**Instruction of the sample codes of input–output geographic cascade (IOGC) model**

1 Description

This document is used to introduce the operating principles and methods of a new model combining economics and geography, the IOGC model. The IOGC model mainly includes two operating modules: ARIO module and GPN module. For the detailed introduction and principle basis of these two modules, please refer to (Ge et al., 2010; Hallegatte, 2008). Here we mainly introduce the improvement of the new model, the setting of this experiment on the food crisis caused by the Russian-Ukrainian conflict, and the use of sample code.

2 ARIO module

The basis of the ARIO module is the input-output model in economics. Its main principle is to use the relationship between production, orders, and inventory, and based on the input-output share in the supply chain, to calculate the impact on the overall production capacity caused by the disruption of a certain link in the supply chain. In the new model, we use ARIO as a tool for calculating economic losses following global supply chain disturbances. Its role is to act as a constraint on the economic loss caused by the cascading consequences.

At present, the ARIO module takes half a month as the minimum time step and assumes that the global inventory can support the normal production level for one month when the world faces a major crisis (such as a food crisis). The model requires the following data as inputs: (1) The input-output table at the sector level (InputOutput\_Z.csv); (2) The theoretical production value of the sector under equilibrium conditions calculated through the production relationship (InputOutput\_X.csv); (3) The code matrix representing the region and sector (mat\_index.csv); (4) The table (cof.csv) of the location and degree of disturbance in the hypothetical supply chain.

3 GPN module

The GPN module is derived from Geographic Petri Net. Its main principle and function is to use the interdependence relationship between nodes in the network to simulate the disturbance transmission process of the entire network after some nodes fail, which is also called the cascade effect. In the new model, we incorporate the concept of time steps from the ARIO module and use ARIO as a constraint on the economic loss within each time step to prevent the cascading effect from expanding infinitely. Take the globally balanced input-output relationship as the interdependence among various countries and departments. Through a large number of independent repeated experiments, the model simulates which paths will affect the production of other regions and departments after a major production accident in a certain region or department, thus causing greater indirect economic losses. The model requires the following data as input conditions: (1) direct consumption coefficient matrix (InputOutput\_A.csv) calculated using the input-output table; (2) global stepwise long loss value (loss\_acc\_steps.csv) calculated using the ARIO module; ( 3) Country and sector of initial failure.

4 Sample Code

4.1 The experiment of the Russia-Ukraine conflict

Here, we conducted an experiment on the food crisis caused by the Russia-Ukraine conflict to reveal the degree and path of the impact of sudden regional conflicts on the global supply chain. The real A matrix comes from the global trade data purchased by the Global Trade Analysis Project (GTAP). We used multiple scenario assumptions of grain production reduction in the ARIO module and averaged the results, which were input into the GPN module as constraints. The final simulation results are placed in another folder. Results can be visualized using our provided sample code and tools such as ArcGIS.

4.2 The use of sample code

This section describes how to use our example code. The sample code consists of the following parts: (1) ARIO module, GPN module, GPN result processing, and R script code for drawing; (2) sample input-output data; (3) sample simulation result data. R script code can be run directly in R software (such as RStudio) and output the results. Note that the code needs to be run sequentially. The order is ARIO module (ARIO\_module.R), GPN module (GPN\_module.R), result processing module (Result\_conversion.R), and plotting module (Plot\_code.R). Each module requires the result of the previous step as input to function correctly.

In this example, the input-output table is a small virtual trade relationship. Where C stands for country and S stands for sector, for example, C1S1 stands for sector 1 of country 1. In real experiments, the number of countries and sectors in each script and table needs to be replaced by the number of countries and sectors that actually supply the network.

The plotting module can use the uploaded real experimental results as input, and get the cascaded Sankey diagram of each month and the overall.