Theories in Regional Economics in the Light of Local Development

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Abstract The spatial dimensions of economics are discussed in the sub-field of Regional Economics. The theories formalize a wide range of issues on a local level. Typical research topics, for instance, are the location choice of firms or workers, economic divergence and convergence of regions, agglomeration advantages and disadvantages, specialization of cities and regions or the importance of knowledge spillovers. This chapter jointly reviews the most important theories on regional economics along with empirical evidence. It aims at identifying factors that important for understanding mechanism of local development along with interregional exchange. As a specific case, the chapter addresses the importance of agglomeration (dis)advantages in developing countries. In general, a deeper understanding of the spatial dimension of economic development can be fruitful for policy guidance on escaping the poverty trap.

Keywords: • regional economics • agglomeration • market potential approach • gravity model • Germany

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1 Two principles of regional economics

Regional economics is a sub-discipline of economics that introduces spatial aspects into economic analysis. It starts with the observation that productive activities and per-capita income are not evenly distributed across space. In this context, two interrelated principles in regional economics come into play: (i) population density matters for economic outcomes, and (ii) distance hinders exchange.

The concentration of population in space matters for economic outcomes because of a number of factors. If people live close together, there are more intensive transactions between them. These transactions could involve the exchange of knowledge through direct communication; i.e., face-to-face contact. Alternatively, it could mean close supplier-customer relationships either for business-to-business activity or producers to consumers. These locational networks allow for better logistics or for more direct feedback from customers to producers that improves the quality of products and services, for example. Moreover, high population density in an agglomeration fosters the development of patterns of specialization, which increases efficiency and therefore reduces cost. If specialization moves along the value chain then typical cluster phenomena arise that strengthen the economic performance of a region (Marshall 1890; Porter 1990; 1998; 2008). Last but not least, the concentration of people in space generates a big domestic market so that producers in that location are faced with high demand and can profit from economies of scale. A further consideration is that agglomeration fosters diversity (Jacobs 1970). The accessible pool of knowledge and competences in a highly populated location is simply much bigger than that of a sparsely populated area in the periphery.

The second principle, “distance matters,” is closely related to the first. Distance can be seen as a hurdle to economic and knowledge exchange. The latter is important in the innovation process. Economic innovation typically occurs in the form of the combination of ideas that are already known about by experts from different specializations. For instance, constructing robots for nursing care assistance requires combining mechanical engineering and medical knowledge. A higher spatial concentration of (highly) skilled people in areas increases the probability that such forms of co-operation will occur.

Overcoming distance typically involves transport costs in one direction or the other. This immediately becomes clear to any supplier who delivers an intermediate product to another firm – for instance, a producer of car seats delivering to an automotive plant. Greater distance simply means higher transport costs. However, there is another cost component that typically declines with growing distance: reliability of delivery. Today’s high-performance logistics require delivery of intermediate products not only “just in time” but also “just in sequence”; i.e., a seat of the right color, material, shape, etc. within the right time window, as required by the production process for an individual car. Such high-performance logistics are almost impossible over long distances because transport streams over such distances are more likely to be disturbed by unforeseen events such as traffic jams, etc.

Imagine for a moment that through a technical revolution all transport costs were reduced to zero. In this case, population density would also become economically irrelevant. For instance, the location of a supplier would be of no significance. If communication takes place regardless of distance, then knowledge spillovers[1] are not attached to a specific place. Some scholars are indeed arguing that advances in communication technology and the internet in particular are leading to a situation in which distance becomes increasingly irrelevant to exchange between humans. The "death of distance" (Cairncross 1997) would imply the "end of geography" (O'Brien 1992). This type of argument is also used by Thomas Friedman (2005) in his bestseller *"The world is flat"*. Friedman argues that obstacles to economic exchange and communication have been reduced significantly since the invention of the internet and the end of political block confrontation in the early 1990s.

There is, however, overwhelming empirical evidence that the "death of distance" hypothesis is wrong. Although pieces of information can easily be exchanged worldwide through the internet, there also exists "sticky knowledge"; i.e. knowledge that is attached to specific locations. The importance of informal face-to-face-contact, oral communication, etc. in the innovation process has been widely documented. Here, we refer to "creative milieus," "something in the air," "the place to be for a specific business," etc. All this points to the fact that the choice of location is in many circumstances not arbitrary, and therefore distance plays an important role. With respect to knowledge, this is well expressed in a well-known sentence by Glaeser *et al.* (1992, 1127): "After all, intellectual breakthroughs must cross hallways and streets more easily than oceans and continents".

The title of an article by Philip McCann (2008) expresses the conviction of the vast majority of regional economists: "Globalization and economic geography: the world is curved, not flat". Numerous authors have discussed the seeming contradiction that in times of globalization local factors have gained in importance. In this context, Michael Enright has coined the notion "glocalisation" as an artificial composite of globalization and localization (Enright 2003). Enright argues that although competition and economic activities are becoming more globalized, the decisive competitive factors are locational.

2 Agglomerations: advantages and disadvantages

A spatial concentration of population with the corresponding economic resources is called an agglomeration. Agglomerations are typically characterized by high population density, and provide specific functions for the surrounding space, known as the periphery. Agglomerations include important cultural and administrative institutions such as universities, research institutes, opera houses and supreme courts. Moreover, central transport infrastructure such as big airports and railway hubs are typically located in agglomerations.

Why do agglomerations exist? There must be economic advantages of the concentration of populations and economic activities. Traditionally, a distinction is made between two advantages of agglomeration: urbanization, and locational advantages. Urbanization advantages arise due to the general concentration of population and production activities in an agglomeration. Knowledge spillovers, cooperation between different actors, common innovation activity, diversity, close customer-supplier relationships, the shared use of general infrastructure or sheer market size are factors that can be alluded to in this context. By contrast, locational advantages refer to advantages created by firms from the same industry becoming concentrated in specific locations. Important reasons for this phenomenon are the shared use of specific infrastructure and the emergence of a specialized workforce or specialized suppliers for that industry. Localization advantages lead to cost savings and higher levels of competitiveness for firms in specific industries.

Urbanization and locational advantages can explain the occurrence of agglomerations in general. However, agglomerations are not like black holes that draw in all economic activity. The reason for this is that counter-forces in the form of disadvantages to agglomeration also exist. In comparison to the periphery, agglomerations are expensive locations where rent and housing costs are significantly higher. Moreover, agglomerations suffer from traffic jams and other forms of congestion. Typically, social problems like criminality are also concentrated in agglomerations. Hence, there are centrifugal and centripetal forces that at least partly compensate each other.

In Paul Krugman's famous centre/periphery model, factors that foster agglomeration can be identified (e.g. Krugman 1993). In this model lower transport costs and the higher fixed costs of setting up production sites favor agglomeration. The same is true of a higher share of mobile workers.

In the following we introduce two workhorse models in regional economics that show how the elements of distance and density can be combined. The first approach, market potential, can be used to compare different locations with respect to the access to the purchasing power of customers. The second approach, the gravity model, aims to explain the transport streams of persons and goods between different locations.

3 The concept of market potential

The concept of market potential dates back to work by Harris (1954). It represents an example of the combination of the two principles that are discussed in the section above. Market potential is a way of describing a location with respect to accessible purchasing power. The question is how much purchasing power is available at which distance from the location. Purchasing power depends on population density and, of course, on disposable income. However, it should be clear that purchasing power within 20 or 30 kilometers' distance is less relevant to a location than the same amount of purchasing power nearby. Hence, distance matters.

The market potential of a location can be defined as the sum of distance-weighted total accessible purchasing power of that location. Hence, it measures the relevant purchasing power at a location and in the neighborhood of that location. The concept implies that distance is a barrier to economic transactions. Consider, for instance, a customer who seeks to acquire a specific piece of furniture. Of course, it is much more convenient for them if a store is close by. The likelihood that this consumer will choose to visit a furniture store 20 or 30 kilometers away is much lower.

The probability that purchases will decline with distance can be described by a so-called distance-deterrence function. A distance-deterrence function simply generates declining weights for purchasing power located further away. One application of the concept of market potential concerns the choice of a location for a department store, for instance. Other things being equal, the location with the highest market potential should be selected.

Formally, the market potential of a location *i* in a region *J* can be defined as

$$M_{i,J} = \sum_{i \in J} PP_j \, f\left(d_{ij,}\right) \qquad (0.1)$$

Here, PP_j is the total purchasing power in location *j*, while d_{ij} is the (economic) distance between locations *i* and *j*, for example, measured in travel time. The purchasing power of a location can be calculated as per capita income multiplied by population. The function $f(d_{ij})$ with $f' < 0$ is the distance deterrence function (DTF). DTF awards the purchasing power of a nearby location a higher weight, and a more distant locations a lower weight.

Several propositions have been made regarding the concrete specification of the DTF. The most prominent ones are:

$$f\left(d_{ij}\right) = d_{ij}^{-\gamma} \qquad (0.2)$$

and,

$$f\left(d_{ij}\right) = \exp(-\gamma d_{ij}) = e^{-\gamma d_{ij}} \qquad (0.3)$$

In these equations, γ is the so-called distance deterrent parameter (equation (0.2) originates in original work by Harris (1954)). One specific drawback of this formulation is that the function goes to infinity as distance goes to zero. By contrast, the formulation in equation (0.3) implies that the value of the function goes to unity if the distance becomes very low. Although the latter supposition seems to be more plausible, many applications in the literature use Harris' original specification.

Figure 1 shows the weight given to purchasing power as a function of distance for alternative specifications of the distance deterrence function. The original DTF of Harris awards high weights to areas in direct proximity to the chosen location and then declines steeply. The exponential function with similar weights for low distance taper off more smoothly. For instance, within a distance of two kilometers the Harris DTF with γ=0.5 gives a weight of 0.75, whereas the exponential function gives a weight of 0.82 (γ=0.1) or 0.90 (γ=0.05). For distances within ten kilometers the weights for the Harris DTF shrink to 0.15 and to 0.37 and 0.58 for the exponential functions. Of course, for a relatively high parameter in the exponential function (γ=0.5), the weights also taper off very quickly.

Consider the example in Table 1 where we calculate the market potential of fictitious "City A" for two alternative exponential distance deterrence functions with a relatively high distance deterrence parameter γ=0.1 (Model 1) and a relatively low parameter γ=0.05 (Model 2), respectively. One can observe in the table that in Model 1, City A exhibits lower market potential than in Model 2. The bulk of the market potential with a high deterrence parameter lies in close proximity to the location that is the subject of observation. In Model 2, the lion's share of market potential is not in City A, but in its neighborhood, especially in the large settlement at 50 kilometers' distance. In general, the contribution of neighboring cities to the market potential of a given location depends on the size, richness and distance of the settlements in the neighborhood. Of course, the smaller the distance deterrence, the greater the weight of more distant neighbors.

Figure 1: Weight given to purchasing power for specific distances for alternative distance deterrence functions

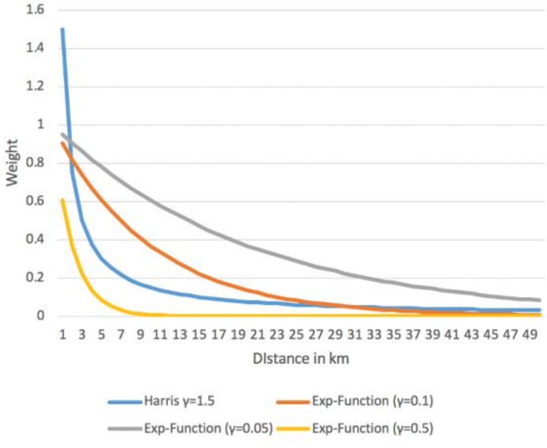


Table 1: Calculation of the market potential of City A for two alternative exponential distance deterrence functions (fictitious example)

City	Population in 1000	Disp. income per capita in 1000€	Purch. power in million €	Distance to City A	Model 1 (γ=0.1) Exp. weight	Model 1 (γ=0.1) Weighted purch. power	Model 2 (γ=0.05) Exp. weight	Model 2 (γ=0.05) Weighted purch. power
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A	75	25	1875	0	1	1875	1	1875
B	50	20	1000	10	0.368	367.9	0.607	606.5
C	10	40	400	25	0.082	32.8	0.287	114.5
D	60	35	2100	30	0.050	104.6	0.223	468.6
E	1000	22	22000	50	0.007	148.2	0.082	1805.9
	Market potential of city A:					2528.5		4870.6

* Notes: Exp. weight calculated as $exp(-\gamma d_{iA})$, where d_{iA} is the distance between City i and City A.

The example shows that the market potential of a location is very sensitive to the distance deterrence parameter. This parameter depends on the nature of the good or service under consideration. To buy an everyday product like a pizza, you would not drive 20 or 50 kilometers under normal circumstances. For a very special cultural event like a concert by your favorite superstar, you certainly would.

The market potential approach has direct applications with respect to border regions. A border is typically a significant obstacle to economic exchange or customer relationships. To investigate the economic effect of a border, imagine the situation of an evenly populated featureless plain and neglect any differences in the transport infrastructure. Then, in an idealized way, the potential market area of location A would be a circle around A with radius *r*. The radius is determined by the distance within which the corresponding weight remains under a certain level, so that the weighted purchasing power of such a location – and of all more distant locations – can be neglected. Of course, the smaller the radius *r*, the greater the distance deterrence parameter is. Now, consider the situation of a region close to a border through which no transactions are possible. It is immediately clear that the potential market area of a border region is smaller than that of a non-border region. As the weighted purchasing power of the area beyond the border has to be subtracted, the market potential of a border region is typically smaller than that of a non-border region. This effect is frequently used as an argument in regional economic policy for subsidizing border regions to equalize economic conditions.

Of course, opening up of borders produces the opposite effect. An interesting application of the market potential approach concerns EU enlargement. In the analysis of this situation, the fact that western regions typically were much wealthier than eastern regions at the time of EU enlargement played a role. This led to an asymmetric effect of this huge quasi-natural experiment on market potential, as Niebuhr (2005) demonstrated in a study depicts the situation. One can see that the bulk of the effect occurred in central Europe, and was more pronounced in former East Germany, the Czech Republic, Slovakia, Hungary and the Baltic states. Because of distance decay, France, Great Britain, Spain and Portugal were not very much affected.

Figure 2: Potential and relevant market area in the case of a border region

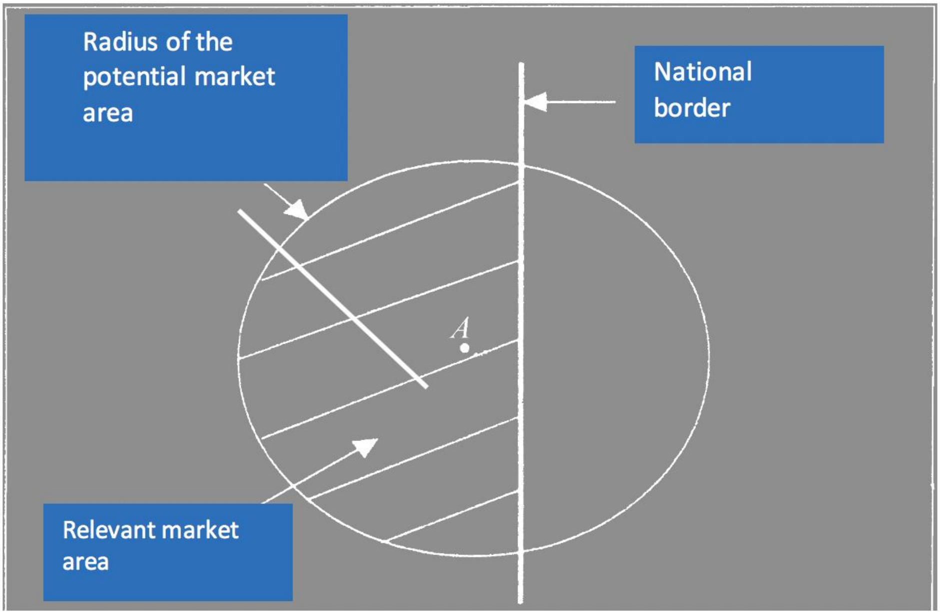
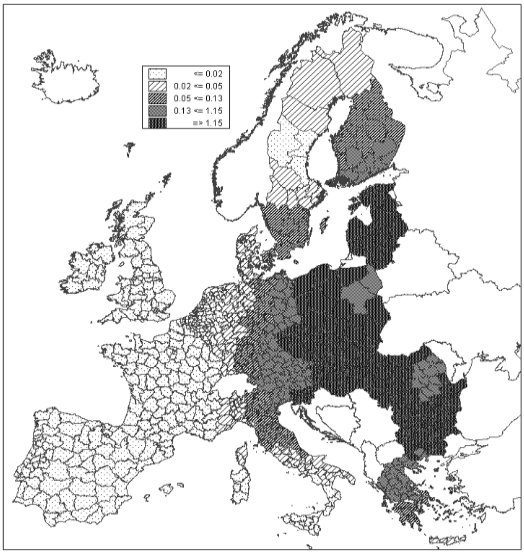


Figure 3: The effect of EU enlargement on the market potential of European regions



Source: Niebuhr (2005).

4 Gravity models

4.1 Basic ideas

The gravity model is a workhorse model in regional economics. The basic idea is taken from astrophysics, as developed by Isaac Newton in the seventeenth century, while adaption to the context here is attributed to Tinbergen (1962). Newton's theory of gravity describes the force of interaction between two objects in space (e.g. between the earth and the moon). The use of the concept of gravity for capturing spatial interaction phenomena in regional economics has turned out to be extremely useful (for a comprehensive overview see Head and Mayer (2014)). Of course, the application of the concept in a completely different context requires some modification.

Formally, Newton postulates that the gravity force a_{ij} between object *i* and *j* in space is proportionate to the product of the masses of the two objects, m_i and m_j, and inversely proportionate to the square of their distance, d_{ij}. Hence, the law of gravity can be written as:

$$a_{ij} = \gamma\, m_i\, m_j\, d_{ij}^{-2}, \qquad (0.4)$$

where γ is a natural constant.

The corresponding model for regional interactions, in direct analogy to the gravity model, would be:

$$t_{ij} = \kappa u_i z_j d_{ij}^{-2}, \qquad (0.5)$$

where t_{ij} stands for a stream of goods, persons or other items originating in *i* and ending in *j*. The variables u_i and z_j are indicators of importance with respect to the region of origin and destination, respectively. As in the original law of gravity, a constant parameter κ is included. Of course, there are several ways of measuring the "importance" of the region of origin and region of destination. A natural choice is to use for u_i the total volume of all streams originating in *i* to *all* relevant destinations $j \in J$, where J includes all relevant destinations for region i. By the same token, the importance of the region of destination z_j could be measured as the total volume of all incoming streams to location *j* from all relevant regions of origin.

As an example, consider the commuter streams within a certain area. A commuter is defined as a person who lives in place *i* and works in place *j*. A natural choice for u_i in this case would be the sum of all outgoing commuters from place *i*, whereas for z_j one could use the sum of all incoming commuters in place *j*.

Of course, there are other ways of specifying the importance of the sending and receiving locations. Using the example of commuters, one could use the potential workforce for the place of origin, and the total number of potentially available jobs in the destination area. The potential workforce comprises all persons of working age (e.g. from 15–69 years old) who could be active on the labor market (i.e. the basic population that may commute). The total number of available jobs at the destination site can be measured as total employment plus vacancies. This is the maximum of workplaces that in principle are available to commuters – even if positions cannot be regarded as immediately available.

4.2 Adaption of the physical model of gravity to the regional context

Let us return to the possibility of measuring the importance of sending and receiving locations by the sum of outgoing and incoming streams. These transactions (t_{ij}) between *n* regions of origin *i* and the same number of regions of destination *j* are collected in the origin/destination matrix $\mathbf{T}$ of dimension $n \times n$ with the typical element $[\mathbf{T}]_{ij} := t_{ij}$.

Table 2 shows this matrix together with the sum of transactions over the rows and columns of matrix $\mathbf{T}$. Note that u_i, the sum of row *i*, collects all outgoing streams of that location, whereas z_j, the sum of column *j*, collects all the incoming streams of the corresponding location.

The next step is to consider the information about distances between locations or regions. According to the law of gravity in physics, "distance" refers to Euclidean distance (i.e. the minimum length between [the centers of] locations *i* and *j*). In our context, "distance" means *economic distance*. Economic distance typically differs from Euclidean distance and includes the cost of bridging the distance between locations *i* and *j*. For instance, travelling 50 kilometers between two locations means something completely different if there is an express highway connection or only a sand track. Therefore, it might be more appropriate to consider travel time instead of total distance. Note that economic distance is not necessarily symmetrical. Think of the traffic jams in a greater agglomeration. If there are a lot of workplaces at the centre, incoming roads will be typically congested during morning hours, and outgoing roads in the evening.

Assume that an adequate indicator for economic distance between the locations under consideration is available. This information can be collected, analogously to the transaction matrix, in a distance matrix $\mathbf{D}$ with typical element $[\mathbf{D}]_{ij} := d_{ij}$ (see Table 3).

Table 2: Transactions between the place of origin and the destination area

	destination				Σ
origin	R_1	R_2	..	R_n	
R_1	t_{11}	t_{12}	..	t_{1n}	u_1
R_2	t_{21}	t_{22}	..	t_{2n}	u_2
⋮	⋮	⋮		⋮	⋮
R_n	t_{n1}	t_{n2}	..	t_{nn}	u_n
Σ	z_1	z_2	..	z_n	

Table 3: The distance matrix

origin	destination R$_1$	R$_2$	..	R$_n$
R$_1$	d_1	d_1	..	d_{1n}
R$_2$	d_2	d_2	..	d_{2n}
⋮	⋮	⋮		⋮
R$_n$	d_n	d_n	..	d_{nn}

Note that the entries on the main diagonal of the matrix ($d_{11}, d_{22}, \cdots$) stand for the average travel time (or travel cost) within the corresponding region.

Direct application of Newton's law to modelling regional interdependencies does not seem to be reasonable. At least two adjustments are required:

1. The gravity model in physics implies that doubling the mass of two interacting objects in space quadruples the force of gravity between these objects. This implication is questionable. Doubling of the importance of the region of origin and the destination region leading to four times more transactions is not plausible.
2. Distance dependence is very specific. Why should the volume of transactions between *i* and *j* decline exactly in accordance with the squared distance between the locations? This calls for a modified formulation of distance deterrence.

Considering objections (i) and (ii) leads to a more general formulation of the model of gravity in the context of regional economics. This can be written as follows:

$$t_{ij} = \kappa u_i^{\alpha} z_j^{\beta} f(d_{ij}) . \qquad (0.6)$$

Here, the two new parameters α and β are introduced to measure the impact of changes in the importance of origin and destination in a less restrictive way than in Newton's law. For instance, $\alpha = \beta = 0.5$ would imply that the volume of transactions between *i* and *k* doubles if importance doubles. The general function $f(d_{ij})$ with $f' < 0$ stands for the *distance deference function*. In the present context it measures how a higher (economic) distance between locations *i* and *k* influences the volume of transactions. Several proposals have been made for the concrete specification of the distance deterrence function. The most prominent ones are:

$$f\left(d_{ij}\right) = d_{ij}^{-\gamma} , \qquad (0.7)$$

and,

$$f\left(d_{ij}\right) = \exp(-\gamma d_{ij}) = e^{-\gamma d_{ij}} \quad . \qquad (0.8)$$

A specific drawback of the formulation in equation (0.7) is that the function approaches infinity as distance approaches zero. By contrast, the formulation in equation (0.8) implies that the value of the function goes to infinity if the distance becomes very low. The latter assumption seems to be more plausible.

4.3 Transformation of the model into a regression approach

Assume we have data for all t_{ij} so that matrix $\mathbf{T}$ is known. From the row and column sums we can then calculate u_i and z_j. How should we then obtain the unknown parameters α, β, γ and κ? The answer is by regression analysis. However, the model considered so far is a non-linear model. The ordinary least squares (OLS) method requires linearity. By taking logs we can transform the gravity model into a linear version:

$$\ln t_{ij} = \ln \kappa + \alpha \ln u_i + \beta \ln z_j - \gamma \ln d_{ij}, \qquad (0.9)$$

for a distance deterrence function as in equation (0.7), or,

$$\ln t_{ij} = \ln \kappa + \alpha \ln u_i + \beta \ln z_j - \gamma d_{ij} \qquad (0.10)$$

for the alternative specification (0.8). In the following, we use the latter equation.

Reparametrisation of the model and inclusion of a disturbance term yields:

$$\ln t_{ij} = \beta_1 + \beta_2 \ln u_i + \beta_3 \ln z_j + \beta_4 d_{ij} + \varepsilon_{ij}, \qquad (0.11)$$

where $\beta_1 := \ln \kappa, \beta_2 := \alpha, \beta_3 := \beta, \beta_4 := -\gamma$. The parameters in equation (0.11) are collected in a vector $\boldsymbol{\beta} := \left(\beta_1, \beta_2, \beta_3, \beta_4\right)'$. Let $\mathbf{y}$ be the vector of variables to be explained, $\mathbf{X}$ be the matrix of explanatory or independent variables, and $\boldsymbol{\varepsilon}$ a vector of stochastic disturbances that describes non-systematic random influences on the relationship under consideration. Then the regression approach can be written in a more compact matrix/ vector form, as follows:

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon}, \qquad (0.12)$$

Vector $\mathbf{y}$ can be formed through a simple transformation and re-organization of the elements of the origin/destination matrix $\mathbf{T}$. All the elements of the matrix are taken in logarithmic terms and the matrix is “vectorized” (the columns of the matrix are stacked above each other). Formally, this can be written as:

$$y = \text{vec } \ln \mathbf{T} := \left(\ln \mathbf{t}_1', \ln \mathbf{t}_2', \cdots, \ln \mathbf{t}_n'\right)', \qquad (0.13)$$

where $\mathbf{t_i}$ is the *i*th column of matrix $\mathbf{T}$.

The matrix of explanatory variables, $\mathbf{X}$, consists of four columns. Let us consider as an example rail travellers per month between three cities such as Munich (1), Nuremberg, (2) and Frankfurt (3). If we have data for one month only, the origin/ destination matrix and the distance matrix are given as:

$$\mathbf{T} := \begin{pmatrix} t_{11} & t_{12} & t_{13} \\ t_{21} & t_{22} & t_{23} \\ t_{31} & t_{32} & t_{33} \end{pmatrix}; \quad \mathbf{D} = \begin{pmatrix} d_{11} & d_{12} & d_{13} \\ d_{21} & d_{22} & d_{23} \\ d_{31} & d_{32} & d_{33} \end{pmatrix}. \qquad (0.14)$$

Here t_{11} stands for the number of rail travellers within Munich, t_{12} for the travellers between Munich and Nuremberg, and t_{21} for travellers between Nuremberg and Munich, for instance. The variable d_{11} stands for average travelling time in minutes for rides within Munich, whereas d_{21} denotes travelling time from Nuremberg to Munich, and so on. Then the regression equation can be written as follows:

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon}\ ,$$

or more explicitly:

$$\begin{pmatrix} t_{11} \\ t_{21} \\ t_{31} \\ t_{12} \\ t_{22} \\ t_{32} \\ t_{13} \\ t_{23} \\ t_{33} \end{pmatrix} = \begin{pmatrix} 1 & \ln u_1 & \ln z_1 & d_{11} \\ 1 & \ln u_2 & \ln z_1 & d_{21} \\ 1 & \ln u_3 & \ln z_1 & d_{31} \\ 1 & \ln u_1 & \ln z_2 & d_{12} \\ 1 & \ln u_2 & \ln z_2 & d_{22} \\ 1 & \ln u_3 & \ln z_2 & d_{32} \\ 1 & \ln u_1 & \ln z_3 & d_{13} \\ 1 & \ln u_2 & \ln z_3 & d_{23} \\ 1 & \ln u_3 & \ln z_3 & d_{33} \end{pmatrix} \begin{pmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \end{pmatrix} + \begin{pmatrix} \varepsilon_{11} \\ \varepsilon_{21} \\ \varepsilon_{31} \\ \varepsilon_{12} \\ \varepsilon_{22} \\ \varepsilon_{32} \\ \varepsilon_{13} \\ \varepsilon_{23} \\ \varepsilon_{33} \end{pmatrix}. \qquad (0.15)$$

If observations for several periods are available, then a more general model would include a repeating structure of $\mathbf{y}, \mathbf{X}$ and $\boldsymbol{\varepsilon}$ for each time period (1,2, ...*T*):

$$\mathbf{y} := \begin{pmatrix} \mathbf{y}_1 \\ \mathbf{y}_2 \\ \vdots \\ \mathbf{y}_T \end{pmatrix}; \quad \mathbf{X} := \begin{pmatrix} \mathbf{X}_1 \\ \mathbf{X}_2 \\ \vdots \\ \mathbf{X}_T \end{pmatrix}; \quad \varepsilon := \begin{pmatrix} \varepsilon_1 \\ \varepsilon_1 \\ \vdots \\ \varepsilon_T \end{pmatrix}. \qquad (0.16)$$

The Ordinary Least Squares (OLS) method yields an estimate $\hat{\beta}$ for the coefficient vector β. With the help of this estimate it is straightforward to calculate the fitted values of the dependent variable $\hat{\mathbf{y}} = \mathbf{X}\hat{\beta}$.[2] Moreover, it will then be possible to determine the expected values of transport streams if there are changes in the explanatory variables.

As an example, consider that the travelling time between Munich and Nuremberg is reduced by a significant amount because of the opening of a rapid new railway connection. In this case, the model allows us to make predictions about the corresponding transport streams t_{ij} that would be highly valuable in public planning procedures, among other uses.

4.4 Intervening opportunities

The application of the gravitation model considered so far suffers from specific drawbacks. It relies on an unrealistic "as if" assumption: the analysis implicitly assumes that between the cities under consideration there are no competing places that might distract transport streams. As with Newton's model, the analysis of gravitation forces on the earth might be heavily biased if only the force of gravity between the sun and earth were considered and other spatial objects like the moon were neglected. If transport streams are generated by economic opportunities, then locations between City A and City B could be influenced by places between A and B that also represent economic opportunities. This situation becomes immediately clear in the situation that the transport streams are mainly associated with commuting or shopping trips.

Let the intervening opportunities of A be defined as opportunities that are more easily accessible from A than the opportunities in B. The recognition that the intervening opportunities might play an important role in the analysis of spatial economic interaction dates back to the work of Stouffer (1940),[3] who formulated a kind of law in relation to this context. In the present case, Stouffer's law might be formulated as follows:

> *The number of trips between a zone of origin and a zone of destination are proportionate to the number of opportunities in the zone of destination, and inversely proportionate to the number of intervening opportunities.*

As an example, consider customers who are interested in buying furniture. The number of shopping trips of this group of customers from origin A to destination B might be proportionate to the total sales area in square meters of furnishing shops in B, and inversely proportionate to the total sales area of furnishing shops that are situated between A and B, because these intervening opportunities diminish the chance of customers choosing a shop to visit in B.

Stouffer's approach was first applied in the famous *Chicago Area Transportation Study* (1960). There can be no doubt that his basic argument is valid. However, the concrete formulation of his law is quite unlikely to be relevant in reality. The problem concerns the postulated proportional relationship. Moreover, the original Stouffer approach assumes a one-dimensional economic space and should be generalized. Intervening opportunities should be understood not as opportunities directly situated between A and B, but all opportunities that are more easily accessible than opportunities in B. To extend our example, assume that B is situated north of A and the travelling time is 30 minutes. A furniture shop to the East, South or West that could be reached within 20 minutes clearly belongs to the set of intervening opportunities. Hence intervening opportunities in this example are defined as all furniture shops that are reachable in less than 30 minutes from location A.

In empirical studies, the consideration of intervening opportunities requires an augmented gravity model. If the importance of intervening opportunities between origin *i* and destination *j* can be measured by v_{ij}, then the model that should be estimated can be written as:

$$\ln t_{ij} = \beta_1 + \beta_2 \ln u_i + \beta_3 \ln z_j + \beta_4 v_{ij} + \beta_5 d_{ij} + \varepsilon_{ij}$$

Its transformation into a regression model is analogous to that undertaken for the classical gravity model.

5 Summary

Regional economics has developed several workhorse models. Starting with the fact that distance and the spatial distribution of population matters for economic outcomes, we introduced the concept of market potential and demonstrated some applications of this. We then described the classical gravity model and transformed it into a simple regression model. This model is capable of describing spatial interactions such as commuter streams and trade flows, etc. The classical gravity model is extended by the intervening opportunities approach. A labour market model that captures the basic idea is used to show that the "law" of indirect proportionality postulated by Stouffer is typically not appropriate in an economic context. However, in a generalized form the intervening opportunity approach is helpful for avoiding the biased estimates of the classical gravity model.

Notes:

[1] Knowledge spillover refers to the voluntary exchange or the involuntary leakage of information that is useful in the production process or to businesses providing services.

[2] The goodness of fit can be checked using various statistical measures such as the coefficient of determination, the standard error of the estimation, or the average root mean squared error.

[3] Stouffer, S. A. 1940. Intervening Opportunities: A Theory Relating Mobility and Distance. *American Sociological Review* 5 (6): 845–867.

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