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Quantitative Analysis of Road Transport Organization for Agricultural Product Distribution in South - East Romania

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Abstract. *Transportation organization in the field of high production volumes and geographically dispersed supply depends largely on an efficient and profitable agricultural distribution system. The South-East Development Region of Romania obtains high yields of cereals and horticultural products and delivers them by road. This potential is however compromised by transportation costs and inefficiencies in the system that leave agricultural distribution vulnerable. The South-East Region of Romania's road transportation infrastructure for distributing agricultural goods is looked at in this quantitative, model-based study. The study looks at the size and density of farming in the area by using modeling of transportation costs, allocating space, and measuring economic performance. The demand-weighted transportation distances are reduced by the aggregation depot location at the center of gravity. A population-based consumption model is used to estimate transport demand. The total transport costs consist of fixed and variable costs. The baseline distribution scenario and two alternative hypotheses are analysed in a detailed case study of the urban markets of Galaţi, Brăila and Tecuci: an increase in consumption of 20% and the creation of a new urban market to improve the distribution network. Income depends on the daily volume of sales and the unit price. Elasticity-based metrics are used to evaluate the transport performance. The results show that with the increase of the demand there are economies of density (density return > 1) and diseconomies of scale through spatial extension (scale return < 1). The results show that volume concentration and spatial closeness are important for the economy and the efficiency of transportation. The study adds to regional transportation planning and agricultural logistics policy with new facts and methods. It also gives other agricultural areas a way to easily use the same analytical framework.*

Keywords: road transport; distribution logistics; transport cost; economies of density; diseconomies of scale.

DOI: 10.2478/picbe-2026-0323
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Introduction

Agricultural production is one of the important pillars of the Romanian economy contributing significantly to the national output, employment and export performance. In recent years the transport and logistics systems have been more and more recognized as important to improve the efficiency and competitiveness of agricultural supply chains. This is more relevant in areas with large volumes of production and spatially dispersed farms where transportation logistics have a direct bearing on market access, price determination and post-harvest losses (Christopher, 2016).

The South-East Development Region of Romania has a special position in the national agricultural system. The region, which includes the counties of Brăila, Buzău, Constanța, Galați, Tulcea and Vrancea, contributes significantly to the cereal, oilseed and horticultural production in Romania. Official statistics show that the South-East region is a regular top contributor to the national production of wheat, maize and sunflower, also covering large vegetable producing areas for local and international markets (INS, 2024; Eurostat, 2024).

The distribution system of agricultural products is mainly road transit. Road transportation represents the most important mode for agricultural freight transportation in Romania, due to its flexibility and the easy access to farms and urban markets. Thus transportation costs are a substantial part of the total cost of distribution and reduce the producer's profit margins and capacity to compete on price.

Recent gains have only made these difficulties worse. As climate becomes more variable, volumes and times of harvest are less predictable, making transport planning and use of capacity more difficult. Other wider economic pressures such as energy prices and inflation have also pushed up operating expenses for road transport. The effectiveness of transport organization is a key aspect of the economic sustainability of agricultural distribution systems.

Besides cost factors, the organization of transport has become relevant in terms of efficiency and sustainability goals. Based on literature, the layout of transport networks, shipment consolidation and distance minimization are important factors for improving logistics performance, especially in the case of road-based freight systems (McKinnon, 2010). In the distribution of agricultural products, which is characterized by high volumes and relatively low unit values, a poor transport organization can have a marked effect on the economic performance.

At the regional level, transport systems for agricultural markets should strike a compromise between economic efficiency and spatial coverage. Many parts of Europe are becoming more and more dependent on road transport and this has increased the need for mathematical tools to determine how volume concentration and network design influence the cost of transport.

The organization of transport is an important link between agricultural production and the access to the market. Transport organization is more than infrastructure availability and also decisions on route planning, volume consolidation, vehicle utilization and cost allocation. In the case of agricultural products, these are usually low unit value and high volume items, where small inefficiencies in the transport organization may lead to large aggregate cost increases (Ballou, 2004). The improvement of the transport organization is thus a logistical issue and an economic requirement for the strengthening of the competitiveness of the regional agricultural systems.

The situation is especially acute in the South-East Development Region, where the concentration of agricultural output is predominantly in rural areas and consumption and processing mainly in urban areas. Galaţi, Brăila and Tecuci are cities which are key centres of aggregation, wholesale and distribution, linking the local agricultural districts to the regional and national markets. The spatial relations between these cities and its agricultural environment result

in stable and large transport flows. This makes the region a good case study for the implications on cost and efficiency of transport organization (INS, 2024).

From a methodological point of view, the study of transport organization at the regional level requires an approach combining spatial characteristics, volumes of demand and cost frameworks. The economics of transport provides a set of quantitative analytical tools, including cost-decomposition models and efficiency measures in terms of distance and volume. In particular, these instruments are valuable in the assessment of economies of density that are generated when huge volumes are transported via established routes and average costs reduce (Button, 2010). Demand is geographically distributed and scattered; so, economies of density are highly significant in agricultural distribution.

However, actual applications at the regional level in Romania are still sparse, despite the significance of these notions. Most current research is on the need for infrastructure investment or national logistics performance indicators and there is limited understanding of the operational structure of agricultural transport systems (OECD/FAO, 2023). Hence there is a need for empirical research with real data to measure the costs and efficiency of transportation at the level where planning and coordination decisions are effectively implemented.

This paper covers this gap by providing a quantitative analysis of the organization of road transport for the agricultural distribution in the South-East Development Region of Romania. The study focuses on the urban markets of Galați, Brăila and Tecuci, which are important in the local agricultural production and distribution system. This paper uses recent demographic, production and transportation data for 2024-2025 to evaluate the effect of distance, volume concentration and structure of transportation costs on the overall distribution efficiency.

The main purpose of the research is to determine the impact of transport organization on the cost-effectiveness of agricultural distribution in the regions. The aim of this paper is to answer the following research questions: (i) what is the effect of transport distances and demand volumes on total and average transport costs; (ii) what is the degree of economies of density in the regional distribution system; and (iii) what are the implications of these results for transport planning and agricultural logistics policy for the South-East region.

These issues are discussed in this paper, in some good ways that advance the research. It contributes to the little research that has been done on the organization of Romanian agricultural transport, providing a new empirical analysis at the level of the region, based on official statistical data. The findings are relevant not only for researchers but also for lawmakers, people who plan regional transportation and people who manage agricultural supply chains.

The subsequent section gives the literature assessment on transportation and distribution logistics of agriculture. The next part describes the methodology of the study, comprising the analytical models and the indicators used. The section of case studies presents the empirical application and results for the selected cities. The last section discusses the key conclusions and consequences of the research.

Literature review

The organization of transport and distribution in agricultural supply chains is a well known important determinant of economic performance especially in places with high levels of production and dispersed spatial arrangements . Agricultural logistics are different from industrial supply chains and confined by seasonality, perishability, fluctuation in output and dependency on environmental factors. These qualities highlight the importance of efficient transportation management and cost control (Christopher, 2016).

The early studies in logistics and transport economics indicate that the transport costs constitute a considerable percentage of the total distribution costs of agricultural products, particularly those with low unit value and high volume such as grains and vegetables (Ballou, 2004). If these efficiencies are slight, the transportation planning and utilisation of vehicles can have a substantial impact on the margins of producers and end market prices. Therefore the organization of transport is not only a problem of operation but also a significant aspect of competitiveness of agriculture.

One of the main themes in the literature is the relationship between cost, volume and distance. Models of transport economics invariably show that the total cost of transport is positively correlated with distance. The average cost, however, is highly sensitive to the concentration of volumes along the already existing routes (Button, 2010). This is particularly relevant for agricultural distribution where demand is spread among many producers and destinations. Economies of density are related to the fact that more traffic on the same transport infrastructure leads to lower average costs because vehicles and fixed assets are used more efficiently (Button, 2010).

Empirical research in developed and emerging economies confirms the importance of economies of density in transportation systems of agriculture. Regions strong in consolidating agricultural flows and coordinating transportation operations tend to have lower unit costs and be more resilient to cost shocks such as a rise in fuel prices (OECD/FAO, 2023). Alternatively, fragmented distribution systems with small shipment sizes and long distances are associated with higher costs and lower competitiveness.

Road transport is the principal distribution method for agricultural for most European countries because of its flexibility and door-to-door service provided (Rushton et al., 2017). But other modes like rail and inland waterways might give economic advantages for long haul bulk transport. Their utilization is typically hampered by infrastructure availability, transshipment fees and lack of flexibility. Road transport thus remains the dominating route, especially for distribution in regional agricultural logistics over short and medium distances.

However, agricultural supply lines are vulnerable to a multitude of dangers, as most items are transported by road. OECD/FAO (2023) study reveals that the pattern of road travel can be affected by changes in fuel prices, labor market constraints and laws on driving hours and pollution. And all of this has loomed larger in recent years with the cost of moving commodities around Europe rising, adding even more pressure on farmers and merchants.

The spatial distribution of production and consumption is a key aspect impacting the transport performance from the regional point of view. Where producing zones are near metropolitan markets, distribution costs are generally lower and the supply chain more stable (Bowersox et al., 2019). On the other hand, production in remote areas from consumption centers results in higher transportation costs and higher vulnerability to shocks. This spatial dimension underlines the need for the analysis to be done at the regional level, not the national average.

The spatial organization of logistics networks has been extensively studied in the transport geography literature. The spatial concentration of demand, network structure and transportation costs influence the goods distribution systems (Hesse and Rodrigue, 2004). The need to reduce costs and increase operating efficiency, especially when production and consumption take place in different places, causes the development of centralized distribution models.

According to Hesse and Rodrigue (2004) the performance of goods transport systems depends not only on the total volume, but also on the geographical distribution of flows. In general,

higher concentration is associated with efficiency gains through lower average costs, but the geographic dispersion of networks could result in higher complexity and cost burdens.
The literature of Central and Eastern Europe, especially Romania, indicates ongoing structural problems with agricultural logistics systems. Fragmented agricultural systems, poor collaboration amongst producers, limited aggregation facilities and high dependence on road transportation are among them (FAO, 2023). As many studies have shown, these characteristics prevent the realization of economies of density and raise the overall cost of agricultural distribution.

The South-East Development Region is a typical example of the need to remedy this deficiency. One of the most productive agricultural areas of Romania, it is distinguished by the large quantities of output, and by various spacial distribution of production and consumption. The region's reliance on road transport and its vulnerability to cost variations offer an appropriate framework for studying the impact of transport organization on the efficiency of distribution.

The literature stresses the crucial role of transport organization in agricultural distribution systems, pointing out the importance of distance, volume concentration and spatial structure. Theoretical and empirical studies provide important insights into these relationships, but there is a clear need for the use of transport economics models in practice that are region-specific and data-driven. The objective of this article is to present an applied evaluation of the organization of road transport and its influence on the efficiency of agricultural distribution in the case of the South-East Development Region of Romania, contributing to the existing literature.

Methodology

The methods of this study are based on standard transportation economics and logistics research modified to suit the needs of agricultural distribution systems. The method is based on well-known methods from transportation and logistics research, which aims at the most efficient and cost effective solutions (Ballou, 2004; Button, 2010).

Sources of data and extent of analysis

The data for demand estimation is demographic data from the National Institute of Statistics of Romania (INS, 2024), while the characteristics of agricultural production are from the national agricultural reports issued by the Ministry of Agriculture and Rural Development (MADR, 2023).

The road distances, cost coefficients and other transport related parameters are based on real market values and standards for transport economics, as indicated in the literature (OECD/FAO, 2023).

The analysis is limited to road transport, the main distribution mode of agricultural products in Romania. Other transportation modes such as rail and inland waterways are not included in order to keep the consistency of the methodology and to reflect the actual situation of the regional agricultural logistics systems in operation. Transport demand is the total amount of agricultural products transported from production zones to urban markets in the given region. You can't be too specific on shipments so you use a population consumption method to see how much people want to buy. This is a typical way of understanding the food distribution in various regions (FAO 2023).

This section will discuss the research methods that were used, the main research theories and why they should be accepted.

Let q_i denote the daily quantity of agricultural products delivered to urban market i. This quantity is estimated as:

$$q_i = \frac{P_i \cdot c}{1000}$$

where:

- P_i represents the population of urban market i,
- c denotes the average per capita daily consumption of agricultural products (kg/inhabitant/day),
- q_i is expressed in tons per day.

The total daily transport requirement at the regional level is then defined as:

$$Q = \sum_{i=1}^{n} q_i$$

where n is the number of served urban markets. This formulation captures the aggregation of agricultural flows to some destinations and is the basis for the subsequent computations of costs (Ballou, 2004).

Distance assessment and spatial distribution

This paper assesses the spatial aspect of transport organization by analyzing the road distances from a regional aggregation point to the selected urban markets. Let d_i be the one-way road distance (km) from the aggregation point to market i. The total travelled distance per day of transport vehicles is defined as follows:

$$L = \sum_{i=1}^{n} 2 \cdot d_i$$

assuming round-trips for each collection route. This simplified version is convenient for regional distribution systems which gather directly from a central point to urban markets and simplifies the process. It works pretty well for these kind of systems. Further, the costs involved with the distance between the two points assist in the understanding of the impact of the system (Button, 2010).

Modeling transportation costs

Following the known methodology in transport economics (Button, 2010; Rushton et al., 2017), the total transportation cost is divided into fixed and variable components. The total transportation cost per day C_T is formulated as:

$$C_T = C_F + C_V$$

where:

- C_F is fixed costs,
- C_V is variable costs.

Fixed costs are costs that do not vary with distance or volume for a short time period, such as administrative overhead, vehicle depreciation and permanent labor costs. For the empirical application, fixed costs are calculated on a daily basis to be consistent with the variable cost calculations.

The variable costs are influenced by the distance travelled and the amount carried and are defined as:

$$C_V = c_{km} \cdot L + c_q \cdot Q$$

where:

- c_{km} is the variable cost per kilometer travelled (lei/km), which includes fuel, maintenance and driver costs,
- c_q is the handling cost per ton of agricultural products (lei/ton),

- L is the total distance travelled (km),
- Q Q is the total amount carried (tons/day).

This formula shows the two main factors that influence the variable costs of transport in the agricultural distribution by road: distance and volume (Ballou, 2004)

Density economies and efficiency metrics

To assess the efficiency of transport organization, the study uses two main indicators: average transport costs and a density efficiency indicator. The average transportation cost C_{avg} is given by:

$$C_{avg} = \frac{C_T}{Q}$$

This measure indicates the cost of transporting a ton of agricultural products and is an immediate indicator of the efficiency of distribution.

In addition, economies of density are evaluated by a density efficiency indicator E_d , defined as:

$$E_d = \frac{Q}{L}$$

Higher values of E_d mean a greater concentration of transported volume per unit of distance. According to the theory of transport economics, when E_d goes up, average transportation prices go down. This means that transportation capacity is used more efficiently (Button, 2010).

We test the existence of economies of density by estimating the impact of variations in transported volume on average transport costs, controlling for distance. Average costs are said to decline with volume in the presence of economies of density.

Analytical methodology

The empirical analysis is based on a sequential methodology. First, demographic data are used to estimate daily transportation demand for each selected urban market. Second, road distances are estimated and aggregated to estimate total distance traveled. Third, fixed and variable transportation costs are estimated based on observed cost coefficients. Finally, efficiency measures are estimated to evaluate the efficiency of the transportation system and to test for the presence of economies of density.

The methodological approach is simple and can be applied more than once. Therefore, the scope of the study can be expanded to include more areas or urban markets. The method is directed towards providing a comprehensive picture of the organization of road transport in farm distribution systems by integrating demand estimation, spatial analysis and cost modelling.

Case study: Integrated analysis of the mathematical and economic organization of road transport in the distribution of agricultural products

Regional distribution system definition

The empirical study is concerned with the logistics of road transport in the distribution of agricultural products in three urban markets from the South-East Development Region of Romania: Galați, Brăila and Tecuci. They were selected because they are important centers of consumption and aggregation and are surrounded by highly productive agricultural lands, especially in terms of cereal and horticultural production (INS, 2024; MADR, 2023).

Distribution is done only by road transport, which is the main mode of transport for agricultural freight in Romania (OECD/FAO, 2023). The case study is applied using the

methodological framework described in the previous section with the current demographic and transport data for the period 2024–2025.

The aggregation depot has index M. The set of urban markets is given by:

$$i \in \{1,2,3\}$$

where:

i =1 : Galați

i =2 : Brăila

i =3 : Tecuci

Center of gravity method for depot location determination

The case study relates to a centralized system of distribution of road transport, where agricultural products are collected in one regional depot and then delivered to urban markets. The aggregation depot is assumed to be located in the commune of Șendreni, Galați County, locality near the city of Galați and the intersection of important regional roads, connecting Galați, Brăila and the north of Galați County.

The location of the regional depot at Șendreni is justified by spatial and economic criteria. Șendreni's geographical position is close to the main areas of agricultural production of the south and centre counties of Galaţi and to the direct road access to the urban markets of Galaţi and Brăila. The site is suitable for efficient aggregation of agricultural produce from nearby rural areas and for short distance deliveries to two largest demand centers studied.

The choice of a depot location is consistent with the principles of spatial allocation underlying the transport cost model. As discussed in the methodology section, the total distance travelled by distribution vehicles is an important determinant of transport costs. The depot's location near Galaţi reduces the average distance to the main market, which accounts for the lion's share of total demand. The closeness to Brăila enables an efficient servicing of the market with a major increase of the total travelled distance.

Demand weighted spatial allocation can also be used to evaluate the suitability of the chosen depot location. Because the total daily transported volume of Galați and Brăila, together, is over 90%, it is relevant to consider how the aggregation point is positioned closer to these points of high demand, and the benefits of a reduction in total transport distance and average cost. Moving the depot further to the north or east would increase the distances for the main flows and lead to increased transportation costs, without any gains in efficiency.

Thus, the case study considers a depot location that is the approximate centroid of the distribution system weighted by the demand. No explicit formal calculation for the center of gravity is made but the location chosen embodies the same basic principle: minimizing the sum of the distance weighted flows. This is often the case in regional logistics planning, particularly when transport demand is dominated by only few destinations with very high volumes.

The location of the aggregation depot is clearly indicated in the case study, linking the choice of the location of the aggregation depot to empirical data and transportation cost models.

Let (x_i, y_i) represent the geographic coordinates of demand point i, and q_i the daily transported quantity (Raicu et al., 2011).

$$x_M = \frac{\sum_{i=1}^{n} q_i x_i}{\sum_{i=1}^{n} q_i},\ y_M = \frac{\sum_{i=1}^{n} q_i y_i}{\sum_{i=1}^{n} q_i}$$

Daily transport demand is estimated using a population-based consumption model:

$$q_i = \frac{P_i \cdot c}{1000}$$

where P_i represents the population of city i and $c = 0{,}95$ kg/inhabitant/day.

Using INS (2024) population data:

$$q_1 = 285{,}52 \text{ t/ day},\ q_2 = 176{,}97 \text{ t/ day},\ q_3 = 45{,}85 \text{ t/ day}$$

Total daily transported quantity is:

$$Q = \sum_{i=1}^{3} q_i = 508{,}34 \text{ t/day}$$

Using approximate coordinates:

Galați (45,435 °N 28,046 °E)
Brăila: (45,269 ° N, 27,957 ° E)
Tecuci: (45,849 °N, 27,434 °E)

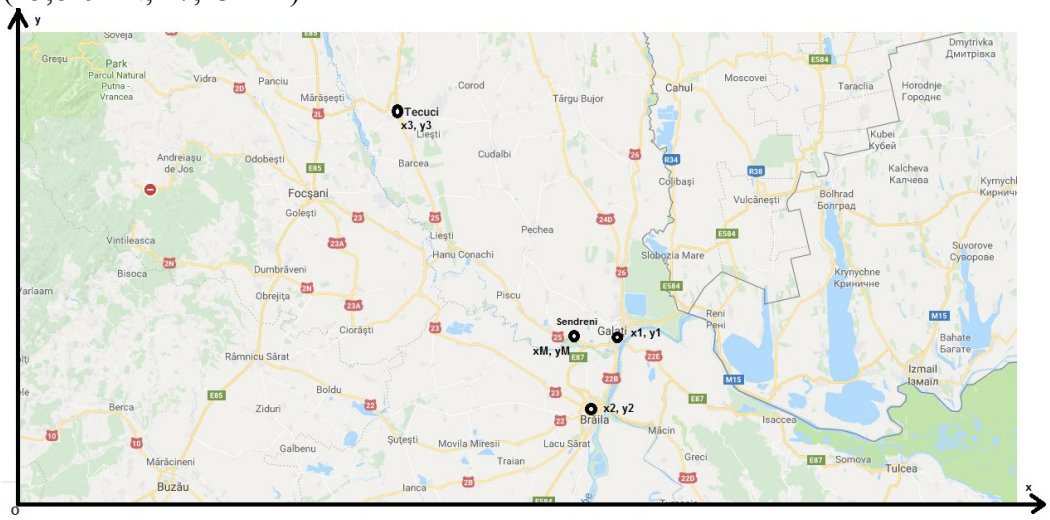


Figure 1. Depot location

Source: Authors' own research.

Spatial configuration and distance modeling

Let d_i be the one-way road distance from the depot to urban market i:

$$d_1 = 12 \text{ km},\ d_2 = 22 \text{ km},\ d_3 = 72 \text{ km}$$

Total distance travelled per day (assuming round trip deliveries):

$$L = 2\sum_{i=1}^{3} d_i = 212 \text{ km/day}$$

Transport cost model

Total daily cost of transport is defined as:

$$CT = CF + CV$$

Fixed costs are estimated to be:

$$CF = 18200 \text{ lei/day}$$

Transport costs vary with the quantity and the distance:

$$CV = c_{km} \cdot L + c_q \cdot Q$$

with:

$$c_{km} = \frac{5{,}1\text{lei}}{\text{km}},\ c_q = 150\ \text{lei/ton}$$

$$CV = 5{,}1 \cdot 212 + 150 \cdot 508{,}34 = 77332{,}2\ \text{lei/day}$$

$$CT = 95532{,}2\ \text{lei/day}$$

Efficiency indicators (reference case)

Average cost of transport:

$$C_{avg} = \frac{C_T}{Q} = 187{,}96\ \text{lei/ton}$$

Density indicator:

$$E_d = \frac{Q}{L} = 2{,}40\ \text{tons /km}$$

Income and profitability analysis

Daily incomes are calculated as follows:

$$P = (p_s - p_a) \cdot q_{day}$$

where:

- p_s is the average selling price per kg (lei/kg),
- p_a is the average acquisition price per kg (lei/kg),
- q_{day} is the quantity (kg/day) sold daily.

It is given:

$$q_{day} = Q \cdot 1000 = 508340\ \text{kg/ day}$$

$$p_s = 1{,}80\ \text{lei/kg}\ ;\ p_a = 1{,}30\ \text{lei/kg}$$

$$P = 0{,}50 \cdot 508340 = 254170\ \text{lei/ day}$$

Total profit per day:

$$\Pi = P - CT = 254170 - 95532{,}2 = 158637{,}8\ \text{lei/day}$$

Hypothesis 1: 20% rise in consumption (density effects)

$$Q' = 1{,}2 \cdot Q = 600{,}84\ \text{t/ day}$$

$$q'_{zi} = 600840\ \text{kg/ day}$$

$$P' = 0{,}50 \cdot 600840 = 300420\ \text{lei / day}$$

Distance is permanent. Average cost is:

$$C'_{avg} = 182{,}1\ \text{lei/ton}$$

Total transportation Cost:

$$CT' = 109407{,}2\ \text{lei/day}$$

Elasticity of transport cost with respect to incomes (Raicu et al., 2011):

$$e_{CT,P} = \frac{\Delta CT/CT}{\Delta P/P}$$

$$\frac{\Delta CT}{CT} = \frac{109407{,}2 - 95532{,}2}{95{,}532.2} = 0{,}1452$$

$$\frac{\Delta P}{P} = \frac{300420 - 254170}{254170} = 0{,}1819$$

$$e_{CT,P} = \frac{0{,}1452}{0{,}1819} = 0{,}798$$

Density return:

$$RD = \frac{1}{e_{CT,P}} = \frac{1}{0{,}798} = 1{,}253$$

The system has economies of density since RD>1.

Hypothesis 2: introduction of a new urban market (effects of scale)

The fourth urban market is introduced (Tulcea) and the number of served markets will increase from N=4, to N=5.

$$Q'' = 561{,}35 \text{ t/ day}\ ,\ q''_{zi} = 561350 \text{ kg/ day}$$

$$P'' = 0{,}50 \cdot 561350 = 280675 \text{ lei / day}$$

Total cost of transport:

$$CT'' = 104401{,}7 \text{ lei/day}$$

Average cost:

$$C''_{avg} = 186 \text{ lei/ton}$$

Elasticities for transport cost. (Raicu et al., 2011):

$$e_{CT,P} = \frac{\Delta CT/CT}{\Delta P/P}$$

$$\frac{\Delta CT}{CT} = \frac{104401{,}7 - 95532{,}2}{95532{,}2} = 0{,}0928$$

$$\frac{\Delta P}{P} = \frac{280675 - 254170}{254170} = 0{,}1043$$

$$e_{CT,P} = 0{,}889$$

$$e_{CT,N} = \frac{\Delta CT/CT}{\Delta N/N} = \frac{0{,}0928}{(5-4)/4} = 0{,}372$$

Return scale:

$$RS = \frac{1}{\left(e_{CT,P} + e_{CT,N}\right)} = \frac{1}{1{,}169} = 0{,}856$$

Because RS < 1, the system has diseconomies of scale.

Integrated Interpretations

The results show that the greater the consumption in the current distribution network, the greater the economies of density and the better the financial performance. This is the other hand, the addition of new urban markets to the network increases complexity and distance and causes diseconomies of scale in the existing, centralized structure.

Conclusion

Based on a quantitative analysis of the road-based agricultural distribution system in Romania's South-East Development Region, we identified different quantifiable links between the geographical arrangement, the transportation costs, the efficiency indicators and the economic performance. The conclusions below are directly drawn from the results achieved in the case study.

The transport efficiency is a function of the layout of the distribution system. The location of the aggregation depot in the peri-urban area of Șendreni leads to a total daily distance of 212 km for the supply of the urban markets of Galați, Brăila and Tecuci.

The total daily costs of transport in the baseline conditions are 95,532.2 lei. Variable costs are about 81% and fixed prices 19%. The average transport cost is 187.96 lei/ton, which shows an effective distribution of the costs for a total daily volume of 508.34 tons. The results confirm the cost structure of the regional distribution system is dominated by volume concentration on short routes.

In the base scenario the density indicator is reached at 2.40 tons/km which means a rather high usage of transport capacity. Total daily volume is 600.84 tons and total distance is the same with 20% increase in consumption under Hypothesis 1. The total transport costs increase at 109,407.2 lei and the average transport cost decreases at 182.10 lei/ton. The elasticity of total transport costs with respect to income is 0.798, corresponding to a density return of 1.253. The numerical results clearly show economies of density from volume increase in a static spatial network.

According to Hypothesis 2, the results are quantitatively different when the distribution network is expanded. The total volume per day increases to 561.35 tons and the total distance traveled increases to 392 km. with the addition of a new urban market. The total transport costs would increase to 104,401.7 lei, while the transport cost per ton would remain close to the baseline of 186.03 lei. The elasticity of transport costs to income is 0.889 and the elasticity of the increase in number of supplied markets is 0.857, with the resulting scale return being 0.857. These values indicate the presence of diseconomies of scale, because of the disproportionate growth of distance compared with the volume transported.

The income analysis supports these findings. The baseline scenario has daily revenues of 915,012 lei. Hypothesis 1. Incomes are increased to 1,081,512 lei, the growth being volume driven and more efficient. Hypothesis 2 supposes the earnings to reach 1,010,430 lei, but the increase in travel effort has the effect of limiting the improvements in efficiency. The results show that income growth based on demand concentration is more economically feasible than income growth based on spatial expansion.

Numbers indicate that in regional agricultural distribution systems density effects rather than scale effects are the main reasons for transportation efficiency. Shorter distances and consolidated volumes make it possible to quantify reductions in average transport costs and improve economic efficiency. Insufficient volume consolidation in developing networks, however, creates inefficiencies. The results can quantitatively verify the transport planning strategies of centralized aggregation and improved spatial layout. The analysis is restricted to one region and centralized distribution scheme, but it can be generalized to other regions or modified to other configurations.

Further work might consider multi-depot systems, different vehicle capacities or seasonal variation in demand to determine under what conditions economies of scale could be realized. However, the present study provides some important quantitative evidence for transport planning and agricultural logistics policy in the South-East Development Region of Romania.

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