本著作獲得國立彰化師範大學 **109** 年度教師研究成果獎勵

New Economic Geography*†

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* This is a draft of an article that has been published by Oxford University Press in the *Oxford Research Encyclopedia of Economics and Finance* edited by Jonathan H. Hamilton (Editor in Chief) in 2020. (https://doi.org/10.1093/acrefore/9780190625979.013.338)

† Please use the following format to cite the article: Chen, C., & Peng, S. (2020, October 27). New economic geography. In *Oxford Research Encyclopedia of Economics and Finance*. Oxford University Press. doi: https://doi.org/10.1093/acrefore/9780190625979.013.338

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Summary

For research attempting to investigate why economic activities are distributed unevenly across geographic space, new economic geography (NEG) provides a general equilibrium-based and microfounded approach to modeling a spatial economy characterized by a large variety of economic agglomerations. NEG emphasizes how agglomeration (centripetal) and dispersion (centrifugal) forces interact to generate observed spatial configurations and uneven distributions of economic activity. However, numerous economic geographers prefer to refer to the term *new economic geographies* as vigorous and diversified academic outputs that are inspired by the institutional-cultural turn of economic geography. Accordingly, the term *geographical economics* has been suggested as an alternative to NEG.

Approaches for modeling a spatial economy through the use of a general equilibrium framework have not only rendered existing concepts amenable to empirical scrutiny and policy analysis but also drawn economic geography and location theories from the periphery to the center of mainstream economic theory. Reduced-form empirical studies have attempted to test certain implications of NEG. However, due to NEG's simplified geographic settings, the developed NEG models cannot be easily applied to observed data. The recent development of quantitative spatial models based on the mechanisms formalized by previous NEG theories has been a breakthrough in building an empirically relevant framework for implementing counterfactual policy exercises. If quantitative spatial models can connect with observed data in an empirically meaningful manner, they can enable the decomposition of key theoretical mechanisms and afford specificity in the evaluation of the general equilibrium effects of policy interventions in particular settings.

Several decades since its proposal, NEG has been criticized for its parsimonious assumptions about the economy across space and time. Therefore, existing challenges still require theoretical and quantitative models on new microfoundations pertaining to the interactions between economic agents across geographical space and the relationship between geography and economic development.

Keywords

agglomeration, core–periphery, dispersion, trade costs, increasing returns to scale, technological externalities, labor mobility, monopolistic competition, policy exercise, quantitative spatial models

What Is the "New Economic Geography"?

The defining problem of the new economic geography (NEG) is how to explain the formation of numerous economic agglomerations (concentration) in geographical space (Fujita & Krugman, 2004; Fujita & Thisse, 2009). Human economic activities are typically distributed unevenly across countries and regions. Some regions are core centers where households and firms cluster at higher densities, whereas other regions comprise the surrounding peripheries where households and firms cluster at lower densities. Therefore, wealth inequality prevails across countries and regions. Questions related to how these uneven distributions emerge and the factors that cause this unevenness and inequality remain unanswered. To explain why a specific place becomes the center of an industrial cluster, traditional neoclassical theory emphasizes "first-nature geography" (i.e., the physical geography of climate, topology, and resource endowments). By contrast, NEG emphasizes the role of "second-nature geography" (i.e., the location of economic agents relative to one another; Krugman, 1993).

Considering an initial situation in which space is homogeneous in terms of endowment and in which production activities are equally distributed at all sites, proponents of NEG have attempted to identify the forces through which a small asymmetric shock across sites engenders a considerable permanent imbalance in the distribution of economic activity. First-nature geography is relevant for explaining the emergence of civilization in a few specific locations. However, first-nature geography cannot be the main explanatory factor for second-nature geography, which involves extensive agglomerations of activities and substantial trade flows (Fujita & Thisse, 2002, 2013; Ottaviano & Thisse, 2004). Moreover, addressing questions of how the spatial economy responds to exogenous shocks—such as technological changes, globalization, and policy measures—is difficult without a precise understanding of the interplay between the driving economic forces.

The goal of NEG is to devise a theoretical approach to understanding how the geographic structure of an economy is shaped by the tension between agglomeration (a centripetal force) and dispersion (a centrifugal force). Moreover, these forces should be explained in terms of agents' fundamental microdecisions. The key task of this approach is to specify the sources of increasing returns driven by spatial concentration and thus determine how and when the returns may change. Accordingly, the economy's behavioral changes with the returns can be explored. The studies conducted by Fujita (1988), Krugman (1991a, 1991b), and Venables (1996) are considered the foundation of NEG. Partially motivated by the integration of national economies within trading blocks in the 1990s, such as the EU-15 or the North American Free Trade Agreement, Krugman and several other trade theorists turned their attention to spatial problems. By adopting concepts from industrial organizations and new trade theory (see Helpman & Krugman, 1985), these authors employed general equilibrium models that involve the concepts of monopolistic competition and increasing returns to scale to analyze various spatial agglomerations. The primary results obtained by the same authors after a decade of research have been presented in *The Spatial Economy: Cities, Regions, and International Trade* (Fujita, Krugman, & Venables, 1999).

Possibly because of its provocative name, NEG has stimulated debate about the suitability of the terms *economic geography* and *geographical economics*. Some economic geographers have criticized NEG for intellectual imperialism (Mäki & Marchionni, 2011; Martin & Sunley, 2011). They prefer to refer to "new economic geographies" as the vigorous and diversified academic outputs inspired by the institutional-cultural turn of economic geography (see Yeung, 2003); therefore, Martin and Sunley (1996) suggested that NEG should be classified as "geographic economics" and should be regarded as a "new geographical turn" in economics. To encourage dialogue across disciplines, the *Journal of Economic Geography* was launched in 2000 under dual editorship and dual board systems.

Contribution and Components of NEG

The novelty of NEG has been questioned by geographers and regional scientists (Isserman, 1996; Martin, 1999). For example, von Thünen (1826/1966) argued that economies of scale at the individual firm level are essential for industrial agglomeration (Fujita & Krugman, 2004). Early location theorists, including Alonso (1964), Launhardt (1885/1993), Lösch (1940/1954), and Hoover (1948), have noted that the trade-off between increasing returns and transportation costs is a fundamental mechanism for explaining geographic economics (Fujita & Thisse, 2002, 2013). Moreover, Henderson (1974), Ogawa and Fujita (1980), and Papageorgiou and Thisse (1985) have observed NEG-related concepts concerning economies of scale and externalities. Despite these early outstanding contributions, economic geography and location theory have remained on the periphery of mainstream economic theories.

This peripherality is related to the difficulty of using the competitive paradigm to explain the formation of economic agglomerations (Ottaviano & Thisse, 2004). Because economies of scale are inconsistent with perfect competition, modeling spatial agglomerations of economic activities through a general equilibrium approach is difficult. However, from a methodological perspective, a general equilibrium-based approach is necessary because it clarifies the source and the destination of each payment as well as requires that all payments are balanced and that all markets clear in the economic system. Such an approach explains both concentration and dispersion forces: that is, why some agents (consumers or firms) cluster and why other agents (consumers or firms) do not. Moreover, if the trade or transportation costs should be considered in a general equilibrium model, the inputs used and income generated by the transportation industry must be part of the integrated economic picture. This further complicates the model.

NEG can be considered an attempt to overcome the aforementioned theoretical challenge. As stated by Fujita et al. (1999), modeling strategies in NEG are based on the following elements: Dixit-Stiglitz, icebergs, evolution, and the computer. The first two elements—adopted from industrial organization and new trade theories—constitute the foundation of NEG models. These strategic simplifications enable researchers to overcome technical problems and successfully narrate general equilibrium stories about the entire spatial economy.

This breakthrough has led to the inclusion of geography in mainstream economic theory. Although NEG has roots in new trade theory, it differs from its predecessor in terms of allowing the interregional mobility of production factors. The distribution of capital and labor across space determines the interregional distribution of economic activities and the intensity of spatial inequality. Thus, NEG can provide a detailed explanation of spatial inequalities as an equilibrium-based outcome. Moreover, new growth theories involve a modeling device similar to that in new trade theories; hence, NEG also has strong links to new growth theories in which cities are regarded as key growth engines. Accordingly, on the basis of its rigorous microeconomic foundations that demonstrate how and why economic activities are distributed in a standard format, NEG has contributed to the development of a unified framework that integrates industrial structure, trade, inequality, and growth at various spatial levels. Ottaviano and Thisse (2005) suggested that NEG's most crucial contribution is that "it has made already existing ideas more amenable to empirical scrutiny and policy analysis."

As mentioned, location theorists like von Thünen (1826/1966) have identified increasing returns or indivisibilities at the individual producer level; therefore, ensuring that the economy does not degenerate into "backyard capitalism" is imperative (Starrett, 1978). Backyard capitalism is explained as follows: For given transportation costs and dispersed consumers, firms choose to produce a small number of products in all locations if they reveal constant or diminishing returns. Increasing returns, in turn, cause the market structure to be one of imperfect competition. To solve the theoretical problems encountered in the incorporation of economies of scale and perfect competition in a general equilibrium framework, Dixit and Stiglitz (1977) introduced the constant elasticity of substitution (CES) model of Chamberlinian monopolistic competition. The monopolistic competition specification introduced by the Dixit-Stiglitz model (1977) and its international trade extensions (Krugman, 1980) constitute the basic framework used by NEG theorists. In monopolistic competition, every firm has a monopoly on its own unique product; nevertheless, other firms can introduce products that are (imperfect) substitutes for that product. Moreover, firms are assumed to act in a completely unilateral manner; specifically, they never attempt to organize cartels or even tacitly collude on prices. Accordingly, an economy with increasing returns can be depicted without confronting complex problems posed by a realistic oligopoly.

The other core component of NEG is trade costs or transportation costs, which constitute a broadly defined aspect; location affects this component. Instead of describing an industry that produces transportation services, Samuelson (1952) modeled transportation costs using an "iceberg" format. In this format, certain parts of a product are assumed to "melt" during the transit process. This simplification eliminates firms' incentive to absorb transportation costs by charging a lower free-on-board price for exports than for domestic sales. Thus, most scholars developing NEG frameworks, such as Fujita and Krugman (1995, 2004), Fujita et al. (1999), Fujita and Thisse (2002, 2013), and Krugman (1991a, 1991b, 1993, 1997), have specified trade costs as an exogenous variable that is determined by iceberg costs. However, Mai, Peng, and Tabuchi (2008) treated some parts of trade costs as a tariff that is endogenously determined by the government.

Theoretical Models

NEG models established through the aforementioned modeling strategies identify agglomeration forces that induce agents to concentrate and dispersion forces that push agents to scatter. These models can be divided into three classes, namely the core–periphery (CP), vertical linkage, and urban system models, as summarized by Fujita et al. (1999), who described the basic mechanisms that shape spatial economic structures. Numerous variants of the CP model have also been developed to address the various forces at work (Baldwin, Forslid, Martin, Ottaviano, & Robert-Nicoud, 2003).

- ***Core and Periphery***

Krugman's (1991a) seminal CP model illustrates how the interactions between firm-level scale economies, transportation costs, and interregional factor mobility affect the configuration of a spatial economy. An economy has two identical regions, two production sectors (agriculture and manufacturing), and two labor types (immobile farmers and interregional mobile workers). The agriculture sector employs farmers' labor as an input to produce a homogeneous good under constant returns. The manufacturing sector has numerous firms; these firms have identical production technologies, produce a distinct horizontally differentiated variety of goods in a single location under increasing returns to scale, and engage in monopolistic competition. Although an agricultural good can be traded across regions without cost, the interregional trade of manufactured goods involves an iceberg-form transportation cost. By using mobile workers' labor as an input, manufacturing firms make location-related decisions to maximize profits. Workers (i.e., a type of consumer) maximize their utility (i.e., real wages) by choosing their residential (and also working) location. Additionally, market entry and exit occur until profits are bid down to zero.

Finally, the centripetal force pulling economic activities to a region is generated through a circular causation of forward linkages (i.e., incentives gained by mobile workers when they live near the firms producing differentiated manufactured goods) and backward linkages (i.e., incentives gained by manufacturers when they concentrate on relatively large markets). The backward linkages are engendered by the home-market effect (Krugman, 1980). However, the centrifugal force pushing economic activities away from a region is generated by immobile farmers because they must consume both types of goods. Centripetal force dominates centrifugal force when (a) the transportation costs for manufacturers are sufficiently low, (b) products are sufficiently differentiated, and (c) expenditures incurred by manufacturers are sufficiently high. When centripetal force is stronger than centrifugal force, a CP pattern emerges. Specifically, all manufacturing activities are concentrated in one region, whereas the other region retains only the agricultural sector.

Because the CP model rules out first-nature geography by assuming that locations are symmetric (i.e., identical ex ante), it cannot determine which region becomes the core and which becomes the periphery. Consequently, for a given range of parameter values, the distribution of economic activities is not determined by locational fundamentals only; instead, it exhibits multiple equilibria and locational "lock-in" hysteresis (or path dependence).

The modified CP model proposed by Forslid and Ottaviano (2003) specifies skilled labor as a fixed production input and immobile workers' labor as a variable input that can also be used in the agricultural sector; in addition, skilled labor is mobile across regions. The alternative CP model presented by Martin and Rogers (1995) assumes that mobile capital is a fixed production input and that immobile labor is a variable input. Both of these variant CP models are solvable analytically and have typically been called the "footloose entrepreneur model" and "footloose capital model," respectively.

The full agglomeration specified in the CP model is rare in reality. Congestion is a critical dispersion force, particularly in major cities. Helpman (1998) and Tabuchi (1998) have explored the effects of land use for urban housing and commuting costs. In their models, land is the immobile production factor and serves as the dispersion force. By examining the tension between market access and competition in the residential land market, Helpman (1998) revealed that low transport costs imply the dispersion of economic activities and that high transport costs lead to agglomeration. This implication is precisely opposite to that of the CP model. In Tabuchi's (1998) two-region model, the strength of the agglomeration force relative to that of the dispersion force reveals an inverse U-shaped pattern with decreased transportation costs. In particular, when the transportation costs of manufactured goods become sufficiently low, the industry again disperses to the periphery to avoid the relatively high rental costs of land at the core.

- ***Vertical Linkage***

The interregional mobility of labor or capital is the primary aspect of the CP model. However, empirical evidence reveals that agglomeration can exist even in the absence of labor mobility (Ottaviano & Thisse, 2004). Furthermore, numerous cities specialize in a narrow range of industries. Whether NEG models reveal information on such geographical concentrations in particular industries is a critical research question. The key to explaining this question is to assume the existence of input–output linkages in production, in which upstream sectors produce intermediate inputs for downstream sectors and both upstream and downstream producers are subject to increasing returns and transportation costs. In such situations, backward linkages (i.e., demand from downstream firms to their suppliers) and forward linkages (i.e., supply from intermediate producers to downstream activities) cause upstream and downstream producers to cluster in a single location, as reported by Venables (1996).

This insight can be either elaborated upon or simplified. To elaborate on it, as in the study by Puga and Venables (1996), a more realistic input–output structure can be considered, and researchers can discuss which characteristics of the input–output matrix lead to the formation of industrial clusters. Alternatively, the assumption that all manufactured goods are consumed and used as inputs to produce other goods, as demonstrated by Krugman and Venables (1995a), yields an isomorphic version of the CP model. This model highlights the essential similarities of the reasons why workers and firms are concentrated in particular locations.

- ***Urban System***

Although the aforementioned two-region models are useful for proposing insights into the trade-off between agglomeration and dispersion forces, they are excessively abstract for real-world application. Researchers should consider how these insights can be extended to a multiregional world and how deadlock can be avoided when numerous equilibria conceal meaningful insights. Fujita and Krugman (1995), Fujita and Mori (1997), and Fujita et al. (1999) have described space as a real line or a circumference along which land is distributed uniformly. All workers in the economy are assumed to be identical and to be free to select their location and occupation. Agricultural goods are produced using both land and labor. Finally, transportation costs are assumed to be positive for both agricultural and industrial goods. In this type of model, the only immobile factor is agricultural land, which is the source of the centrifugal force.

The assumption of location as a continuum of points along a line or a circumference yields three pieces of insight. First, equilibrium for a city occurs as a manufacturing core that is surrounded by an agricultural periphery. How the size and number of manufacturing centers change with trade costs and population size has been investigated. Second, this growth experiment involves the emergence of new cities. Finally, the relative strengths of the centripetal and centrifugal forces are calculated to determine the constant level of the size of the cities. This outcome justifies the central place theory presented by Lösch (1940/1954). When multiple manufacturing sectors are present with heterogeneous economies of scale or transportation costs, cities evolve to form a hierarchical structure that is similar to that proposed by Christaller (1933/1966). This approach of examining urban hierarchy is related to traditions in location theory and economic geography. In addition, this line of study illustrates that first-nature geography always has a catalytic role in a location's transformation into an agglomeration core. However, after the core is established, its selfreinforcement becomes the dominant concentration force, but its initial location advantage is less crucial.

- ***Nonhomothetic Preferences***

Most studies on NEG have employed the CES preferences in the Dixit-Stiglitz model (1977) to facilitate the modeling process. However, this specific functional form exhibits questionable features, including constant markups of firms and extreme consumer love of variety. Thus, an alternative set of functional forms and technological assumptions must be devised to investigate the robustness of the results established by the CES models. To ensure that elasticities of demand vary with prices, Ottaviano, Tabuchi, and Thisse (2002) presented a quadratic quasilinear utility and revisited CP agglomeration in an economy in which price competition matters. Peng, Thisse, and Wang (2006) applied the quadratic quasilinear functional form proposed by Ottaviano et al. (2002) to the production side to examine the interactions between economic integration and employment agglomeration in a neoclassical growth, middle-product economy.

Studies have explored other variable elasticity of substitution (VES) preferences, in addition to the quadratic quasilinear setup. Behrens and Murata (2007) proposed the constant absolute risk aversion (CARA) utility, which captures price competition effects. Continuing Krugman's (1979) work, Zhelobodko, Kokovin, Parenti, and Thisse (2012) proposed a model of monopolistic competition with additive separable preferences and variable markups; they revealed that whether a market generates procompetitive effects depends on whether the relative love for variety increases or decreases with individual consumption. Parenti, Ushchev, and Thisse (2017) proposed a general model of monopolistic competition that encompasses existing models—including those with CES, quadratic, CARA, and trans-log preferences—and is simultaneously flexible enough to consider new demand and competitive features.

The studies on VES preferences have provided considerable insights into the influence of varying firm markups, induced by competition, on agglomeration. The aspects of home-market effects constitute an example. According to Krugman (1980), home-market effects occur in two aspects. In a world comprising two countries, (a) wages are higher in the larger country, and (b) a more-than-proportionate relationship exists between the larger country's share of world production and its share of world demand. The CES model proposed by Takahashi, Takatsuka, and Zeng (2013) revealed these two aspects to be equivalent, and they were determined to be highly robust in a general framework of multiple countries (Zeng & Uchikawa, 2014). However, Chen and Zeng (2018) proved that these two aspects of home-market effects are not equivalent in a framework of general additive separable preferences because of the existence of choke prices in the VES preferences.

- ***Other Sources of Agglomeration Forces***

Marshall (1890/1920) was among the most influential early analysts of agglomeration. He suggested that industrial agglomerations are due to (a) knowledge spillovers, (b) the advantages of thick markets for specialized skills, and (c) the backward and forward linkages associated with large local markets. NEG models consider only the third reason, which is arguably less crucial in practice but is easier to formalize than the other two reasons (Fujita & Krugman, 2004).

Ellison and Glaeser (1997) documented the empirical importance of thick labor markets in agglomeration. Agglomeration economies emerge due to matching externalities, and dense labor markets may enable improving the match between worker skills and firm requirements (Helsley & Strange, 1990). Incentives to acquire skills may be greater when workers have more prospective employers (Matouschek & Robert-Nicoud, 2005). In addition, knowledge spillovers constitute a clustering force. Depending on the firms' proximity to one another, they can learn or copy ideas from one another (Fujita & Thisse, 2002, Chapter 6; Henderson, 1988). Thus, multiregional growth models (Baldwin, Martin, & Ottaviano, 2001; Fujita & Thisse, 2002, Chapter 11; Martin & Ottaviano, 1999) also accommodate a CP spatial configuration of economic activities in a Grossman-Helpman-Romer-type model of endogenous growth.

To review models of urban agglomeration economies, rather than using Marshall's (1890/1920) taxonomy-based approach, Duranton and Puga (2004) distinguished between three theoretical microfoundations in terms of sharing, matching, and learning mechanisms. The sharing mechanisms involve sharing indivisible facilities (Berliant & Wang, 1993), sharing gains from a wide variety of input suppliers that can be sustained by a substantial final goods industry (Fujita & Hamaguchi, 2001), sharing gains from narrow specializations that can be sustained with large-scale production (Becker & Henderson, 2000), and sharing risks (Krugman, 1991b). The matching mechanisms correspond to the fact that agglomeration improves either the expected quality of matching (Helsley & Strange, 1990) or the probability of matching (Lagos, 2000), and that it alleviates delay problems (Matouschek &

Robert-Nicoud, 2005). Finally, the learning mechanisms comprise the generation (Duranton & Puga, 2001), diffusion (Berliant, Peng, & Wang, 2002; Lucas & Rossi-Hansberg, 2002), and accumulation of knowledge (Palivos & Wang, 1996).

Research on the microeconomic foundations of urban agglomeration economies has advanced considerably; this can partially be attributed to advancements in related fields, such as industrial organization, labor economics, and growth theory. However, empirically identifying and separating these mechanisms in the final results would be extremely difficult. Duranton and Puga (2004) suggested that these issues merit considerable attention and that specific predictions are required for the empirical assessment of the importance of each mechanism.

Empirics

Empirical research on the spatial aspects of economic activity has advanced substantially over the decades because of the emergence of new theories, availability of new data, and intense interest in the role of policymakers. Numerous reduced-form empirical studies have tested specific implications of NEG. The development of quantitative spatial models has been a breakthrough in the establishment of an empirically relevant framework for executing counterfactual policy exercises.

- ***Reduced-Form Studies***

Studies have empirically verified some elemental implications of NEG. First, geography is an influencing factor of trade. Anderson and van Wincoop (2004) demonstrated that trade costs are high and distance impedes bilateral trade flows between country pairs. Second, firms in certain sectors are more likely to cluster compared with firms in other sectors. Econometric studies have established that some sectors are more prone to clustering than other sectors, which can be explained by chance or comparative advantage (Dumais, Ellison, & Glaeser, 2002). Third, the wages, population, and land prices are higher in locations with superior market access (Gallup & Sachs, 1999; Hanson, 2005; Head & Mayer, 2011; Redding & Venables, 2004). Fourth, an increase in expenditure on a good should cause more than a proportionate increase in the production of that good; this is a prediction of home-market effects (Costinot, Donaldson, Kyle, & Williams, 2019; Davis & Weinstein, 1999, 2003). Fifth, wages, land prices, productivity, employment, and employment growth are positively correlated with population density (Combes, Duranton, Gobillon, & Roux, 2010; Diamond, 2016; Greenstone, Hornbeck, & Moretti, 2010; Kline & Moretti, 2014; Rosenthal & Strange, 2004, 2008; Rossi-Hansberg, Sarte, & Owens, 2010). Finally, changes in the spatial distribution of economic activity over time are indicative of hysteresis (i.e., path dependence). Hysteresis can be defined as the property that temporary shocks permanently affect the distribution of economic activity (Bleakley & Lin, 2012; Michaels & Rauch, 2016; Redding, Sturm, & Wolf, 2011).

After reviewing the empirical literature on agglomeration, Combes and Gobillon (2015) addressed several crucial econometric issues, including: endogeneity at the local and individual levels; the selection of a productivity measure between wages and total factor productivity; and the roles of spatial scales, firm characteristics, and functional forms. They also discussed attempts to identify and quantify channels that influence agglomeration economies.

- ***Quantitative Spatial Models***

Because of the highly nonlinear nature of agglomeration mechanisms, early NEG models are based on simplified spatial settings, such as a limited number of locations, a circle, or a line. This simplification results in the models' exhibiting inconsistency with the obtained data, and it raises questions about whether the theoretical results derived from the simplified spatial settings are valid in the real world. Because the mapping from a theoretical model to an empirical specification is unclear, empirical studies can be conducted in only a reduced format. The estimated reduced-form coefficients have unclear structural interpretations, implying that the coefficients of these reduced-form relationships may not be invariant to policy intervention. This incurs the prominent "Lucas critique" (Redding & Rossi-Hansberg, 2017).

Several studies over the past decades have presented approaches for analyzing economic activity on a surface with a continuum of locations (Beckmann, 1952; Beckmann & Puu, 1985; Krugman & Venables, 1995b; Mossay & Picard, 2011). However, such approaches increase the dimensionality of the problem and render the corresponding models intractable and unsolvable in the presence of mobility frictions, such as transportation or commuting costs. To address these problems, some frameworks have been developed to analyze geography and trade and to study geography and growth.

- Geography and Trade

Many quantitative spatial models have been developed after the introduction of quantitative models in international trade, such as the Eaton and Kortum (2002) model. Eaton and Kortum (2002) developed a Ricardian model of international trade (i.e., a model based on technological differences) that incorporates the role of geography. They circumvented the aforementioned difficulties by analyzing a finite (although potentially large) number of locations in the presence of random realizations of productivity for a continuum of goods. In this methodology, countries are assumed to have differential access to technology; therefore, efficiency varies across both commodities and countries. In particular, country i's efficiency in producing good j is the realization of a random variable Z_i (drawn independently for each j) from its country-specific probability distribution $F_i(z) = \Pr[Z_i \leq z]$. They sought a probabilistic representation of technologies that can relate trade flows to underlying parameters for an arbitrary number of countries across the continuum of goods; this can thus render their model sufficiently tractable and flexible to incorporate geographical features into a general equilibrium analysis. The model yields a simple gravity expression through which bilateral trade volumes are related to deviations in purchasing power parity and to technological and geographical barriers. These relationships can be used to estimate the parameters required for solving the world trade equilibrium in the model and to examine how the equilibrium changes with various trade policies.

Another approach to addressing the aforementioned problem is to use the traditional Armington model (1969), which has been adopted by Anderson (1979) and Anderson and van Wincoop (2003). Under the assumptions of the Armington model, goods are differentiated by their countries of production. Consumers' love of variety causes them to consume all these country-specific goods, which are inherently imperfect substitutes. Computable general equilibrium models are typically based on this framework. Moreover, by assuming that productivity and amenities depend in part on the local population, Allen and Arkolakis (2014) proved that under certain conditions, for the welfare change responsive to change in trade costs, models of constant returns to scale and transport costs, such as the Arminton model (1969), are isomorphic to those of local increasing returns to scale, such as the Krugman (1991a) model or the Helpman (1998) model.

According to Armington (1969) and Eaton and Kortum (2002), specialization across countries is simply engendered by exogenous local characteristics augmented by endogenous economic mechanisms. Thus, both Armington's (1969) differentiation by location of origin and Eaton and Kortum's (2002) Ricardian technology heterogeneity provide different mechanisms for specialization from that in the love-for-variety preferences and the increasing-returns-to-scale production in NEG models. For a surface with a continuum of locations, these frameworks can accommodate many asymmetric locations that differ in terms of their productivity, amenities, and transport and mobility connections.

For instance, on the basis of the framework presented by Anderson (1979), Anderson and van Wincoop (2003) introduced the concept of multilateral resistance terms and provided a theoretical foundation for the gravity equation to solve the McCallum (1995) border puzzle. Allen and Arkolakis (2014) also used an Armington setup with differentiated varieties to estimate the extent of spatial inequality in U.S. wages caused by variations in trade costs between geographic locations.

Studies conducted on the basis of Eaton and Kortum's (2002) framework include those performed by Ahlfeldt, Redding, Sturm, and Wolf (2015), Donaldson and Hornbeck (2016), Donaldson (2018), Caliendo, Parro, Rossi-Hansberg, and Sarte (2018), and Monte, Redding, and Rossi-Hansberg (2018). Ahlfeldt et al. (2015) developed a quantitative model of an internal city structure to structurally estimate the agglomeration and dispersion forces for 15,937 city blocks in Berlin in 1936, 1986, and 2006 in order to determine exogenous variations in the city's division and reunification. They revealed that a model that contains estimated agglomeration parameters can both qualitatively and quantitatively account for the observed changes in the city structure. Donaldson and Hornbeck (2016) examined the historical influence of railroads on the American economy, with a focus on quantifying railroads' aggregate influence on the agricultural sector in 1890. Donaldson (2018) studied historical data from India to estimate the effects of railroad infrastructure projects on the aggregate welfare (i.e., real income). Caliendo et al. (2018) studied the influence of intersectoral and interregional trade linkages on the propagation of disaggregated productivity variation in the remainder of the U.S. economy. Monte et al. (2018) quantified their model to match observed gravity equation relationships of trade in goods, migration, and commuting for U.S. county-level data. They discovered that empirically observed reductions in commuting costs generate gains in welfare (i.e., change rate of real income) of approximately 3.3%.

- Geography and Growth

How the spatial distribution of economic activity changes as economies develop and grow is a pertinent research question. Empirical evidence reveals that different sectors exhibit very different spatial growth patterns (Desmet & Fafchamps, 2006; Desmet & Rossi-Hansberg, 2009). However, for the interaction between space and the macroeconomy, the aforementioned static frameworks fail to address different spatial growth patterns across industries because they cannot determine the dynamic change in aggregate trade flows over time (Desmet & Rossi-Hansberg, 2010). Moreover, incorporating a continuum of locations into dynamic growth models is complex because agents' decisions depend on the distribution of economic activity over time and space (Desmet & Henderson, 2015). Developing a common framework that incorporates spatial and temporal dimensions is probably the most critical challenge (Krugman, 1997).

Desmet and Rossi-Hansberg (2014) simplified this problem by imposing the following assumptions. First, workers are freely mobile and can relocate at any time. Thus, all workers maximize and obtain an equal utility level in equilibrium. Second, firms invest in innovation despite a perfectly competitive environment. Competition for land use, which is a fixed input, means that firms will bid for the required land until break-even (i.e., zero profit). Third, the ex post benefits from an innovation last for only one period because any possible benefits are diffused and incorporated into land rents. Thus, given that firms' returns on their current choices are not affected by their future allocation paths, they are not required to consider the future equilibrium path when making decisions. These assumptions result in agents' decisions being static, and market clearing is thus conducted sequentially. This model is equitably tractable and has a rich spatial structure that enables its fit with the data. This framework provides implications for the interaction between density and growth at the local level, and it can be used to analyze the interaction between the spatial distribution of economic activity and aggregate growth.

Desmet and Rossi-Hansberg (2014) applied their theoretical framework to study the spatial and aggregate evolution of the U.S. economy over the past half century. In another study, Desmet and Rossi-Hansberg (2015) used a similar setup to quantitatively analyze the influence of global warming on the spatial distribution of economic activities and global welfare. In addition, by representing the global economy at a 1° longitude × 1° latitude geographic resolution, Desmet, Nagy, and Rossi-Hansberg (2018) used this dynamic framework to quantify the gains from relaxing migration restrictions.

- ***Quantitative Spatial Models Versus NEG Models***

While earlier NEG theoretical models aim to identify fundamental explanations for the agglomeration of economic activities, quantitative spatial models focus on combining, measuring, and quantifying existing theoretical mechanisms and identifying the key structural parameters that must be estimated. Both approaches may address the same research problem: for example, the relative importance of physical geography (e.g., mountains and coasts) versus that of economic geography (i.e., the location of agents relative to one another). Quantitative spatial models offer quantitative answers, whereas theoretical NEG models provide qualitative ones.

Empirically relevant quantitative models enable researchers to implement general equilibrium-based counterfactual policy exercises. On the basis of their structural connection with data, quantitative spatial models can be used to address counterfactual questions of interest, such as: If tariffs (or trade costs) are reduced by a free trade agreement signed by some countries, what are the welfare effects among the countries and what is the impact on the inequality among the heterogenous agents within each country? If a transportation project is built at this time, what is the quantitative influence on the country's welfare? Moreover, contrasting predictions of quantitative models with real policy outcomes enables scholars to gauge the empirical importance of different theoretical mechanisms (Redding & Rossi-Hansberg, 2017, p. 24). Redding and Rossi-Hansberg (2017) reviewed the key building blocks and associated assumptions that can be combined in quantitative spatial models to capture different dimensions of the spatial economy. They also discussed the criteria and trade-offs for selecting among such model components.

Future Challenges of NEG

The delicate balance between agglomeration and dispersion forces shapes the geographic distribution of economic activities, which in turn determines the prices of mobile and immobile factors, the magnitude of investments, the aggregate productivity levels of cities and countries, income inequality, and welfare. Exogenous shocks, such as technological changes, globalization, and policy measures, change economic agents' behaviors and in turn the equilibrium between agglomeration and dispersion forces. Accordingly, NEG examines the impacts on economic geography by investigating how economic agents respond to these shocks.

By overcoming the theoretical challenge of the competitive paradigm in economics, pioneers of NEG have brought geography to the forefront of economic thought. Although some geographers have criticized NEG for promoting intellectual imperialism and have questioned some ideas and concepts of NEG as having been borrowed from traditional location theories or economic geography, NEG has rendered these concepts more amenable to empirical scrutiny and policy analysis than they were previously. NEG has contributed to the development of a unified approach for modeling the interactions between economic agents across geographical space.

Krugman (2011) claimed that NEG has already become “middle aged.” This implies that “NEG is at risk of having its middle age turn into a less relevant old age through an excessive love for parsimony and certain kinds of substantive assumptions about the economy over space and time” (Storper, 2011, p. 15). Based on the mechanisms formalized by early NEG theories, recent developments in quantitative spatial models have heralded a breakthrough in building an empirically relevant framework. Quantitative spatial models connect with observed data in an empirically meaningful manner. Thus, these models enable the decomposition of key theoretical mechanisms and afford specificity in the evaluation of the counterfactual effects of policy interventions under particular settings.

Inherently, each quantitative study is conditionally based on an assumed model. Different models imply different estimated structural fundamentals and decompositions. Therefore, research domains exist that require theoretical and quantitative models of new microeconomic foundations pertaining to the interactions between economic agents across geographical space (Desmet & Henderson, 2015).

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