PRODUCTIVITY OF COKE AND REFINED PETROLEUM USE IN AGRICULTURE, FORESTRY AND FISHING INDUSTRIES IN THE BALTIC STATES AND FINLAND

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Abstract. This study examines how marginal changes in individual technological coefficients affect equilibrium in an input–output system when the adjustment process is interpreted through short-run managerial decisions. While classical input–output analysis mainly addresses changes in total output or final demand, the study focuses on perturbations in interindustry technological relations and their implications for value added and final demand. The methodological framework combines linear algebra and input–output analysis to derive elasticity-based indicators that measure the marginal sensitivity of value added and final demand to changes in purchases of coke and refined petroleum products. Using OECD input–output data for Estonia, Finland, Latvia, and Lithuania for 2018–2022, the paper applies the proposed approach to three primary sectors: agriculture and hunting, forestry and logging, and fishing and aquaculture. The novelty of the study lies in the interpretation of technological coefficient perturbations through a managerial-response framework and in the empirical application of this approach to cross-country sectoral comparison in the Baltic States and Finland.

Keywords: input-output analysis, technological coefficients, elasticity analysis, marginal perturbation.

Introduction

The Input-output model (also known as the Leontief model) and subsequent methodological developments [1-4] in monetary term is widely used to analyse interdependence between industries as sellers and buyers, and the creation of value added and final demand for each industry.

The input-output model is based on strong postulates. Each industry of national economy by definition produces one and only one kind of product, and different industries produce different products. The prices of products remain constant; therefore, the value of some product volume can be interpreted as quantity of product. The basic concept of the input-output analysis is the concept of national economy equilibrium: the purchases and sales of each industry are equal. The basic problem: how changes in input and output lead the economy away from equilibrium and how the new equilibrium will arise. The classical input-output theory does not investigate the equilibrium changes caused by perturbation of an individual technological coefficient, thus exposing a methodological gap [5]. Other authors have also discussed the changes in technology [6-8], but not in the same framework as is used in this study, that is, the influence of marginal technological changes.

The aim of this study is to evaluate the short run managerial response to the changed equilibrium caused by perturbation of the technological coefficients. If the change in some technological coefficient occurs there is not one determinate way to the new equilibrium since in that case the new equilibrium depends on the managerial decisions. The originality of this research: the aspiration to explain the most believable behaviour of a manager in the short run marginal sense. This study focuses on the consequences of the possible managerial decisions.

The methodology used in this study is sourced from the System of National Accounts (SNA) [9], and International Standard Industrial Classification of All Economic Activities (ISIC) [10]. The data used in this study is sourced from OECD data base (2025 release) [11-12], this is the newest available data.

Materials and methods

The basic mathematical method used in this research is linear algebra. The following symbolic designations for matrix, matrix rows and matrix columns are used.

Let $i = 1, 2, \dots, m; j = 1, 2, \dots, n$.

$$X(i\,j) := (x(i\,j)) \in \boldsymbol{R}^{m,\,n}$$

$$X := X(i\,j) = (X(1\cdot)\,X(2\,\cdot)\,\dots\,X(m\,\cdot))^T = (X(\cdot 1)\,X(\cdot 2)\,\dots\,X(\cdot n)) \in \boldsymbol{R}^{m,\,n}$$

$$X(i\cdot) \in \boldsymbol{R}^{1,\,n},\ X(\cdot\,j) \in \boldsymbol{R}^{m,\,1}.$$

The sum of the components of i-th row of matrix X denoted as $SUM[X(i\ \cdot)] \in \boldsymbol{R}$,

The sum of the components of j-th column of matrix X denoted as $SUM[X(\cdot\ j)] \in \boldsymbol{R}$,

Herinafter, the mathematical framework used is explained.

In order to be concise, often the matrix form of the input-output model is used and under the axiom of linearity the input-output model is expressed in form

- direct model

$$X = A\,X + Y,$$

- dual model

$$P = A^T P + V,$$

where $a(i\,j) := x(i\,j)/x(j) \in \boldsymbol{R}$;
$x(i\,j)$ – sum of money paid by i-th industry to the j-th industry in the considered statistical time period as charge for bought j-th industry product;
$A = (a(i\,j)) \in \boldsymbol{R}^{n,\,n}$, $(i, j = 1, 2, \ldots\, n)$ is the matrix determined by technological standards characterizing the interindustry technological linkages in monetary terms (traditionally denoted as A);
$P = (p(1)\ p(2)\ \ldots\ p(n))^T \in \boldsymbol{R}^{n,\,1}$ – vector of prices indices;
$X = (x(1)\ x(2)\ \ldots\ x(n))^T \in \boldsymbol{R}^{n,\,1}$ – gross output;
$Y = (y(1)\ y(2)\ \ldots\ y(n))^T \in \boldsymbol{R}^{n,\,1}$ – net output or final product (final demand);
$V = (v(1)\ v(2)\ \ldots\ v(n))^T \in \boldsymbol{R}^{n,\,1}$ – vector of value added with respect to unit of gross output.

Results and discussion

The study looked at the interindustry sales-purchases relations reflected in the input-output table in monetary terms. One unit of industry product is defined as quantity what costs one monetary unit. If prices of products are assumed to be unchanged than the value variations and quantity variations mean the same. However, variations of some indicators may be interpreted also as price variations.

The industry is considered as an abstract subject "producer-seller" that holds the equilibrium: for each unit produced sum of purchasing expenditures (intermediate consumptions) plus value added equals sum of sales revenues plus final demand.

Each industry acts like abstract agent without its own strategy because individuals are the sole decision making subjects. The separate industries of the national economy are abstract economic units, the actions of which are dialectic fusion of the firm owners' economic decisions and actions in the real time and under the real multiple PESTILB factors. Therefore, the terms "industry behaviour", "final demander behaviour" are conventional. (The abbreviator PESTILB means "political, economical, social, technological, international, legal, bio-environmental").

Let $i, j = 1, 2, \ldots, n$.

The structure of the balancing equation

$$x(1\,j) + x(2\,j) + \ldots + x(n\,j) + va(j) = x(j\ 1) + x(j\ 2) + \ldots + x(j\ n) + y(j),$$

where $va(j)$ – means value added, characterizes the structure of purchases utilized for producing in the j-th industry $x(j)$ units of j-th product, and structure of sales of the j-th industry $x(j)$ units to ensure its necessary purchases.

It is well-known that in market economy it is easy to buy and difficult to sell. Economists are more concerned about chances to get revenue $x(j\ 1) + x(j\ 2) + \ldots + x(j\ n) + y(j)$ than about the perspectives of purchases $x(1\,j) + x(2\,j) + \ldots + x(n\,j) + va(j)$.

Table 1 contains values of purchasing and sales.

The input-output analysis precisely answers the questions concerning the new economic equilibrium roused in the input-output model after the marginal perturbances of components of total output or components of final demand.

Note. The terms "perturb" and "perturbation" are often used by scientists. "Perturbation" is a small disturbance of the previous equilibrium state of system. Perturbing means a deviation of a system caused by an outside influence.

Table 1

Purchasing - sales table

Industry	Industry 1	Industry 2	…	Industry j	…	Industry n	Final demand	Total
industry 1	$x(1\ 1)$	$x(1\ 2)$	...	$x(1\ j)$	...	$x(1\ n)$	$y(1)$	$x(1)$
industry 2	$x(2\ 1)$	$x(2\ 2)$	...	$x(2\ j)$	...	$x(2\ n)$	$y(2)$	$x(2)$
…								
industry i	$x(i\ 1)$	$x(i\ 2)$	...	$\boldsymbol{x(i\ j)}$	...	$x(i\ n)$	$y(i)$	$x(i)$
…								
industry n	$x(n\ 1)$	$x(n\ 2)$	...	$x(n\ j)$	...	$x(n\ n)$	$y(n)$	$x(n)$
value added	$va(1)$	$va(2)$	...	$va(j)$	...	$va(n)$		
total	$x(1)$	$x(2)$	...	$x(j)$	...	$x(n)$		

The central methodological question of the paper is the following: what happens if a single intermediate transaction $x(i\ j)$, and therefore the corresponding technological coefficient $a(i\ j)$, increases marginally while all other initial conditions remain unchanged?

Formulation of the problem.

What will happen with the economic system reflected in Table 1, if $x(i\ j)$ becomes 1.01 $x(i\ j)$, namely, if the indicator $x(i\ j)$ increases per 1%?

Obviously, in such a case the initial equilibrium ceases to exist.

What new equilibrium spontaneous economic forces could be found?

First of all, it should be stressed that there does not exist solely one determined answer.

This study assumes a short-run managerial response in which the buyer offsets the additional expenditure by reducing value added in industry j, while the seller offsets the corresponding receipt by reducing final demand in industry i. If $x(i\ j)$ increases by 1%, the disturbance is represented by replacing $x(i\ j)$ with 1.01 $x(i\ j)$, reducing $va(j)$ by 0.01 $x(i\ j)$, and reducing $y(i)$ by the same amount. Under this assumption, the disturbed balance remains interpretable within the accounting structure of the input–output table. See Table 2.

Table 2

Disturbed initial balance

Industry	Industry 1	Industry 2	…	Industry j	…	Industry n	Final demand	Total output
industry 1	$x(1\ 1)$	$x(1\ 2)$	...	$x(1\ j)$	...	$x(1\ n)$	$y(1)$	$x(1)$
industry 2	$x(2\ 1)$	$x(2\ 2)$	...	$x(2\ j)$	...	$x(2\ n)$	$y(2)$	$x(2)$
…								
industry i	$x(i\ 1)$	$x(i\ 2)$	...	$1.01\ \boldsymbol{x(i\ j)}$	...	$x(i\ n)$	$\boldsymbol{y(i)} - 0.01\ \boldsymbol{x(i\ j)}$	$x(i)$
…								
industry n	$x(n\ 1)$	$x(n\ 2)$	...	$x(n\ j)$	...	$x(n\ n)$	$y(n)$	$x(n)$
value added	$va(1)$	$va(2)$	...	$\boldsymbol{va(j)} - 0.01\ \boldsymbol{x(i\ j)}$	...	$va(n)$		
total output	$x(1)$	$x(2)$	...	$x(j)$	...	$x(n)$		

Elasticity of the j-th industry value added with respect to purchases of i-th industry products is:

$$\text{elasticity } [va(j) \text{ with respect to } x(i\ j)] = -\,x(i\ j)/va(j).$$

Elasticity of the i-th industry final demand with respect to sales of i-th industry products is

$$\text{elasticity } [y(i) \text{ with respect to } x(i\ j)] = -\,x(i\ j)/y(i).$$

Obviously, the same assertions remains correct also for coefficients

$$a(i\ j) := x(i\ j)/x(j).$$

To illustrate the logic of the method, the paper retains the standard two-sector Leontief [1] example in natural and monetary units (Table 3, Table 4). The example shows how the same marginal disturbance can be interpreted both as a technological perturbation and as a managerial response.

Table 3

Leontief input-output example in natural units

	Agriculture	Production	Final product	Total output
agriculture	25	20	55	100
production	14	6	30	50
primary factor	80	180	-	-

Let the price of one unit of an agriculture product be 2 USD, the price of one unit of production product is 5 USD, the price of one unit of primary factor is 1 USD.

Next, we get direct and dual balances in the monetary terms (Table 4).

Table 4

Leontief input-output example in monetary terms

	Agriculture	Production	Final product $y(i)$	Total $x(i)$
agriculture $x(1\ j)$	50	40	110	200
production $x(2\ j)$	70	30	150	250
primary factor $va(j)$	80	180	-	-
total $x(j)$	200	250	-	-

Let us assume that caused by some technological reasons the indicator $x(2\ 1)$ increases per one percent and as a result the initial equilibrium is disturbed. What will happen?

One of the possible short run scenarios is: the decision maker of agriculture as a buyer decides to decrease the value added by 0.01 70 units, but the manager of production as a seller decides to subtract 0.01 70 units from final demand (Table 5).

Exactly such behaviour of managers will be assumed.

Table 5

Disturbed input-output example in monetary terms, based on Leontief [1]

	Agriculture	Production	Final product $y(i)$	Total output $x(i)$
agriculture $x(1\ j)$	50	40	110	200
production $x(2\ j)$	$1.01 \cdot 70$	30	$150 - 0.01 \cdot 70$	250
primary factor $v(j)$	$80 - 0.01 \cdot 70$	180	-	-
total output $x(j)$	200	250	-	-

Calculation of elasticities:

- elasticity[$v(1)$ with respect to $x(1\ 1)$] = $-$ 50/80 ≈ -0.63;
- elasticity[$v(1)$ with respect to $x(2\ 1)$] = $-$ 70/80 ≈ -0.88;
- elasticity[$v(2)$ with respect to $x(1\ 2)$] = $-$ 40/180 ≈ -0.22;
- elasticity[$v(2)$ with respect to $x(2\ 2)$] = $-$ 30/180 ≈ -0.17;
- elasticity[$y(1)$ with respect to $x(1\ 1)$] = $-$ 50/110 ≈ -0.45;
- elasticity[$y(1)$ with respect to $x(1\ 2)$] = $-$ 40/110 ≈ -0.36;
- elasticity[$y(2)$ with respect to $x(2\ 1)$] = $-$ 70/150 ≈ -0.47;
- elasticity[$y(2)$ with respect to $x(2\ 2)$] = $-$ 30/150 ≈ -0.20.

Elasticities in economics are widely used indicators.

For example, the elasticity[$v(1)$ with respect to $x(2\ 1)$] = -0.88 means: increasing of $x(2\ 1)$ per 1 percent causes decreasing of $v(1)$ by 0.88 percent.

The elasticity[$y(2)$ with respect to $x(2\ 1)$] = -0.47 means: increasing of $x(2\ 1)$ per 1 percent causes decreasing of $y(2)$ by 0.47 percent.

Therefore, the elasticities allow to estimate the influence of utilized volumes of factors in the value added and final demand creation.

The original theoretical results apply for the investigation the practical technological problem: What is the marginal productivity of usage coke and refined petroleum products (C19) in the industries agriculture and hunting (A01), forestry and logging (A02), fishing and aquaculture (A03) in the Baltic States and Finland?

The empirical analysis applies the elasticity formulas to purchases of coke and refined petroleum products (C19) by agriculture and hunting (A01), forestry and logging (A02), and fishing and aquaculture (A03) in Estonia, Finland, Latvia, and Lithuania for 2018-2022. Tables 6, 7, 8, 9, 10, 11 contain the authors' original results about elasticities of the industries.

The general result of this study is that all value-added elasticities are negative. Under the proposed short-run interpretation, a marginal increase in purchases of coke and refined petroleum products reduces the share of value added in every country and every analysed sector. However, the magnitude of this effect differs substantially across countries, industries, and years, which indicates important structural differences in production systems and input dependence.

Table 6

Elasticities of value added in A01 (Agriculture and hunting) with respect to purchases of coke and refined petroleum products in the Baltic States and Finland

Year	EST	FIN	LVA	LTU
2018	−0.139	−0.143	−0.107	−0.095
2019	−0.106	−0.101	−0.099	−0.056
2020	−0.083	−0.071	−0.044	−0.029
2021	−0.103	−0.086	−0.068	−0.055
2022	−0.125	−0.107	−0.069	−0.039

The results for value-added elasticities show a consistent negative relationship between purchases of coke and refined petroleum products and sectoral value added in all countries and all analysed industries. In agriculture and hunting (Table 6), Estonia and Finland generally exhibit stronger negative elasticities than Latvia and Lithuania; for example, in 2022 the elasticity reaches −0.125 in Estonia and −0.107 in Finland, compared with −0.069 in Latvia and −0.039 in Lithuania.

Table 7

Elasticities of value added in A02 (Forestry and logging) with respect to purchases of coke and refined petroleum products in the Baltic States and Finland

Year	EST	FIN	LVA	LTU
2018	−0.058	−0.036	−0.024	−0.120
2019	−0.052	−0.035	−0.039	−0.083
2020	−0.038	−0.027	−0.026	−0.065
2021	−0.039	−0.035	−0.029	−0.047
2022	−0.079	−0.010	−0.036	−0.019

In forestry and logging (Table 7), the elasticities are smaller in absolute value than in agriculture and fishing, indicating a lower sensitivity of value added to this input category. Lithuania records a comparatively large negative value in 2018 (−0.120), whereas Finland shows a very small absolute value in 2022 (−0.010).

Table 8

Elasticities of value added in A03 (Fishing and aquaculture) with respect to purchases of coke and refined petroleum products in the Baltic States and Finland

Year	EST	FIN	LVA	LTU
2018	−0.132	−0.071	−0.051	−0.547
2019	−0.144	−0.107	−0.027	−0.237
2020	−0.103	−0.079	−0.011	−0.110
2021	−0.116	−0.082	−0.014	−0.137
2022	−0.241	−0.103	−0.083	−0.197

Fishing and aquaculture (Table 8) displays the greatest volatility and the strongest country differences. Lithuania shows an especially high absolute value in 2018 (−0.547), while Estonia records a marked increase in sensitivity in 2022 (−0.241).

Table 9

Elasticities of final demand in A01 (Agriculture and hunting) with respect to sales of coke and refined petroleum products in the Baltic States and Finland

Year	EST	FIN	LVA	LTU
2018	0.104	−0.085	0.074	−0.038
2019	0.109	−0.068	0.087	−0.026
2020	0.183	−0.084	0.077	−0.040
2021	0.127	−0.075	0.090	−0.045
2022	0.066	−0.069	0.056	−0.023

Table 10

Elasticities of final demand in A02 (Forestry and logging) with respect to sales of coke and refined petroleum products in the Baltic States and Finland

Year	EST	FIN	LVA	LTU
2018	0.060	−0.059	0.021	−0.013
2019	0.059	−0.053	0.034	−0.008
2020	0.083	−0.065	0.035	−0.013
2021	0.054	−0.066	0.031	−0.008
2022	0.034	−0.013	0.028	−0.003

The final-demand elasticities reveal a more heterogeneous pattern than the value-added indicators. In agriculture and hunting (Table 9) and forestry and logging (Table 10), Estonia and Latvia frequently show positive elasticities, whereas Finland and Lithuania mostly display negative values.

Table 11

Elasticities of final demand in A03 (Fishing and aquaculture) with respect to sales of coke and refined petroleum products in the Baltic States and Finland

Year	EST	FIN	LVA	LTU
2018	0.018	−0.004	0.003	−0.006
2019	0.021	−0.005	0.002	−0.004
2020	0.029	−0.007	0.002	−0.005
2021	0.016	−0.006	0.002	−0.004
2022	0.010	−0.006	0.005	−0.002

In fishing and aquaculture (Table 11), the final-demand elasticities are small in magnitude, yet the sign pattern remains stable: Estonia and Latvia display positive values, while Finland and Lithuania display negative values throughout the period.

Source of data in Tables 6 to 11 is authors' calculations based on OECD Input-Output Tables Database (2025 release).

Conclusions

1. The study proposes a modified interpretation of input–output equilibrium adjustment by examining marginal perturbations of individual technological coefficients through short-run managerial-responses.
2. For all analysed countries and sectors, value-added elasticities with respect to purchases of coke and refined petroleum products are negative, confirming that an increase in these intermediate inputs reduces the share of value added under the assumed adjustment mechanism. In agriculture and hunting in 2022, for example, the elasticity ranges from −0.125 in Estonia and −0.107 in Finland to −0.069 in Latvia and −0.039 in Lithuania.
3. Forestry and logging shows lower sensitivity than agriculture and especially fishing and aquaculture, where the strongest absolute effects are observed. The most pronounced result is found

for Lithuania in fishing and aquaculture in 2018 (−0.547), while Estonia also records a relatively high sensitivity in 2022 (−0.241).
4. Final-demand elasticities differ in significance across countries, indicating structural differences in how petroleum-related technological disturbances are transmitted through sectoral demand systems.
5. Cross-country differences suggest that the economic implications of petroleum-related input use are not uniform and should be interpreted in relation to each country's interindustry structure.

Author contributions

Both authors have contributed equally to the study and preparation of this publication. The authors have read and agreed to the published version of the manuscript.

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