# Innovative approach for assessment the interactions between inland and aquaculture fishery


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**Abstract**
The interconnection between inland fisheries and aquaculture is considered as the mean for the assessment of the contribution of aquacultural farms in total fish production of the state. To highlight this contribution the vector autoregression models are given. As the case studies fishery industries are considered for country with access to ocean resources and landlocked country. This approach allows to assess the contribution of aquaculture production in fishery industry of the state. The importance of inland fishery is noted and simultaneously the contribution of aquaculture production in total fishery industry is assessed.



**Keywords:** fishery and aquaculture production, VAR system, model, costal, landlocked.


## 1. Introduction

The growth of inland seafood consumption leads to changes in the ecosystem, disruption of the ecological balance of natural water resources, and reduces the dynamics of sustainable development and management of the fisheries industry [1, 2, 3]. The creation of artificial reservoirs and the development of the aquaculture industry contributed to the reduction in the volume of consumption of inland seafood, which made it possible to establish a balance between the consumption of inland and aquatic products. Aquaculture has become an important component that ensures sustainability in the fisheries industry [3, 4].

The analysis of the relationship between inland and aquaculture production necessitated the study of the relationship and interaction between the volumes of fish catched in natural water resources and fish farmed in aquaculture. To study the interaction between natural and artificial fish production, we conducted research and provided a literature review devoted to the analysis of the production of the fishing industry in inland and landlocked states. The study presents models that allow us to assess the correspondence between artificial fish production and inland fish catch in Armenia (landlocked state) and Romania (inland state).

The research methodology is based on econometric methods that allow us to obtain a comparative assessment of the relationship and interaction between the volumes of natural fish catch and fish grown in natural water bodies.

## 2. Literature review.

### *2.1. Romanian case study.*

The research of Evans (2011) [5] is devoted to the study of the sustainability of the consumption as a hot topic formed in 1992 Earth Summit. Author gives the system of factors and determinants needed to involve in the process of the research devoted to the study of fish consumption and its ecological consequences.

The study of Romanian fish consumption sustainability is considered in Rosca, V., Raluca I (2014) [4]. Authors find out sustainability of the fish consumption in Romania based on the use SPSS software. Two different timespans have been considered. First "one prior to the country's adherence to the European Union and the one after". Determinants of the analysis of the sustainability of fish consumption has been studied. Authors argued a high pressure placed on the natural environment and as a consequent possibility of the improvement of aquaculture production. Authors are arguing that Romanian fish consumption continues to be unsustainable.

The study Pila M, Stanciu S. (2022) [6] is devoted to the analysis of the sustainable development of the fishing sector as a priority of the European policy. According to the authors, the reduction in imports is due to the allocation of financial resources for the development of public production. However, the reduction in the number of aquaculture farms and the absence of a fishing fleet leads to the dependence of the domestic market on imports. The average per capita consumption of fish in Romania is significantly lower than the average annual consumption in the EU.

The Ibanescu D.C., Popescu A., Vasilea I. (2020) [7] based on the feature of Romanian legislation allowing the adjustment of Romanian commercial fishing analysis the dynamics of fishing catches in inland waters in the period 2008 - 2018. Using Romanian National Agency of Fisheries and Aquaculture authors presented an overview of the dynamics of Romanian freshwater fisheries in the period 2008 – 2018.

The Totoiu A., Galatchi M., Radu G. (2016) [8] studied the importance of sprat, as a fish species of particular commercial importance in the Romanian maritime zone. Based on long-term statistical data, the authors conducted a dynamic analysis of sprat catch volumes, assessed the evolution of fishing effort, determined the state of sprat stocks, and studied the biological parameters of sprat.

The Maximov V, Radu G., Anton E., Zaharia T. (2010) [9] Analysis of the evolution of fishing and biological characteristics of main fish from the Romanian Pontic Basin, between 2000 - 2008 determines the species structure of catches by the composition of the Black Sea ichthyofauna, seasonal fluctuations in the population of fish aggregations; data and information on the catch, fishing conditions, fish population biomass, and age of the caught fish are provided. Of particular importance in light of the development of the fishing industry in Romania is the document Multi-annual National Strategic Plans for the development of sustainable Aquaculture for the period 2021 to 2030 [10].

The document gives targets for the measures for 2021-2027, which are consistent with the 13 key areas set out in the "EU Strategic Guidelines for a More Sustainable and Competitive Aquaculture 2021-2030". The development objectives in line with the EU strategic guidelines for sustainable and competitive aquaculture include: "Access to space and water, Regulatory and administrative procedures, Animal and public health, Climate change adaptation and mitigation, Producer and market organizations".

The document "Romania's SUSTAINABLE DEVELOPMENT Strategy 2030" [11] provides statistical data on Romanian economy, the status and characteristics of Romanian inland and aquatic fish production: Fish utilization including Post-harvest use and Fish production as a mean for human consumption; Fish markets; Fishery sector performance. The importance of this document is its plan for the development of Romanian fish industry.

### *2.2. Armenian case study.*

The review of fisheries and aquaculture development potentials in Armenia [3]. FAO Fisheries and Aquaculture Circular. No. 1055/2. Rome, FAO. 2011. 48p presents data on updating and presenting natural, economic and social resources aimed at ensuring sustainable development and management of the fisheries and aquaculture sector in Armenia. The objective of the work is to present evidence related to the fact that fisheries and aquaculture have significant development potential in Armenia. Despite the fact that Armenia has rich inland water resources, however, the potential of the fisheries sector is not fully utilized. To achieve and improve the efficiency of water resources use, it is necessary to improve coordination and administration through the establishment and implementation of rules and regulations for inland fisheries, as well as the expansion of national and international markets. The paper presents possible avenues and a range of data and information needed to facilitate and identify further areas for fisheries and aquaculture development.

The Khanamirian G. and Aghababyan K. (2015) [12] studies the implementation of rainbow trout production for small farms in Armenia. The developed approach is based on increasing production intensity, introducing new production processes, attracting investments, reducing production costs. A new approach for the rational use of limited artesian water resources has been developed.

The Nazaryan A., Sergey Avetisyan S. (2015) [13] goal of the project is to increase the attractiveness of investments in the aquaculture industry and promote export competitiveness of not only aquaculture, but also the entire agricultural production. Giving importance to the aquaculture sector and its great potential, the project contains an overview of aquaculture supply chains. It is aimed at identifying problems in the implementation of supply chains, which in particular contain fish products. The project identifies shortcomings in the fish products market. Based on the development of recommendations for improving the investment environment, approaches are proposed to improve and increase the competitiveness of the fish industry in Armenia.

## 3. Vector autoregession system of Romanian and Armenian aquaculture and fishery production

The VAR model was estimated for Romania (ROU) and Armenia (ARM) aquaculture and fishery production. The purpose of this study is the assessment of the relationship between Romanian (as inland state) and Armenian (as landlocked state) aquaculture and fishery production. We used annual data over the period 1988-2022 for Romania and the period 1992-2022 for Armenia. The VAR model for two endogenous variables is represented by the following system of equations:

$$Y1_t = \propto_1 + \sum_{j=1}^{k} \beta_{1j} Y1_{t-j} + \sum_{j=1}^{k} \delta_{1j} Y2_{t-j} + u_{1t} \quad (1)$$

$$Y2_t = \propto_2 + \sum_{j=1}^{k} \beta_{2j} Y1_{t-j} + \sum_{j=1}^{k} \delta_{2j} Y2_{t-j} + u_{2t} \quad (2)$$

***Where:***

*$Y1_t$ and $Y2_t$ - endogenous variables,*

*$\beta_{1j}, \beta_{2j}, \delta_{1j}, \delta_{2j}$ - the coefficients,*

*$k$ - the lag length of the model,*

*$u_{1t}$ and $u_{2t}$ - the stochastic errors, which are «white noise» processes.*

The maximum value of the volume of aquaculture production in Romania (ROUAQUA) during the period 1988-2022 is 50680 tons (1988), the minimum value is 7284 tons (2005), the annual average is 15291.96 tons. The maximum value of the volume of fishery production is 216938 tons (1988), the minimum value is 2688 tons (2010), the annual average is 27109 (see Table 1).

The maximum value of aquaculture production in Armenia is 24000 tons (2022), the minimum value is 437 tons (1998), the annual average is 7125 tons. The maximum value of fishing production is 8140 tons (2015), the minimum value is 218 tons (2004), the annual average is 1347 tons (see Table 1).

Table 1. Descriptive Statistics

| | ARMAQUA | ARMFISH | ROUAQUA | ROUFISH |
|---|---|---|---|---|
| Mean | 7124.935 | 1346.936 | 15291.96 | 27109.21 |
| Median | 3650 | 770 | 11210.78 | 7972.88 |
| Maximum | 24000 | 8140 | 50680.00 | 216938 |
| Minimum | 437 | 218 | 7284 | 2688 |
| Std. Dev | 7383.317 | 1678.166 | 10434.46 | 48709.21 |
| Skewness | 0.7737 | 2.7182 | 2.2274 | 2.7699 |
| Kurtosis | 2.0932 | 10.2989 | 7.2461 | 10.0015 |
| Jarque-Bera | 4.1553 | 106.9870 | 55.2333 | 116.2439 |
| Probability | 0.1252 | 0.0000 | 0.0000 | 0.0000 |
| Sum | 220873.0 | 41755.01 | 535218.6 | 948822.3 |
| Sum Sq.Dev | 1.64E+09 | 84487216 | 3.70E+09 | 8.07E+10 |
| Observations | 31 | 31 | 35 | 35 |

Source: Calculated from World Bank, https://data.worldbank.org/indicator/SP.POP.GROW?locations=IR

The data in the VAR model were taken as the natural base logarithms of the variables. Fig.1. shows the graphs of the variables of the model.

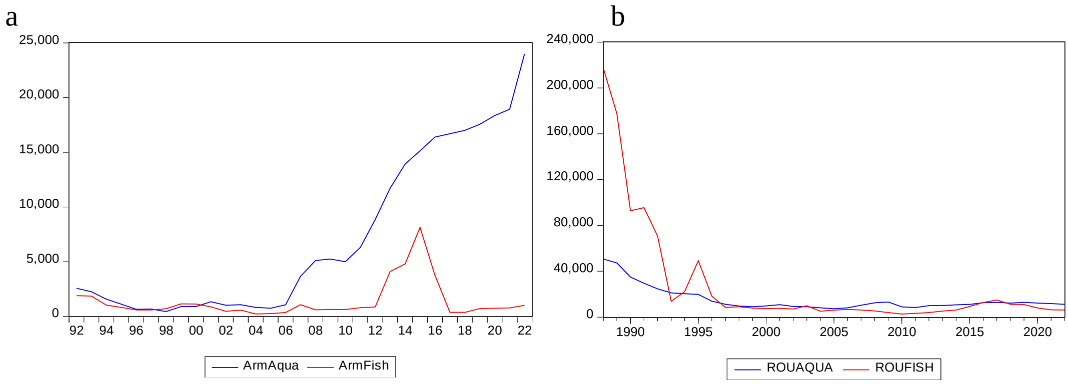


Fig. 1. (a) ARMAQUA and ARMFISH; (b) ROUAQUA and ROUFISH.
Source: World Bank

Augmented Dickey–Fuller (ADF) test is used to test the non-stationarity of the variables ($H_0$ hypothesis – the variable is not stationary). The test is evaluated with three different zero hypotheses: Random Walk, Random Walk with Drift and Random Walk with Drift and Trend.

For variable LROUAQUA we have chosen a model including an intercept, and for LROUFISH - a model including an intercept and Linear Trend. Table 2 shows the results of the ADF test. The variable LROUAQUA is stationary at the 5% significance level, and the null hypothesis is rejected. The time series LROUFISH is not stationary. To eliminate the non-stationarity, the successive difference operator was used (see Table 2).

For Armenia, both variables LARMAQUA and LARMFISH are non-stationary before differencing. For both variables LROUAQUA and LROUFISH we have chosen a model including an intercept and Linear Trend. To eliminate the non-stationarity, the successive difference operator (d indicates the first difference of the variables) was used (see Table 2).

Table 2. The results of the ADF test.

| Country | Variable | ADF test statistic | Prob.* | Test critical values: 1% level | 5% level | 10% level |
|---|---|---|---|---|---|---|
| ARM | LARMAQUA | -3.243826 | 0.0959 | -4.309824 | -3.574244 | -3.221728 |
| | d(LARMAQUA) | -3.892928 | 0.0266 | -4.339330 | -3.587527 | -3.229230 |
| | LARMFISH | -2.440023 | 0.3532 | -4.296729 | -3.568379 | -3.218382 |
| | d(LARMFISH) | -4.504287 | 0.0064 | -4.309824 | -3.574244 | -3.221728 |
| ROU | LROUAQUA | -3.506323 | 0.0141 | -3.646342 | -2.954021 | -2.615817 |
| | LROUFISH | -2.831946 | 0.0644 | -3.639407 | -2.951125 | -2.614300 |
| | d(LROUFISH) | -5.643791 | 0.0000 | -3.646342 | -2.954021 | -2.615817 |

The variables LARMAQUA and LARMFISH were expressed to be I(1). As a result of the Johansen cointegration test used in the VAR model, the Trace and Maximum eigenvalue tests show that there is no cointegration in the model for Armenia: both the Trace statistic and the Maximum eigenvalue statistic are less than their respective critical values at 5%, indicating that we cannot reject the null hypothesis that there are zero cointegrating relations (see Table 3). Therefore, long-run equilibrium does not exist between LARMAQUA and LARMFISH. Since long-run equilibrium does not exist between the two time-series, VECM cannot be used, a short-run dynamic relationship can be estimated through the VAR estimation.

Table 3. Cointegration test results on LARMAQUA and LARMFISH.

| Hypothesized No. of CE(s) | Eigenvalue | Trace Statistic | 0.05 Critical Value | Prob.** | Max-Eigen Statistic | 0.05 Critical Value | Prob.** |
|---|---|---|---|---|---|---|---|
| None | 0.299896 | 10.36712 | 15.49471 | 0.2536 | 10.33926 | 14.2646 | 0.1906 |

Trace test indicates no cointegration at 0.05 the level. Max-Eigenvalue test indicates no cointegration at 0.05 the level. **MacKinnon-Haug-Michelis (1999) p-values.

The lag length in the VAR model for Romania is two and one, based on LR test statistic, FPE, AIC, SC, and HQ (Table 4). We estimated VAR models with both one and two lags and chose two lag model according to AIC and SIC minimum values.

The optimal lag length in the VAR model for Armenia is one, based on LR test statistic, FPE, AIC, SC, and HQ (Table 4).

Table 4. VAR Lag Order Selection Criteria.

| Variables | Lag | LogL | LR | FPE | AIC | SC | HQ |
|---|---|---|---|---|---|---|---|
| LROUAQUA d(LROUFISH) | 0 | -24.92097 | NA | 0.019470 | 1.736837 | 1.829352 | 1.766994 |
| | 1 | 6.415495 | 56.60781 | 0.003341 | -0.026806 | 0.250740* | 0.063667 |
| | 2 | 12.38344 | 10.01074* | 0.002956* | -0.153770* | 0.308806 | -0.002982* |
| | 3 | 15.39406 | 4.661608 | 0.003183 | -0.089939 | 0.557668 | 0.121164 |
| d(LARMAQUA) d(LARMFISH) | 0 | -82.41975 | NA | 1.157604 | 5.822052 | 5.916348 | 5.851584 |
| | 1 | -33.85499 | 87.08164* | 0.053630* | 2.748620* | 3.031509* | 2.837218* |
| | 2 | -30.08463 | 6.240606 | 0.054785 | 2.764457 | 3.235938 | 2.912119 |

* indicates lag order selected by the criterion

According to the results of the Granger causality test, the null hypothesis that LROUAQUA does not Granger cause d(LROUFISH) is rejected at the 10% significance level based on the chi-squared test of 5.857 with df=2 and a p-value=0.0535 and therefore LROUAQUA is the cause of d(LROUFISH) at the 10% significance level. But d(LROUFISH) does not the cause of LROUAQUA at any significance level, because of prob(Chi-sq)=0.6028 (see Table 5).

According to the results of the Granger causality test, d(LARMFISH) does not the cause of d(LARMAQUA) at any significance level, because of prob(Chi-sq)=0.4224 and d(LARMAQUA) does not the cause of d(LARMFISH) at any significance level, because of prob(Chi-sq)=0.4860 (see Table 5).

Table 5. The results of Granger causality tests.

| d(LARMAQUA) and d(LARMFISH) | | | | LROUAQUA and d((LROUFISH) | | | |
|---|---|---|---|---|---|---|---|
| Depended variable: d(LARMAQUA) | | | | Depended variable: LROUAQUA | | | |
| Excluded | Chi-sq | df | Prob. | Excluded | Chi-sq | df | Prob. |
| d(LARMFISH) | 0.993497 | 1 | 0.3189 | d(LROUFISH) | 1.012493 | 2 | 0.6028 |
| All | 0.993497 | 1 | 0.3189 | ALL | 1.012493 | 2 | 0.6028 |
| Depended variable: d(LARMFISH) | | | | Depended variable: d(LROUFISH) | | | |
| Excluded | Chi-sq | df | Prob. | Excluded | Chi-sq | df | Prob. |
| d(LARMAQUA) | 0.202617 | 1 | 0.6526 | LROUAQUA | 5.857362 | 2 | 0.0535 |
| All | 0.202617 | 1 | 0.6526 | All | 5.857362 | 2 | 0.0535 |

Table 6 represents the results of the VAR model for Romania, and Table 7 – for Armenia.

Table 6. VAR model results (Romania).

| | | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|---|
| Dependent variable: LROUAQUA | LROUAQUA(-1) | 1.164968 | 0.19780 | 5.88972 | 0.0000 |
| | LROUAQUA(-2) | -0.334609 | 0.17720 | -1.88828 | 0.0644 |
| | DLROUFISH(-1) | -0.023380 | 0.05474 | -0.42708 | 0.6710 |
| | DLROUFISH(-2) | -0.046463 | 0.04825 | -0.96301 | 0.3398 |
| | c | 1.568847 | 0.56552 | 2.77415 | 0.0076 |
| Dependent variable: DLROUFISH | LROUAQUA(-1) | 0.247930 | 0.68080 | 0.36418 | 0.7171 |
| | LROUAQUA(-2) | -0.648552 | 0.60992 | -1.06335 | 0.2924 |
| | DLROUFISH(-1) | -0.200056 | 0.18842 | -1.06173 | 0.2931 |
| | DLROUFISH(-2) | -0.431500 | 0.16606 | -2.59838 | 0.0120 |
| | c | 3.650152 | 1.94647 | 1.87526 | 0.0662 |
| VAR Estimate | | | | | |
| Determinant resid covariance (dof adj.) | | | 0.002267 | | |
| Determinant resid covariance | | | 0.001614 | | |
| Log likelihood | | | 12.05185 | | |
| Akaike AIC | | | -0.128240 | | |
| Schwarz SC | | | 0.329802 | | |

Table 7. VAR model results (Armenia).

| | | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|---|
| Dependent variable: DLARMAQUA | DLARMAQUA(-1) | 0.149121 | 0.20697 | 0.72049 | 0.4744 |
| | DLARMFISH(-1) | 0.106274 | 0.10662 | 0.99674 | 0.3235 |
| | c | 0.074628 | 0.06667 | 1.11928 | 0.2682 |
| Dependent variable: DLROUFISH | DLARMAQUA(-1) | -0.188562 | 0.41890 | -0.45013 | 0.6545 |
| | DLARMFISH(-1) | 0.168683 | 0.21580 | 0.78166 | 0.4380 |
| | c | -0.003009 | 0.13495 | -0.02230 | 0.9823 |
| VAR Estimate | | | | | |
| Determinant resid covariance (dof adj.) | | | 0.048555 | | |
| Determinant resid covariance | | | 0.039028 | | |
| Log likelihood | | | -35.26819 | | |
| Akaike AIC | | | 2.846082 | | |
| Schwarz SC | | | 3.128971 | | |

The results from Table 7 show that p-values of the VAR model coefficients are greather than any significance level α (the null hypothesis is not rejected), and the all coefficients are statistically non-significant, so we will continue our discussions for Romania.

In order to check the stability of the model for Romania, an inverse root test of the regression coefficients was performed. All the roots of the characteristic polynomial of the

VAR model are less than one in absolute value and are inside the unit circle, therefore the stability condition of the model is satisfied (see Fig. 2).

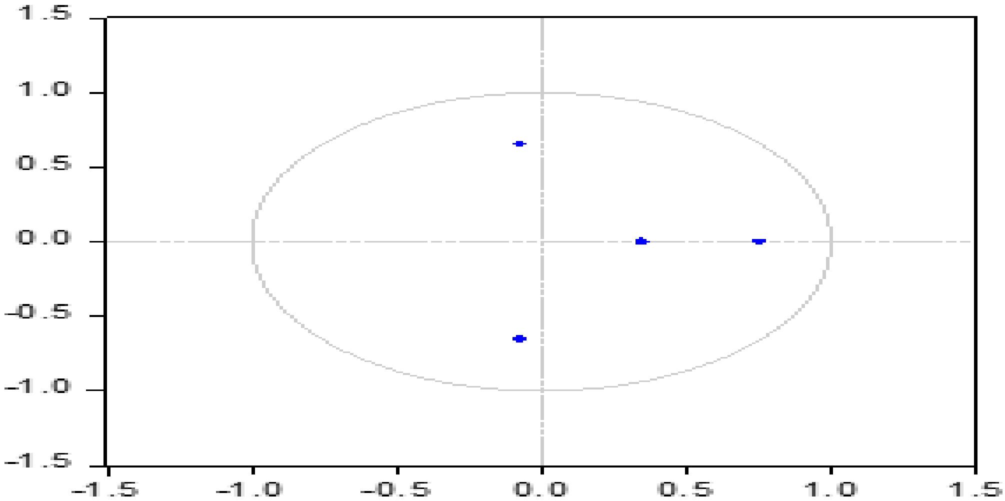

Fig. 2. VAR model stability (Romania).

In order to ensure the credibility of the obtained results and the quality of the model for Romania, tests of non-autocorrelation and homoscedasticity of the residuals of the VAR model was tested. With the LM test results for lags 1 to 3, the LRE stat and Rao F-stat test probabilities are greater than 0.05, suggesting that the residuals in the VAR model are not autocorrelated (see Table 8).

Table 8. VAR Residual Serial Correlation LM Tests (Romania). Null hypothesis: No serial correlation at lags 1 to h

| Lag | LRE*stat | df | Prob | Rao F-stat | df | Prob. |
|---|---|---|---|---|---|---|
| 1 | 4.807255 | 4 | 0.3077 | 1.236973 | (4,48.0) | 0.3078 |
| 2 | 5.847648 | 8 | 0.6643 | 0.728691 | (8.44.0) | 0.6655 |
| 3 | 10.20563 | 12 | 0.5979 | 0.848562 | (12,40.0) | 0.6024 |

With the results of the heteroscedasticity test of the residuals in the combined test of Prob. Chi Square=0.5611, so the null hypothesis that the residuals are homoscedastic is not rejected for Romania (see table 9).

Table 9. VAR Residual Heteroskedasticity Tests (Levels and Squares). Joint test (Romania)

| Chi-sq | df | Prob |
|---|---|---|
| 22.30524 | 24 | 0.5611 |

Based on the estimation of the VAR model for Romania, we obtained the following results:
(1) Accelerating aquaculture production by 1 ton leads to 1.165 tons increase in the same production after one year at the 5% significance level (p-value = 0.0000).
(2) Accelerating fishery production by 1% leads to a 0.43% decrease in the same production after 2 years at the 5% significance level (p-value = 0.0120).

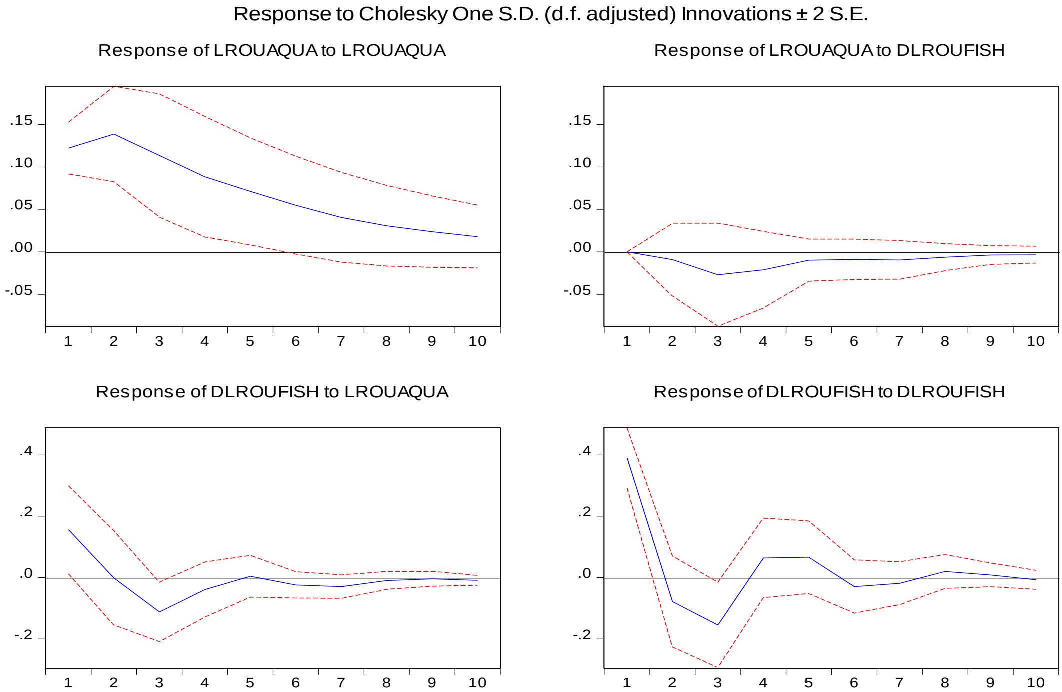

Fig. 3. The impact of random shocks on variables in VAR models (Romania)

The dynamic impact of random shocks on variables are estimated using the Impulse Response Function (see Fig. 3). As a result of one standard deviation increase in own shock, the LROUAQUA variable increases sharply in the first year, then decreases in the long term, remaining positive. A positive shock of DLROUFISH variable leads to a decline in LROUAQUA during the first three years. LROUAQUA decreases, becomes negative, then starts to increase and approaches zero, remaining negative. A positive shock of LROUAQUA variable leads to a decline in DLROUFISH during the first three years. DLROUFISH decreases, becomes negative, then starts to increase and approaches zero remaining negative. As a result of one standard deviation increase in own shock, the DLROUFISH variable decreases sharply during the first three years, becomes negative, then begins to increase and approaches zero.

## 4. Conclusion

The features of fish consumption in Romania, the dynamics of its production as well the features of the fishing industry in Romania and Armenia are studied. The impact of overfishing of marine fish on the ecosystem and the importance of aquaculture as a component that reduces the intensity of inland fishery production are noted. An attempt is made to compare and evaluate the interaction between inland fishery production and aquaculture. This approach allows to estimate the impact of aquaculture's contribution to the total volume of fishery production. The importance of the vector autoregression models developed in the study is that they allow to estimate the possibility of achieving a balance in fishery production based on the study of the interaction between inland fishery production and aquaculture. We also argue that the study of the fishing industry for coastal countries allows us to estimate the importance of aquaculture in reducing the volume of fish catch in inland waters by increasing aquaculture production. We also argue that the results obtained in the study are of great practical importance for inland and landlocked countries.

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