EFFECTS OF THE CRISIS ON AGRICULTURE IN UKRAINE: A MIXED INPUT-OUTPUT ANALYSIS

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Abstract - The purpose of this study is to use a mixed input-output model to analyze and quantify the likely effects of the conflict between Russia and Ukraine on the latter's agricultural economy. Using the latter, the study also assesses the extent of the effects of the conflict on macroeconomic aggregates (GDP, foreign trade, etc.) and on other sectoral activities in 2022 compared with 2021.
The choice of the agricultural sector was motivated firstly by the fact that, in recent years, Ukraine has become a major player on the international commodities markets, producing and exporting large quantities of cereals and oilseeds, and secondly by the weight it represents in the GDP of the local economy.
Depending on the scenario adopted, estimates indicate a loss of GDP in 2022 of -7.55% compared with a situation in which the war had not taken place. The simulations show that the sectors that are the biggest consumers of agricultural products, such as refined petroleum, the automotive industry and the chemicals industry, are the hardest hit by this shock.

Keywords - Agricultural sector, Leontief, Mixed Input-Output Model, Supply shock, Ukraine.

I. INTRODUCTION

Ukraine, hit by the destruction and bombardments, not only sees its food security directly threatened in the present, but even more so in the future, even though it is the largest agricultural country on the European continent in terms of size and rich, fertile land ("tchernoziom" or black earth). Remember that agriculture and agri-food normally employ 20% of the working population, generate 15% of the country's GDP and 40% of exports. This is achieved through a wide range of crops, including cereals (wheat, maize, barley), oilseeds (sunflower and rapeseed), potatoes, etc. On average, between 2017 and 2021, Ukraine was the world's leading exporter of sunflower oil and seed, the fourth largest exporter of maize and the sixth largest exporter of wheat (Brun, 2022).

Starting from the current evidence on the effects of the war shock in Ukraine on its agricultural yields, we assess its implications for macroeconomic aggregates (GDP, foreign trade, consumption, etc.), via its effects on sectoral activities in 2022. In effect, the shock of the war is translated into changes in agricultural production and, consequently, is propagated through the economy via the sector's upstream and downstream links with the rest of the economy. Our study uses the mixed input-output model (Koller etLuptacik, 2007**;** Hambÿe,2012; Miller et Blair, 2009; Dietzenbacher et Miller, 2015) to account for this interrelationship between the supply-constrained agricultural sector and the non-agricultural sectors.

The rest of the paper is as follows. First, we present the mixed model constructed in its matrix dimension. The calibration of supply shocks in the agricultural sector is then discussed, with a reminder of the sources of information used. Finally, we present the results and conclude.

II. MATRIX WRITING OF THE MODEL WITH AN AGRICULTURAL SUPPLY SHOCK

In Leontief's classic open model (1936), production is not subject to supply constraints and is determined solely by final demand, which is assumed to be exogenous. However, if we wish to estimate the impact of a variation in agricultural output on the total output of the economy, via direct, indirect and induced effects, it is possible to specify in the same model an exogenous output for the agricultural product and an exogenous final demand for the rest of the products.

The specification of the mixed input-output model starts from the equalities of the classical Leontief model (J equations with J unknowns), whose branches have been reordered so that the first k branches have an exogenous final demand $d^{ex} = [d_1, \dots, d_k]$and an endogenous production $PQ^{en} = [P_1Q_1, \dots, P_kQ_k]$and the last J-k branches (e. g. agricultural sector) have an exogenous production $Q^{ex} = [P_{k+1}Q_{k+1}, \dots, P_JQ_J] = \min(v, u)$ and an endogenous final demand $d^{en} = [d_{k+1}, \dots, d_J]$.

$v_j \in [0,1]$represents the proportion of employees able to work during the confrontation. In parallel, the disruption of supply chains may limit the output of

the agricultural industry due to the impossibility of having recourse to intermediate consumption needed in the productive process. We assume that a share $u_j \in [0,1]$; of orders for intermediate goods cannot be guaranteed (e.g. by a break in the supply chain).

Then, the equilibrium accounting relationships of this economy can be rewritten as follows:

$$\begin{aligned} P_1Q_1 &= a_{11}P_1Q_1 + \cdots + a_{1k}P_kQ_k + a_{1k+1}P_{k+1}Q_{k+1} \\ &\quad + \cdots + a_{1J}P_JQ_J + d_1 \\ &\vdots \\ P_kQ_k &= a_{k1}P_1Q_1 + \cdots + a_{kk}P_kQ_k + a_{kk+1}P_{k+1}Q_{k+1} \\ &\quad + \cdots + a_{kJ}P_JQ_J + d_k \\ P_{k+1}Q_{k+1} &= a_{k+11}P_1Q_1 + \cdots + a_{k+1k}P_kQ_k \\ &\quad + a_{k+1k+1}P_{k+1}Q_{k+1} + \cdots \\ &\quad + a_{k+1J}P_JQ_J + d_{k+1} \\ &\vdots \\ P_JQ_J &= a_{J1}P_1Q_1 + \cdots + a_{Jk}P_kQ_k + a_{Jk+1}P_{k+1}Q_{k+1} + \\ &\quad \cdots + a_{JJ}P_JQ_J + d_J \quad (1) \end{aligned}$$

Where a_{ij} indicates the quantity of product i (from domestic production) that is used to produce one unit of product j.

In matrix form and by rearranging the terms so as to have the endogenous variables (k production and J - k final demands) expressed as a function of the exogenous variables, we have:

$$X_{mixte} = M^{-1} \times N \times Y_{mixte} \quad (2)$$

With :

$$X_{mixte} = \begin{pmatrix} P_1Q_1 \\ \vdots \\ P_kQ_k \\ d_{k+1} \\ \vdots \\ d_J \end{pmatrix}, \quad Y_{mixte} = \begin{pmatrix} d_1 \\ \vdots \\ d_k \\ P_{k+1}Q_{k+1} \\ \vdots \\ P_JQ_J \end{pmatrix}, \quad M = \begin{pmatrix} 1-a_{11} & \cdots & -a_{1k} & 0 & \cdots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ -a_{k1} & \cdots & 1-a_{kk} & 0 & \cdots & 0 \\ -a_{k+11} & \cdots & -a_{k+1k} & -1 & \cdots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ -a_{J1} & \cdots & -a_{Jk} & 0 & \cdots & -1 \end{pmatrix} \text{ and}$$

$$N = \begin{pmatrix} 1 & \cdots & 0 & a_{1k+1} & \cdots & a_{1J} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \cdots & 1 & a_{kk+1} & \cdots & a_{kJ} \\ 0 & \cdots & 0 & -(1-a_{k+1k+1}) & \cdots & a_{k+1J} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \cdots & 0 & a_{Jk+1} & \cdots & -(1-a_{JJ}) \end{pmatrix}.$$

The elements of the $M^{-1} \times N$ matrix represent multipliers that link endogenous variables to exogenous variables. Thus, a rearrangement of the Leontief model, by setting constraints at the level of production and not exclusively at the level of demand, makes it possible to exploit the input-output table (IOT) to analyse the isolated diffusion of the supply shock that reduces the productive capacity of the agricultural sector.

Finally, for given variations in agricultural production, the mixed input-output model makes it possible to estimate variations in aggregate and sectoral production and to decompose them according to two approaches (demand and supply), while maintaining the assumption that the coefficients are fixed.

III. DATA USED AND APPROXIMATION OF SUPPLY SHOCK USING EXTERNAL INFORMATION

The results of the qualitative survey "Impact of the war on agriculture and rural livelihoods in Ukraine - Findings of a nation-wide rural household survey (December 2022)" conducted by the FAO served as the initial information base for calibrating the labor supply shock. The main objective of this survey was to assess the immediate impact of the conflict about farmers in Ukraine. The field survey was carried out from 01 October to 31 November 2022 and targeted a representative sample of 5,200 farmers located in different regions. During the year 2022, according to the results of the institution issuing the data, almost 25% of all farmers declared that they had definitively stopped their activities.

Thus, keeping the notation of the mixed model, we have:

$$v_{it} = v_{it}^{o} + \varepsilon_{it} \quad (3)$$

Where v_{it} is the labour shock suffered by branch i (agriculture in our case) at date t. This is broken down into v_{it}^{o}, a shock deduced and observed from the FAO survey, which is equal to 75% of Ukrainian farmers who continued to ensure agricultural production, and ε_{it}, a measurement error. The latter may be explained by other absenteeism factors not considered in our initial assessment from the survey results.

About supply shock, we do not have a precise ex ante measure of the extent of supply problems. In this context, we will measure the shock suffered by the agricultural sector as the product of the immediate effect of the diffusion of the labour shock in the transport sector (v_{Tt}). We assume that the magnitude of the shock would be of the same order as that of agriculture.

We therefore assume that our approximation of the supply shock (u_{it}) is equal to:

$$u_{it} = v_{Tt} \quad (4)$$

The application to the Ukrainian case of the methods proposed above for calculating the effects of the war on agricultural activity and the rest of the economy has been carried out based on the latest version of the TES, available on the URKSTAT website, that of

2021. The analysis is based on the aggregated 42-branch national accounts nomenclature.

IV. ASSESSMENT OF THE MACRO-ECONOMIC AND SECTORAL IMPACT OF THE WAR ON AGRICULTURAL ACTIVITY AND THE REST OF ECONOMY

The simulation of the shock makes it possible to estimate the loss of GDP that the national economy would suffer for the current year, which in the base scenario is -7.55% compared with a situation in which the conflict did not take place.

Table 1 also shows the breakdown of this fall in activity by type of income. According to the results, the reaction to the fall in capital remuneration (-8.82%) would be stronger than that of labor remuneration (-6.33%). The reason for this can be found in the unbalanced distribution of value added in Ukraine, to the detriment of wages. As a result, there is little scope for further wage cuts, and the fall in activity will be borne by the factor of production whose primary distribution is favorable, in this case capital. As for tax revenues net of subsidies, the loss amounts to -7.19% and -0.17% in terms of contribution.

Macroeconomic variables	Variation	Contribution
GDP (income approach)	-7,55%	-7,55%
Wages	-6,33%	-3,14%
Profits	-8,82%	-4,24%
Taxes net of subsidies	-7,19%	-0,17%
GDP (demand approach)	-7,55%	-7,55%
Final consumption	-4,59%	-4,27%
Investment	3,87%	0,35%
Exports	-11,83%	-5,19%
Imports	-3,40%	1,56%

Table 1: Macroeconomic results of the simulation v_j=75%; u_j=75%.
Source: authors' calculations

In terms of the components of demand, exports are expected to be the main contributor to the loss of GDP, with a contribution of -5.19 percentage points. This will be followed by final consumption (private and public), which should contribute -4.27 percentage points to the loss of output. Investment is expected to act as a shock absorber, reducing the impact of the crisis, as the fall in changes in inventories in volume terms is expected to be stronger than that of gross fixed capital formation. Lastly, imports would record a decline of around 3.40%, enabling them to explain 1.56% of the gain in activity at national level.

At a disaggregated level and according to the same scenario, the estimates indicate that virtually all sectors are affected by the fall in activity compared with a year 2022 without conflict, but to different degrees. As expected, the sectors suffering most from the crisis are those that are the biggest consumers of agricultural products, such as refined petroleum, automobiles and chemicals. Their loss of GDP over the year is estimated at 46.35%, 42.43% and 34.04% respectively. The crude oil and gas and machinery sectors followed, with GDP declines of 25.47% and 15.60% respectively. On the other hand, the impact of the war shock on most tertiary activities, via the agricultural sector, remains very slight.

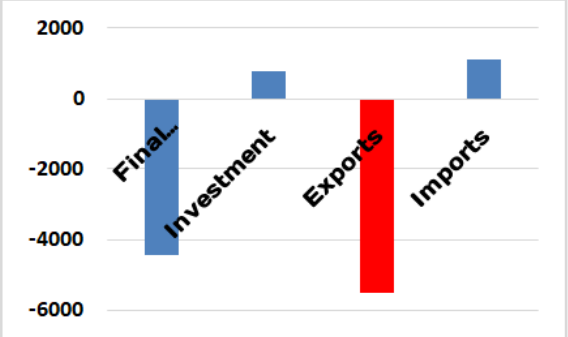

Figure 1: Results of the effect of the shock v_j=75%; u_j=75% on the components of final agricultural demand
Source: authors' calculations

At the same time, agricultural exports are expected to fall by $5.5 billion, threatening global food security. Many food-importing countries, many of which fall into the category of low-income food-deficit countries, are dependent on Russian and Ukrainian food supplies to meet domestic demand. Several African and MENA countries import more than half, and sometimes as much as 100%, of their wheat from Russia and Ukraine. What's more, some of these countries are experiencing internal conflicts and precarious food security. For these countries, it is imperative to find other sources of supply to meet their needs.

However, according to the simulation results, this fall in exports, in absolute terms, would be 1080 million dollars less than the fall in final consumption. However, domestic logistics circuits must be maintained to supply food and other essential goods and services, particularly in regions where large numbers of Ukrainians have taken refuge from the fighting.

V. CONCLUSIONS

The economic crisis currently affecting Ukraine's agricultural economy is likely to leave its mark both locally (economic and social structures) and internationally (rising commodity prices, food insecurity, etc.). The way out of this crisis and the state towards which the Ukrainian economy will move will depend on the vision and degree of involvement of the public authorities in dealing with it, particularly in terms of the content and scope of the economic policies envisaged, but also in terms of

the scale of the shock suffered, which will put all the components of the economy to the test over the long term. Faced with this kind of shock, a return to pre-crisis 'normality' is out of the question in the short term, especially as the trough will be so deep. Indeed, estimates of the loss of production point to a fall of around -7.55% of GDP in a median scenario, compared with GDP without the crisis. This loss could be greater in a pessimistic scenario, where recovery would be even slower.

However, this study suffers from several limitations. Indeed:
i- We assume that the supply and demand shocks will not be additive and that only the larger supply shock will affect the agricultural industry.
ii- In the absence of exhaustive information on the interdependent relationships between firms belonging to the agricultural industry, we have assumed that the latter is represented by a single firm within the TES (a typical firm that verifies "a synthesis" of the characteristics of all firms in the sector). The resulting estimates are therefore reduced by the amplifying effect of the propagation rate of supply shocks.
iii- The assumptions of fixed technical coefficients of production, price rigidity and the non-appearance of new products are strong but admissible. The same applies to the linearity of the relationships. However, the use of a recent IOT (that of 2021) mitigates the limitations inherent in these assumptions.

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