Available online at http://www.journalijdr.com

IJDR

ISSN: 2230-9926

International Journal of Development Research
Vol. 08, Issue, 08, pp. 22570-22676, August, 2018

ORIGINAL RESEARCH ARTICLE

OPEN ACCESS

POTENTIAL TO ATTRACT PEOPLE WEIGHTED BY ECONOMIC FACTORS

***[1]SCHNEIDER Alessandro Vinicios, [2]HOSOKAWA, Roberto Tuyoshi, [3]ROCHADELLI Roberto and [4]BEHLING, Alexandre**

[1]Doctor in Forest Policy and Economics – UFPR, ParanáState University, Paranaguá, Paraná, Brazil
[2]Ph. D. Economics of Natural Resources, Doctor Honoris Causa. CNPq Researcher - Ministry of Science and Technology – BR, President of the Institute of Economics and Technology, Parana-BR and Hyogo-JP.
[3]Doctor in Forest Policy and Economics – UFPR Campus Palotina. Paraná Federal University, Palotina, Paraná Brazil
[4]Doctor Forestry Engineering – UFPR, Paraná Federal University, Curitiba, Paraná, Brazil

ARTICLE INFO

Article History:

Received 18th May, 2018
Received in revised form
07th June, 2018
Accepted 26th July, 2018
Published online 31st August, 2018

Key Words:

Gravity model,
Economic variables,
Attraction force.

ABSTRACT

In this study, we address the modification of Newton's gravity model to explain the potential to attract people between cities. The variables introduced as a weighting factor were of economic nature, as follows: Gross Value Added at Basic Prices in Industrial Activity, Gross Value Added at Basic Prices in Services Activity, Gross Value Added at Basic Prices in Agricultural Activity. We tested the modified model in an experiment developed in the area of the Second Paraná Plateau, State of Paraná, Brazil, with the purpose of investigating the regional economic dynamics by means of the flow of passengers in intercity public transportation in the region. The addition of the weighting factor to the original gravity model provided a better fit concerning to the measured statistics and facilitated the interpretation of results. We concluded that the greater the centrality of the weighting factor, the greater the potential to attract people. Among the weighting factors that make up the local economic activities, the Gross Value Added at Basic Prices in Industrial Activity provided the greatest potential to attract people in the cities of the Second Paraná Plateau. The proposed model is an important tool for developing leading strategies for the cities.

Citation: SCHNEIDER Alessandro Vinicios, HOSOKAWA, Roberto Tuyoshi, ROCHADELLI Roberto and BEHLING, Alexandre. 2018. "Potential to attract people weighted by economic factors", *International Journal of Development Research*, 8, (08), 22570-22676.

INTRODUCTION

Establishing meaningful relationships between several economic units (sectors or regions) requires the creation of technical, geographical, human or decision-making links between units, in order to provide their unification. The increase in the degree of integration between such units is done by creating new links between the production units, roads and other means of transportation and communication, as well as by further developing the already existing facilities. These interactions take place by means of the various flows generated between them, such as passenger travel, transportation of goods, circulation of newspapers and magazines, telephone calls and transmission of information and/or business conduction via the worldwide web.

****Corresponding author: SCHNEIDER Alessandro Vinicios***
Doctor in Forest Policy and Economics – UFPR, ParanáState University, Paranaguá, Paraná, Brazil.

This provides an attraction potential between these units. Some of the factors that encourage people to travel are: commuting to work, school, leisure and shopping. As factors that hinder the achievement of these short trips, there are the cost of travel, distance traveled and the time required to perform them. These relationships provide a regional dynamics that, in the economy, can comprise a coverage area where buyers and sellers market their products and services at a given price level. Thus, the larger the population, the greater the demand, and consequently, the greater the investment in the production of goods and services, product development, job offers, among other factors. This creates a larger movement of people, which consequently causes a certain attraction potential. Passenger tripsusing the intercity public transportation in a particular region represent a flow or interaction pattern between the cities. As a result, these flows generate a certain level of attraction potential between them, without taking into account the factors that stimulate the realization of trips or those that prevent or hinder them. Thus, the potential to attract people due to the flows in the intercity public transportation can be represented by models, in order to be a simplified representation of reality. The basic purpose of this research is to identify abnormalities of economic, social, environmental, urban and regional natures in a given region. Over the years, some mathematical models have been developed and ameliorated in order to improve the accuracy of these estimates. In Social Sciences, in comparison to the Exact Sciences, the difficulties for constructing the models are even bigger, as an individual's behavior is sometimes unexplainable. Throughout the twentieth century, the gravity model developed by Isaac Newton was used in the Social Sciences to explain phenomena of immigration and emigration (Migration Laws), trade flows between regions (Law of Retail Gravitation), as well as applications to the traffic engineering of the Law of Retail Gravitation. Isard (1975) adapted Newton's gravity model by replacing the "masses" of the original model for the size of the population, and the radius for the distance separating them.

A number of authors have used the gravitational model as a data analysis tool to explain their research. Portes *et al*. (2005), and Head *et al*. (2008) employed the gravitational model and observed that a large part of the foreign direct investment (FDI) takes the form of mergers and acquisitions. Vietze (2008) believes that in social phenomena the dependent variable is the interaction force between two social elements that would represent the "masses" in Newton's traditional model. These social elements could be the population, the GDP, the quantities of beds available in hotels, the amount of food companies or educational institutions, and so forth, that is, any kind of social element. Družić*et al*. (2011) observed that the use of relatively simple and easy to obtain data, such as GDP and distance, made the gravitational model notably popular in explaining the trade patterns of economies in transition, which lack more sophisticated data and longer series on foreign trade. Arkolakis*et al*. (2012) investigated how micro-level data have had a deep influence on trade research in the last ten years. Nijkamp (2013) addresses the validity of Newton's law of universal gravitation in the emerging world. Schneider et al. (2016) studied the potential to attract people of different cities.

Allen *et al*. (2017) suggested a new strategy to estimate the gravity constant by using an instrumental variable approach based on the overall equilibrium structure of the model. Chaney (2018) studied bilateral international trade. We aimed in this study to investigate the regional economic dynamics by means of passenger flows in intercity public transportation in the cities of the Second Paraná Plateau, and to estimate the potential to attract people using the gravity model adapted by Isard (1975). As a result of the research, mapping this potential in the cities may show the economic variables that influence the determination of intercity public transportation flows.

MATERIALS AND METHODS

Data origin

This research was developed in the region of the Second Paraná Plateau, State of Paraná, Brazil. In the experiment we especially observed the cities of TelêmacoBorba, Ortigueira, Sapopema, Curiúva, Figueira, São Jerônimo da Serra, Imbaú, Reserva, Tibagi and Ventania. The main reason for choosing this region is that its economy is widely diverse and it consists mainly of the timber sector. The city of TelêmacoBorba was initially driven by timber activities for the production of pulp and paper, which were later spread to the neighboring cities. In this context, it is worth recalling a brief statement by Myrdal (1957): "from an initial cluster, a region where there were economies of scale and technological development would bring new resources that could reinforce its expansion". In the application of the modeling proposed by Isard (1975), we used the distances between cities, their respective populations and passenger flows in 2010 in intercity public transportation. The mass of the gravity model in this study corresponds to the variable Population (P_i). The data come from the census conducted in 1991, 2000 and 2010 by IBGE. To compose the original gravity model, the distance values (d_{ij}, in kilometers) between the cities were provided by the Department of Highways of the State of Paraná (DER/PR, 2010). The number of trips made in the study area was obtained from data observed by DER/PR (2010), and it corresponds to the number of intercity flows using public transportation in the region in 2010. Among the 90 possibilities of flows, only 43 were obtained, as there were no regular and direct lines between some of the cities.

Application of the modeling proposed by Isard (1975)

For the application of the model proposed by Isard (1975), we used the distances between the cities, their respective populations and passenger flows observed in the intercity public transportation. The gravity constant "G" is a quantity that does not depend on any factor, and does not depend on the environment where the masses are placed (or absence of environment), in other words, its contents are simple and clear. Thus, according to Newton's proposals, the value of the force of attraction (F) is directly proportional to the masses of the two bodies and it is inversely proportional to the square of the distance between them. The forces appear in pairs, that is, if a body attracts another, it is also attracted by the latter. In this study, the constant (G) represents a correction factor between the mass units and the distance that separates them. Mathematically, it is linked to the constant "k", which represents the average number of flowsperformed by the population, to the constant "c", which comes from the antilog of b_0, and to the total population (P). With all variables and constants obtained by means of these mathematical procedures, we applied the model developed by Isard (1975) in order to obtain a new flow estimated by the gravity model of the flow of people using intercity public transportation. It is expressed by:

$$I_{ij} = G \frac{P_i * P_j}{(d_{ij})^b} \qquad \text{...............(1)}$$

Where:I_{ij} = Estimated flow; G = Correction factor; P_i = Population of "i"; P_j = Population of "j"; d_{ij} = Distance between "i" and "j"; b = Exponential coefficient

Method proposed for estimating the attraction potential (V_i)

In order to determine or estimate the attraction potential (V_i) of the cities of the Second Paraná Plateau, we observed the principle of superposition. When two or more waves propagate simultaneously in the same medium, moment and direction, there is a superposition of waves. The resulting wave is equal to the algebraic sum of waves that each one would produce individually. This principle can be applied to obtain a scalar result. Thus, considering the flows of passengers in intercity public transportation as waves, the greater the volume and intensity of these flows for the same city, the greater its attraction potential (V_i). There may be two interpretations of the concept of attraction potential (V_i). On the one hand, it is a measurement of the influence or impact exerted upon the point "i" and the range of masses distributed in space (including the mass of "i"). On the other hand, it is a measurement of the accessibility of the point "i" to the set of masses distributed in space. Thus, the greater the intensity at the point "i" when compared with other points, the greater its attraction potential (V_i). In this context, the interaction (or flow) between the points "i" and "j" estimated by the model can be calculated so as to provide the interaction between "i" and all "j" points, which represents the attraction potential (V_i) of the point "i". The attraction potential (V_i) of the point "i" is equal to its own mass (P_i) plus the masses of the remaining points, each one corrected according to their distance from "i" multiplied by a constant (G). As described, the interaction between "i" and "j" is expressed by:

$$V_i = 1 + (I_{i1} + I_{i2} + I_{i3} + \cdots + I_{in}) \qquad \text{.................(2)}$$

Where: V_i = Attraction potential of the city "i"; I_{i1} = Estimated flow from city "1" to "i"; I_{i2} = Estimated flow from city "2" to "i"; I_{i3} = Estimated flow from city "3" to "i"; I_{in} = Estimated flow from city "n" to "i".

Based on that expression, the attraction potential (V_i) of the city can be described by:

$$V_i = \mathrm{G} * \mathrm{P_i}w_i + \mathrm{G} * \frac{\mathrm{P_i}w_i * \mathrm{P_1}w_1}{(\mathrm{d_{i1}})^{\mathrm{b}}} + \mathrm{G} * \frac{\mathrm{P_i}w_i * \mathrm{P_2}w_2}{(\mathrm{d_{i2}})^{\mathrm{b}}} + \cdots + \mathrm{G} * \frac{\mathrm{P_i}w_i * \mathrm{P_n}w_n}{(\mathrm{d_{in}})^{\mathrm{b}}} \qquad \text{....................(3)}$$

Where: V_i = Attraction potential of the city "i"; G = Correction factor; P_iw_i = Weighting factor of "i"; P_1w_1= Weighting factor of city 1; P_2w_2 = Weighting factor of city 2; P_nw_n = Weighting factor of city n; d_{i1} = Distance between city "i" and city "1"; d_{i2} = Distance between city "i" and city "2"; d_{in} = Distance between city "i" and city "n"; b = Exponential coefficient.

Addition of economic variables to the gravity model

The composition of mass values (P_iw_i) proposed by Isard (1975) shows that values can become enormous quantities, what hinders the analysis of results. Thus, we proposed to add the variable (*wi*) in values concerning to the analyzed group, which gives us the new value for the variable Weighting Factor (*wi*).

The new mass (P_iw_i) was obtained by using the following expression:

$$\mathrm{P_i}w_i = \mathrm{P_i} * (1 + \mathrm{w_i}/\mathrm{w_T}) \qquad \text{...........................(4)}$$

Where: P_iw_i = Mass value with the weighting factor; P_i = Population of city "i"; w_i = Weighting factor; w_T= Σ of the weighting factor.

The results of the multiplication between the population (P_{ij}) and the weighting factor (*wi*) were applied to the data of probable flows (*Tij*), transforming the original expression into:

$$T_{ij} = \mathrm{k} * \left(\frac{\mathrm{P_i}w_i * \mathrm{P_j}w_j}{\mathrm{P}}\right) \qquad \text{...........................(5)}$$

Where: T_{ij} = Probable flows; k = Average flows; P = Total population of the region; P_iw_i = Weighting factor of "i"; P_jw_j = Weighting factor of "j".

The T_{ij} values were then used in the new fit of the logarithmic expression:

$$\mathrm{Log}\ \frac{\mathrm{I_{ij}}}{T_{ij}} = \mathrm{a} - \mathrm{b}\ \mathrm{Log}\ (\mathrm{d_{ij}}) + \mu \qquad \text{............................(6)}$$

Where: I_{ij} = Estimated flows; T_{ij} = Probable flows; d_{ij} = Distance between cities; a = Coefficient b_0; b = Coefficient b_1; μ = Estimate error

The new mass value (P_iw_i) is in the same dimensional unit as when compared with the values of the original model proposed by Isard (1975), including only the variable Population (P_i). The variables introduced as Weighting Factor (w_i) were of economic nature and consisted of the Gross Value Added at Basic Prices in Industrial, Services and Agricultural activities. These variables represent the city's Gross Domestic Product in 2010. We then observed the variables that make up the Agricultural Sector. As Weighting Factor (w_i) we used the Value of Forest Production, the Value of Agricultural Production and the Value of Livestock Production, that is, the variables that made up the GDP of this sector in 2010. Posteriorly, we introduced the Weighting Factor (w_i) to the original gravity model. Its variables represent the city's Gross Domestic Product. In the Gravity Model #1 we used the Gross Value Added at Basic Prices in Industrial Activity. In the Gravity Model #2 we used the Gross Value Added at Basic Prices in Services Activity. In the Gravity Model #3 we used the Gross Value Added at Basic Prices in Agricultural Activity.

RESULTS AND DISCUSSION

RESULTS

The Gravity Model #1 presented the highest coefficient of determination (R^2) (0.787) followed by Gravity Model #2 (0.761) and Gravity Model #3 (0.741) (Table 1). The addition of a weighting factor (w_i) to the original gravity model provided a better fit concerning to the measured statistics.

Table 1. Fitting parameters of the models referring to the flows and the distance between the cities of the Second Paraná Plateau

MODELS	R^2	Sxy%	F	b_0	b_1
Gravity Model #1	0.787	19	151.64	5.53	-3.45
Gravity Model #2	0.761	20	131.17	5.25	-3.27
Gravity Model #3	0.741	20	117.74	5.09	-3.16

In the Gravity Model #1 (b_1 = -3.45) the population showed more elasticity in relation to the friction of the distance to be covered in the flows or trips between them (Table 2). Contrarily, the Gravity Model #3 (b_1 = -3.16) showed less elasticity to movements.

Table 2. Fitting constants of the models of passenger flows by means of intercity public transportation in the Second Paraná Plateau

MODELS	k	G
Gravity Model #1	1.55	2.63
Gravity Model #2	1.55	1.38
Gravity Model #3	1.55	0.94

Gravity Model #1 presented the highest correction factor (2.63), which provided an increase in the value of the product between masses and the distance that separates them. This caused the equations of the gravity model to have mathematical equality. The estimated flows (I_{ij}) were smaller than the ratio between the size of the masses and the distance that separates them. Gravity Model #2 (1.38) had the same behavior as Gravity Model #1, showing an increase in the value of the product between masses and the distance that separates them. Gravity Model #3 presented a correction factor below 1.0. Therefore, it can be stated that this factor caused a decrease in the product of the masses and the distances that separates them so there could be a balance on both sides of the equation (Table 2). The observed flows (I_{ij}) represented a total of 309,079 people (T) that used intercity transportation in 2010. The total value of the new mass represents 199,288 (P). The values added to the new mass ($P_i w_i$) are shown in Table 3.

Table 3. Weighting factor ($p_i w_i$) population versus Gross Value Added at Basic Prices in Industrial Activity in the cities of the Second Paraná Plateau region

Cities	(P_i)	Industrial Activity (R$)*	(w_i/w_T)	($P_i w_i$)
Telêmaco borba	69,872	534,723	0.82	127,304
Imbaú	11,274	11,137	0.02	11,467
Reserva	25,172	18,941	0.03	25,904
Ortigueira	23,380	14,590	0.02	23,904
Tibagi	19,344	16,568	0.03	19,836
Curiúva	13,923	10,229	0.02	14,141
Ventania	9,957	17,201	0.03	10,220
Figueira	8,293	15,687	0.02	8,492
Sapopema	6,736	4,986	0.01	6,787
São jerônimo da serra	11,337	6,475	0.01	11,449
Total	199,288	650,537	1	

* Value (R$ 1,000.00)

After performing the regression, we obtained the following equation:

$$\text{Log}\,(I_{ij}/T_{ij}) = 5.05303 - 3.4477\,\text{Log}\,(d_{ij}) \quad \ldots\ldots\ldots\ldots\ldots..(7)$$

The model showed a coefficient of determination (R^2) of 0.78 and an elevated F value of 151.64, which was considered significant at 95% probability. The standard error of the estimate ($S_{xy}\%$) was 19%. There was a better fit in the coefficient of determination than in the original gravity model, which included only the variable Population (P_i). Thus, it can be stated that the product between the population and the share of the Gross Value Added at Basic Prices in Industrial activity increased the power of explanation of people's behavior in what concerns to flows using intercity public transportation.

The new model, with the weighting factor (w_i) and the Gross Value Added at Basic Prices in Industrial Activity, combined with the variable Population (P_i) formed a new Mass ($P_i w_i$), which when related to the distance between the cities gives a better idea of the flow variation between them than by using only the variable Population (P_i).

With the new values of "k", "c" and "P", we achieved a new correction factor (G) of 2.63. We noticed that the estimated flows (I_{ij}) observed in the public intercity transportation should have happened less frequently in order for the equation of the model to be balanced. The correction factor provided a significant increase in the ratio of the size of the masses and the distance that separates them, so there would be a mathematical equality in the gravity model.

Thus, the gravity model can be written as:

$$I_{ij} = 2.63\,\frac{P_i w_i * P_j w_j}{(d_{ij})^{3.44}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

The equation that represents the attraction potential (V_i), that is, the capacity of the city to attract people, is described below:

$$V_i = 2.63\,P_i w_i + 2.63\,\frac{P_i w_i P_1 w_1}{(d_{i1})^{3.44}} + 2.63\,\frac{P_i w_i P_2 w_2}{(d_{i2})^{3.44}} + .. + 2.63\,\frac{P_i w_i P_n w_n}{(d_{in})^{3.44}} \quad \ldots\ldots\ldots\ldots\ldots(9)$$

After the addition of the weighting factor (w_i) to the original gravity model, the city that presented the highest potential to attract people (V_i) was TelêmacoBorba (335,926; 49.05%), followed by Reserva (68,358; 9.98%). Ortigueira had the third best attraction potential (63,078; 9.21%). The cities with the lowest attraction potential were Tibagi (52,345; 7.64%), Curiúva (37,318; 5.45%), Imbaú (30,266; 4.42%), São Jerônimo da Serra (30,213; 4.41%), Ventania (26,969; 3.94%), Figueira (22,411; 3.27%) and Sapopema (17,912; 2.62%).

The Gravity Model #1 allowed us to estimate the attraction potential (V_i) of the cities of the Second Paraná Plateau region. We noticed that the higher the weighting factor (w_i) to be added to the original model, the higher the potential of the central point to attract people (V_i).

The addition of the Gross Value Added at Basic Prices in Industrial Activity as weighting factor to the original gravity model resulted in a higher concentration of the attraction potential (V_i) in TelêmacoBorba, therefore considered the central point. This characteristic is directly related to the level of industrialization of the city, which accounted for 82.2% of the revenue generated in the region in 2010. The level of industrialization in TelêmacoBorba, mostly because of its local productive arrangement (LPA), generated an increase in the city's potential to attract people due to the opportunities created by the natural facilities that the LPA provides to the city, and consequently to the Second Paraná Plateau region.One of the advantages of the agglomeration of companies that act in the same industrial activity is the close access to sources of raw materials and/or the benefit of not having to transport resources. According to Richardson (1973), the polarization flows in the national and regional economies are more frequently related to the connection of the industry than the connection of the services that dominate the intercity flows. Therefore, the articulation of companies of every size in the LPA and the synergy generated by their interactions increase the potential to attract people of the most-representative, most-centralized and most-industrialized location. This synergy originates in the central point (Telêmaco Borba), reaches the closest cities and eventually, with less intensity, the cities further from the center. The closest cities benefit from the advantages provided by the

LPA, mainly regarding the distance between raw materials and the manufacturing place, especially if compared to the further cities. The investments made into those cities closer to the central point (Imbaú, Curiúva and Ventania), either in forest plantation or in manufacturing companies, increased their attraction potential (V_i). This trend of movement of resources, caused by the scarcity of some of these resources, might represent an increase of the central point's influence area. In this case, land, a scarce resource in TelêmacoBorba, enabled for more investments in land acquisition for forest plantation in new areas as a consequence of the increase in demand for this resource. This increase in the regional demand for forests happens because of the increase in the production of forest products caused by the expansion of the national and international markets. TelêmacoBorba, with its pulp and paper industry as well as the LPA, is the largest consumer of forests in the region. The observed flows (I_{ij}) represent a total of 309.079 people (T) that used the intercity transportation in 2010. The total value of the new mass represents 199.288 (P). Table 4 presents the values added to the new mass ($P_i w_i$).

Table 4. Weighting factor ($p_i w_i$) population versus the Gross Value Added at Basic Prices in Service Activity in the cities of the Second Paraná Plateau region

Cities	(P_i)	Services Activity (R$)*	(w_i/w_T)	($P_i w_i$)
Telêmaco borba	69,872	534,096	0.45	101,143
Imbaú	11,274	50,143	0.04	11,747
Reserva	25,172	128,984	0.11	27,892
Ortigueira	23,380	103,477	0.09	25,407
Tibagi	19,344	151,845	0.13	21,805
Curiúva	13,923	64,252	0.05	14,672
Ventania	9,957	45,753	0.04	10,338
Figueira	8,293	35,824	0.03	8,541
Sapopema	6,736	28,488	0.02	6,896
São jerônimo da serra	11,337	50,510	0.04	11,816
Total	199,288	1,193.372	1	

* Value (R$ 1,000.00)

After performing the regression of the variables, in which we used as dependent variable Log I_{ij}/T_{ij} and as independent variable Log d_{ij}, we obtained the following equation:

$$\text{Log}\,(I_{ij}/T_{ij}) = 5.2489 - 3.2693\,\text{Log}\,(d_{ij}) \qquad \text{…………….(10)}$$

The model presented a coefficient of determination (R^2) of 0.76 and an elevated F value of 131.17, which was considered significant at 95% probability. The standard error of the estimate was 20% (S_{xy}%). The new model, with the weighting factor (w_i) and the Gross Value Added at Basic Prices in Services Activity, combined to the variable Population (P_i) formed a new mass ($P_i w_i$), which when related to the distance between the cities gives a better idea of the flow variation between them than by only using the variable Population (P_i). With the new values of "k", "c" and "P", we achieved a new correction factor (G) of 1.38. We noticed that the estimated flows (I_{ij}) observed in the public intercity transportation should have happened less frequently in order for the equation of the model to be balanced. The correction factor provided a significant increase in the ratio of the size of the masses and the distance that separates them so there would be a mathematical equality in the gravity model.

Thus, the gravity model can be written as:

$$I_{ij} = 1.38\,\frac{P_i w_i * P_j w_j}{(d_{ij})^{3.26}} \qquad \text{……………..(11)}$$

The equation that represents the attraction potential (V_i), that is, the capacity of the city in attracting people, is described below:

$$V_i = 1.38 * P_i w_i + 1.38 * \frac{P_i w_i * P_1 w_1}{(d_{i1})^{3.26}} + 1.38 * \frac{P_i w_i * P_2 w_2}{(d_{i2})^{3.26}} + .. + 1.38 * \frac{P_i w_i * P_n w_n}{(d_{in})^{3.26}} \qquad \text{………….(12)}$$

The city that presented the highest potential to attract people (V_i) was TelêmacoBorba (139,633; 42.10%), followed by Reserva (38,508; 11.61%). Ortigueira had the third best attraction potential (35,076; 10.57%). The cities with the lowest attraction potential were Tibagi (30,104; 9.08%), Curiúva(20,257; 6.11%), São Jerônimo da Serra (16,314; 4.92%), Imbaú (16,224; 4.89%), Ventania (14,273; 4.30%), Figueira (11,793; 3.56%) and Sapopema (9,522; 2.87%). The attraction potential (V_i) follows the same trend of behavior of the Gravity Model #1.

Thus, it can be stated that in the central point (TelêmacoBorba) there is a higher offer of services and specialized services in several areas, suchas health, trade, education, law and others. It is worth mentioning that Tibagi, due to its natural landscape, has become a place for adventure tourism, what caused an increase in the proportion of its service production, especially services that are related to hospitality. Therefore, there was a decrease in the proportional centrality between cities when compared to the Gravity Model #4,due to a better proportional distribution of the weighting factor (w_i). The observed flows (I_{ij}) represent a total of 309.079 people (T) that used the intercity transportation in 2010. The total value of the new mass represents 199.288 (P). Table 5 presents the values added to the new mass ($P_i w_i$).

After performing the regression of the variables, in which we used as dependent variable Log I_{ij}/T_{ij} and as independent variable Log d_{ij}, we obtained the following equation:

$$\text{Log}\,(I_{ij}/T_{ij}) = 5.0853 - 3.1625\,\text{Log}\,(d_{ij}) \qquad \text{……………..(13)}$$

The model presented a coefficient of determination (R^2) of 0.74 and an elevated F value of 117.74, which was considered significant at 95% probability. The standard error of the estimate (S_{xy}%) was 20%. The new model, with the weighting factor (w_i) and the Gross Value Added at Basic Prices in Agricultural Activity, combined with the variable Population (P_i) formed a new mass ($P_i w_i$), which when related to the distance between the cities gives a better idea of the flow variation between them than by using only the variable Population (P_i).

With the new values of "k", "c" and "P", we achieved a new correction factor (G) of 1.38. We noticed that the estimated flows (I_{ij}) observed in the public intercity transportation should have happened more frequently in order for the equation of the model to be balanced. The correction factor caused a decrease in the ratio of the size of the masses and the distance that separates them so there would be a mathematical equality in the gravity model.

Thus, the gravity model can be written as:

$$I_{ij} = 0.94\,\frac{P_i w_i * P_j w_j}{(d_{ij})^{3.16}} \qquad \text{………………………(14)}$$

Table 5. Weighting factor ($p_i w_i$) population versus the Gross Value Added at Basic Prices in Agricultural Activity in the cities of the Second Paraná Plateau region

Cities	(P_i)	Agricultural Activity (R$)*	(w_i/w_T)	($P_i w_i$)
Telêmaco borba	69,872	232,053	0.27	88,639
Imbaú	11,274	48,633	0.06	11,908
Reserva	25,172	124,785	0.14	28,807
Ortigueira	23,380	130,862	0.15	26,921
Tibagi	19,344	176,828	0.20	23,303
Curiúva	13,923	47,694	0.06	14,691
Ventania	9,957	42,953	0.05	10,452
Figueira	8,293	8,895	0.01	8,378
Sapopema	6,736	27,854	0.03	6,953
São jerônimo da serra	11,337	23,394	0.03	11,643
Total	199,288	863,951	1	

* Value (R$ 1,000.00)

Table 6. Attraction potential of the weighting factors that make up the income indicator of the Second Paraná Plateau

City	Gravity Model #1	(%)	Gravity model #2	(%)	Gravity model #3	(%)
Telêmaco borba	335,926	49.1	139,633	42.1	83,953	38.3
Imbaú	30,266	4.4	16,224	4.9	11,284	5.1
Reserva	68,358	10	38,508	11.6	27,286	12.4
Ortigueira	63,078	9.2	35,076	10.6	25,498	11.6
Tibagi	52,345	7.6	30,104	9.1	22,072	10.1
Curiúva	37,318	5.4	20,257	6.1	13,916	6.3
Ventania	26,969	3.9	14,273	4.3	9,900	4.5
Figueira	22,411	3.3	11,793	3.6	7,936	3.6
Sapopema	17,912	2.6	9,522	2.9	6,586	3
São jerônimo da serra	30,213	4.4	16,314	4.9	11,029	5
Attraction potential	684,796	100	331,704	100	219,460	100

The equation that represents the attraction potential (V_i), that is, the capacity of the city to attract people, is described below:

$$V_i = 0.94 * \mathrm{P_i} w_i + 0.94 * \frac{\mathrm{P_i} w_i * \mathrm{P_1} w_1}{(\mathrm{d_{i1}})^{3.16}} + 0.94 * \frac{\mathrm{P_i} w_i * \mathrm{P_2} w_2}{(\mathrm{d_{i2}})^{3.16}} + .. + 0.94 * \frac{\mathrm{P_i} w_i * \mathrm{P_n} w_n}{(\mathrm{d_{in}})^{3.16}} \quad \ldots\ldots\ldots\ldots.(15)$$

The city that presented the highest potential to attract people (V_i) was TelêmacoBorba (83,953; 38.26%), followed by Reserva (27,286; 12.43%). Ortigueira had the third best attraction potential (25,498; 11.62%). The cities with the lowest attraction potential were Tibagi (22,072; 10.06%), Curiúva (13,916; 6.34%), Imbaú (11,284; 5.14%), São Jerônimo da Serra (11,029; 5.03%), Ventania (9,900; 4.51%), Figueira (7,936; 3.62%) and Sapopema (6,586; 3.00%). There is a diversified use of the soil for agricultural activities in the region. The cities of TelêmacoBorba, Curiúva and Imbaú invest more in forest plantation – there are large areas of Eucalyptus and Pinus plantation – and present a higher level of technological development. The other cities make more investments in agriculture, mostly in maize, soybean, tomato, potato and beans, among others. In these cities, there is less investment in forest plantation and livestock farming. The cities of TelêmacoBorba, Tibagi, Reserva and Ortigueirashow a more proportional distribution of the livestock activity than of other economic activities that make up these cities' Gross Domestic Product. Such characteristic of this weighting factor (w_i) provided a lower centrality of the potential to attract people (V_i) than in the weighting by Industrial and Services activities.

DISCUSSION

With the addition of the weighting factors (w_i) (Gross Value Added at Basic Prices in Industrial Activity, Gross Value Added at Basic Prices in Services Activity and Gross Value Added at Basic Prices in Agricultural Activity) to the original gravity model, we observed different behavior of the potential to attract people (V_i) in each of the analyses. The potential to attract people (V_i) of the Industrial Activity was 2.06 times higher than that of the Services Activity and 3.12 times higher than that of the Agricultural Activity (Table 6). The proportional distribution of the potential to attract people (V_i) of the Industrial Activity is more concentrated in TelêmacoBorba, representing 49.1%. There is a large pulp and paper manufacturer company in the city, and in its surroundings there is a conglomerate of companies that manufacture forest products. Such companies represented 36% of all companies in the region in 2010. The centrality of this weighting factor (w_i) presented a more proportional new mass value than that of the variable Population without the addition of this factor. The proportional distribution of the potential to attract people of the Services Activity is less concentrated than the potential to attract people of the Industrial Activity Thus, there is a lower centrality of the attraction potential (V_i) of the Services Activity because of the more proportional distribution of the service companies in the cities of the Second Paraná Plateau. When comparing the proportional distribution of the potential to attract people of the Agricultural Activity with that of other sectors, one can notice that there is lower centrality. This happens because the GDP of the region consists mainly of the revenue generated by agricultural activities, with the exception of TelêmacoBorba. The proportionality of the concentration of the weighting factor (w_i) added to the original gravity model resulted in a higher centrality of the attraction potential (V_i). Therefore, the higher the centrality of this factor, the higher the centrality of the new mass, and consequently, the higher the potential to attract people, which will lead to higher volumes of capital and human resources polarization. The potential to attract people of the Industrial Activity (V_i) of TelêmacoBorba was 2.4 times higher than the potential to attract people of the Services Activity and 4.0 times higher than the potential to attract people of the Agricultural Activity. There was a higher concentration of the attraction potential (V_i) in this city because of the large number of companies located in the city's LPA. Tibagi presented the smallest differences between weighting factors. Its potential to attract people (V_i) concerning to the Industrial Activity was only 1.73 times higher than that of the Services Activity and 2.37 times higher than that of the Agricultural Activity. The city is a tourism spot and a big part of its GDP consists of the revenue generated by services activities. Tibagi has the second largest revenue generated by Services and Agricultural activities in the region but only an incipient Industrial Activity. The gravity model developed by Newton and adapted by Isard might provide good results in what concerns to practical applications for the development of the region. This tool might be applied in the development of public policies related to the growth of a determined sector with the intention of mapping situations to be known. For instance, the consequences of the investments, or perhaps tax breaks, in the industrial and services sectors of a city, or in relation to the agricultural sector, the improvement of rural roads and what impact it will have on the population growth rate as well as on the improvement of life quality in general. Another aspect that can be observed with the mapping generated by this tool is the visualization of the best location for installing new private sector companies, regardless of what market they are in, and the consequences that this installation would bring. Thus, the investor can compare this information with those obtained with other known tools, such as the input-output model. One example would be a lumber manufacturing company that needs to acquire raw materials that are located near and at a low cost in order to make the investment possible. The model can also be used to develop future scenarios in order to compare them with the present situation and analyze the impact that new investments would have. Moreover, the model can be used to determine the information level of a city through the replacement of the flows of the intercity public transportation by the flows of intercity telephone calls, what would result in the potential to attract information.

Conclusions

The addition of the weighting factor (w_i) to the original gravity model provided a better fit concerning to the assessed statistics. The higher the centrality of the weighting factor (w_i), the higher the potential to attract people (V_i). The population variable by itself does not fully explain the behavior of people in what concerns to the use of public transportation between cities. The model developed by Newton is static and closed, thus demonstrating limitations in the explanation of each city's potential to attract people. Hence the importance of establishing the correction and weighting factors presented in this work. Of the weighting factors (w_i) that make up the cities' economic activities, the Gross Value Added to Basic Prices in the Industrial Activity provides the best potential to attract people (V_i) in the cities of the Second Paraná Plateau.

The modifications in Newton's gravitational model presented in this work allow positive results with respect to practical applications for regional development, that is, they promote the development of studies on regional economic development. By using the proposed model, future scenarios can be developed and compared to current scenarios, which will evidence the impact generated by new regional investments in a quantified fashion.

REFERENCES

Allen T., Arkolakis C., e Takahashi Y. 2017. Universal Gravity. Disponível em: <http://www.econ.yale.edu/~ka265/research/UniversalGravity/AAT%20%20Universal%20Gravity%20-%20paper.pdf>, Acesso em 10 de abril 2018.

Arkolakis, C, Costinot, A, e Rodríguez-CLARE, A. 2012. New Trade Models, SameOldGains? American Economic Review, 102(1): 94–130.

Chaney T. 2018. The Gravity Equation in International Trade: An Explanation, *Journal of Political Economy.*126, no. 1: 150-177.

DER – Departamento de Estrada e Rodagem 2010. Anuário estatístico do sistema de transporte coletivo regular intermunicipal de passageiros do estado do Paraná. Curitiba.

Družić, I., Anić, M., e Sekur, T. 2011. GravityModelofCroatian Regional Foreign Trade. Proceedings of 8th International Conference: Economic Integration, Competition and Cooperation, 6-9 April, Opatija, Universityof Rijeka – Faculty of Economics, CD withFullpapers.

HEAD, K. e RIES, J. 2008. FDI as anoutcomeofthemarket for corporatecontrol: Theory and evidence. *Journal of International Economics,* Elsevier, vol. 74(1), pages 2-20.

IBGE - Instituto Brasileiro de Geografia e Estatística 2010. Censo demográfico. Rio de Janeiro.

ISARD, W. 1975. Introduction to Regional Science. Englewood Cliffs, New Jersey: Prentice-Hall.

MYRDAL, G. 1957. Economic theory and under-developed regions. London: Gerald Duckworth & CO. LTD.

NIJKAMPP. 2013. The universal law of gravitation and the death of distance. *Romanian Journalof Regional Science,* vol. 7, issue2, 1-10.

PORTES, R, REY, H. 2005. The determinantsofcross-borderequityflows. Journal of International Economics, vol 65, 269–296.

RICHARDSON, H. W. 1975. Elementos de economia regional. Rio de Janeiro: Zahar Editores.

SCHNEIDER, A.V. HOSOKAWA, R.T., JUNIOR, R.T., BERGER, R. 2016. Potencial de atração de pessoasnaregião do Segundo PlanaltoParanaense. Floresta, vol 46, Nº 3, pag 379-386.

VIETZE, C. 2008. Cultural effects on in bound tourism in to the USA: A gravity approach. *Jena Economic Research Papers.* Jena, Germany.

****