Modeling agglomeration and dispersion in space: The role of labor migration, capital mobility and vertical linkages

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Abstract
In this paper we investigate the role played by capital mobility, labor migration and input–output linkages in shaping the spatial distribution of economic activity in a spatial computable general equilibrium framework. We identify European Union core and periphery regions based on an accessibility index and simulate the impact of a homogeneous transport shock. Our results suggest that agglomeration patterns are magnified by labor and capital mobility, the latter exerting a stronger influence than the former. Results are more nuanced for vertical linkages, which are associated with more agglomeration in terms of GDP, but more dispersion in terms of number of firms and labor demand. These results shed additional light on location mechanisms in applied general equilibrium applications of the new economic geography (NEG) theory and complement the theoretical NEG literature based on analytically solvable models.

1 | INTRODUCTION

In this paper we analyze numerically the role played by capital mobility, labor migration and vertical linkages in bringing agglomeration and dispersion of economic activities about in a spatial general equilibrium framework. We study their impact through the lens of the effects that are well documented in the new economic geography (NEG) literature: the market access effect, the price index effect and the market crowding effect. Each effect contributes to a different extent to determine the spatial patterns of economic outcomes. The market access effect captures the fact that firms in central regions have better access to consumers and suppliers than firms in peripheral regions, thus pushing workers and firms to co-locate in more central regions. The price index effect captures the impact of firms’...
location and transportation costs on the cost of living of workers and the cost of intermediate inputs for producers of final demand goods. Hence, workers would enjoy a higher level of welfare by moving to central regions with lower prices, but the impact for firms is more nuanced because on the one hand they can source cheaper intermediate goods but on the other hand they have to charge lower prices and mark-ups on local consumers. Finally, the market crowding effect captures the fact that, because of higher competition on input and output markets, firms and workers prefer to locate in peripheral regions with fewer competitors, where they can enjoy higher market power. The disadvantage of locating in peripheral regions is that consumers and firms have to pay higher prices for goods purchased and sourced from markets further away, but a reduction in transportation costs, e.g., owing to investment in the transport infrastructure, mitigates this effect.

Our analysis is performed using RHOMOLO, the spatial computable general equilibrium model of the European Commission (Brandsma, Kancs, Monfort, & Rillaers, 2015). The version of RHOMOLO used for this analysis covers 267 NUTS2 regions in the EU27 (nomenclature of territorial units for the group of 27 countries in the European Union), which are disaggregated into six NACE Rev. 1.1 (a statistical classification of economic activities in the European Community) sectors. Our identification strategy consists first in identifying the EU spatial core and periphery based on an index of accessibility, which is constructed from a matrix of inter-regional trade cost data. We then look at differences in economic impacts of a homogenous and proportional improvement in accessibility between the core and periphery under different model assumptions. Four configurations of the model are analyzed by performing numerical simulations: (1) a model specification with labor mobility, capital mobility, and vertical linkages; (2) without labor mobility; (3) without capital mobility; (4) without adjustments in vertical linkages. Finally, we compare differences between the core and periphery in different model settings and, based on a differences-in-differences approach, we identify the role played by each model feature in shaping spatial patterns of regional economic outcomes.

We consider two types of accessibility shocks, one involving a homogeneous reduction in trade barriers and the other a reduction proportional to initial values. Our analysis of a homogeneous positive shock in the accessibility of all EU regions shows the tendency of labor mobility and, to an even larger extent, capital mobility to foster agglomeration, both in the short and long run. In addition, capital mobility fosters agglomeration even when the shock is proportional to the initial level of accessibility, whereas labor mobility is associated with a dispersion of economic activities after this type of shock. The impact of vertical linkages is more nuanced, as they are associated with a higher GDP agglomeration but dispersion of firms and workers in the case of a homogeneous shock. However, the results for vertical linkages are inverted in the case of a proportional shock, highlighting the delicate interactions between the empirical calibration, exogenous model parameters and theoretical features of the underlying NEG.

The added value of the present paper is twofold. First, it aims at drawing the attention of applied policy modelers to the fact that, in contrast to theoretical 2×2×2 models of the new economic geography, real world economic outcomes in the presence of many asymmetric regions, factor endowments and economic sectors are less predictable,1 because of a multitude of spatial interactions and competing channels of adjustment. By performing numerical simulations and by analyzing one agglomeration/dispersion channel at a time, we aim to provide an accessible way of understanding the potential pitfalls and opportunities that a dynamic spatial general equilibrium framework offers for the policy impact assessment. In so doing, we do not have the ambition of replicating the most important stylized facts concerning the macroeconomic dynamics of the regions or account for stylized facts pertaining to entry, profits, and mark-ups as for instance investigated by Bilbiie, Ghironi, and Melitz (2012). Instead, our study attempts to measure the relative magnitude of agglomeration and dispersion forces in affecting the spatial distribution of economic activity in a multi-region, multi-factor, and multi-sector
environment. Second, the present paper contributes to the emerging empirical research on NEG (see Redding, 2010 for a review of empirical works on NEG) and notably on the quantitative analysis of theoretical models of NEG that can be used to analyze counterfactuals and examine numerically the insights derived from theoretical models.

The remainder of the paper is organized as follows. In the next section we briefly outline the model. In Section 3 we discuss simulation results, while in Section 4 we explain the resulting agglomeration and dispersion forces in terms of spatial outcomes of the model. In Section 5 we perform robustness checks and sensitivity analysis. Finally, in Section 6 we draw some concluding remarks.

2 | THE RHOMOLO MODEL

2.1 | Overview

In this section we outline the main characteristics of the model to help the reader to identify the main drivers and determinants of the spatial outcomes generated by the model, whereas a full description of the RHOMOLO model and its equations can be found in Mercenier et al. (2016). The domestic economy (which corresponds to the European Union) consists of \( R - 1 \) endogenous regions \( r = 1, \ldots, R - 1 \), which are included into \( M \) countries \( m = 1, \ldots, M \). The rest of the world is introduced in the model as an exogenous external sector (indexed by \( R \)).

The economy is composed of \( s = 1, \ldots, S \) different sectors (also called industries) in which firms operate under monopolistic competition à la Dixit and Stiglitz (1977). In each region-sector, each firm produces a differentiated variety, which is considered to be an imperfect substitute to the varieties produced elsewhere.

Final goods are consumed by households, governments, and investors (this is the form of capital goods) while firms consume intermediate inputs. Given the relatively small size of many EU regions, the standard monopolistic competition assumption of a mass of negligible, atomistic firms has been generalized to a small-group monopolistic competition framework (Baldwin, Forslid, Martin, Ottaviano, & Robert-Nicoud, 2003) where mark-ups depend on the form of competition, on the degree of substitutability between goods and on the number of firms.

The number of firms in sector \( s \) and region \( r \), denoted by \( N_{s,r} \), is endogenous and determined from the zero-profit equilibrium condition, according to which profits must be equal to fixed costs. In turn, this means that in equilibrium, prices equal average costs.

Trade between and within regions is costly, implying that the shipping of goods entails transportation costs assumed to be of the iceberg type, with \( \tau_{s,r,q} > 1 \) representing the quantity of sector’s \( s \) goods that needs to be sent from region \( r \) in order to have one unit arriving in region \( q \) (see, e.g., Krugman, 1991). Transportation costs are identical across varieties but specific to sectors and trading partners (region pairs). They are related to the distance separating regions \( r \) and \( q \), but also depend on other factors, such as the transport infrastructure or national borders. They are asymmetric (i.e., \( \tau_{s,r,q} \) is allowed to differ from \( \tau_{s,q,r} \)) and positive within regions (i.e., \( \tau_{s,r,r} \neq 1 \)). The source of the asymmetric transport costs used in the RHOMOLO model is TRANSTOOL, the transport network model of the European Commission.3

Regional goods are produced by combining the value added (labor and capital) with domestic and imported intermediates, creating vertical linkages between firms. This means that the spatial configuration of the system of regions has a direct impact on the competitiveness of regions, because firms located in more accessible regions can source their intermediate inputs at a lower price and thus gain larger market shares in local markets. The role played by vertical linkages in shaping the geography of economic outcomes is one of the three features analyzed in this paper.
In RHOMOLO, regional investments are determined by a simple adjustment rule, according to which the additional level of investments is generated in each region by the gap between the desired level of capital and the actual level of capital. This is a typical accelerator model developed originally by Jorgenson and Stephenson (1969) and consistent with the capital adjustment rules of Uzawa (1969). Typically, for higher user cost of capital we would expect a lower desired capital stock; in this case profits are lower resulting in disinvestment. The demand for investment is satisfied by the domestic and external market, where no constraints are imposed and the capital stock in each region is updated period by period through the realized investment adjusted for depreciation.

Each region is inhabited by \( H_r \) households, which rent their work to firms. RHOMOLO distinguishes among three different labor categories: low skill, medium skill, and high skill. For each labor type, the wage setting relationship is represented by a wage curve (Blanchflower & Oswald, 1995), according to which lower levels of unemployment increase the workers’ bargaining power, thereby increasing real wages. The labor supply is fixed at the EU level, but workers, differentiated by skills, can migrate among EU regions according to real wage and unemployment differences. We assume that there is no natural population change but that the labor force in each region adjusts according to a migration function employed in Brandsma, Kancs, and Persyn (2014). The model starts with a zero net migration flow, and in any period migration is taken to be positively related to the gap between real wages, and negatively related to the gap between unemployment rates.4

Following the mobile labor framework of Krugman (1991), we make three assumptions in order to implement labor mobility in RHOMOLO.5 First, we assume that workers are spatially mobile—workers from any EU region can locate in the next period in any EU region (including their own region). Second, mobile workers not only produce in the region where they settle (as the mobile capital does), but they also spend their income there (which is not the case with capital owners). Third, workers’ migration is governed by expected differences in the real income, therefore differences in the costs of living between regions matter. Since the relocation of workers across regions may have a significant impact on the pattern of the regional consumption and on local wages, labor mobility is likely to substantially affect spatial outcomes in the model.

Household income consists of labor revenues (wages), capital revenues and government transfers. A fixed share of the disposable income is allocated to savings, whereas the remaining part is allocated to the consumption of final goods and services. Finally, in each country there is a public sector, which levies taxes on consumption and on the income of local households. Governments use their income for the public consumption, transfers, and subsidies.

2.2 | Calibration and baseline dynamics

The high dimension of RHOMOLO in terms of regions and sectors imply that the number of (nonlinear) equations to be solved simultaneously is very high (in the order of the hundreds of thousands). Therefore, in order to keep the model manageable from a computation point of view, its dynamics is kept relatively simple. The model is solved in a recursively dynamic mode, where a sequence of static equilibria is linked to each other through the law of motion of state variables. This implies that economic agents are myopic and their current decisions are solely based on past information.

The model calibration process assumes the economy to be initially in a steady-state equilibrium. All shift and share parameters are calibrated to reproduce the base-year dataset, represented by the inter-regional social accounting matrix for the year 2010,6 while the elasticities of substitution and other behavioral parameters are based on econometric estimates. For example, the parameters related to the inter-regional labor migration are estimated in a panel data setting (Brandsma et al., 2014; Persyn, Torfs, & Kancs, 2014). The parameters related to the elasticities of substitution both on the
consumer and on the producer side are based on similar models or derived from the econometric literature. In this exercise we assume a rather low elasticity of substitution in production (0.3), a relatively higher elasticity of substitution in consumption (1.2) and a fairly high one for trade between regions (6.0). The elasticity of substitution between different types of skills equates to 0.5. The interest rate (faced by producers, consumers, and investors) is set to 0.04, while the rate of depreciation equates to 0.15.

The selection of the year 2010 for the calibration is based on data availability, as it is the most recent year for which regional social accounting matrices can be built with a sufficient degree of reliability at the time of writing. The selection of the base year for the model calibration is not a straightforward pursuit, as many aspects have to be considered simultaneously. The steady-state equilibrium calibration implies the assumption that the data observed should provide unbiased information about preferences and technologies in each region and therefore relative magnitudes should not vary in the baseline scenario. Therefore, one would ideally aim for a recent year with good enough data and without specific demand or supply shocks. Unfortunately, it is difficult to meet these conditions in reality, particularly at the regional level. In the present study, we are aware that 2010 was a public finance crisis year for many EU regions and countries. However, compared with the 2007/2008 crisis, it had the advantage of being more broadly fledged and so not affecting disproportionately specific regions or sectors of the economy (such as construction or real estate services).

As for the baseline scenario, we assume that there is no natural population change. Similarly, we do not make any assumptions about the economic growth of regions owing to external factors. The main reason behind these baseline scenario assumptions is that in this study we run a set of theoretical hypothetical scenarios, and the simulation results are not intended to provide any direct evidence for the EU policy design. Moreover, by avoiding asymmetric changes in the baseline scenario, such as regionally differentiated population or the GDP growth, greatly facilitates the interpretation of simulation results. Further, to avoid potential distortion driven by innovation externalities present in the main RHOMOLO version, we deactivate the R&D spillover option of the model. This is done to allow for an easier interpretation of the differences between the alternative model configurations simulated below.

2.3 | Agglomeration and dispersion mechanisms

As noted by Krugman (1991), an endogenous modeling of the spatial location of economic activities requires agglomeration and dispersion forces, and mechanisms based on which agglomeration/disispersion are brought about. The theoretical literature proposes a considerable amount of potential agglomeration and dispersion forces (for surveys see Fujita, Krugman, & Venables, 1999; Fujita & Thisse, 2002; Baldwin et al., 2003). In the structure of RHOMOLO, two standard agglomeration forces are incorporated (increasing returns to scale and localized externalities), and two relevant dispersion forces (transportation costs and imperfect competition). As explained in the following section, these forces contribute to the rise of three endogenous NEG effects in RHOMOLO: the market access, the price index, and the market crowding, resulting in an endogenous location of economic activities.

2.3.1 | Increasing returns to scale

Increasing returns to scale are introduced via fixed costs, \( FC_{i,s,r} \), in the firm value-added production function. Fixed costs are measured in output terms, and firms pay them at the beginning of each period (before starting to produce their market output). Therefore, as in conventional NEG models, firms have an incentive to concentrate production in space to benefit more from the advantages of scale
2.3.2 | Localized externalities

Two types of external effects can be distinguished in RHOMOLO: technological externalities and pecuniary externalities. Whereas the former (Marshallian) are restricted to spillovers directly affecting individual utility or firms’ production functions, the latter result from market interactions and affect firms or consumers/workers by means of exchanges. Given the imperfect competition, pecuniary externalities arise owing to the fact that prices do not reflect the social value of individual decisions. Consequently, when agents move, they do not account for all the effects caused by their decisions. The relocation of an economic agent unintentionally affects the welfare of all other agents through pecuniary externalities.

2.3.3 | Costly trade

In spatial economics, it has been recognized for a long time that transportation costs and differences in the relative accessibility of regions drives the location of economic agents to spatially dispersed economic outcomes (Bosker & Garretsen, 2010).

In RHOMOLO, a region’s accessibility is determined by generalized transportation costs consisting of two main components: its spatial location and transportation costs. Whereas the former is exogenous and fixed, the latter can be changed by policy makers, which explains the large interest that transportation costs have triggered in the policy and academic debate (Bairoch, 1974; Spulber, 2011). Transportation costs capture all the costs generated by the various types of spatial frictions that economic agents face in a spatial exchange process.

In order to account for transportation costs in RHOMOLO, the trade of goods and services between (and within) regions is assumed to be costly, implying that the shipment of goods between (and within) regions entails transportation costs that are assumed to be of the iceberg type, with $\tau_{s,r,q} > 1$ representing the quantity of sector’s $s$ goods that need to be sent from region $r$ in order to have one unit arriving in region $q$. Higher transportation costs make it more difficult for firms to serve distant markets and thus they represent a strong dispersion force in the model.

2.3.4 | Imperfect competition

Imperfect competition implies that firms do not consider prices as given but are price makers. Given that the level of prices depends on the spatial distribution of firms and consumers, the resulting interdependence between firms and workers may yield agglomerations (Ottaviano & Thisse, 2002). Two types of imperfect competition settings have been used in NEG models: monopolistic competition and oligopolistic competition. In the case of the monopolistic competition, the main departure from the competitive framework concerns the presence of differentiated varieties, the market power and increasing returns to scale. Firms are price makers and make operating profits that in equilibrium equate fixed costs of entry. This feature also characterizes firms competing in oligopolistic competition frameworks, but on top of that oligopolists are also assumed to be large enough as to influence market indices with their pricing choices, resulting in strategic interactions.

As mentioned above in Subsection 2.1, we follow a generalized Dixit–Stiglitz framework where mark-ups depend not only on the degree of substitutability between goods but also on the form of
competition. First, we assume that each firm produces a differentiated product (variety), which is not a perfect substitute for other firms’ varieties. At the same time, we assume that the real or perceived non-price differences are small enough to eliminate other varieties as substitutes. The product differentiation is captured by the elasticity of substitution between varieties, \( \sigma \), which is larger than one, but smaller than infinity. Second, we assume that there is a free entry and exit on each market, implying that firm profits, \( p_{i,s,r} \), are zero in each period. Third, the number of firms, \( N_{s,r} \), operating in industry \( s \) located in region \( r \) is determined endogenously, based on the fixed cost, \( FC_{i,s,r} \), and the elasticity of substitution, \( \sigma \).

Furthermore, it should be noted that consumers’ preferences for each variety are calibrated in the model base year based on actual inter-regional consumption data. The model calibration assigns a taste parameter on each variety for each consumer, meaning that different product varieties are not perceived as perfectly symmetric by consumers and in the model there is always a certain share of demand for varieties produced in peripheral regions, which also plays against agglomeration.

### 2.4 Expected new economic geography outcomes

Before closing the RHOMOLO description and moving to simulations, we briefly summarize the expected results of our simulation exercise based on the theoretical NEG theory, whereby three NEG effects can be identified as a result of the interaction between agglomeration and dispersion forces: market access, price index, and market crowding.

#### 2.4.1 Market access effect

The so-called “market access effect,” which in the literature is also referred to as the dominant market effect, demand linkage, or backward linkage (Fujita et al., 1999; Fujita & Thisse, 2002; Baldwin et al., 2003), results from differences in the proximity to customers (consumers and other firms) across regions, it may explain why Core regions may attract more economic activity than periphery regions. In RHOMOLO, market access depends not only on the relative size of the region in itself, but also on its position vis-à-vis other regions, as well as on the transportation cost to (and from) other markets (which is why high transportation costs are a dispersion force). Owing to positive transportation costs, the demand for a region’s output increases with its relative accessibility and the economic size of the region. This can be seen by combining the consumption and profit equations:

\[
\pi_{i,s,r} = p_{i,s,r} \cdot \left[ \frac{1}{\beta_s} \tau_{s,r,q} p_{i,s,r} \right]^{\frac{1}{\sigma-1}} \left( \frac{P^c_q}{I_q} \right)^{\sigma-1} I_{i,s,r} - P^v_{i,s,r} X_{i,s,r} - \sum_{u=1}^{S} q^u_s \sigma^{-1} p^u_{i,s,r} X_{i,s,r} - P^v_{i,s,r} FC_{i,s,r} \]

where \( \pi_{i,s,r} \) is the profit of firm \( i \) located in region \( r \) operating in sector \( s \), \( P^c_q \) and \( P^u_{i,s,r} \) are the consumer price index in the destination region, \( q \), and the intermediate input price index in the region-sector where variety \( i \) is produced; \( p_{i,s,r} \) is the price of variety \( i \) of sector \( s \) produced in region \( r \); \( \beta_s \) is the weight given to sector \( s \) in the household’s (firm’s) preferences, \( \tau_{s,r,q} \) is the transportation cost from region \( r \) to region \( q \), \( \sigma \) is the elasticity of substitution between varieties, \( P^v_{i,s,r} \) is the price of value.
added, \( X_{i,s,r} \) is the constant elasticity of substitution (CES) aggregate over final (intermediate) good varieties, \( \alpha_s \) are technical input coefficients in the production function, \( I_q \) is the disposable household income in region \( q \), and \( FC_{i,s,r} \) is the fixed cost, expressed in terms of value-added \( P_{i,s,r} \) (i.e., some capital and labor is used in fixed quantities to set up the firm). According to profit function (1), the total income in region \( i \) is the price of variety \( q \), and hence profit, \( \pi_{i,s,r} \), is increasing with lower transportation costs, \( \tau_{r,q} \), and with a lower elasticity of substitution, \( \sigma \). The weighted average transportation costs can be lower either owing to a large internal market (because \( \tau_{rr} < \tau_{rq} \forall r,q \)), or owing to a central location (good accessibility), or both. A lower elasticity of substitution implies a higher market power about the variety that each firm produces.

### 2.4.2 Price index effect

The so-called “price index effect,” which in the literature is also known as the cost-of-living effect, cost linkage or forward linkage (Fujita et al., 1999; Fujita & Thisse, 2002; Baldwin et al., 2003), captures the effect of transportation costs on the cost of living of workers, and the cost of intermediate inputs for the producers of final demand goods. Given that consumers in core regions with more firms have to pay less for the transport of goods, reducing in such a way the resources spent on transporting goods from producers to consumers, goods and traded services tend to be less expensive in core regions than in periphery regions. In RHOMOLO, this can be seen in the consumer price index (2), and the intermediate input price index (3), respectively:

\[
P_q^c = \left( \sum_{r=1}^{R} \sum_{s=1}^{S} \sum_{i=1}^{N_r} \beta_s^p (\tau_{s,r,q} P_{i,s,r})^{1-\sigma} \right)^{\frac{1}{1-\sigma}}
\]

\[
P_{i,s,r}^\mu = \left( \sum_{q=1}^{R} \sum_{j=1}^{S} \sum_{u=1}^{N_q} \beta_s^p (\tau_{r,q,p_{j,q}}^{\mu})^{1-\sigma} \right)^{\frac{1}{1-\sigma}}
\]

whereas \( P_q^c \) and \( P_{i,s,r}^\mu \) are the consumer price index and the intermediate input price index, respectively, \( p_{i,s,r} \) is the price of variety \( i \) in sector \( s \) produced in region \( r \), \( \beta_s \) is weight given to sector \( s \) in the household’s (firm’s) preferences, \( \tau_{s,r,q} \) is the transportation cost from region \( r \) to region \( q \), \( p_{j,u,q} \) is the price of variety \( j \), \( u \), \( q \) of final goods, and \( \sigma \) is the elasticity of substitution between varieties.

Both price indices suggest that the total transportation costs in each sector, \( \sum_{s=1}^{S} (\tau_{r,q} - 1) \), and hence the cost of living and producing, are lower in core regions. Note that, as explained above, the asymmetric region-pair-specific transportation costs, \( \tau_{s,r,q} \), are extracted from a bilateral trade cost data base. The regional price index increases in transportation costs. Because of lower costs of living/production, consumers (purchasing final goods) and firms (purchasing intermediate inputs) prefer to locate in core regions.

In the absence of dispersion forces, the described price index effect could become self-sustained in the sense that the availability of more locally produced varieties lowers the regional price index, prices in the region and, in turn, attracts more firms and workers to the region.

### 2.4.3 Market crowding effect

The so-called “market crowding effect,” which in the literature is also referred to as the competition effect (Fujita et al., 1999; Fujita & Thisse, 2002; Baldwin et al., 2003), reflects the fact that, because of a higher competition on input and output markets, economic activities prefer to locate in periphery regions with fewer
competitors. When the number of firms in core regions increases, the consumption of differentiated goods is fragmented over a larger number of varieties (firms), implying that each firm’s output and profit decreases. Given that the entry of new firms has a negative effect on the profitability of incumbents in more crowded core regions, the competition effect works against the tendency to concentrate economic activities in the core.

In RHOMOLO, the impact of the market crowding effect on firm output can be seen in the demand function (4):

$$X_{h,q}^C = \left( \frac{1}{R} \frac{1}{S} N_{s,r} \sum_{i=1}^{R} \sum_{s=1}^{S} \beta_s \left( \sum_{r=1}^{R} x_{h,q}^{i,s,r} \right)^{\frac{1}{\gamma}} \right)^{\frac{1}{\gamma}}$$

where $x_{h,q}^{i,s,r}$ is the demand for variety $i$ of sector $s$ produced in region $r$ from household $h$ located in region $q$, $\beta_s$ is the weight given to sector $s$ in the household’s (firm’s) preferences. For a given level of the total consumption, Equation 4 shows that the demand for the output produced by firm $i$ in sector $s$ in region $r$, $x_{h,q}^{i,s,r}$, decreases in the sales of competitors in region $q$. In Equation 4, this can be seen by holding the total demand, $X_{h,q}^C$, fixed. If the number of firms, $N_{s,r}$, increases, then $x_{h,q}^{i,s,r}$ must decrease, everything else constant. Lower output, and hence profits, induce firms to move away from core regions to periphery regions with fewer competitors.

The market crowding effect also affects input markets through prices of spatially immobile (semi-mobile in the short run) production factors. Spatial concentration of firms in core regions bid up prices for immobile (semi-mobile) production factors, making production more costly, which reduces firm profits.

3 | NUMERICAL SIMULATIONS OF AGGLOMERATION AND DISPERSION MECHANISMS

3.1 | Setup

In order to illustrate the impact of specific model features on location choices of economic agents in RHOMOLO, in this section we perform numerical simulations and compare the core–periphery patterns resulting from a deeper integration of EU regions in different model configurations. We perform numerical simulations to show the impact of agglomeration because, owing to the complexity of the model, analytical derivations of the overall impact are not possible.

In the illustrative simulations we implement a permanent, homogeneous reduction in transportation cost of 0.2 percentage points to all EU regions and compare differences in resulting agglomeration patterns under different model specifications, then for robustness we analyze also the patterns associated with a proportional shock. As detailed in the previous section, transportation costs are of a particular interest for studying location decisions of economic agents, because they are inherent attributes of exchanges across space, they play an important role in spatial transactions, and they can be affected by policy (Anas, Arnott, & Small, 1998; Broecker, Kancs, Schuermann, & Wegener, 2001).

From a costless reduction in transportation costs applied to all economic sectors and regions we would expect a general fall in commodity prices, making domestic goods cheaper and more competitive on both local and external markets. Given that all regions in the EU benefit from a positive accessibility shock, we expect a general increase in the competitiveness in all EU regions. However, given that the positive accessibility shock affects all EU regions, it is likely to generate only a limited capacity to exploit the gains of trade within the EU itself in terms of relative market shares, channeling the expansion of demand to the rest of the world (ROW) as the most important channel to absorb the
excess supply. In relative terms, we would expect that regions that are more open and exposed towards the ROW are also the ones benefiting the most.

While the direction and sign of simulation results are relatively straightforward to predict using the theory of NEG, the exact magnitude and spatial distribution of the impacts of individual channels of adjustment are more complex. For the sake of an easier interpretation of simulation results within the context of NEG, we regroup all EU regions into two groups, the core and periphery, based on their level of accessibility in the base year, measured as a weighted average transportation cost incurred to the transportation of goods produced in each region to all other regions in the EU. We regroup all EU regions with accessibility below the median as the periphery, and those regions with accessibility above the median as the core. Figure 1 shows on the left-hand side the value of the accessibility index for each EU region and on the right-hand side the EU regions composing the core (dark shade) and the periphery (light shade) in our analysis. In addition to mapping simulation results, we also report results as the difference between economic outcomes in the core and periphery.

### TABLE 1
Selected calibrated base year shares for the core and periphery

|                              | Core  | Periphery |
|------------------------------|-------|-----------|
| Regional GDP/EU GDP          | 0.58  | 0.42      |
| Regional GDP per capita/EU GDP per capita | 1.20  | 0.80      |
| Population/EU population     | 0.49  | 0.51      |
| Labour remuneration/GDP      | 0.45  | 0.42      |
| Export to ROW/GDP            | 0.22  | 0.17      |
| Export to REU/GDP            | 0.15  | 0.14      |
| Investment/GDP               | 0.20  | 0.22      |
| Average iceberg transportation cost share | 0.20  | 0.22      |
| Number of regions            | 134   | 133       |

*Note.* ROW, rest of the world; REU, rest of the EU.
In Table 1 we report selected benchmark values to characterize the main features of regions in the core and periphery. We observe that the core contributes more than the periphery to the overall EU GDP and furthermore, the core has a GDP per capita above the EU average GDP per capita. On average, the core is more export intensive than the periphery and enjoys lower transportation costs. The investment to the GDP ratio and the labor to GDP ratio are higher in the periphery than in the core.

In order to disentangle the main agglomeration and dispersion forces associated with the integration of regional economies, we directly compare the default (full) model including labor mobility, capital mobility, and vertical linkages with three different NEG configurations of the RHOMOLO model, where each of the three features is deactivated in turn. The impact of each mechanism is then studied by comparing differences between the core and periphery outcomes under each specific model configuration, an approach that we refer to as differences-in-differences (or diff-in-diff). In this way, we are able to identify (in terms of sign, magnitude, and dynamics) how each of the three location mechanisms affects the location pattern and dynamics in spatial economic outcomes following a uniform accessibility shock. In terms of interpretation, if a difference of difference is positive, when comparing the outcome of the full model with the model where a selected location mechanism is turned off, then the NEG model feature can be interpreted as fostering agglomeration. In the opposite case, we can say that dispersion prevails owing to the particular NEG feature.

3.2 Regional integration shock in the full model

We start explaining simulation results by showing the aggregate macroeconomic impact of a regional integration shock simulated with the full model. Notice that we run the model for 65 periods. This is a sufficient time horizon to reach a new steady state, where all variables grow at constant rates. The first period of the model is identified as the short run, where capacity constraints are imposed (namely labor and capital supplies are fixed to their base-year values) while period 65 is reported as the long-run equilibrium.

All simulation outcomes are expressed in percentage changes from the base-year values, unless stated otherwise, for a set of key economic indicators: the GDP, the regional employment, the consumer price index (CPI) and the number of firms. The results obtained running the full model configuration are reported in Figure 2 for EU region and Figure 3 for EU aggregates.
In Figure 2 we report the spatial distribution of the GDP impact in EU regions for the short run (left-hand pane) and the long run (right-hand pane) where darker colors denote higher regional changes in the GDP with respect to the base-year values. These simulation results suggest that in both time frames, the spatial pattern of the GDP impact is distributed unevenly across EU regions. There are regions that benefit relatively more from a regional integration shock. Among periphery regions, we can notice that some regions in Bulgaria benefit more than others, while in the core, regions in Belgium, Slovakia, and Poland, and Luxembourg are gaining relatively more than other regions. It is worth noticing that the spatial pattern changes from the short to the long run. Generally, we observe more variation in the long run than the short run. The computed standard deviation from these two periods equate to 0.1 and 0.5 for the short and the long run, respectively. We also observe that in the short run 85 core regions and 34 periphery regions are above the EU average GDP impact while in the long run 80 regions in the core and 68 regions in the periphery have recorded a GDP impact greater than that observed for the whole EU.

On the left-hand side panel of Figure 3, we summarize the above results for the EU as a whole while on the right-hand side of the same figure, we show differences between the core and periphery.

In Figure 2 we report the spatial distribution of the GDP impact in EU regions for the short run (left-hand pane) and the long run (right-hand pane) where darker colors denote higher regional changes in the GDP with respect to the base-year values. These simulation results suggest that in both time frames, the spatial pattern of the GDP impact is distributed unevenly across EU regions. There are regions that benefit relatively more from a regional integration shock. Among periphery regions, we can notice that some regions in Bulgaria benefit more than others, while in the core, regions in Belgium, Slovakia, and Poland, and Luxembourg are gaining relatively more than other regions. It is worth noticing that the spatial pattern changes from the short to the long run. Generally, we observe more variation in the long run than the short run. The computed standard deviation from these two periods equate to 0.1 and 0.5 for the short and the long run, respectively. We also observe that in the short run 85 core regions and 34 periphery regions are above the EU average GDP impact while in the long run 80 regions in the core and 68 regions in the periphery have recorded a GDP impact greater than that observed for the whole EU.

On the left-hand side panel of Figure 3, we summarize the above results for the EU as a whole while on the right-hand side of the same figure, we show differences between the core and periphery.

As expected, from the left-hand side of Figure 3, we can see that a reduction in intra-EU transportation costs has positive effects for the overall EU economy, as both the GDP and employment are above their base-year values. Furthermore, the number of firms increases, after a very short-lived reduction in the first five periods, and prices fall, as captured by the consumer price index. In the short run, both the GDP and employment increase by 0.5 percent above their base-year values, while in the long run we observe a 2.1 percent and 1.3 percent increase in the GDP and employment, respectively. In the long run, the GDP grows more than employment, signaling that the capital stock is increasing faster than the human capital and hence reflecting the nonlinearity of the model. Prices start falling right from the beginning of the shock, until they settle at around −0.5 percent of the initial steady state. Considering that iceberg transportation costs in the model account for around 20 percent of the traded goods’ value (see Table 1), a 0.2 percent of 20 percent implies a direct cost saving effect on final good prices of just −0.04 percent. Hence, an overall CPI decrease of −0.5 percent in the new steady state signals a significant reallocation of resources across sectors and productive factors in the system that are induced by changes in relative prices.

On the right-hand side of Figure 3, we show percentage differences between the core and periphery for the same set of variables plotted on the left-hand side. The positive differences in the GDP and employment indicate that the core is benefiting relatively more than the periphery after a positive accessibility shock. However, the positive difference in the CPI implies that competitiveness gains are higher for periphery regions than for core regions, which is reflected in the negative difference in the number of firms, which is increasing more in the periphery than in the core.
As pointed out in the NEG literature (Baldwin et al., 2003), it is not surprising to see higher positive effects in core regions in terms of GDP and employment, with the difference increasing over time, as both economies expand. It is more surprising to see an increasing competitiveness and the number of firms in the periphery, which can be attributed to the higher share of imports in peripheral regions, making a reduction in transportation costs more appealing for firms importing intermediates goods and becoming relatively more competitive. However, it should be noticed that the scale of the difference between the core and periphery is much smaller than the scale of the overall effects, by an order of magnitude of 10 to 1, suggesting that the sign and direction of the impacts are similar for the two groups.

The results in terms of GDP and employment suggest that agglomeration forces outweigh dispersion forces on those accounts. The reason for these results could be the relatively better position of core regions with respect to periphery regions, as far as the size of the internal market penetration and the external market penetration is concerned. Core regions are indeed typically characterized by a larger domestic market and a larger share of goods and services produced internally that are exported to the ROW. For example, in the initial steady-state equilibrium, exports to the ROW as a share of the GDP are 22 percent in the core and 17 percent in the periphery. Hence, the GDP effect is likely to be larger in the core than for regions in the periphery. However, the relative gains in the competitiveness of the periphery cause dispersion, as far as the number of firms is concerned.

In order to decompose these aggregate results, in the next three sections, we investigate how spatial outcomes would differ under alternative agglomeration and dispersion modeling choices concerning labor mobility, capital mobility, and vertical linkages.

3.3 | Labor mobility

In order to identify the impact of labor mobility on the spatial distribution of economic activities, we compare the results obtained from the full model with a model specification, where labor mobility is turned off. Given that the labor supply is fixed at the EU level in both model configurations, the overall magnitude of the impact on the economic activity is expected to be similar. However, the spatial pattern resulting from the absence of this spatial location mechanism is expected to be notable.

On the left-hand side of Figure 4 we show the core–periphery differences obtained by turning off labor mobility in RHOMOLO. We can see again that, while core regions are gaining more in terms of GDP and employment, the resulting relocation of firms is such that the increase in the number of firms is higher in the periphery than in the core. The relatively higher relocation of firms towards the periphery is mainly determined by an increasing competitiveness in peripheral regions. This is reflected in an
upward shift in the CPI curve. In each period we observe a higher fall in prices in the periphery than in the core. Therefore, the periphery becomes relatively more competitive than the core, boosting in turn the exports of goods and services towards the rest of the EU and the ROW. Hence the market share in the periphery increases more than in the core, generating as a result a larger mark up and thus a relatively larger expansion in the number of firms in the periphery.

By and large, the absence of migration reduces the gap between the core and periphery. This can be seen by comparing core–periphery differences in the GDP or employment as reported on the left-hand side of Figure 4 with the right-hand side of Figure 3. Indeed, we observe that in the long run the difference in the GDP between the core and periphery is 0.12 percent when migration is not present, while the GDP growth between the two types of regions is higher (ca 0.15 percent) when the labor migration is turned on.

The focus of this simulation is also to judge whether regional labor adjustments through migration can be interpreted as an agglomeration or a dispersion force. To do so, we use the difference in difference approach and plot on the right-hand side of Figure 4 core–periphery differences between the full model and the model without the labor mobility. Our simulation results suggest that for all displayed variables, differences between the core and periphery become larger over time, when migration comes into play. The mobility of workers generates an increase in the labor supply in the core, causing downward pressure on wages and prices. This stimulates an increase in employment and in turn in the GDP, which is greater in the core than the periphery. Furthermore, in the presence of labor mobility, the larger gains derived from a fall in prices are fully translated into higher real wages producing as a consequence greater internal consumption in the core.

These results are not surprising in light of the underlying theoretical framework of the mobile labor framework (Krugman, 1991). When mobile workers migrate between regions, they earn and spend their income in the destination region, where the final demand increases, while it decreases in the origin region. An increase in the market size (owing to more workers and consumers) tends to increase firm profits, and attract firms to regions with an improved accessibility vis-à-vis other regions. This in turn triggers two further effects in RHOMOLO. On the one hand, a concentration of firms makes real wages in regions with a relatively more improved accessibility more attractive than the same wage in other regions, because of lower weighted average transportation costs stimulating further migration. On the other hand, the concentration of firms in regions with an improved accessibility increases the competition for local inputs and customers, while it reduces the competition in other regions.

Our simulation results confirm that agglomeration forces are stronger than dispersion forces in the mobile labor setting, because the labor migration triggers the agglomeration of workers and firms, resulting in more mobile workers and firms to co-locate in core regions. Firms’ migration towards the core in the presence of labor mobility offsets the relocation incentives of firms in the periphery, observed in the full model, therefore reducing the dispersion of economic activities.

### 3.4 Capital mobility

Next, we turn to analyze the effect of capital mobility on the location choices of economic agents, adopting the same differences-in-differences approach in the comparison between the full model and the model specification without capital mobility. To do so, we simulate once again a permanent and costless reduction in transportation costs of 0.2 percentage points in the two model settings, which display differences in the adjustment of investments. In fact, whereas in the full model investments are sensitive to the gap between the rate of return to capital and the overall EU replacement cost of capital,
when capital mobility is absent, region-specific investments are simply driven by the distance between the regional rate of return to capital and the corresponding replacement cost of capital.

On the left-hand side of Figure 5, we show core–periphery percentage differences resulting from the reduction in the transportation cost without capital mobility. Both in the short-run and the long-run equilibrium the percentage change differences in the GDP and employment between the core and periphery are positive, implying that the core is again gaining more than the periphery. However, over the whole simulation horizon, the gap between the core and periphery tends to become smaller in terms of GDP changes, while the gap in employment stabilizes rather quickly. It is worth noticing that for the first 15 periods core–periphery differences in GDP are higher than those in employment. Afterwards, the employment gap becomes larger than the GDP gap. This means that, as the regional economy is expanding and approaching a new steady state, the accumulation of capital is higher in the periphery than in the core. A greater capital expansion in the periphery is supported by competitiveness effects associated to the export growth that originates from favorable price changes. In this respect, we can see that the core–periphery differences in prices tend to increase over time as depicted in Figure 4. Even though economic activities are expanding more in the core than the periphery, over the simulation horizon, by and large the lack of capital mobility constraints the core region to expand further at the advantage of the periphery.

This is indeed the effect one would expect in the absence of the capital mobility. In this particular case, capital is prevented from moving from the periphery to the core, where the capital profitability is higher. Constraints on capital mobility are then reflected in negative core–periphery differences of the number of firms. Preventing capital to move between regions generates higher marginal costs in the core, by causing the fixed costs of setting up new firms to rise more than in the periphery.

The difference in difference approach reveals that capital mobility can be confirmed to be a force of agglomeration both in the short and long run, as shown on the right-hand side of Figure 5, as far as the GDP and employment are concerned. We can see that the core–periphery differences between the full model and the model without capital mobility generate a long-run GDP difference of around 0.14 percent, while the labor demand settles to around 0.06 percent in the same time frame. This means that the core–periphery gap between the two model configurations is substantially driven by capital movement. Therefore, differences between the full model and the model specification without capital mobility suggest that capital movements make core regions better off in terms of GDP, employment and competitiveness, even if the number of firms increase faster in the periphery. When capital mobility is activated, the core–periphery gap tends to increase from the short to the long run. On the contrary, the absence of capital mobility generates certain dispersion forces toward the periphery, therefore slightly shrinking the potential core–periphery gap.

By comparing the right-hand side of Figures 4 and 5, we can also see that in the long run capital mobility is able to generate greater agglomeration effects than labor mobility in terms of GDP and employment. The core–periphery gap between the full model and the model where capital mobility is

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**FIGURE 5** Simulated impacts of a reduction of 0.2 percentage points in transportation costs in all EU regions (a), and differences between the core and periphery in the full model and in the model without capital mobility. (a) Differences between core and periphery; (b) Differences in differences.
absent generates GDP differences of 0.14 percent while differences between the full model and the model without labor mobility are much lower at around 0.025 percent.

3.5 | Vertical linkages

To identify the role of vertical linkages, we alter the settings of RHOMOLO by comparing the full model configuration with one where only primary factors are allowed to adjust, while the demand for intermediate inputs is kept fixed at the base-year level. In this way, the effects of vertical linkages are deactivated, and any multiplier effect arising from an increase in the consumption of intermediate inputs is fully removed. As above, we perform numerical simulations of a homogeneous reduction in transportation costs. Contrary to the case of labor mobility and the capital mobility analyzed above, when vertical linkages are turned off, the spatial impact is expected to be significantly lower.

Whereas the location mechanisms analyzed above would be only affecting model adjustment paths and the spatial distribution of impacts while maintaining the overall impact at the EU level unchanged, constraints in the operation of vertical linkages curb the expansionary effect of transport infrastructure improvements. This is because intermediate inputs comprise a significant share in the total production for most of the EU economies and, by turning off vertical linkages, we remove an important channel of adjustment of the productive process owing to lower input prices. Hence, the capacity constraints generated by the lack of vertical linkages prevent the EU economy to take the full advantage of the intrinsic competitiveness effects arising from the reduction in transportation costs.

On the left-hand side of Figure 6 we plot core–periphery differences for the usual set of variables. Our results suggest that the core is generally gaining more than the periphery as far as the GDP, employment and the number of firms are concerned. However, we observe greater competitiveness effects in the periphery than in the core. This means that, although prices of goods and services are higher in the core, the absence of vertical linkages still operate in a manner to favor centrally located regions.

Looking at the core–periphery differences between the full model results and the results without vertical linkages displayed on the right-hand side of Figure 6, we register that the presence of vertical linkages favors the core as opposed to the periphery only in terms of the GDP. In contrast, workers and firms tend to concentrate relatively more in the periphery. By and large, when vertical linkages are deactivated, there is a lower incentive to invest in centrally located regions, consequently firms move to the periphery, which increases the labor and capital demand. This is the main reason why the employment curve in the differences-in-differences chart is negative. Furthermore, firms located in the periphery source their fixed level of intermediates at a lower price and grow more than in core regions, because they use a lower share of the value added in production and more imported intermediate inputs vis-à-vis core regions.
4.1 Summing up results

It is intrinsically difficult to separate out the sources of agglomeration and dispersion in large scale multi-region, multi-factor, and multi-sector NEG models such as RHOMOLO, and furthermore, the choice of the variable that could best measure the agglomeration and dispersions effects is not always intuitive. In our experiments, we have seen cases where a particular NEG feature acts as a source of agglomeration in terms of GDP but at the same time generates dispersion in terms of workers or the number of firms. To better understand these complex relationships, in Figure 7 we summarize the simulated core–periphery patterns as differences between the three alternative model specifications analyzed in previous sections.

The results reported in Figure 7 suggest that all three location mechanisms have been identified as a source of agglomeration in terms of GDP and competitiveness. However when workers and the number of firms are considered, contrasting results arise. For instance, the differences-in-differences approach suggests that vertical linkages can foster dispersion in terms of labor demand and number of firms. Another observation that can be made by comparing the effects of the three spatial model features is that the relative importance in terms of agglomeration patterns may vary over time. For example, as far as the GDP is concerned, capital mobility outperforms labor mobility and vertical linkages in the long run, but in the short run vertical linkages appear to foster more agglomeration and to determine a steeper price fall (and increase in competitiveness) in core regions. Capital mobility appears to be more important than labor mobility in fostering agglomeration measured by all key economic variables highlighted in this exercise, in both the short and long run.
5 | ROBUSTNESS CHECKS AND SENSITIVITY ANALYSIS

5.1 | Robustness checks

In the analysis described above we have performed a homogenous reduction in transportation costs in all EU regions of 0.2 percentage points. However, in order to check the robustness of our results to the inter-regional transportation costs present in the base-year values, we run again the four model variations simulating a proportional shock: 1 percent reduction in transportation costs for all EU regions. In this case, the centrally located regions, with a lower initial level of transportation costs, will receive a smaller accessibility boost compared with the peripheral regions.

In Figure 8 we reproduce the difference in the core–periphery gap in the GDP and the number of firms for the homogenous and proportional integration shocks. We can see that only capital mobility is a source of agglomerations in both integration scenarios, with the impact on agglomeration even higher in the case of a proportional shock.

As for labor mobility, the impacts on spatial patterns of economic outcomes seem to be more sensitive to the type of shock simulated. In fact, comparing Figure 8 (a) and (b), we notice that, when the shock is proportional to the initial level of accessibility, labor mobility appears to foster dispersion, both in terms of GDP and number of firms.

Turning to vertical linkages, we can notice that moving from a homogeneous to a proportional accessibility improvement would have opposite implications on the spatial concentration of GDP and number of firms. Whereas the GDP impacts become less concentrated in the core with a proportional shock, the opposite is true for the number of firms.

The reversal in the spatial properties of model features in the case of a small change in the design of the shocks highlights the complexity of model interactions, the difficulty of making nonnumerical predictions, and the complexity of spatial implications of a policy intervention.

Even though the results differ depending on the type of integration shock, however, we deem the homogeneous shock less distortive to interpret the properties of model features for the current analysis. Thus, we consider the results of the previous section as the most accurate to describe the spatial implication of the RHOMOLO model features used in this analysis, and better understanding the complexity of spatial implications of policy interventions.

5.2 | Sensitivity analysis

In this section we present the results of the sensitivity analysis associated with a homogenous reduction in transportation costs. We lower and increase our default elasticities by 20 percent, respectively, and compare the effects with the default model assumptions. The main purpose of this exercise is to evaluate the extent to which changes in the numerical values of model parameters could alter the way the three model features affect location patterns, when the integration between regional economies takes place. The results are reported in Figure 9.

The elasticities subject to modifications are those described in Section 3, with the exception of trade elasticities. The change in trade elasticities modifies the Lerner index and thus firm mark-ups in each region. Given that fixed costs are calibrated and not exogenously determined, variations in the mark-up should result in new sets of fixed costs and, in turn, in new estimates of value added from which fixed costs are to be withdrawn. Thus, in order to keep the mark-up prices and the calibrated fixed costs at the same level as default assumptions, we opt to keep trade elasticities unchanged in the sensitivity analysis exercise.

By inspecting Figure 9, we notice that, by lowering the elasticities of substitution in RHOMOLO, the spatial implications of the three spatial model features analyzed in this study do not change
FIGURE 8  Robustness check. Simulated impacts of a homogeneous reduction of 0.2 percentage points in the transportation costs in all EU regions and a proportional 1% reduction in transportation costs on the GDP and the number of firms. Differences between the core and periphery in the full model and in the three model variations. (a) GDP, diff-in-diff, labor mobility; (b) GDP, diff-in-diff, capital mobility; (c) GDP, diff-in-diff, vertical linkages; (d) Firms, diff-in-diff, labor mobility; (e) Firms, diff-in-diff, capital mobility; (f) Firms, diff-in-diff, vertical linkages
**FIGURE 9** Sensitivity analysis. Simulated impacts of a reduction of 0.2 percentage points in the transportation costs in all EU regions and different levels of model elasticities (±20%) on differences between the core and periphery in the full model and in the three model variations. (a) GDP, diff-in-diff, labor mobility; (b) GDP, diff-in-diff, capital mobility; (c) GDP, diff-in-diff, vertical linkages; (d) Firms, diff-in-diff, labor mobility; (e) Firms, diff-in-diff, capital mobility; (f) Firms, diff-in-diff, vertical linkages.
substantially, with the only exception being vertical linkages, which are associated with more agglomeration of the GDP and dispersion of firms for low levels of elasticities.

6 | CONCLUSIONS

Modeling space in a micro-founded general equilibrium framework is a challenging task, particularly if the focus is on system-wide impacts at the subnational level. Because of the heterogeneity of regional economies and asymmetries in linkages between them, the overall properties and implications of different modeling choices are difficult to predict a priori and study analytically. In this paper we have therefore analyzed numerically the properties associated with alternative specifications focusing in particular on the spatial patterns of economic outcomes. Specifically, the model features studied in this paper include labor mobility, capital mobility and vertical linkages, whose role in shaping the economic space in the short and long run has been singled out by activating and deactivating each of the features, and performing the same set of simulations.

Illustrative simulations with the RHOMOLO model suggest that, in the case of a homogeneous shock, labor and capital mobility magnify agglomeration patterns in terms of both GDP and number of firms. As for vertical linkages, their presence favors the GDP agglomeration, but it is associated with dispersion in terms of number of firms. We look at these results through the lens of well documented effects in the NEG literature—market access effect, the price index effect and the market crowding effect—which can be pushing regional outcomes in different directions. They all contribute to a different extent in shaping spatial outcomes when different NEG features of the model are activated, interacting with exogenous model parameters and the empirical calibration.

Our simulation results also suggest that a small change in the design of the policy intervention may revert the spatial outcomes in terms of GDP, population, and firms. These results highlight the complexity of inter-regional interactions, the difficulty of making nonnumerical predictions, and the complexity of spatial implications of a policy intervention.

Turning to limitations of our analysis, one issue associated with the use of a dynamic spatial general equilibrium approach is that almost all model-related data are used for calibration, whereas very little data is left for testing the validity of the model (Broecker and Korzhenevych, 2013). The approach we adopt in this study is rather deterministic; in contrast to theoretical \(2 \times 2 \times 2\) models, errors in model specifications and parameterization can co-determine spatial outcomes. Hence, the empirical validation of the RHOMOLO model is still an open issue to be addressed in future. Another limitation of the model is that the dynamic structure adopted is rather simple and does not allow to evaluate anticipated effects.

Interestingly, the RHOMOLO model shows that the spatial features of the EU regions are such that the system does not reach corner solutions in the spatial equilibrium, as is sometimes the case in theoretical NEG models with symmetric varieties and agglomeration forces. Although our results do not suggest a presence of multiple equilibria, we acknowledge that more research has to be devoted to the analysis of the uniqueness and stability of the spatial equilibrium in empirical spatial computable general equilibrium models with multiple asymmetric regions, sectors, factors, and multiple endogenous channels of adjustment. This is a promising avenue for the future research.

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NOTES
1 For instance, the predictions derived in analytical two-region models can be different from those obtained from a multi-country model, as shown in Behrens, Lamorgese, Ottaviano, and Tabuchi (2009).
2 See Brandsma et al. (2015) for a formal description of the key mechanisms in the RHOMOLO model.
3 More information can be found at http://energy.jrc.ec.europa.eu/transtools/
4 A detailed description of migration in RHOMOLO can be found in Brandsma et al. (2014).
5 Krugman (1991) proposed a framework, where the mobility of the labor force brings the agglomeration/dispersion about. In addition to the market access effect and market crowding effect in the mobile labor framework, the cost-of-living effect also plays an important role in location decisions of firms and workers.
6 Details on data and calibration can be found in Mercenier et al. (2016).
7 The transportation cost shock of 0.2 percentage points is chosen arbitrarily for illustrative purposes of endogenous agglomeration and dispersion mechanisms. However, the qualitative results of simulations would not change if the shock is lower or higher by an order of magnitude.
8 This result is consistent with the work of Ottaviano and Robert-Nicoud (2006) according to which the presence of vertical linkages should generally benefit centrally located regions as well as peripheral regions.

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