%	1.65%	1.14%	1.65%
Rovigo	0.00%	0.24%	0.24%	0.00%	0.01%	0.31%	1.14%	0.26%
Treviso	0.00%	1.28%	1.33%	0.00%	0.04%	1.29%	1.05%	1.27%
Venezia	0.00%	1.68%	1.70%	0.00%	0.06%	1.59%	1.11%	1.59%
Verona	0.00%	2.01%	1.98%	0.00%	0.08%	1.81%	1.22%	1.83%
Vicenza	0.00%	1.23%	1.27%	0.00%	0.04%	1.21%	1.15%	1.19%
Center	**3.05%**	**23.93%**	**22.80%**	**0.02%**	**10.52%**	**22.67%**	**23.21%**	**23.55%**
Lazio	**3.05%**	**15.46%**	**13.83%**	**0.02%**	**10.28%**	**12.96%**	**5.30%**	**14.52%**
Frosinone	0.00%	0.51%	0.56%	0.00%	0.01%	0.63%	1.00%	0.58%
Latina	0.00%	0.76%	0.84%	0.00%	0.02%	0.89%	0.92%	0.84%
Rieti	0.00%	0.11%	0.11%	0.00%	0.00%	0.18%	0.97%	0.13%
Roma	3.05%	13.75%	11.96%	0.02%	10.24%	10.81%	1.40%	12.57%

Viterbo	0.00%	0.33%	0.36%	0.00%	0.01%	0.44%	1.00%	0.39%
Marche	**0.00%**	**1.68%**	**1.85%**	**0.00%**	**0.03%**	**2.17%**	**4.92%**	**1.95%**
Ancona	0.00%	0.67%	0.74%	0.00%	0.01%	0.77%	1.02%	0.73%
Ascoli Piceno	0.00%	0.19%	0.20%	0.00%	0.00%	0.28%	0.95%	0.24%
Fermo	0.00%	0.11%	0.11%	0.00%	0.00%	0.18%	0.98%	0.14%
Macerata	0.00%	0.33%	0.37%	0.00%	0.01%	0.44%	0.98%	0.39%
Pesaro Urbino	0.00%	0.38%	0.43%	0.00%	0.01%	0.50%	0.99%	0.45%
Toscana	**0.00%**	**5.52%**	**5.76%**	**0.00%**	**0.18%**	**6.12%**	**10.91%**	**5.74%**
Arezzo	0.00%	0.37%	0.40%	0.00%	0.01%	0.47%	1.10%	0.42%
Firenze	0.00%	2.30%	2.27%	0.00%	0.12%	2.07%	1.17%	2.12%
Grosseto	0.00%	0.27%	0.31%	0.00%	0.00%	0.39%	0.99%	0.34%
Livorno	0.00%	0.45%	0.50%	0.00%	0.01%	0.56%	1.05%	0.51%
Lucca	0.00%	0.46%	0.50%	0.00%	0.01%	0.55%	1.09%	0.50%
Massa-Carrara	0.00%	0.17%	0.18%	0.00%	0.00%	0.25%	1.03%	0.21%
Pisa	0.00%	0.59%	0.64%	0.00%	0.01%	0.68%	1.09%	0.64%
Pistoia	0.00%	0.31%	0.32%	0.00%	0.01%	0.39%	1.15%	0.34%
Prato	0.00%	0.25%	0.25%	0.00%	0.01%	0.31%	1.17%	0.26%
Siena	0.00%	0.35%	0.39%	0.00%	0.01%	0.46%	1.07%	0.41%
Umbria	**0.00%**	**1.28%**	**1.37%**	**0.00%**	**0.03%**	**1.43%**	**2.08%**	**1.35%**
Perugia	0.00%	1.07%	1.14%	0.00%	0.03%	1.12%	1.05%	1.09%
Terni	0.00%	0.22%	0.23%	0.00%	0.00%	0.31%	1.02%	0.26%
South	**0.00%**	**27.54%**	**29.13%**	**0.00%**	**2.48%**	**30.17%**	**26.65%**	**29.28%**
Abruzzo	**0.00%**	**1.35%**	**1.52%**	**0.00%**	**0.02%**	**1.81%**	**3.83%**	**1.61%**
Chieti	0.00%	0.44%	0.50%	0.00%	0.01%	0.56%	0.96%	0.51%
L'Aquila	0.00%	0.29%	0.33%	0.00%	0.00%	0.41%	0.94%	0.36%
Pescara	0.00%	0.33%	0.37%	0.00%	0.01%	0.44%	0.96%	0.39%

Teramo	0.00%	0.29%	0.32%	0.00%	0.00%	0.40%	0.97%	0.35%
Basilicata	**0.00%**	**0.53%**	**0.61%**	**0.00%**	**0.01%**	**0.77%**	**1.53%**	**0.68%**
Matera	0.00%	0.17%	0.20%	0.00%	0.00%	0.28%	0.75%	0.24%
Potenza	0.00%	0.36%	0.42%	0.00%	0.01%	0.49%	0.78%	0.45%
Calabria	**0.00%**	**2.31%**	**2.59%**	**0.00%**	**0.05%**	**2.85%**	**3.22%**	**2.66%**
Catanzaro	0.00%	0.41%	0.48%	0.00%	0.01%	0.54%	0.64%	0.50%
Cosenza	0.00%	0.92%	1.01%	0.00%	0.03%	1.03%	0.71%	0.99%
Crotone	0.00%	0.12%	0.15%	0.00%	0.00%	0.22%	0.59%	0.19%
Reggio Calabria	0.00%	0.74%	0.83%	0.00%	0.02%	0.86%	0.63%	0.82%
Vibo Valentia	0.00%	0.11%	0.13%	0.00%	0.00%	0.20%	0.64%	0.17%
Campania	**0.00%**	**9.18%**	**8.95%**	**0.00%**	**1.83%**	**8.54%**	**4.70%**	**8.82%**
Avellino	0.00%	0.43%	0.48%	0.00%	0.01%	0.55%	0.89%	0.50%
Benevento	0.00%	0.23%	0.25%	0.00%	0.00%	0.34%	0.88%	0.29%
Caserta	0.00%	1.13%	1.20%	0.00%	0.04%	1.20%	0.95%	1.16%
Napoli	0.00%	5.61%	5.20%	0.00%	1.67%	4.72%	1.05%	5.12%
Salerno	0.00%	1.78%	1.81%	0.00%	0.10%	1.73%	0.93%	1.74%
Molise	**0.00%**	**0.23%**	**0.24%**	**0.00%**	**0.00%**	**0.37%**	**1.74%**	**0.29%**
Campobasso	0.00%	0.18%	0.20%	0.00%	0.00%	0.29%	0.85%	0.24%
Isernia	0.00%	0.05%	0.04%	0.00%	0.00%	0.08%	0.89%	0.05%
Puglia	**0.00%**	**5.54%**	**5.92%**	**0.00%**	**0.24%**	**6.00%**	**4.65%**	**5.84%**
Bari	0.00%	2.19%	2.21%	0.00%	0.17%	2.08%	0.83%	2.12%
Barletta-Andria-Trani	0.00%	0.38%	0.43%	0.00%	0.01%	0.50%	0.82%	0.46%
Brindisi	0.00%	0.44%	0.50%	0.00%	0.01%	0.57%	0.70%	0.52%
Foggia	0.00%	0.85%	0.93%	0.00%	0.02%	0.94%	0.87%	0.91%
Lecce	0.00%	0.99%	1.08%	0.00%	0.03%	1.09%	0.68%	1.06%

Taranto	0.00%	0.69%	0.77%	0.00%	0.01%	0.81%	0.74%	0.77%
Sardegna	**0.00%**	**2.12%**	**2.46%**	**0.00%**	**0.03%**	**2.72%**	**2.11%**	**2.53%**
Cagliari	0.00%	0.77%	0.86%	0.00%	0.01%	0.89%	0.41%	0.85%
Nuoro	0.00%	0.21%	0.26%	0.00%	0.00%	0.32%	0.43%	0.29%
Oristano	0.00%	0.14%	0.18%	0.00%	0.00%	0.24%	0.41%	0.21%
Sassari	0.00%	0.70%	0.79%	0.00%	0.01%	0.83%	0.44%	0.79%
Sud Sardegna	0.00%	0.31%	0.38%	0.00%	0.00%	0.44%	0.42%	0.40%
Sicilia	**0.00%**	**6.28%**	**6.83%**	**0.00%**	**0.29%**	**7.12%**	**4.86%**	**6.86%**
Agrigento	0.00%	0.46%	0.54%	0.00%	0.01%	0.60%	0.51%	0.56%
Caltanissetta	0.00%	0.18%	0.22%	0.00%	0.00%	0.29%	0.52%	0.25%
Catania	0.00%	1.67%	1.72%	0.00%	0.11%	1.66%	0.61%	1.66%
Enna	0.00%	0.09%	0.11%	0.00%	0.00%	0.18%	0.53%	0.15%
Messina	0.00%	0.84%	0.92%	0.00%	0.02%	0.94%	0.64%	0.90%
Palermo	0.00%	1.81%	1.87%	0.00%	0.14%	1.83%	0.54%	1.84%
Ragusa	0.00%	0.40%	0.47%	0.00%	0.00%	0.53%	0.50%	0.49%
Siracusa	0.00%	0.39%	0.46%	0.00%	0.01%	0.52%	0.54%	0.48%
Trapani	0.00%	0.44%	0.52%	0.00%	0.01%	0.58%	0.47%	0.54%

The main goal of this section was to measure the model's sensitivity and understand how the main parameters that determine the geographical allocation of economic activity work.

As explained at the beginning of the chapter, all these simulations have been conducted through the distance Excel file adjusted for the Strait of Messina Bridge. However, without running the simulation using the original Excel file and comparing the results with the simulations conducted using the Excel file adjusted for the bridge while varying the parameter values, it is difficult to evaluate the impact of the bridge on the geographic distribution of economic activity. Therefore, an extension of this paper could compare these simulations with the ones conducted through the original Excel distance file.

The chapter on results ends here. The conclusion chapter will resume all the research work and add some considerations on possible improvements/limitations.

4. Conclusions

The Strait of Messina Bridge would, therefore, have a (macro-)regional impact on the geographical distribution of economic activity. In particular, within the regional context, this infrastructure would foster an agglomeration equilibrium towards the biggest provinces in the long run. In this respect, Catania, Messina, and Palermo would attract footloose workers from the other peripheral Sicilian provinces such as Syracuse and Trapani, increasing the intra-regional inequalities.

On the other side of the Strait, the Strait of Messina Bridge would have a positive effect on some provinces like Reggio Calabria, Cosenza, Vibo Valentia, but such impact would not reverse the negative trend of the Calabrian region over time.

According to the results, Catania would be the biggest "winner" from the development of a stable connection with the mainland. There may be several reasons behind such results; the geographical proximity with the potential bridge and the size of the population may explain why Catania would perform better than Palermo and Messina.

On the other hand, Syracuse would experience the highest outflow of manufacturing workers after the construction of the bridge. The province shares borders with the province of Catania to a large extent, which places it in a periphery position within a core-periphery pattern.

Our paper's findings partly contrast with those of Altafini et al. (2022): within the context of the Strait, our simulations demonstrate that the development of the bridge has a greater positive impact on the province of Reggio Calabria than the one of Messina. However, this does not reverse the hierarchical relationship between the two provinces; over the long-run, Messina still remains bigger than Reggio Calabria in terms of manufacturing activity.

By applying the NEG model to the Italian framework, we were able to study the impact of a big infrastructure such as the Strait of Messina Bridge on the geographical distribution of economic activity within the country. We conducted thorough data collection and meticulous analysis, striving to replicate reality as closely as possible. However, this cannot be conceived as the best way to represent the reality yet. As a matter of fact, the model does not take into account the external environment represented by the other countries. In such a sense, it can be considered as a closed model which has some limitations that have affect its alignment with the reality. For example, an isolated environment may often overlook the influences and interactions from the external environment, potentially leading to inaccuracies or an incomplete understanding of the system under study.

Another limitation of the study arises from the subjective selection of footloose sectors. In the elaboration of data, we categorized the labor market into footloose and bounded sectors, aiming to adhere to the definition of footloose industries as closely as possible. However, the division of sectors is subjective and debateable. As explained in Chapter 3, this process is crucial to ensure the accuracy and reliability of our simulations and to draw a comprehensive picture of the situation following the development of the Bridge. Therefore, a meaningful improvement of the study could be defining some parameters that allow an unbiased categorization of the labor market.

Overall, the paper contributes to the academic literature, allowing an economic geography perspective to the Strait of Messina Bridge. Developing a big infrastructural project such that requires many studies of different nature: from the economic to the social, from the technical to the environmental ones. Therefore, defining the feasibility of a project from just one perspective could be both reductive and counterproductive. Our main goal was to provide other insights to the geographical viewpoint and allowing a better understanding of such phenomenon. In this sense, we can confirm our work succeeded.

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