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## Article

# The technologies of the future in the field of fertilisers and Romania's opportunities to recover this industry

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# THE TECHNOLOGIES OF THE FUTURE IN THE FIELD OF FERTILISERS AND ROMANIA'S OPPORTUNITIES TO RECOVER THIS INDUSTRY

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## Abstract

The fertiliser industry in the European Union is undergoing structural transformations imposed by EU commitments to become carbon neutral by 2050. In terms of the existing possibilities, the industry is in the attention of decision-makers and investors, with various business models being analysed that enable technologies of the fourth industrial revolution that will improve the efficiency of manufacturing of fertilisers necessary for sustainable agriculture, with the reduction of carbon dioxide emissions. The present paper aims to analyse the evolution of the fertiliser industry in Romania, in terms of international competitiveness and economic performance of companies, as well as to evaluate the existing possibilities for modernising and recovering the industry. These analyses and evaluations can provide a basis for formulating recommendations to decision-makers in reindustrialisation policies, taking into account new technologies that can capitalise on the resources and opportunities of the regional market, while maintaining or intensifying the policies undertaken to decarbonise the energy-intensive industries.

**Keywords:** industrial policies, foreign trade, international competitiveness, fertilisers industry, green technologies, green transition, green and blue ammonia

**JEL Classification:** L52, L65, L81, O33, Q58

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## Introduction

The fertiliser industry is one of the heavy industries of strategic importance for Romania. Given the size of the agricultural sector and the areas dedicated to agricultural crops, Romania is one of the main consumers of fertilisers for agriculture in the EU. Against the backdrop of structural transformations taking place in the economy and the EU's commitments to become carbon neutral by 2050, the fertiliser industry needs a significant boost for retrofitting and modernisation. At the beginning of the 1990s, Romania had 11 chemical plants that produced raw materials for fertilisers and nitrogen fertilisers. Currently, only three of them are still functional, but they also operate at a very low capacity and with temporary interruptions of production, due to unfavourable market factors. In recent years, the increase in energy prices, especially natural gas, which is the main raw material used in the technological process, in conjunction with the tightening of environmental restrictions, has led to an increase in the cost of production to an uncompetitive level. Although Romania has a demand of raw materials and fertilisers of about 1.5 million tons annually, currently, it covers most of the demand by imports.

In terms of drivers of change, the technological progress and the shaping of the fourth industrial revolution (IR4.0), in a fiercely competitive environment worldwide (Jora et al., 2025), are the premises for the relaunch of the chemical industry, including fertilisers manufacturing, bringing advanced, physical and digital technologies (Van Thienen, 2016). Solutions for the decarbonisation of the chemical industry bring new manufacturing and business models, which involve the adoption of green technologies. One such solution is blue ammonia, using natural gas to obtain ammonia, while capturing and storing carbon dioxide from manufacturing processes. Companies that pursue such investments also come up with models for optimising production through technologies of the fourth industrial revolution.

The present paper aims to analyse the evolution of the fertiliser sector in Romania, in terms of economic performance at the level of companies in the sector and in the context of international competitiveness, as well as to evaluate the existing possibilities for the recovery of the fertiliser manufacturing through refurbishment and implementation of new business models. These analyses and evaluations can provide a basis for making recommendations to decision-makers in reindustrialisation policies, taking into account new technologies that can capitalise on existing resources and regional market opportunities, while maintaining or intensifying the policies committed to decarbonising the energy-intensive industries. For the authors, the topic is also interesting in terms of direct professional commitments to the elaboration and implementation of Romania's industrial policies.

### 1. The fertiliser industry and the fourth industrial revolution in the literature

Industry 4.0 combines interconnected technologies such as the Internet of Things, Big Data, Robotics, Artificial Intelligence, Advanced Materials and Additive Manufacturing, etc. With technological progress, the interest of academia and companies to identify possible capitalisations of those technologies in manufactures has also increased. Companies in the manufacture sectors have realised that automation solutions by moving towards the Internet of Things and digitalisation can bring significant improvements in the efficiency of the processes. One can improve the productivity of chemical plants by various smart techniques:

predictive asset management, process control, manufacture simulation, etc. The new technologies can be integrated into the core conversion processes of chemical plants, marketing, and the activation of smart supply chains, as well as to set up new business models (Van Thienen, 2016). In any case, studies on the applications of Industry 4.0 technologies in the fertiliser industry in each country are just at the beginning (Shabur, 2024). Due to the nature of manufacturing processes, which imply basic chemical reactions, the fertiliser industry is not among the first industries to be impacted by technological advances. Studies on the applications of Industry 4.0 in chemical fertilisers have evolved mainly in the direction of streamlining agricultural processes, which leads to limiting soil pollution with nitrates, in accordance with sustainable objectives (Subei, 2023), at the same time as an improvement in plant yield. Nanotechnologies have the potential to improve fertilisation formulas (DeRosa, 2010).

The green and digital transition creates the opportunity for companies to evolve in both directions. The refurbishment of old chemical plants or the development of new factories for ammonia go together with new digital solutions to streamline the production process and its conversion into physical products. Environmental pressures and climate policies have led companies to adopt sustainable manufacturing processes. In that sense, new chemical plants consume a third less energy per ton of ammonia than older plants. Innovations in advanced catalytic processes, which facilitate the chemical reactions required to obtain ammonia, have led to an 85% reduction in nitrogen oxide emissions in the manufacturing process (International Finance Corporation, 2023).

**Table no. 1. IR4.0 and green technologies available for the fertiliser industry**

<b>IR4.0 Technologies</b>	<b>Positive outcomes</b>
<ul style="list-style-type: none"> <li>Internet of Things</li> <li>Sensors and connected devices for real-time monitoring of temperature, pressure, and chemical concentrations</li> </ul>	<ul style="list-style-type: none"> <li>Predictive management of chemical reactions</li> </ul>
<ul style="list-style-type: none"> <li>Big data analysis</li> </ul>	<ul style="list-style-type: none"> <li>Process optimisation,</li> <li>Reduction of energy consumption</li> </ul>
<ul style="list-style-type: none"> <li>Artificial intelligence</li> <li>Algorithms predict equipment wear, optimise supply chains, and improve process control</li> </ul>	<ul style="list-style-type: none"> <li>Minimisation of interruptions,</li> <li>Program optimisation,</li> </ul>
<ul style="list-style-type: none"> <li>Advanced process control</li> <li>Use of real-time data to adjust parameters in the technological process</li> </ul>	<ul style="list-style-type: none"> <li>Improving the stability and efficiency of production processes, reducing residual losses</li> </ul>
<ul style="list-style-type: none"> <li>Automation and robots</li> </ul>	<ul style="list-style-type: none"> <li>Reducing labour costs,</li> <li>Minimising human error,</li> <li>Improving safety</li> </ul>
<ul style="list-style-type: none"> <li>Energy Management Systems</li> </ul>	<ul style="list-style-type: none"> <li>Reducing energy costs and carbon emissions</li> </ul>
<b>Green technologies</b>	<b>Positive outcomes</b>
<ul style="list-style-type: none"> <li>NH<sub>3</sub> blue = natural gas + CCS</li> </ul>	<ul style="list-style-type: none"> <li>Reducing carbon emissions</li> </ul>
<ul style="list-style-type: none"> <li>Green NH<sub>3</sub> = hydrolysis + green energy + nitrogen obtained by air separation +</li> <li>H<sub>2</sub> + N<sub>2</sub></li> </ul>	<ul style="list-style-type: none"> <li>Net-zero emissions</li> </ul>

Source: prepared by the authors.

## 2. Ammonia in a global and regional context

The global demand for fertilisers will continue to grow due to the increase in population and implicitly for the demand in agriculture. Also, ammonia, a raw material for nitrogen fertilisers (urea and nitrates), can be used as a sustainable fuel especially in maritime transport, but also as a transport vehicle for hydrogen, which will play a significant role in the green transition in transport. As a result, ammonia plays a key role in the global economy.

The European Union has set itself the goal of becoming carbon neutral by 2050. As an intermediate step, the European Commission agreed on a package of measures in 2021 (*Fitfor55*) to reduce carbon emissions by 55% by 2030, compared to 1990 levels (European Commission, 2021). Pressures to reduce carbon dioxide emissions will increase internationally, so incentives and support policies from states are rising. Hydrogen and ammonia will be of particular relevance for achieving the 2030 and 2050 targets.

Ammonia (NH<sub>3</sub>) is a gaseous chemical compound that can be obtained either from natural gas through conventional methods (“grey ammonia”), or by using hydrogen resulting from the process of electrolysis in combination at high temperatures with nitrogen obtained from air, using an air separation unit (“green ammonia”). “Blue hydrogen” is the hydrogen obtained from the electrolysis by using electricity from conventional sources, together with the storage of carbon emissions. “Green hydrogen” is the one obtained by using renewable energy in the electrolysis process. “Blue ammonia” results from natural gas through the conventional method and the capture and storage of carbon emissions.

As subjects of the EU-ETS trading system, the producers in the chemical industry will have to purchase emission allowances and bear the cost of carbon as soon as the free allocation of permits drops. As an exception, producers of ammonia and blue hydrogen will not have to bear the cost of pollution if they meet European standards for storing carbon dioxide emissions (European Commission, 2023).

With the rising price of carbon, the production of fertilisers by conventional methods becomes uncompetitive as compared to countries that have not committed to equally restrictive environmental policies. Lately, the crisis of energy prices on regional markets has generated major fluctuations in the price of fertilisers. Even after the gas price stabilised after the peaks of 2022, it is still too high for domestic producers to be able to produce fertilisers at a competitive price level. Additionally, with the imposition of economic sanctions against Russia as a result of its aggression against Ukraine, the volume of EU natural gas imports from Russia decreased by 59% (volumes imported in the second quarter of 2024 compared to the first quarter of 2021) (Eurostat, 2024). At the same time, although the import volumes of fertilisers from Russia decreased by 52% compared to the volume in 2021, there is a suspicion that part of the volumes imported by the EU from other countries contain intermediary goods (ammonia) from Russia. The Russian Federation can export chemicals at a much lower price than regional competitors due to the cheap gas and the surplus of domestic production it achieves following the decline in natural gas exports.

If we refer to the construction of new plants for the production of green ammonia, this has great potential globally, but it is not yet economically feasible, the investment costs being too high to be able to offer a competitive price.

Therefore, blue ammonia is considered a transitional solution in the next 20-30 years, with a lower carbon footprint than grey ammonia, until green ammonia becomes economically feasible. This approach allows for the continued use of existing ammonia production infrastructure, requiring investment only in carbon capture and storage solutions in technical or natural reservoirs. Because there are too many conventional ammonia plants, there is an opportunity to reduce carbon dioxide emissions from these plants either by capturing and storing the carbon dioxide resulting from the production process or by developing adjacent green ammonia plants. Global ammonia production capacity is expected to expand from 240 million metric tons in 2022 to 290 million metric tons by 2030. There are plans to build about 107 new ammonia plants, located mainly in Asia and the Middle East, which are expected to enter production by 2030. The global blue ammonia market is projected to grow from \$78 billion in 2023 to \$17.9 billion in 2030. The global green ammonia market is expected to grow from USD 40 million in 2023 to USD 4.7 billion in 2030 (Statista, 2024). Green ammonia is currently 1.5 times more expensive than ammonia produced from natural gas, but as green energy becomes cheaper, green ammonia production will overtake that of grey ammonia. This is expected to happen by 2040 (Subei, 2023).

The regions targeted by investments in blue ammonia are those that have significant gas reserves, such as the Middle East, North America, and Russia (Tanzeem, 2023). The regions targeted by investments in green ammonia are those that have cheap renewable energy, such as Australia, South America, the Middle East, and Northern Europe. Investment projects for nitrogen-based fertilisers are also concentrated in Russia, North America, Asia, the Middle East, the presence in Europe being almost non-existent (Urea Know How, 2024).

### 3. Methodology

In the present paper, we used data from official national and international sources in order to perform the quantitative analysis. The data were extracted both at the level of the NACE code Rev.2 2015 branch – *Manufacture of fertilisers and nitrogen products* – and at the level of representative companies in this branch of activity (companies that accumulated over 98% of the total turnover of the branch in the period 2000-2023 were selected). The main sources of the data are:

- National Institute for Statistics (TEMPO Database, annual, monthly statistics),
- Top Companies Romania, published on the *topfirme.com* website, which centralises public data and taken from the website of the Ministry of Finance and other public government sources,
- Eurostat.

Based on the time series, we generated some graphs regarding the main economic and financial indicators of the industrial branch and we performed an econometric analysis to exemplify the recent developments in the case of a flagship company for the Romanian nitrogen fertiliser industry, namely Azomureş S.A.

The econometric analysis consisted of two stages:

- Verification of the stationarity of the time series used in the econometric analysis,
- Linear regression with the error correction mechanism attached.

In verifying the stationarity of the time series, the Integrated Durbin-Watson (IDW) test was used (Charemza, 1997), which in cases with statistically consistent results is simpler to apply than complex tests with equal margins of error, such as Augmented Dickey Fuller (ADF).

The linear regression used was performed on stationary time series by deriving the initial series, which were economic indicators in current prices, time series that are usually integral at level 1 (in other words, they become stationary by compiling the logarithm/derivation). In order to avoid the possible error arising from the autocorrelation between the tested economic variables, regression was used, in which an error correction mechanism was introduced among the independent variables, i.e., an error compensation term calculated on the basis of linear regression between the level 1 integral variables (not yet unconditional).

In a separate section, we performed a qualitative analysis, using the SWOT model, targeting the strengths, weaknesses, opportunities and threats of the fertiliser industry.

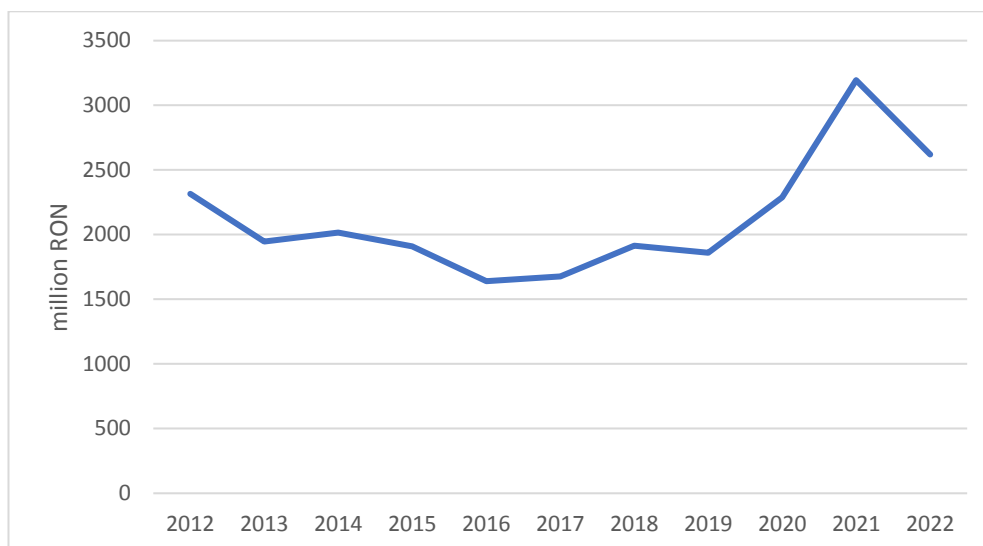
#### 4. The current state of the fertiliser industry in Romania

In the fertiliser sector in Romania, three large chemical plants are still operational: Azomureş, CICH Năvodari, and Nitramonia BC Slobozia (formerly Amonil, then ChemGas Holding Corporation S.R.L.). Two others could still be functional: Donau Chem Turnu Măgurele and Ga Pro Co Săvineşti (formerly Azochim), which are in liquidation following bankruptcy. In addition to these, several dozen SMEs also operate at national level.

Romania has a chemical fertiliser demand of about 1.5 million tons annually, of which about 450-500 thousand tons of nitrogen-based fertilisers for agriculture (the sixth consumer in the EU, 5.2% of the total consumption in the EU) and 80-100 thousand tons of phosphorus-based fertilisers (Eurostat, 2024).

Currently, all functional Romanian chemical plants either have closed or are operating at low capacity or with temporary interruptions. Azomureş is the main producer of fertilisers for agriculture and raw materials for fertilisers, with an annual capacity of 1.8 million tons. The company temporarily seized the production during 2023-2024, due to the price of gas in conjunction with the decrease in fertiliser prices (Economica, 2024). The Chemical Fertilizer Plant S.R.L. Năvodari (CICH) produces nitrogen-based fertilisers, phosphorus-based fertilisers, professional biostimulants (the only producer in the country on this type of products), with a theoretical capacity of 1,400 tons/day. Three former plants of the former Interagro group, in bankruptcy, were taken over by Pambac S.A. Bacău: Amurco Bacău, Nitroporos Făgăraş, and Nitramonia BC S.R.L. Two other plants part of the Interagro Group are in liquidation following bankruptcy and are in the process of being sold through direct negotiation: Donau Chem Turnu Măgurele and Ga Pro Co Chemicals Săvineşti. Another plant part of the Interagro Group is in insolvency, namely Viromet S.A. Victoria.

The chemical fertiliser sector achieved a turnover of RON 2.62 billion in 2022, a decrease of 18% compared to the previous year, amid the decrease in domestic production as a result of natural gas prices (Figure 1).



**Figure no. 1.** Turnover of the nitrogen fertilisers sector, 2012-2022, million lei

*Source:* processed by the authors with data from INS (2024).

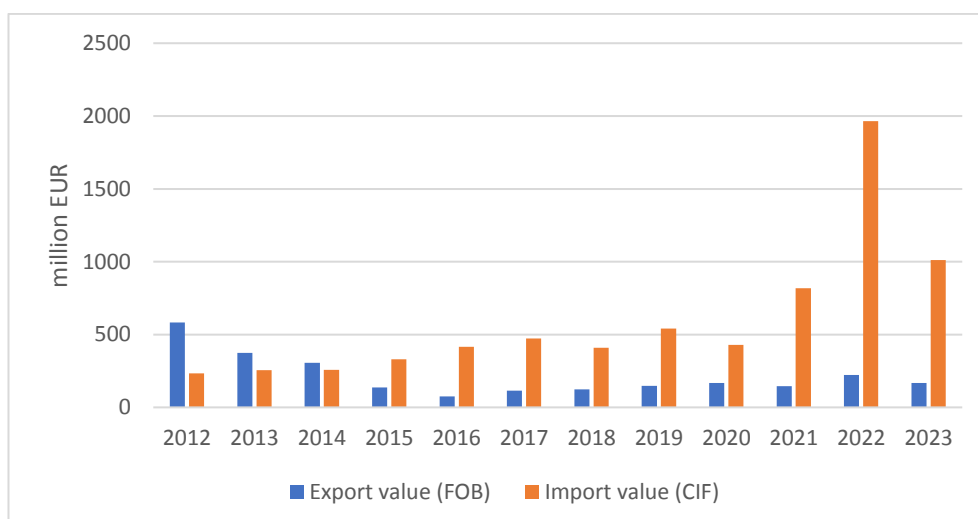
Since 2015, Romania has experienced a steady decrease in the domestic production of chemical fertilisers, so that the volume of imports has increased rapidly, with an annual pace of over 15% (INS, 2023). The evolution of employees in the sector, from over 6,500 employees in 2012 to 1550 in 2022, also reflects the losses of competitiveness (INS, 2024).

The main factors that influenced the decrease in the competitiveness of this industrial branch both in Romania and in the European Union were the unfavourable evolution of the price of natural gas for non-household consumers, as well as the increase in real terms of the average salary on the NACE code 2015 branch. The gross salary in the chemical industry exceeded the average salary in the Romanian industry, and, in certain years, its increase was above the increases in the prices of industrial production.

#### 4.1. Foreign trade analysis

In 2023, Romania produced only 95 thousand tons of nitrogen-based fertilisers, 90% less than in 2021, but 18% above the 2022 level (Economica, 2024). Therefore, the domestic demand is covered by imports. In 2023, Romania imported a volume of 1.6 million tons of nitrogen fertilisers, respectively 0.77 million tons of raw materials for fertilisers. Exports of nitrogen fertilisers amounted to 236 thousand tons and raw materials for fertilisers amounting to 95 thousand tons. Therefore, the trade deficit in the category of chemical fertiliser products was EUR 884 million in value. The record was reached in 2022, when imports valued EUR 1.96 billion, amid the escalation of prices on the global market as a result of Russia's invasion of Ukraine, thus generating a trade deficit of EUR 1.74 billion (5% of the total trade deficit of the country) (INS, 2023) (Figure 2).



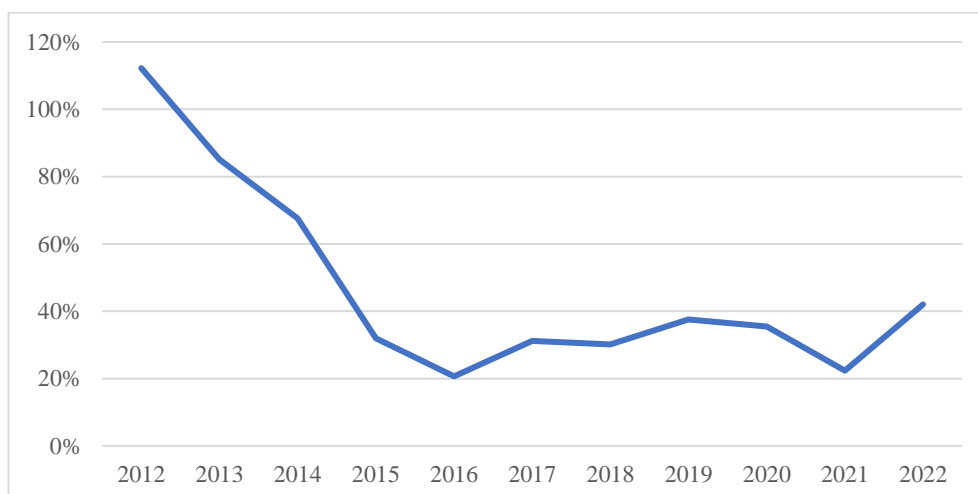


**Figure no. 2. Evolution of Romania's foreign trade in chemical fertilisers, 2012-2023, million euros**

Source: ARICE (2024).

The main countries of origin of imports of nitrogen fertilisers were in 2023, Bulgaria (20.9%), Egypt (16.8%), Turkmenistan (10.6%), Hungary (7%), Azerbaijan (5.8%), and Russia (4.7%). Regarding chemical raw materials for fertilisers, the main countries of origin of imports were Greece (16.5%), Russia (14%), Bulgaria (13.6%), Morocco (12.1%), and Austria (11.6%).

The negative evolution of domestic production in the last 10 years has reflected in a downward trend in the export rate (Figure 3).



**Figure no. 3. Ratio of exports to turnover in the chemical fertilisers sector, 2012-2022**

Source: developed by the authors, based on data from INS (2024) and ARICE (2024).

#### 4.2. Case study: analysis of correlations between turnover and gross profit and economic indicators in the case of a representative company in the chemical fertiliser industry

Based on the time series covering a period of 24 years, we tried to analyse the behaviour of a flagship company for the fertiliser and nitrogen products in Romania, namely Azomureş S.A. In fact, Azomureş weighted between 50% and 80% of the turnover of the entire branch over the analysed periods and between 40 and 65% of the total number of employees of the branch. The company was not part of the Interagro holding and did not benefit from conditions distinct from those of the Romanian market, such as the targeted policy measures (positively discriminatory or not). As a result, we considered that it would be the most relevant case study for the fertiliser manufacturing branch and the most appropriate for testing specific behaviours of the Romanian market and correlations between economic variables describing the performance of companies.

Normally, a firm's turnover depends on its output sold, which in turn is dependent on the evolution of input costs, its overall competitiveness on the domestic and international market, investment and capitalisation decisions. Consequently, the evolution of the company's profitability is influenced by the costs of the production factors and the decisions of the actors in the company's markets.

For the companies in the analysed industrial branch, there were no continuous official annual reports throughout the period, so we used only the existing public data for all companies in the NACE rev2 2015 branch, as collected from the [www.topfirme.com](http://www.topfirme.com) website. This limited the availability of relevant company data on turnover, net and gross profit, number of employees, inventories, receivables, without having access to the investment situation, research-innovation-development (RDI) expenditure, exports or imports, actual gross salaries, except for the average salaries at branch level. As a result, we tried to test the correlations between turnover and gross profit, on the one hand, and labour cost and the price of the main raw material, on the other hand.

Mainly, we tested the possibility of determining the price elasticity of natural gas (domestic price for industrial consumers), the turnover or gross profit of the firm, as well as the elasticity of the average gross labour cost (gross annual salary) of the same two economic variables of interest. Economic theory can lead to expectations of negative elasticity towards both independent variables (costs/price), in the case of the gross profit of the firm, as well as to the same negative price elasticity of the raw material in the case of turnover. At the same time, we expect there to be a strong autocorrelation between turnover and total payroll, which holds a very large share in the company's total expenses.

We tested features such as:

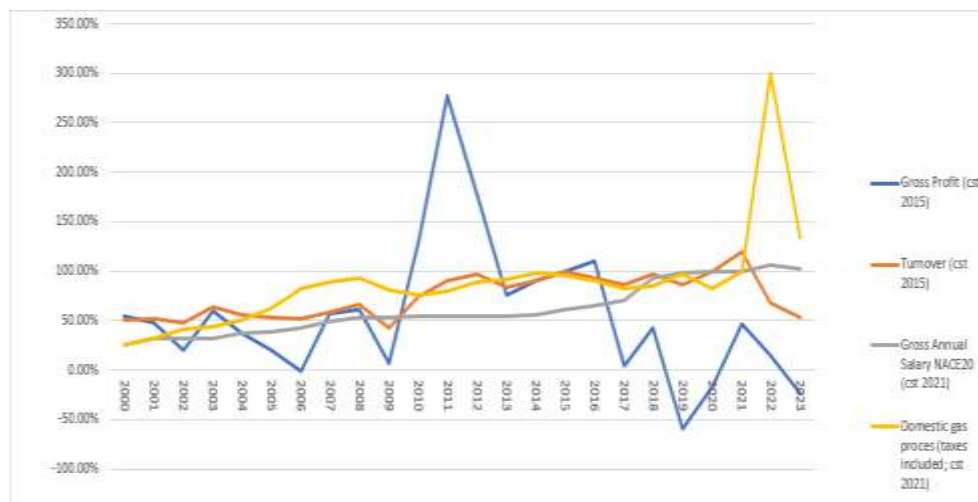
$CA = f(\text{SalBrut}, \text{Pret Gaz})$ , respectively

$\text{Prof Brut} = f(\text{SalBrut}, \text{Pret Gaz})$

We specify that the time series collected are expressed in nominal RON, in the case of turnover, gross profit, or annual salary, and in RON/KWh in the case of the domestic price of natural gas for industrial consumers. We compiled the annual salary by adding the average monthly salaries and multiplying them by the average number of employees. The functions tested were linear regressions built around the economic variables mentioned above, consequently using logarithmic representations of the variables, so that the coefficients of the

linear regressions represent elasticities of the dependent variables in relation to the independent variables.

To allow for correct econometric testing, the time series used must be stationary. In general, the time series of a nominal economic variable have intrinsically in their component the non-stationarity specific to the inflationary phenomenon, so it is necessary to verify the integral level of each of the time series and to bring them to stationary equivalents by derivation (differentiation). In addition, it is desirable to work with normalised quantities, so that the difference in calibre of the variables does not increase the possibility of statistical errors. All four economic variables used were initially processed and transformed into indices in constant prices (in the case of turnover and gross profit, we considered 2015 as a base year of 100%, and in the case of wages and the price of natural gas, the base year is 2021). Subsequently, we normalised the data set by reporting to their value in the base year in constant prices, in percentage. Figure 4 shows the evolutions in the period 2000-2023 of the four variables, expressed in constant prices and then normalised.



**Figure no. 4. Evolution of turnover, gross profit, gross annual salary, and domestic gas price in the period 2000-2023 (constant prices, normalised)**

*Source:* prepared by the authors.

All variables involved in the tested regressions resulted in non-nativity, with integral of 1st degree as a time series (stationarity tested by the Integrated Durbin-Watson method, the value of the IDW test resulting much lower than 2). By 1st degree derivation, all these series became stationary (IDW between 1.9 and 2.6). In addition, the final regressions incorporated an error correction mechanism (ECM) term, to avoid autocorrelation between the variables tested (dependent and independent). We preferred the ECM regression method to a matrix econometric testing of the VAR (vector autoregression) type, on the grounds of economically demonstrated causality between the dependent variables and those considered independent (all the more so as the aim was to test price/cost elasticities).

The results of the ECM regressions as well as those of the final elasticity regressions analysed are reported in detail in the Annex. The article summarises the results of the econometric analysis, from which we drafted the conclusions. One should note that, following the visual

observation of the time series, it resulted in the possibility that the price of gas could influence the turnover predominantly in the immediately following period. This is explainable by the inertia of production response, as well as by the potential decisions to sell from stocks in order to avoid the short-term negative effects of an unexpected increase in production costs. We tested both the price variable in the current period and in the previous one, or both simultaneously. The greatest statistical relevance resulted when using the price of the previous year. A causality test would have led to the same results, but we took into account that economic theory prevails in this case, and the causal relationship is evident between the economic variables considered.

The linear regression expressing the correlation between the turnover differential (Delta(LN(CA cst))) and the differentials of the gross salary and the domestic price of natural gas in the previous year led to the following coefficients and statistical data:

**Table no. 2. Regression of turnover in constant prices 2015 according to gross annual salaries and domestic price of natural gas (constant prices 2021)**

Independent variable	Coefficients	t Stat
$\Delta(\ln(\text{Sal}_{cst}))$	0.547155	1.039630755
$\Delta(\ln(\text{PrGaz}_{cst}(t-1)))$	-0.49710	-2.739939205
$\text{ECM2}(t-1)$	-0.82945	-2.778144147

Note: the R2 test explains about 36% of the dependent variable by the independent variables considered

Source: prepared by the authors

The results raise a question mark on the statistical relevance of the turnover elasticity coefficient in relation to gross salaries. It is both about the reported value of the t-State (relatively low in absolute value, therefore, with a low level of confidence) and about economic intuition, the expectations on the elasticity of labour cost being for a negative coefficient. The introduction of a *dummy* variable that partially captures market shocks and the effect of policy intervention decisions in the market in certain years of the period under review led to improved results (R2 to almost 50%), but reduced the number of observations considerably. In this variant, the gross annual salary does not seem to be more relevant to the turnover, or the two variables turn out to be self-correlated (causality or mutual influence, which would explain a possible positive sign of the coefficient). The value and sign of the coefficient associated with the domestic price of natural gas for industrial consumers in the previous year, on the other hand, remain almost unchanged (the statistical test in confidence level even increases), which gives us a consistent result on the price elasticity of the raw material.

In conclusion, the elasticity in relation to the price of natural gas of the turnover of the most important Romanian company producing fertilisers and nitrogen products, Azomureş S.A., is around 0.5, which demonstrates *a relatively inelastic response of the producer to the increase in the price of the raw material*. One should note that the price of raw materials and the cost of labour seem to be responsible for no more than 30-50% of the evolution of turnover, at least in the short and medium term.

We performed similar tests to determine the correlations between the company's gross profit and the same two independent variables (price/cost) and obtained the following results:

**Table no. 3. Regression of the gross profit at constant prices 2015 according to the annual gross salaries and the domestic price of natural gas (constant prices 2021)**

Independent variable	Coefficients	t Stat
<i>Intercept</i>	0.186224081	0.690678079
<i>Delta(LN(Sal cst))</i>	-2.1746993	-0.734445558
<i>Delta(LN(PrGaz cst (t-1)))</i>	-0.92103909	-1.214126981
<i>ECM2(t-1)</i>	-0.95853295	-2.099342491

Source: prepared by the authors.

The R2 test is only 23% (the multiple R test at the level of 47%), showing that these two independent variables explain a small number of factors influencing the company's gross profit. Also, the values of the t-Stat test do not demonstrate a very high level of confidence (statistical relevance starts at absolute values above 1.6). The explanation of the term Intercept (fixed explanatory term for the dependent variable) lies in the way we constructed the analysed time series, adding RON 100 million to all the values in the series, so that they become all positive values and can be logarithm mathematically. Obviously, in the analysis of properties and correlations, the change in the reference level only affects the predictions, but by derivation, the elasticities are not decisively affected. In the case of performing a forecast, the real values can finally be restored, by taking the resulting fixed term and then subtracting the value that we initially added, after compiling the integral.

We also performed calculations with the dummy variable in this case (apparently, in the year 2011, in the post-financial crisis period, it also had shock effects), which, however, reduced the number of observations so drastically that the associated intercept coefficient no longer appears to be relevant at all. On the other hand, the statistical relevance of the coefficient associated with the price increases to almost 1.3 t-Stat and the elasticity coefficient associated with gross wages decreases (absolute value) to the value -1.8, from -2.2, still demonstrating supra-unit elasticity. The value of the R2 test increases to almost 50%, giving more confidence in the results obtained.

In conclusion, the elasticity coefficients of the gross profit in relation to the price of natural gas, as well as to the annual gross wages, are negative, as expected. The elasticity in relation to the price of the raw material is still sub-unit, at the level of -0.85/-0.9, but close to -1 (normal behaviour of reaction to the price increase). The elasticity in relation to wages is much higher in absolute value (values between -1.6 and -2.2). This explains the decrease in competitiveness in the last analysed period, when gross salaries increased in constant prices well above the increases recorded by the value of production or sales. It also explains the drastic reduction in the number of employees and the general economic performance of the company.

A final remark can be made about the existence of other influencing factors of the turnover and the gross profit, which can be suspected, such as stocks, exports and imports: in certain short periods, firms in the sector have resorted to re-exports or the sale of previous stocks in order to survive market shocks.

#### 4.3. The SWOT analysis of the chemical fertiliser industry in Romania

Table no. 4. The SWOT analysis of the chemical fertiliser industry in Romania

<b>Strengths</b> <ul style="list-style-type: none"> <li>• Tradition in the chemical industry,</li> <li>• Considerable domestic demand,</li> <li>• Availability of natural gas resources (Neptun Deep, Black Sea Oil &amp; Gas, Caragele),</li> <li>• Availability of green energy,</li> <li>• Carbon storage capacity (in depleted oil and gas fields),</li> <li>• Connectivity and access to all means of transport, with connections to Central Europe: sea, river, rail, road,</li> <li>• Specialised workforce.</li> </ul>	<b>Weaknesses</b> <ul style="list-style-type: none"> <li>• The missing of a national strategy and feasibility studies for the relaunch of domestic production,</li> <li>• The lack of tax incentives to stimulate investments in the sector, budgetary constraints, and support limits through EU rules on state aid for energy-intensive industries,</li> <li>• The bankruptcy of most chemical plants and the degradation of production assets,</li> <li>• The current high price of natural gas, the basic raw material in the production of ammonia,</li> <li>• Delays in developing studies on carbon storage in viable deposits.</li> </ul>
<b>Opportunities</b> <ul style="list-style-type: none"> <li>• The high global and regional demand for blue/green ammonia in the 2030 perspective, generated by net-zero policies,</li> <li>• Small number of investment projects in the EU in chemical fertiliser plants,</li> <li>• The prospects of ammonia as a solution in sustainable transport, especially by sea,</li> <li>• Efficient exploitation of natural gas from domestic production for the production of high value-added goods (e.g., ammonia),</li> <li>• The high interest of investors in developing new chemical fertiliser production capacities closer to the customer and the place of consumption,</li> <li>• Projects for the construction of ammonia storage terminals in Europe, for security of supply (Wilhelmshaven Green Hub, Yara, Rotterdam, Immingham).</li> </ul>	<b>Threats</b> <ul style="list-style-type: none"> <li>• Complete cessation of domestic production and exclusive dependence on imports of chemical fertilisers, affecting the trade balance,</li> <li>• low productivity and low production in horizontal industries (plastics, building materials, etc.),</li> <li>• Loss of foreign investment opportunities due to global competition (investors are looking for the optimal conditions for making investments, especially where there are natural gas resources and carbon storage),</li> <li>• Higher costs with the net-zero transition,</li> <li>• Sub-optimal use of gases obtained from domestic production,</li> <li>• Ageing or labour migration in the sector.</li> </ul>

Source: prepared by the authors

Based on the SWOT analysis, one can realise that there are favorable premises for the development of the chemical fertiliser industry in Romania, with a focus on blue ammonia. The strong points herein would be the possibility to capitalise on natural gas resources, on the energy mix, the green energy potential, and the availability of deposits for carbon dioxide capture and storage. In terms of comparative and competitive advantages, *Romania ranks first among EU countries for the development potential of the blue ammonia industry*. In order to be able to assess the opportunity of investments, both for the refurbishment of existing plants or in new factories, additional research is required. One should observe the issues related to economic and technical feasibility, financial analyses of individual solutions, as well as technical and economic studies on carbon capture and storage.

#### Conclusions

This article brings to the attention of the scientific community, but also of other stakeholders, the subject of reindustrialisation in the energy-intensive sector of chemical fertiliser manufacturing. The main drivers of change are the consumption needs for agriculture, the

size of the Romanian market, the possibilities of exporting to the European single market, and the possibilities of developing ammonia as a fuel for sustainable transport. The analysis reflects the fact that this industry has possibilities to recover and regain international competitiveness. Currently, the state of this industrial sector in Romania is defective, under the pressure of making the green transition and under the impact of energy prices.

The econometric analysis in the case of the most important company on the Romanian fertiliser market, Azomureș, indicates a normal market behaviour in terms of response to market signals such as the variation of raw material prices (natural gas, in this case) or labour costs. The price elasticity in the case of turnover and gross profit is negative and sub-unit, indicating a lack of elasticity in relation to the natural gas price variations of turnover (-0.5 elasticity) and close to -1 in the case of gross profit. This suggests the vulnerability of fertiliser producers to price variation, which cannot easily adapt to shocks. It also resulted in a high negative elasticity in absolute terms of gross profit to changes in gross wages, which leads to drastic measures in the short to medium term to adapt to market shocks, such as reductions in the number of employees. There are also temporary crisis measures in many cases, such as sales from existing stocks or re-exports (these are only possible if the company benefits from favourable discriminatory special conditions between potential import and export markets).

The analysis of foreign trade in the last 10 years on the industrial branch of fertilisers reflects a significant increase in imports of nitrogen fertilisers and raw materials for fertilisers, with a negative effect on the country's trade balance.

The SWOT analysis shows the strengths and opportunities that Romania has to obtain a domestic production of clean fertilisers at a competitive price. The existence of domestic production of natural gas, green energy, depleted oil, and gas deposits for carbon storage offers more advantageous economic conditions than other European Union member states. Thus, it is worth further analysing the opportunity of investing in the manufacture of blue ammonia, which could be an optimal solution for the transition to low-carbon fertiliser production.

Recovery solutions involve both investments in green technologies, such as carbon capture and storage, and digital, including the Internet of Things, big data analytics, predictive asset management, process control, automation, etc. These technologies have the potential to be introduced into manufacturing processes, significantly improving production efficiency.

As a public policy recommendation, in the context of Romania's Industrial Strategy 2024-2030, *the analysis reflects the opportunity to support the recovery of Romania's fertiliser sector as a priority through government policies, investments in modernisation of plants and manufacture of blue ammonia.*

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## Annex

### Summary – Testing the Gross Profit error correction mechanism

<i>Regression Statistics</i>								
Multiple R	0.316863206							
R Square	0.100402291							
Adjusted R Square	0.01044252							
Standard Error	0.428100926							
Observations	23							
ANOVA	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>			
Regression	2	0.409088822	0.204544411	1.11608	0.34712301			
Residual	20	3.665408062	0.183270403					
Total	22	4.074496884						
	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	<b>1.075868499</b>	0.246640665	4.362088859	0.000302	0.56138509	1.590351911	0.561385	1.590352
Salariu brut anual CAEN20 (RON) cst 2021	<b>-0.54876415</b>	0.452114916	-1.213771391	0.238975	-1.49185934	0.394331038	-1.49186	0.394331
Pret gaze intern cu taxe cst 2021 (t-1)	<b>0.00086256</b>	0.217511338	0.003965587	0.996875	-0.45285814	0.454583261	-0.45286	0.454583

**Summary – Testing of the turnover error correction mechanism**

<i>Regression Statistics</i>								
Multiple R	0.61343065							
R Square	0.37629716							
Adjusted R Square	0.31392688							
Standard Error	0.17667894							
Observations	23							
ANOVA	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>			
Regression	2	0.37666283	0.188331	6.03327638	0.008907939			
Residual	20	0.62430893	0.031215					
Total	22	1.00097177						
	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	<b>0.48956639</b>	0.10178957	4.809593	0.00010661	0.277237057	0.701896	0.277237	0.701896
Salariu brut anual CAEN20 (RON) cst 2021	<b>0.64693025</b>	0.1865896	3.467129	0.00243333	0.257711153	1.036149	0.257711	1.036149
Pret gaze intern cu taxe cst 2021	<b>-0.166611</b>	0.08976779	-1.85602	0.07824637	-0.353863366	0.020641	-0.35386	0.020641

**Regression of the Gross Profit Differential in relation to the Annual Gross Salaries Differential and the Natural Gas Price Differential**

Regression Statistics								
Multiple R	0.467259904							
R Square	0.218331818							
Adjusted R Square	0.088053788							
Standard Error	0.810109384							
Observations	22							
ANOVA	df	SS	MS	F	Significance F			
Regression	3	3.299547831	1.099849277	1.675891	0.2077234			
Residual	18	11.81298985	0.656277214					
Total	21	15.11253768						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.186224081	0.269625006	0.690678079	0.498578	-0.38023704	0.752685198	-0.38024	0.752685
Delta(LN(Sal cst))	-2.1746993	2.961008173	-0.734445558	0.472137	-8.39554663	4.046148033	-8.39555	4.046148
Delta(LN(PrGaz cst)-1)	-0.92103909	0.758601944	-1.214126981	0.240389	-2.51480263	0.672724456	-2.5148	0.672724
ECM1(t-1)	-0.95853295	0.456587218	-2.099342491	0.050155	-1.9177871	0.000721202	-1.91779	0.000721

**Regression of the Turnover differential in relation to the annual gross salaries differential and the Natural Gas Price differential**

<i>Regression Statistics</i>								
Multiple R	0.599078							
R Square	0.358894							
Adjusted R Square	0.238778							
Standard Error	0.204437							
Observations	22							
ANOVA	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>			
Regression	3	0.44453785	0.148179285	3.545435	0.035502			
Residual	19	0.79409327	0.041794383					
Total	22	1.23863112						
	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Delta(LN(Sal cst))	<b>0.547155</b>	0.52629779	1.039630755	0.311561	-0.5544	1.648709	-0.5544	1.648709
Delta(LN(PrGaz cst)) (t-1)	<b>-0.49710</b>	0.18142749	-2.739939205	0.013016	-0.87683	-0.11737	-0.87683	-0.11737
ECM2(t-1)	<b>-0.82945</b>	0.29856351	-2.778144147	0.01198	-1.45435	-0.20455	-1.45435	-0.20455