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Kuhn's Hungarian Algorithm using a Commercial Network of Wholesale Warehouses and Retail Stores

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A R T I C L E I N F O

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A B S T R A C T

Econometrics is a discipline that can be used for decision profitability. To this end, using Kuhn's algorithm, we analyzed the profitability problem for chain stores. An econometric model shows the economic relationships that may occur between variables. These relationships describe the behavior of economic variables and try to shape reality as well.

1. Introduction

Econometrics allows developing and adopting decisions necessary for corporate profitability. Among them is also the commercial activity being a real challenge in Romania by competing natives by large commercial systems in the EU. Everyone acknowledges the problem, and attack authorities and continued the "national sport" of the store on the corner of the street, even this being stocked by supermarkets while local producers accuse their spoliation by major stores like Kaufland. or even ignoring them by the same stores preferring imports. Why? Missing courage to develop, adopt, promote, operate and expand pragmatic solution. The solution is very simple, network purchasing wholesale deposits from small and medium sized agro-food and retail stores providing consumers the necessary domestic agro-food products. It's just the solution presented in the case study illustrated below. Furthermore, the solution can be generalized in the sense of a network of wholesale warehouses, small and medium purchasing goods whose owners are small producers associations or other legal persons who have undertaken the task in question. It's just the solution presented an overview of the case illustrated at the end of this paper, **personal contribution** to the study of this pressing issues for the economy, entrepreneurship and consumption in Romania considering it entertaining factor of the national economy. To solve this problem requires the ability to manage such a network to ensure the profitability without discouraging the profit source, the consumer.

Solving the problem of inter-connection of small and medium-sized business with consumers interested in buying agro-food products for domestic consumption is the area where econometrics, science and art at the same time, it may be imposed as essential working tool of economic activity, exceed the prosaic level of accounting and financial accounting analysis and reaching performance achieved scholarly approach to financiers and managers of large companies.

Let it be consumer network as rural stores and / or district as aggregate $C_1, C_2, \ldots C_n$, domestic consumer products as aggregate $P_1, P_2, \ldots P_m$ and deposits foodservice purchasing products from local small and medium producers as aggregate $D_1, D_2, \ldots D_p$, ensemble for which the question arises of the choice the warehouse for each product provider for each store without excluding the possibility of trade between deposits if necessary. It, therefore, of making and adoption decisions on the choice of supply sources with various products traded by retail network for domestic consumption.

2. Solving problem

Solving the problem is a matter of optimization, consists in minimizing the total volume of products monthly traded, this volume is the sum total monthly consumption of each consumer product multiplied by the distance to the warehouse from that source. Otherwise speaking, the optimization is to minimize the volume transported and therefore minimize transport costs inherent supply store network.

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We know matrices [L] of distances [km] from warehouses and shops, and [I] intensities [t / month] consumption of each product in each store. Total monthly traffic volume

$$[Q_{i,j}] = \sum_{k=1}^{p} I_{k,i} \times L_{j,k} \quad (1)$$

and the issue is resolved minimizing function

$$F_i = \sum_{i=1}^{n} \sum_{j=1}^{m} Q_{i,j} \times x_{i,j} \quad (2)$$

where the element

$x_{i,j}=1$ when the product P_i is brought from the warehouse D_j, otherwise

$x_{i,j}=0$.

Once minimized function F_i, identify the deposit that will be brought to each product agro-food to satisfy domestic consumption.

The above wording is perfectly valid if the unit network of wholesale warehouses and retail stores, not if wholesale deposits owned by other legal entities than retail store owner, whether third producer associations or legal persons: in this case it requires generalization of solving the problem presented here-this is illustrated in the end of study - personal contribution on the implementation of this tool to develop, adopt, promote, operate and expand pragmatic solution to commercial networks of domestic consumption in Romania to encourage development small and medium producers. In this way, it triggered a chain reaction of encouraging domestic consumption and encourage food production what could be the decisive factor of national economy by engaging effort of natives. However, it must adopt proper tools. Kuhn's Hungarian algorithm is too well known like many other econometric tools, imposing, so proper training of economists decisively to support the efforts of entrepreneurs.

Apropos of training economists, there is a chance: in "merit list" of economic faculties in the country, some of which is noted by banking specialties, accounting, etc.-there are still some "niches" between that and econometrics ≡ economic faculty of Galati economic can adopt this field as a priority and to impose in the "merit list" by economists specialized training in econometrics and therefore in managing commercial networks much needed national economy.

3. **Kuhn's Hungarian algorithm**

Once defined the problem and established procedure for drawing up the decision, the matter shall be reduced to an algorithm, which is in this case Hungarian Kuhn's algorithm. It is conducted as follows:

- It will calculate
  $Q^1_{i,j} = Q_{i,j} - min_i Q_{i,j}$
  and
  $Q^2_{i,j} = Q^1_{i,j} - min_j Q_{i,j}$
- Looking l_{ix} line matrix with fewer zeros and fall one of these zeros, $l_{ixp}=0$, then are barred zeros from line x and column p. Repeats this step for all possible zeros, without taking into account zeros cut before. If zero was reached one framed in each line and column, then obtained the optimal solution, otherwise the next step.
- Processing further search of the optimal solution:
  - all lines are marked with an asterisk who have a zero framed,
  - be marked each column having at least one zero in the marked lines,
  - be marked every line has at least one zero in the columns marked

  and
  - reiterate last two actions until it becomes impossible to obtain other marked lines and columns.
- cut each line and each column marked.
- take into account the table with the lowest number of rows and columns that were not cut from the original matrix.
- It reiterates everything from step two until all lines and all columns are marked.

Practical, it seeks monthly minimum traffic volume between warehouses and shops satisfying monthly domestic consumption to minimize transport costs: commercial network operating costs are reduced and therefore sales prices been tempted for consumers-it encourages consumption, is triggered so the above-mentioned chain reaction between domestic consumption and production of agro-food, chain reaction being entertaining factor of the domestic economy. Obviously, there is a limit, but it is imperative to reach this limit and who can do this, is just the econometrist, endowed with the ability to manage a commercial network: exactly because it make a fuss of service standards regarding of the success of supermarket chains EU who invading Romania, should be noted that the tax and accounting standards are or may be the same standard and local entrepreneurs can meet these standards. If local entrepreneur lacks an ability to impose, when it is that of managing the commercial network, the burden of the econometrist.

4. Case study

Considering that D_1 was initially chosen supplier for the supply of meat, matrix [I] is next:

Table 1. Matrix [I] for provider D_1

Items to be specified	Items already specified [t / month]			
	Meat	Store 1°	Store 2°	Store 3°
Poultry	-	20	30	24
Fish	50	90	12	6
Dairy	40	10	30	20
Flour	6	8	10	12
Sweets	3	9	15	12

and matrix [L] is the following:

Table 2. Matrix [L] for provider D_1

Sender	Receiver [km]								
	D_1	D_2	D_3	D_4	D_5	D_6	C_1	C_2	C_3
D_1	-	500	400	800	1.000	600	-	-	-
D_2	-	-	600	500	300	300	-	-	-
D_3	-	-	-	400	800	450	-	-	-
D_4	-	-	-	-	500	800	-	-	-
D_5	-	-	-	-	-	280	-	-	-
D_6	-	-	-	-	-	-	300	500	480

Doing the supply of meat from the warehouse D_1, resulting

$$Matrix\ [I] = \begin{vmatrix} 0 & 20 & 30 & 24 \\ 50 & 9 & 12 & 6 \end{vmatrix} \qquad Matrix\ [L] = \begin{vmatrix} 0 & 500 & 400 & 800 & 1000 & 500 \\ 300 & 400 & 500 & 290 & 600 & 300 \end{vmatrix}$$

$$Q_{i,j} = \sum_{k=1}^{p} I_{k,i} \times L_{j,k} = \begin{vmatrix} 40 & 10 & 30 & 20 \\ 6 & 8 & 10 & 12 \\ 3 & 9 & 15 & 12 \end{vmatrix} x \begin{vmatrix} 900 & 800 & 340 & 600 & 390 & 500 \\ 400 & 500 & 700 & 320 & 700 & 480 \end{vmatrix}$$

$$= \begin{vmatrix} 42600 & 44000 & 37000 & 31480 & 40500 & 32520 \\ 15900 & 41200 & 32780 & 51730 & 64280 & 36580 \\ 38000 & 58000 & 45200 & 59300 & 71700 & 47600 \\ 16200 & 20200 & 18200 & 16960 & 23100 & 16160 \\ 21000 & 23100 & 19200 & 17850 & 22650 & 17460 \end{vmatrix} \tag{3}$$

Ignoring the first column, one that includes at least one zero, and applying Kuhn's Hungarian algorithm, resulting deposits list who supplying shops for domestic consumption:

- meat from D_1,
- flour from D_2,
- fish from D_3,
- poultry from D_4,
- sweets from D_5

and

- dairy from D_6.

The value of function F: F_1 = 42.600 + 31.480+32.780 + 47.600 + 20.200 + 22.650 = 197.310

The procedure is repeated successively considering the supply of meat from each other deposits, D_2, D_3, D_4, D_5 and D_6 to set the supply scheme in each of these cases. It should be noted that if the matrix [I] remains the same since the intensity of consumption remains unchanged, then the matrix [L] will change each time due to changing sources of supply by bringing meat from another warehouse. In this paper, it was considered that wholesale deposits could supply any product to generalize application using of Kuhn's Hungarian algorithm. In reality, a deposit provides a narrower range of products, which simplifies the matrix [L] by increasing the number of elements equal to zero as a result of uselessness transport certain routes and thus simplifies the calculation.

The case of meat supply from deposit D_2:

$$Matrix\ [I] = \begin{vmatrix} 0 & 20 & 30 & 24 \\ 50 & 9 & 12 & 6 \end{vmatrix} \qquad Matrix\ [L] = \begin{vmatrix} 500 & 0 & 600 & 500 & 300 & 300 \\ 300 & 400 & 500 & 290 & 600 & 300 \end{vmatrix}$$

$$Q_{i,j} = \sum_{k=1}^{p} I_{k,i} \times L_{j,k} = \begin{vmatrix} 40 & 10 & 30 & 20 \\ 6 & 8 & 10 & 12 \\ 3 & 9 & 15 & 12 \end{vmatrix} x \begin{vmatrix} 900 & 800 & 340 & 600 & 390 & 500 \\ 400 & 500 & 700 & 320 & 700 & 480 \end{vmatrix}$$

$$= \begin{vmatrix} 42600 & 44000 & 37000 & 31480 & 40500 & 32520 \\ 40900 & 16200 & 42780 & 36730 & 29280 & 26580 \\ 58000 & 38000 & 53200 & 47300 & 43700 & 59600 \\ 19200 & 17200 & 19200 & 15160 & 18900 & 14960 \\ 23500 & 21600 & 19800 & 16950 & 20550 & 16860 \end{vmatrix} \quad (4)$$

Ignoring the second column, one that includes at least one zero, and applying Kuhn's Hungarian algorithm, resulting deposits list who supplying shops for domestic consumption:

- sweets from D_1,
- meat from D_2,
- flour from D_3,
- poultry from D_4,
- fish from D_5

and

- dairy from D_6.

The value of function F: F_2 = 183.360

The case of meat supply from deposit D_3:

$$Matrix\ [I] = \begin{vmatrix} 0 & 20 & 30 & 24 \\ 50 & 9 & 12 & 6 \end{vmatrix} \qquad Matrix\ [L] = \begin{vmatrix} 400 & 600 & 0 & 600 & 800 & 450 \\ 300 & 400 & 500 & 290 & 600 & 300 \end{vmatrix}$$

$$Q_{i,j} = \sum_{k=1}^{p} I_{k,i} \times L_{j,k} - \begin{vmatrix} 40 & 10 & 30 & 20 \\ 6 & 8 & 10 & 12 \\ 3 & 9 & 15 & 12 \end{vmatrix} x \begin{vmatrix} 900 & 800 & 340 & 600 & 390 & 500 \\ 400 & 500 & 700 & 320 & 700 & 480 \end{vmatrix}$$

$$= \begin{vmatrix} 42600 & 44000 & 37000 & 31480 & 40500 & 32520 \\ 35900 & 46200 & 17780 & 31730 & 54280 & 34080 \\ 54000 & 62000 & 29200 & 43300 & 63700 & 45600 \\ 27800 & 20800 & 15800 & 14560 & 21900 & 15060 \\ 22200 & 23400 & 18000 & 16650 & 22050 & 17310 \end{vmatrix} \quad (4)$$

Ignoring the third column, one that includes at least one zero, and applying Kuhn's Hungarian algorithm, resulting deposits list who supplying shops for domestic consumption:

- dairy from D_1,
- sweets from D_2,
- meat from D_3,
- fish from D_4,
- flour from D_5

and

- poultry from D_6.

The value of function F: F_3 = 191.570

The case of meat supply from deposit D_4:

$$Matrix\ [I] = \begin{vmatrix} 0 & 20 & 30 & 24 \\ 50 & 9 & 12 & 6 \end{vmatrix} \qquad Matrix\ [L] = \begin{vmatrix} 800 & 500 & 400 & 0 & 900 & 800 \\ 300 & 400 & 500 & 290 & 600 & 300 \end{vmatrix}$$

$$Q_{i,j} = \sum_{k=1}^{p} I_{k,i} \times L_{j,k} = \begin{vmatrix} 40 & 10 & 30 & 20 \\ 6 & 8 & 10 & 12 \\ 3 & 9 & 15 & 12 \end{vmatrix} x \begin{vmatrix} 900 & 800 & 340 & 600 & 390 & 500 \\ 400 & 500 & 700 & 320 & 700 & 480 \end{vmatrix}$$

$$= \begin{vmatrix} 42600 & 44000 & 37000 & 31480 & 40500 & 32520 \\ 55900 & 41200 & 32780 & 11730 & 59280 & 51580 \\ 70000 & 58000 & 45200 & 27300 & 67700 & 59600 \\ 21000 & 20200 & 18200 & 12160 & 22500 & 17960 \\ 23000 & 23100 & 19200 & 15450 & 22350 & 18360 \end{vmatrix} \quad (5)$$

Ignoring the fourth column, one that includes at least one zero, and applying Kuhn's Hungarian algorithm, resulting deposits list who supplying shops for domestic consumption:

- flour from D_1,
- dairy from D_2,
- fish from D_3,
- meat from D_4,
- sweets from D_5

and

- poultry from D_6.

The value of function F: F_4 = 193.750

The case of meat supply from deposit D_5:

$$Matrix\ [I] = \begin{vmatrix} 0 & 20 & 30 & 24 \\ 50 & 9 & 12 & 6 \end{vmatrix} \qquad Matrix\ [L] = \begin{vmatrix} 800 & 500 & 400 & 0 & 900 & 800 \\ 800 & 400 & 500 & 200 & 600 & 300 \end{vmatrix}$$

$$Q_{i,j} = \sum_{k=1}^{p} I_{k,i} \times L_{j,k} = \begin{vmatrix} 40 & 10 & 30 & 20 \\ 6 & 8 & 10 & 12 \\ 3 & 9 & 15 & 12 \end{vmatrix} x \begin{vmatrix} 900 & 800 & 340 & 600 & 390 & 500 \\ 400 & 500 & 700 & 320 & 700 & 480 \end{vmatrix}$$

$$= \begin{vmatrix} 42600 & 44000 & 37000 & 31480 & 40500 & 32520 \\ 40900 & 31200 & 35280 & 52730 & 28280 & 11580 \\ 58000 & 50000 & 47200 & 59300 & 42900 & 27600 \\ 19200 & 19000 & 18500 & 16960 & 18780 & 13160 \\ 21000 & 21600 & 18000 & 15450 & 19650 & 15960 \end{vmatrix} \quad (6)$$

Ignoring the fifth column, one that includes at least one zero, and applying Kuhn's Hungarian algorithm, resulting deposits list who supplying shops for domestic consumption:

- flour from D_1,
- dairy from D_2,
- sweets from D_3,
- poultry from D_4,
- sweets from D_5

and

- fish from D_6.

The value of function F: F_5 = 184.580

The case of meat supply from deposit D_6:

$$Matrix\ [I] = \begin{vmatrix} 0 & 20 & 30 & 24 \\ 50 & 9 & 12 & 6 \end{vmatrix} \qquad Matrix\ [L] = \begin{vmatrix} 500 & 300 & 450 & 800 & 280 & 0 \\ 800 & 400 & 500 & 290 & 600 & 300 \end{vmatrix}$$

$$Q_{i,j} = \sum_{k=1}^{p} I_{k,i} \times L_{j,k} = \begin{vmatrix} 40 & 10 & 30 & 20 \\ 6 & 8 & 10 & 12 \\ 3 & 9 & 15 & 12 \end{vmatrix} x \begin{vmatrix} 900 & 800 & 340 & 600 & 390 & 500 \\ 400 & 500 & 700 & 320 & 700 & 480 \end{vmatrix} \quad (7)$$

$$= \begin{vmatrix} 42600 & 44000 & 37000 & 31480 & 40500 & 32520 \\ 40900 & 31200 & 35280 & 52730 & 28280 & 11580 \\ 58000 & 56000 & 47200 & 59300 & 42900 & 27600 \\ 19200 & 19000 & 18500 & 16960 & 18780 & 13160 \\ 23000 & 21600 & 18000 & 15450 & 19650 & 15960 \end{vmatrix}$$

Ignoring the sixth column, one that includes at least one zero, and applying Kuhn's Hungarian algorithm, resulting deposits list who supplying shops for domestic consumption:

- sweets from D_1,
- dairy from D_2,
- flour from D_3,
- poultry from D_4,
- fish from D_5

and

- meat from D_6.

The value of function F: F_6 = 176.650

Table 3. Function values F

The case of meat supply from deposit:	Function value F [tone.km]
D1	197.310
D2	183.360
D3	191.570
D4	193.750
D5	184.580
D6	**176.650**

The lowest value of the function F was obtained for the last case, which identifies the solution of case study: supplying for the three stores will be in accordance with the following configuration:

Table 4. The solution of the case study

Agro-food product	Deposit
Meat	D_6
Poultry	D_4
Fish	D_5
Dairy	D_2
Flour	D_3
Sweets	D_1

Virtual, deposits were considered universal in this scheme: **Logically**, they are actually places for the location of a deposit strictly specialized in certain food and agriculture in the trade network promoted by entrepreneur and **practical**, deposits must be specialized because each has its own specific equipment for storage and handling, and their staff trained for the work with a certain specified *specific*≡ each warehouse location, it will be done in accordance with its assigned task while shops C_1, C_2, C_3, etc. they will be carried out in accordance with a generalized architecture and standard configuration to maximize the efficiency of operations and maintenance.

We thus revealed "secret" of commercial networks: location stores $C_1, C_2, \ldots C_n$ using marketing methods for segmentation of customer products P1, P2,. . . Pn and then placing deposits with a specific profile $D_1, D_2, \ldots D_p$ using Kuhn's Hungarian algorithm to minimize monthly costs of transport on supply stores-the process outlined here has been simplified enough, but for understanding the "secret" of network, at the end of this paper, I will illustrate the process in all its complexity and it will be easy to understand since the "secret" trade network has been revealed.

5. The practical application of the proposed procedure

Calculations of this procedure can be performed manually, which involves work and risk. The best practice is the development of a worksheet in Excel, in which case proceed as follows for the following:

- write matrix [I] in fields A1 : D5
- write matrix [L] in fields A7 : F10
- obtain matrix [Q] in fields A12 : F16, in each of these fields is writing formula defining element of the array concerned

- achieve value of function F in field A17 that was written in the corresponding calculation formula
- while the matrix [I] remains unchanged, modified matrix [L] depending on the deposit designated for the supply of meat and note the value of the function F
- For the minimum value of the function F, is operating matrix [Q] to designate deposits to which it supplies various products.

This procedure can also be executed using a software specifically developed: it is advisable to avoid it until the time the procedure was performed in Excel, the econometrist can confirm with certitude feasibility of the procedure in Excel and can then verify, by running software, confirming it or, on the contrary, it infirming results.

That is why it requires the econometrist ability to operate in Excel working procedures in this case ≡ otherwise, risks to organize a non-feasible commercial network and therefore, unprofitable , are excessive.

In the final analysis, the econometrist role is to elaborate the last resort decisions should ultimately adopt entrepreneur: trust in econometrist is essential and can be achieved only if proposals it has been validated by the current reality, which is why it is necessary rigorous "translation" of procedures in Excel by econometrist, avoiding the risks of adopting a software product before its testing by a competent person ≡ this is why training is required for econometrist, to "translate" econometrics procedures in Excel.

6. Kuhn's algorithm generalization

In the case study, it was considered that the cost price of each product is the same in all locations required is the market price, which reduced the defining the profile of the deposit to minimize transport costs from warehouse to consumer stores: nothing false, market requiring selling price while the cost price is imposed on the one hand by the price of production of agro-food assortment concerned and on the other, by the technological equipment depreciation costs of deposit in question, if the machine's technological profile is the same, refrigerators, etc., then the price of production, of the agricultural products, vary from one location to another ≡ different production price for fish farming and price for fish obtained in the natural environment.

Consequently, the volume of monthly traffic

$$[Q_{i,j}] = \sum_{k=1}^{p} I_{k,i} \times L_{j,k} \tag{8}$$

It will be replaced by monthly costs of supply

$$[C_{i,j}] = \sum_{k=1}^{p} I_{k,i} \times L_{j,k} \times p_{j,k} \tag{9}$$

where $p_{j,k}$: the cost of the deposit taking account of production price of agro-food assortment in the neighborhood where the deposit is located.

The following procedure remains the same, the novelty of generalizations being replacement of trafficked monthly volume for supply stores consumer in commercial network with total monthly costs of supply for consumer shops of commercial network.

7. Conclusion

This paper has tried to "cut the Gordian knot" of the dispute on EU big chains store that have "invaded" Romania at the expense of autochthon domestic producers of agro-food assortments, searching and revealing the "secret" of their ability on the supply configuration using consumer stores using Kuhn's Hungarian algorithm and the novelty replacing by monthly traffic volume for store consumer supply in commercial network with total monthly costs of supply for consumer shops of commercial network, taking into account the cost of production of agro-food assortments to placed deposits minimizing both production costs and transport costs.

his paper illustrates an example of how it can be managed, monitored and controlled ie commercial activity using econometrics. The word "monitoring" should be understood tracking activity rather than operational business activities to develop the necessary decisions. The word 'controlled' must be understood rather adoption of relevant decision and putting it into practice immediately than just commercial activity tax check to boost it.

In this paper it was intended to supply three stores with meat, poultry, fish, dairy, flour and sweets, following choose sourcing between six wholesale warehouses. Method regarding the establishment of supply is valid for any specific situation. It is advisable to recalculate whenever needed after configuration change by expanding the store network, at appearance or disappearance of a warehouse, and even expand the range of consumer products and/or the appearance of specialized products through processing intermediate of crude products.

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