




# “Global imperatives for development of international production networks: case of Ukraine”

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Ganna Duginets (Ukraine)

# GLOBAL IMPERATIVES FOR DEVELOPMENT OF INTERNATIONAL PRODUCTION NETWORKS: CASE OF UKRAINE

## Abstract

The paper studies the theoretical and methodological principles, regularities, and new trends in the formation of international production networks (IPNs) in the global economic space. It determines the imperatives of their development, substantiating the priority nature of integrating national actors into IPNs. The author applies the methods of fuzzy clustering and classification using the artificial intelligence technologies to data on the dynamics of key economic and technological markers of 35 countries in the 2007–2016 time frame.

The work identifies a clustering-like structure in the sample country set; allowing determining patterns in the correlation between a country's manifested potential for ascending into and within international production networks and certain development and international integration indicators. The sample is thus grouped into six clusters based on the degree of integration into IPNs. Due to the use of classification analysis, the rules for assigning a country to a particular cluster were obtained. According to the results of the study, it was concluded that the main imperative for the development of international production networks is innovative development. The overall concept of localization of Ukrainian enterprises at all stages of value creation within networks was offered.

## Keywords

fragmentation, value-added, export, import, clusterization, innovative development

## JEL Classification

C80, F12, F62, L14

## INTRODUCTION

Among the problems directly related to the development of the world economy in the twenty-first century are the global structural transformations of international economic relations that affect all spheres of public life. The main manifestations of these transformations include, firstly, the intensive development of scientific and technological progress, which has a significant impact on the processes of internationalization and integration in the context of the latest division of labor, and secondly, a change in the public mentality that forms a new stance towards economic activity as such, and contributes to the formation of new stereotypes, models, forms of relationships, and connections in business processes. Thirdly, the fragmentation of economic relations on different levels qualitatively changes the nature of the functioning of the economic systems themselves, giving them new opportunities and generating new risks in the conditions of a structural transformation in the economy. Due to further development of traditional forms of international division of labor, the intensity of exchange and the increasing mobility of factors of production, which manifests itself through the formation and development of international production networks, becomes more and more pronounced. That is, the implementation of the production cycle is divided between actors from dif-

ferent countries in order to optimize the costs of production and circulation. In the conditions of globalization of the modern economy, the networks are the main component of the global gross product creation both in the field of commodity production and in the service segment.

Two or three decades ago, determining the country of origin (production) of goods entering the field of foreign trade was simple; nowadays, goods and services are often the results of the interaction of dozens, if not hundreds, of suppliers of intermediate components and services that may be located in different countries around the world. Today, intermediate goods and productive resources represent more than 50% of world trade in goods and more than 70% of world trade in services. The cycle of production and distribution of goods and services goes far beyond national boundaries and is rapidly becoming networked. As a result, the economic structure gains the features of multilevelness and interdependence, but the global and international levels of economic activity play an important role in this structure.

Modern international production networks belong to complex weakly formalized systems that function in conditions of considerable uncertainty; this uncertainty is due to the constant dynamic transformations in the world economy, and thus the incompleteness of information, as well as the existing obstacles to and uncertainties in evaluation. World practice shows that in a significant number of cases, a thorough study of such systems based on traditional (deterministic or static) modeling becomes ineffective, requiring the development of new approaches to the description of the formation and operation of international production networks (IPNs). One of these approaches can be based on the use of a fuzzy clustering method that employs artificial intelligence technologies. The key task of constructing such models is to determine the structure of source data, i.e., the fuzzy rules and membership functions. Therefore, based on technological information, it would be possible to determine what is fundamental for creating the conditions for the formation of IPNs, taking into account the level of development and the position of the country under consideration in the world economy, as well as the dynamic effects of transformations of global production.

Production activity has become more global in recent years. Given this, it is a priority to study the involvement of Ukrainian enterprises in international production networks and take into account the global imperatives for the development of these networks.

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## 1. LITERATURE REVIEW

The theoretical and methodological foundations of studying the consequences of a country's participation in global value chains (GVCs) and international production networks (IPNs), the assessment of value-added flows and development strategies are considered in the work of Arndt and Kierzkowski (2001). Moreover, this study has been done following a new methodology for the decomposition of gross exports in value-added measures, developed by Koopman, Powers, Wang, and Wei (2010), Koopman, Wang, and Wei (2014).

International organizations also explore the theoretical and practical features of formation, development, and functioning of GVCs and IPNs. So, in 2016, the United Nations Economic Commission for Europe prepared a report on "Global

Manufacturing Measurement Guide," which continues the logic of the report "The Impact of Globalization on National Accounts." However, in the former case, more attention is paid to multinational enterprises involved in global production (UNECE, 2015). This type of international corporate structure is mainly addressed in the Global Manufacturing Measurement Guide. Also, at the end of 2017, the WTO website published a report "Global value chain development report 2017" (World Bank, 2017a) to identify the changing nature of international trade in terms of expansion of international production networks (available for 1995–2014).

The work of Baldwin (2012) is the basis for this study. This article provides a framework for understanding the functional and geographical division of production. The fundamental compromise

in the placement of supply chain elements is between gain from specialization and cost of coordination. At the same time, the author notes that supply chain trading should not be considered as standard trading in parts and components, and not as trade-in final products (Baldwin, 2012).

Another example is the econometric evidence presented by Hermida, Xavier, and Silva (2017) who support the hypothesis that fragmentation and participation in the global value chains provide higher growth rates for countries, depending on their position in the global value chains.

Special attention should be paid to the results of the discussion of potential points of contact between modern theoretical research of IPNs and work in international business. For example, the study of Coe (2018) focuses on the features of interaction in global production in the context of global financial integration, namely short-term earnings for shareholders and the restructuring and reduction of corporations in order to increase shareholder value. Moreover, in the study of Koval, Duginets, Plekhanova, Antonov, and Petrova (2019), the functioning of global value chains (GVCs) takes place by the agreement of various interests of the participating subjects. The researchers determine that the direction of fragmentation of production processes of multinational corporations (MNCs) depends on the comparative advantages of the countries of origin, which explains the constant reconfiguration of GVCs, including the tendency of reconsolidation and repatriation of their links into developed countries taking place in the last decade.

Special attention has been given to studies of various groups of countries in international production networks, as well as to the analysis of the impact of participation in global value chains on the efficiency of enterprises. For example, the results of the study of Del Prete, Giovannetti, and Marvasi (2016) show that the countries of North Africa still cannot fully integrate into international production networks. Most of their trade is due to activities related to the creation of small added value, mainly at the initial stages of the production network. Moreover, the ability to preserve the potential benefits of participating in IPNs depends on the specific characteristics of a particular coun-

try, which leaves a room for political intervention (Del Prete, Giovannetti, & Marvasi, 2016).

Modern studies, such as by Díaz-Mora and López (2019), also deserve attention. By estimating a panel data gravity model, they find that more than one-third of the export of parts and components is highly complex in the three main groups of countries in the world economy. Moreover, this affects the main EU countries to a greater extent, which demonstrates a wider set of high capacities (Díaz-Mora & López, 2019).

Pomfret and Sourdin (2018) present the results of a study on the functioning of international value chains in North America, the European Union and East Asia. Noteworthy is the conclusion drawn about wider participation in the value chain of East Asian countries than the EU member states (Pomfret & Sourdin, 2018).

Several studies are related to the sectoral analysis of the international organization of production. For example, the paper of Smith, Gorgoni, and Cronin (2019) shows a complex relationship between enterprise-level activities in high technology (medical and precision instruments) and international trade models.

The work of Cingolani, Iapadre, and Tajoli (2018) presents the results of a study of bilateral trade in two industries with different technological characteristics – textiles and clothing and electronics. The authors substantiate that a stronger preference and selection of partners takes place for trade in intermediate goods, as the theory of international fragmentation of production suggests (Cingolani, Iapadre, & Tajoli, 2018).

In the literature relating to the subject, one notes a perspective on the IPN that places importance on the role of the technological differences between countries expressed in different trade specializations; however, this perspective gives greater weight to the place in the network and reduces the importance of the sector dimension. In a fragmented production process, these steps form a “smile curve” that correlates the magnitude of value-added in the GVC with the types of activities developed along the chain (stages of the production chain) (OECD-WTO, 2012).

It must be noted, however, that the fact that a final product is completed and exported in one country does not necessarily mean that enterprises of that country dominate the IPN and create a significant share of the total value of that product. A classic case of that is iPods/iPhones, which are completed in China, but the entire production chain is managed by Apple, whose head office is in the United States (Dedrick, Kraemer, & Linden, 2008).

At the same time, there is virtually no comprehensive research on the definition of global imperatives of IPN development in conditions of dynamic changes in the configuration of the international system and the effects of global production.

This article argues that, in the 21st century, such an analysis cannot be adequately understood without considering the existing conditions for the formation of international production networks. Although there are some recent studies on the interconnection of the functioning of these networks and the development of the national economy that empirically include these notes, there is still an empirical gap when it comes to the interconnection of these phenomena with economic growth. In addition, it is noted that there is no consensus in the theoretical literature on the benefits and long-term effects associated with them.

The author does not deny the significant contribution of existing work in the empirical and theoretical development of the conceptual platform and the theoretical and methodological foundations of the problem under study. However, the importance of transformational changes in the functioning of IPCs, the interdependence of the strategies for including a country's enterprises in them, and the models of their economic growth require a more thorough study of the conditions for their formation. The peculiarity of the methodological update lies in the need for a systematic study of the global imperatives of the development of international production networks in the 21st century, as well as justification for a system of optimal parameters targeted at developing national economy in such a way as to create the necessary conditions for the formation and functioning of IPNs.

Thus, the work aims to study the global imperatives of the development of international produc-

tion networks, based on identification of the comparative conditions of their function in the 21st century. This will allow justifying the overall concept of localization of Ukrainian enterprises at all stages of value creation within networks.

## 2. METHODS

For this, a complex of complementary methods of scientific research of economic processes and phenomena has been used. As the main mathematical apparatus, methods of fuzzy clustering and classification using artificial intelligence technologies were used, which allowed determining the interrelations between markers that characterize the conditions of IPN formation. Also, general scientific approaches and methods of modern research based on fundamental theoretical and methodological developments of domestic and foreign scientists in the field of transdisciplinary analysis and synthesis, general theory of systems, analysis, synthesis and optimization in the field of international production and commodity-marketing cooperation are used in the work.

At the beginning of the study, a retrospective analysis of theoretical views and concepts of the economic and methodological nature of international production networks was performed. Considering that the globalization of the world economy leads to a partial separation of the state from industrial and economic structures aimed at attracting them into the system of global production by the principles of international division of labor, special attention was given to identifying the general determinants of its development at the end of the 20th and the beginning of the 21st century. This has led to the assertion that scientific and technical developments cause dramatic changes in the international division of labor and, as a consequence, in the global production system, thus affecting the functional effectiveness of all units of an IPN. Due to scientific and technical development, which has a global nature, the content of production factors changes, as the potential of development and welfare of a country in the 21st century is determined not only by population growth or attraction of human and material resources into the process of economic activity but to a greater extent by increasing the efficiency of production.

Consequently, the ability to develop and swiftly implement the models of production and technologies of new waves of innovation creates the opportunities for changing the totality of factors in international production. Thus, their weight in determining the influence on trade conditions in the world economy changes.

Taking the aforementioned into account, it is concluded that in the conditions of constant transformations in the global production, the formation and development of IPNs should be analyzed while taking into account the global determinants of the world economy's development in the 21st century, namely:

- the modern evolution of the international division of labor, manifesting in the widespread vertical interfirm interactions (vertical and horizontal FDI, international outsourcing, offshore);
- the fragmentation of production taking place in open economies with vertically interconnected industries;
- the accelerated change in technological modes and the forming of a socio-economic system, in which the priority development of human capital aimed at creating, disseminating, and utilizing knowledge to ensure balanced economic growth in a country is the main element.

According to the last determinant, it should be noted that the development of technology leads to the fact that enterprises will be forced to adapt to changing consumer demands. In this case, a paradox arises, in which the economy can grow, and unemployment, at the same time, increases at the expense of new intelligent systems that replace the able workforce. Thus, an economy based on new realities requires more and more highly skilled professionals with the necessary competences and knowledge to create new technologies. But the study of this problem goes beyond the scope of this article; further on, the availability of skilled labor of the necessary level of education in a given country will be considered as a basic condition for scientific and technological development.

Given the considerable number of studies on the formation and development of global value chains and international production networks, it is worth distinguishing the author's understanding of the relation between these definitions. A global value chain is an economic relationship between the participants of a single production process. This process concentrates certain elements of its production, promotion, and distribution of created goods and services in different countries of the global space, which are characterized by an asymmetry in the available factors of production and integration in the network systems. That is, they are the basis for the formation of international production networks in the global economy. Therefore, an IPN is proposed to be understood, first of all, as a unification of legally independent participants in the value chain, aimed at increasing the competitiveness and innovation of network participants, as well as the formation of social capital and the creation of value for consumers, through effective management of external influences. Secondly, it is a network distributed across national boundaries, which combines complete or separate segments of value creation chains located in different national territories.

In turn, IPNs, through vertical and horizontal international connections, combine economic actors in different countries on different continents and, accordingly, on separate stages of production. This leads to the fact that the global economic space is penetrated by a solid network of stable industrial relations, into which millions of large, medium, and small suppliers of intermediates and end-product collecting enterprises are woven. The network of such connections is growing rapidly, covering almost all regions of the world.

Taking into account the abovementioned, as well as the available methodological and statistical material, a system of indicators is proposed. These variables are markers for determining the global developmental imperatives of IPNs and which demonstrate the existing potential for entry into production networks in comparison with other countries of the sample being studied:

- gross value-added (X1) characterizes the country's place in the GVCs and IPNs;

- GDP (X2) characterizes the effectiveness of the functioning of the economic system in the countries, including participation in the international division of labor;
- export (X3) and import (X4) characterize the dynamics of trade balances, and also allow us to assess the degree of inclusion of the country in IPNs;
- FDI inflows (X5) and outflows (X6), million USD, investments in some points of localization of IPNs generate trade flows to other points of the chain. In turn, these operations inevitably cause additional investments of other participants in the networks;
- value of cross-border M&As, million USD (X7) and number of announced greenfield FDI projects (X8) allow us to determine the forms and types of industrial inclusion of the country in the IPNs;
- the Global Innovation Index (place in the ranking) (X9) allows getting a good idea of innovation and the potential for inclusion in the IPNs' most profitable links;
- Doing Business Index (place in the ranking) (X10) is a marker for foreign investors on a comprehensive view of economic development in the country.

It is this set of indicators that best suits the conditions of IPN development in the 21st century since it takes into account the main factors affecting the functioning of IPNs – the movement of capital, the volume of trade, scientific and technological development that is not possible without the presence of skilled labor, as well as the amount of value-added created.

For the clusterization, data on the mentioned ten indicators for ten years (from 2007 to 2016) was used. The sample of countries for analysis is constituted by 35 countries of the world, among which, in the opinion of the author, are some countries that are leaders in the development of IPNs, some that are located in the middle of the production chain, and some countries that are only beginning to enter the network. In contrast, some have a sig-

nificant potential in general, but do not utilize it, as well as other benefits, for economic development.

Statistical and analytical materials of international organizations constitute the database of this research: WTO, OECD, UNCTAD, World Bank Group, IMF, Eurostat; informational materials of rating agencies about the results of their research, analytical and informational materials from open sources.

For further analysis, the data sample was transformed into the form of a training sample, each record of which is a tuple in the following form:

$$R = Year, Country, X1 \dots X10 >. \quad (1)$$

Similar table structure for each of the factors allows automating the process of its formation. For this, a Python script was developed, as a result of which a training sample of 420 records for all countries and from 2005 to 2016 was formed. A feature of the resulting study sample was the presence of missing data in certain tuples; their removal decreased the sample size to 336 records.

To determine the similarity of economies of different countries, it is necessary to group the countries into clusters. However, the different nature of the investigated factors leads to a strong deviation of their absolute values. To eliminate this, all factors were normalized:

$$x_{i,j}^n = \frac{x_{i,j} - x'_i}{\sigma}, \quad (2)$$

$$\sigma_i = \sqrt{\frac{\sum_{j=1}^n (x_{i,j} - x'_i)^2}{n-1}}, \quad (3)$$

where  $(x_{i,j})$  is the  $j$ -th value of the  $i$ -th factor,  $(x'_i)$  – the average value of the  $i$ -th factor,  $(\sigma_i)$  – the variance of the  $i$ -th factor,  $n$  – the total number of records of the study sample.

Besides, the study eliminated the GDP factor, because its value is connected to the calculation of gross output, intermediate consumption, and gross value-added. That is, the correlation between GDP and Gross Value-Added can lead to errors in the calculations.

Today, there are more than 100 different clustering methods. For the study, the method of fuzzy averages (c-means), which is the extension of the classical k-means algorithm, was chosen. The idea of the latter is to determine the centers of k clusters and to assign to each cluster the objects that are most closely located to these centers.

The distance metric, in general, has the following form:

$$d_A^2(m_j, c^{(i)}) = \|m_j - c^{(i)}\|_A^2 = (m_j - c^{(i)})^t A (m_j - c^{(i)}), \quad (4)$$

where the matrix  $A$  defines the distance calculation method (the norm).

The k-mean algorithm, also called rapid cluster analysis, is the most common among non-hierarchical methods. Unlike hierarchical methods that do not require prior assumptions regarding the number of clusters, using this method requires hypothesizing the most probable number of clusters.

The k-mean algorithm builds k clusters located at possibly large distances from each other. The main type of tasks solved by the k-mean algorithm is the presence of assumptions (hypotheses) on the number of clusters; at the same time, they must be as different as possible. The choice of the number k can be based on the results of previous studies, theoretical considerations, or intuitions.

The general idea of the algorithm: a given fixed number of k observation clusters are related to each other so that the clusters' mean values of all variables differ as much as possible from each other. Advantages of the k-mean algorithm are ease of use, speed of use, comprehensibility and transparency of the algorithm. Disadvantages are the algorithm being too sensitive to outstanding observations that can distort the average.

Fuzzy c-mean algorithm is one of the methods widely utilized in fuzzy clustering algorithms that are currently in use is describing the relationship between data by their belonging to certain reference samples – the cluster centers. In these algorithms, the fuzziness manifests itself in the description of clusters as fuzzy sets having a core in

the center of the cluster. This algorithm is a generalization of the previous algorithm; its difference lies in the fact that clusters are now fuzzy sets, and each point belongs to different clusters with varying degrees of belonging. The sum of data element's individual belongings to all the clusters of the distribution space is equal to one:

$$\mu_{ij} \in [0; 1]; \sum_{i=1}^c \mu_{ij} = 1; 0 \quad (5)$$

where  $\mu_{ij}$  – the degree of belonging of the  $j$ -th value of the  $i$ -th factor.

The point is considered to belong to one or the other cluster by the criterion of the maximum degree of belonging.

As a software tool for clustering, MATLAB was chosen, since it employs convenient fuzzy set analysis libraries. The preliminary calculations showed that the adequate clusterization results were obtained with six clusters. As a result of the analysis for each country in each particular year, degrees of belonging to each individual cluster were assigned.

### 3. RESULTS

The obtained clusterization results, as well as the fact that modern IPNs were formed as a result of existing conditions, enabled identifying types of clusters. Thus, the performed clusterization allows, under the conditions of IPN formation, to conclude that countries with a higher level of technological development are leaders in this process (Table 1).

In the sixth cluster (experienced), there was only the United States, which, according to many studies, is a country whose economic agents occupy high value-added links in many IPNs. The fourth (main) and fifth clusters (lead) consist of countries that also occupy top segments in IPNs but fall behind the United States by FDI volumes. Noteworthy are the results of grouping the countries in the third cluster, which can be described as medial. It combines the countries that have the potential to participate in production networks but do not use it for some reason, such as

Luxembourg, Austria, or Belgium. Also, this cluster contains countries that, over the past ten years, have made significant reforms in the economy aimed at entering high-value-added segments of IPNs, such as the Republic of Korea. One does not exclude the possibility that, in the medium term, this cluster will also include the EU countries such as Poland, Bulgaria, Slovenia, and Slovakia, provided that their pace of cluster advancement is maintained.

The maximum value determines the cluster to which the country belongs. It should be noted that countries can change their belonging to a specific cluster depending on the effectiveness of the government policy aimed at improving the conditions for IPN formation. For example, in Poland, in 2009, the Global Innovation Index (GII) value underwent a significant improvement from the 56<sup>th</sup> to the 47<sup>th</sup> place, with almost no other variables changing, which led to the country's transition from the first cluster to the second. In turn, in Greece, in 2014, GII and FDI outflow indicators changed, with almost no change to other variables, which made it possible to assign the country to the second cluster since 2014. Since 2009, Bulgaria can be classified as belonging to the second cluster, thanks to a significant improvement in the Doing Business from the 54<sup>th</sup> to the 44<sup>th</sup> place in the ranking, and the GII from the 81<sup>st</sup> to the 74<sup>th</sup> place. In the sample, negative changes in certain countries' positions in clusters can be traced as well (see Table 1). For example, in 2008, the UK moved from the sixth cluster to the fifth due to a significant reduction in the inflow and outflow of FDI, as well as worsening in its GII position.

Another example is Germany, which moved from the fifth to the fourth cluster in 2009 due to a deteriorating place in GII and a nearly 2-fold decrease in the value of cross-border M&As. Then in 2011, the country was again assigned to the fifth cluster due to increasing the volumes of FDI and maintaining a stable level of GII in conditions of other countries' ascension in the rating. But in 2016, there was a significant deterioration in FDI outflows, value of cross-border M&As, as well as the number of announced greenfield FDI projects, and the country was again assigned to the fourth cluster. It can be assumed that Germany will return to the fifth cluster in the coming years, and in the long term, may enter the sixth, alongside the United States and Britain. Some experts believe that, in modern Germany, there are all conditions for the Fourth Industrial Revolution and the opportunity for a successful transition to Industry 4.0 (Kagermann, Lukas, & Wahlster, 2011). In order to confirm this assumption, it will be necessary to clusterize up to date, for example, in 2020.

Also noteworthy is Japan's transition from the fourth cluster to the fifth for one year in 2010 due to a very significant increase in the value of cross-border M&As and a stable position in the GII rating in conditions of other countries' ascending in it. Japan's industry is characterized by a significant proportion of industries that produce complex technical equipment, branches of final processing and assembly. The success of Japan was due to the implementation of an export-oriented growth model, which relied on the permanent innovation of the technological platform of production business and the output of its products to foreign markets.

**Table 1.** Distribution of countries by clusters by 2016

Source: Author's calculations according to the data from Dutta, Lanvin, and Wunsch-Vincent (2018), World Bank (2017a, 2017b), United Nations (2017), UNCTAD (2018).

Cluster 1 (initial)	Cluster 2 (progressive)	Cluster 3 (medial)	Cluster 4 (basic)	Cluster 5 (leading)	Cluster 6 (experienced)
Vietnam, Cambodia, Ukraine	Lithuania, Latvia, Portugal, Cyprus, Slovenia, Czech Republic, Slovakia, Poland, Greece, Hungary, Romania, Croatia, Bulgaria	Austria, Belgium Denmark, Estonia Ireland, Sweden, Luxembourg, Republic of Korea, Finland	Spain, Italy, The Netherlands, Germany, Japan	UK, China, France	USA
<b>Countries that also belonged to the particular cluster in 2007–2016</b>					
Poland, Croatia, Greece, Bulgaria	Belgium, Vietnam, Estonia, Italy	The Netherlands	Austria, Czech Republic, France, Belgium, Ireland, Luxembourg	Germany, Japan	UK

As for Ukraine, according to the calculations, it is in the first cluster (initial), and during the period under investigation, it has been accompanied by such countries as Poland, Croatia, Greece, Bulgaria, Vietnam, and Cambodia; however, in the last three years, only Vietnam and Cambodia remained in the cluster alongside Ukraine. Other countries moved to the second cluster (progressive) and joined such countries as Lithuania, Portugal, Slovenia, Latvia, Czech Republic, Slovakia, Hungary, Cyprus, and Romania.

It should also be noted that in 2016, Ukraine displayed significant progress towards the second cluster. In 2007, Ukraine's degree of belonging to the first cluster was almost equal to one (maximum belonging); in 2016, this value decreased to 0.52. The main determinants of the country's approach towards the second cluster were the improvement of the GII position from the 71<sup>st</sup> place in 2013 to the 56<sup>th</sup> in 2016, as well as in the Doing Business position from 112 in 2014 to 83 in 2016. It should be noted that other indicators remained almost unchanged or even had negative dynamics in the study period.

Thus, based on the data collected, it is possible to justify the hypothesis that a country's transition between clusters is primarily affected by such indicators as the place in the Global Innovation Index and Doing Business, as well as the volume of investment in other countries, the value of cross-border M&As and the number of announced greenfield FDI projects. Accordingly, with negative dynamics, country transition into a cluster with less developed conditions for the formation of IPNs, and vice versa, with positive dynamics, towards a cluster with the best conditions.

To confirm the hypothesis, a classification analysis was conducted. To carry it out, one can use either the theory of fuzzy sets or the construction of decision trees. The first approach is a continuation of fuzzy clustering, during which a system of fuzzy output is constructed, the number of outputs equal to the number of clusters. The inputs remain unchanged. To do this, a hybrid neural network is trained, which then generates production rules and the form of belonging degree functions. To do this, a corresponding program was developed in MATLAB. The Mamdani function was used as the

output algorithm. This approach permits to trace the dynamics of the transition of a country from one cluster to another to a change of input parameters. For this, the input data models were fixed at the values of Ukraine in 2016, and the input factors changed in turn. The goal was to advance Ukraine to the second cluster. To automate this calculation, the corresponding code was implemented in MATLAB. The factor change necessary for cluster advancement was also analyzed. According to the results of the study, it can be noted that Ukraine is firmly entrenched in the first cluster. Advancing to the second cluster requires a very significant change in each factor. In particular, increasing GVA by 1,273%, exports by 693%, imports by 552%, FDI inflows by 558%, and FDI outflow by 13.755%, value of cross-border M&As by 110.312%, the number of announced greenfield FDI projects by 540%. Also, reduce the place in the Global Innovation Index by 18%, and in the ranking of the Index of Ease of Doing Business by 16%. Such huge "unrealistic" indicators can only indicate that, for the transition between clusters, factors need to change simultaneously, rather than consecutively. That is, there should be a comprehensive state development strategy that will be based on a system of measures and mechanisms for the transition from cluster to cluster. To determine this strategy, the method of constructing a decision tree was used, the essence of which is the method of representing rules in a hierarchical, sequential structure, where every single object corresponds to a single decision-requiring node. A rule is understood as a logical construction of the form "if ... then ...". In the context of this study, the rules obtained are the necessary conditions for a country's ascend to a given cluster; they provide an opportunity to assess the complex impact of the indicators on the country's degree of belonging to one or another cluster. Besides, there is an opportunity to evaluate the adequacy and accuracy of this approach by substituting indicators for the model and comparing the calculated cluster with the real one. The results of these calculations are given in Table 2, from which it is evident that the validity of the rules is quite high. So, as can be seen from Table 2, the first rule in the classification matches seven records (the number of countries that the model correctly assigns to the first cluster according to this rule), whereas according to the results of the verification, there are six. Therefore, the validity of this rule is 85.71%

**Table 2.** Classification rules of a country’s membership in a particular cluster and assessment of the model’s accuracy

Source: Calculated by the author.

No.	Condition	Cluster	Support*		Certainty	
			%	Quantity	%	Quantity
1	X6 < 2.3798E5 and X8 < 714.5 and X9 >= 24.5 and X10 < 89.5 and X7 < 12,241 and X1 < 2.0664E6 and X8 < 395 and X9 >= 54.5 and X10 >= 51.5	1	2.19	7	85.71	6
2	X6 < 2.3798E5 and X8 < 714.5 and X9 >= 24.5 and X10 >= 89.5	1	9.72	31	100	31
3	X6 < 2.3798E5 and X9 >= 24.5 and X10 < 89.5 and X7 < 12,241 and X1 < 2.0664E6 and X8 < 395 and X9 < 54.5	2	36.05	115	95.65	110
4	X6 < 2.3798E5 and X8 < 714.5 and X7 < 12,241 and X1 < 2.0664E6 and X9 >= 54.5 and X10 < 51.5	2	1.25	4	100	4
5	X6 < 2.3798E5 and X8 < 714.5 and X9 < 24.5 and X4 < 6.7079E5 and X6 < 69,098 and X5 < 71819	3	25.39	81	97.53	79
6	X6 < 2.3798E5 and X8 < 714.5 and X9 < 24.5 and X4 < 6.7079E5 and X6 < 69,098 and X5 >= 71819	4	0.63	2	100	2
7	X6 < 2.3798E5 and X8 < 714.5 and X9 < 24.5 and X4 < 6.7079E5 and X6 >= 69,098	4	2.51	8	100	8
8	X6 < 2.3798E5 and X8 < 714.5 and X9 < 24.5 and X4 >= 6.7079E5 and X1 < 5.4052E6	4	5.33	17	94.12	16
9	X6 < 2.3798E5 and X8 < 714.5 and X9 >= 24.5 and X10 < 89.5 and X7 < 12,241 and X1 < 2.0664E6 and X8 >= 395	4	1.25	4	75	3
10	X6 < 2.3798E5 and X8 < 714.5 and X9 >= 24.5 and X10 < 89.5 and X7 < 12,241 and X1 >= 2.0664E6	4	0.63	2	100	2
11	X6 < 2.3798E5 and X8 < 714.5 and X9 >= 24.5 and X10 < 89.5 and X7 >= 12,241	4	2.82	9	100	9
12	X6 < 2.3798E5 and X8 < 714.5 and X9 < 24.5 and X4 >= 6.7079E5 and X1 >= 5.4052E6	5	0.94	3	66.67	2
13	X6 < 2.3798E5 and X8 >= 714.5	5	8.46	27	100	27
14	X6 >= 2.3798E5	6	2.82	9	100	9

Note: \* Support – the number of entries in the study sample that are described by the specified rule and belong to specific clusters in absolute and relative dimensions.

The biggest uncertainty is in rule 12, for the belonging to the 5<sup>th</sup> cluster. However, this cluster is not relevant to the study. For further substantiation of the directions of reforming the economy of Ukraine, rules 3 and 4 belonging to the second cluster deserve particular attention. Table 3 compares these rules with the real values for Ukraine in 2016.

The accuracy of the classification analysis is conveniently presented in the form of a summary table of errors (Table 4), where one can see that the number of errors is rather small (an error is defined as assigning a country in a particular year to a different cluster than it actually is in).

**Table 3.** The rules of a country’s belonging to the 2<sup>nd</sup> cluster in comparison with real values for Ukraine in 2016

Source: Author’s calculations according to the data from Dutta, Lanvin, and Wunsch-Vincent (2018), World Bank (2017a, 2017b), United Nations (2017), UNCTAD (2018).

Indicator	Ukraine		Rule 3	Ukraine		Rule 4
Gross value added, USD	79,073	<	20,664,000,000	79,073	<	20,664,000,000
FDI outflows, USD	173	<	2,379,800,000	173	<	2,379,800,000
Value of cross-border M&As, USD million	8.94	<	12,241.00	8.94	<	12,241.00
Number of announced greenfield FDI projects	39	<	395.00	39	<	714.50
The Global Innovation Index, place in the ranking	56	< >=	54.50 24.5	56	>=	54.5
Doing Business, place in the ranking	83	<	89.50	83	<	51.50

**Table 4.** Reliability of classification analysis

Source: Calculated by the author.

Cluster	1	2	3	4	5	6	Actual records
	Number of records by classification analysis						
1	40	2		1			43
2	1	119	1				121
3		1	82				83
4		3	2	41	1		47
5				2	29		31
6						11	11
Total	41	125	85	44	30	11	336

So, for the cluster we are interested in, the results of the classification analysis show that 119 entries are true out of the actual 121. That is, there are only two errors per 121 records, which confirms that the third and fourth rules of access to the 2<sup>nd</sup> cluster have 96% and 100% certainty, respectively (see Table 2).

Besides, the analysis showed that the transition between clusters requires a complex change in the indicators, the weights of which are presented in Table 5.

**Table 5.** Indicators' weight in attributing a country to a particular cluster

Source: Author's calculations according to the data from Dutta, Lanvin, and Wunsch-Vincent (2018), World Bank (2017a, 2017b), United Nations (2017), UNCTAD (2018).

No.	Indicator	%
1	The Global Innovation Index, place in the ranking	35.660
2	Number of announced greenfield FDI projects	20.558
3	Doing Business, place in the ranking	14.218
4	FDI outflows, USD million	13.580
5	Value of cross-border M&As, USD million	7.403
6	Gross value-added, USD million	1.965
7	FDI inflows, USD million	1.657
8	Export	0.000

As can be seen from the rules in Table 2 of assigning a country to a particular cluster, with each transition to a more developed cluster, it is necessary to modify the policy pursued by the government. According to the data in Table 5, the most important indicators are the Global Innovation Index, the number of announced greenfield FDI projects, the Doing Business, and the FDI outflows. But for the transition to the sixth cluster, the most important is the country's investment in the world economy, provided that all the pre-

vious rules of assignment to the fifth cluster are already fulfilled. It is noteworthy that, according to the calculations, exports and inflows of FDI do not affect the formation of conditions for involvement in the IPN. That is, we can assume that public policy should first of all aim at improving the innovative component of the national structure of production. The main value-added in an IPN is formed in the field of high technology, through the distribution of the cost of production between developed countries (technology manufacturers) and developing countries (producing goods based on technology). Accordingly, a company or country should strive to be present in those parts of an IPN, which generate higher added value. The task of cooperation is facilitated if the country has free trade agreements and the mutual protection of investments with a large number of other states. It is important to take into account that, at the preproduction stage, there is a global competition, and at the stage of post-production, the competition is to a greater extent local. Therefore, to improve existing positions in network segments and to attain new ones, constant monitoring of technological development in the economy is necessary, especially in the segment of high-tech goods and services production.

In the case of Ukraine, according to an analysis of the data presented in Table 3, the conditions for the formation of IPNs in the country as of 2016 are closer to the second (progressive) cluster. Assessing the potential and direction of the formation of the conditions for entering IPNs in the Ukrainian economy, it is important to understand the synergy between the interaction of investments and domestic consumption as factors that determine the potential for transformation of production chains and industrial infrastructure in general. In this connection, domestic investment demand forms the production base for expanding the nomenclature of domestic goods and services with high added value.

In this aspect, improving the conditions of entrepreneurship development is one of the main directions of state policy. Moreover, reforms should be directed to a large number of areas, the improvement of which will lead to the stimulation of business activity in the country.

## CONCLUSION

According to the results of the study, it was concluded that the main imperative for the development of international production networks is innovative development. It is precisely the change of constantly accelerated technological processes that determines the current trend of the development of the IPN, which is determined by the dependence on the changes in material content and the share of value-added in the production process. In determining the conditions for the formation of IPNs in 35 countries of the world, six clusters were obtained based on fuzzy clusterization: the first (initial), the second (progressive), the third (medial), the fourth (main), the fifth (leading), and the sixth (experienced). Moreover, countries with a higher level of technological development are leaders in creating the conditions for the formation of IPNs. So, in the sixth cluster, the United States has been the leader in participating in international production networks, in particular in the segments where the main added value was created.

As a result of the calculations, Ukraine was assigned to the 1<sup>st</sup> cluster (initial) along with many other countries of the world. But in the past three years, only Vietnam and Cambodia remained Ukraine's neighbors in the cluster. Other countries advanced to the second cluster (progressive) through effective government policy aimed at improving the conditions for the formation of IPNs.

Due to the use of classification analysis, the rules for assigning a country to a particular cluster were obtained. Should a country wish to move from the first towards the fifth cluster, then the most important indicators are changes in the Global Innovation Index, the number of announced greenfield FDI projects, the Doing Business rating, and FDI outflows. But for the transition to the sixth cluster, the most important is the volume of the country's investment in the world economy, provided that all the previous rules for the five clusters are already fulfilled.

Also, according to the calculations, exports and inflow of FDI do not affect the conditions of IPN formation. Therefore, state policy should, first of all, aim at improving the innovative component of the national structure of production. The main value-added in an IPN is formed in the field of high technologies because of the distribution of the cost of production between developed countries (technology producers) and developing countries (which produce products based on technology). It should be noted that although the leading countries already have better conditions for the formation of IPNs, they continue to carry out the reforms, considering the dynamic nature of the transformations of the world economy. To the governments, when having attained the conditions of entering the next cluster, it is necessary to understand that in conditions of constant transformation of other countries of the world, a state must not only achieve but also support the reforms in the necessary direction from year to year. Thus, further research will aim at substantiating a long-term strategy for Ukraine's development in order to create the conditions for the entry of national enterprises into IPNs.

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