Cluster Analysis of Countries Inequality due to IT Development

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Abstract. The choice between economic efficiency and social equity has become a key objection in economic development, since in the current economic system, which has become close to the Pareto optimum, the achievement of both of these goals is mutually exclusive. There is only one way to reach both of these goals – the fundamental change of current system of economic relations and getting access to new curves of production capabilities, which may become quite real within development of Industry 4.0 and 6th technological wave. Nevertheless, nobody can predict the social impact of Industry 4.0 on society, which in the context of future technological changes transforms into Society 4.0. The purpose of this paper is to prepare cluster analysis of countries inequality due to IT development using software package. We researched impact of gross capital formation, research and development expenditure to create innovations, intellectual property and high-technology exports on inequality of countries using principal component analysis based on open data 2012-2015. We found 4 main clusters of 45 countries which have convergence and divergence attributes due to IT development. It was also revealed the countries which had inequality due to other reasons which are not connected with IT development.

Keywords: cluster analysis, inequality, IT development, Industry 4.0

1 Introduction

For many centuries, economic science was developing and changing according to the current challenges. Consequently, the purpose of economic activity was changing as well: from profit maximization during original accumulation of capital to optimization of

resources in the second half of the XX century, to the social welfare improvement within the concept of sustainable development. As a result, the choice between economic efficiency and social equity has become a key objection in economic theory, since in the current economic system, which has become close to the Pareto optimum, the achievement of both of these goals is mutually exclusive. There is only one way to reach both of these goals –the fundamental change of current system of economic relations and getting access to new curves of production capabilities, which may become quite real within development of Industry 4.0 and 6th technological wave. Nevertheless, nobody can predict the social impact of Industry 4.0 on society, which in the context of future technological changes transforms into Society 4.0. [8] and its ability to change the existing distribution of revenues where 8% of the world's population earn half of the world's total income, while the remaining 92% of people are left with the other half [11].

The purpose of this paper is to investigate the impact of information technologies and innovations on social inequality for different countries.

The paper has the following structure. Section 2 is devoted to the complex analysis of inequality and its influence with technological process. Section 3 describes how the level of inequality under the influence of IT within different countries in 2012-2015. The last section is the conclusion, which sums up the results of the research.

2 Related works

2.1 Dialectical Essence of the "Inequality"

Usually, category of "inequality" is used for analysis of the social equity during the distribution of material and social benefits and is identified as a negative phenomenon that leads to stratification of society, political instability, etc. However, according to the second law of the dialectics "unity and struggle of contradictions", inequality can be analyzed, as well from the positive point of view, transforming into the concept of "constructive inequality" as opposed to "destructive inequality". Moreover, based on complex approach of inequality analysis, we can talk not only about the distribution of the income in society, but also about the distribution of opportunities in it, which can radically change the logic of this topic. To N. Birdsall's opinion, high inequality might be regarded as a lesser evil if it has a positive or neutral impact on growth prospects, or if it is simply a passing phase that successful countries have to endure on route to a prosperous future [1]. Nevertheless, the main question is about the influence of inequality on parties at different levels of economic system, since the income divergence of individuals may have a positive macroeconomic effect (fig. 1).

At micro level the inequality in income distribution in its classical sense has a negative impact, because it causes demotivation of workers, and may even lead to emigration. However, if a society has equal distribution of opportunities a so-called "social elevator",

divergence of incomes can have a constructive effect by increasing the motivation and productivity, gaining new knowledge and skills, self-development, and, consequently, generating higher incomes by workers. As a real example can be society of United States [1], where income gaps are offset by the possibility of implementing the "American Dream", which is a successful example of constructive inequality.

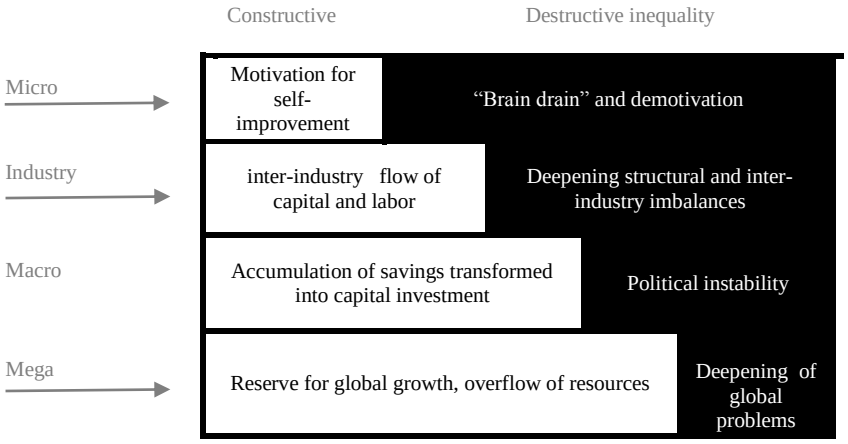

Fig. 1. Influence of inequality at different levels of the economic system

At the industry level, the spontaneous unequal allocation of benefits creates a possibility for floating of capital and labor force from less to more productive industries, contributing the economic growth. However, the deliberately inappropriate interdisciplinary distribution of resources can conserve structural imbalances and slow down the country's economic development.

At macro level, in turn, income inequality may be a necessary condition and a consequence of the economic development of a country at certain stages. First of all, according to Keynes's theory of consumption, when income is growing, the marginal propensity to save (MPS) is growing faster than marginal propensity to consume (MPC), which consequently lead to higher marginal propensity to save of rich people rather than poor [2]. What is more, since savings are the main source of investment potential of the country, it explains why it is important to concentrate a certain amount of capital by relatively richer execution of the population in order to meet future development of capital-intensive industries and infrastructure projects, and structural reforms. Secondly, the inequality of income distribution is a logical consequence of the early stages of economic development, which thanks to natural transfer of labor to more productive sectors, decreases later as far as economic growth of a country [3].

On the other hand, unequal distribution of opportunities and incomes can contribute the emigration of highly skilled labor, deepen social instability and lead to a substantial political crisis that will block the possibility of a country's economic development, as it is in countries with totalitarian political regimes.

At global level, inequalities, according to some scientists, for instance N. Birdsall, cannot produce positive effects, since: globalization is commonly held to be inherently disequalising: global markets work better for more productive assets which are disproportionately owned by better-off individuals in richer countries; globalization results in new types of externalities and market failures which poorer persons and weaker nations are ill equipped to handle; globalization creates a need for continuous revision of the rules governing the global economy which is exploited by rich countries for their own narrow interests [1].

Thus, we can note that the inequality in society is objectively determined and in certain cases, can have a constructive impact on the development of the economic system. This point radically changes the logic of the study from elimination inequalities itself to elimination of destructive inequality. However, the veracity of such findings significantly depends on markets maturity and effectiveness of public institutions, since inequality can create a constructive effect only in well-developed countries where appropriate social infrastructure and high mobility of the population may achieve raise of productivity and efficient resource redistribution. Yet, in developing countries with weak markets, weak governments, and fragile social structures income gaps can only deepen market failures through political instability. This is true because media voter, who has a relatively low level of well-being, will significantly distort political decisions [4] through voting for populist proposals, thus contributing to further ineffective redistribution of income and blocking the development of market mechanisms. In this case, according to many scholars, inequality matters, because developing countries are not developed [5] and this changes the emphasis of research: from managing inequalities to the development of less developed countries. However, it is important to understand which factors can help developing countries to move forward to the class of developed countries and how it will effect on income distribution. One of the variants of radical change in the current distribution of economic benefits in the international economy relates to the Fourth Industrial Revolution often called as Industry 4.0.

2.2 The connection of Inequality and Technological Changes

The second half of the XX century saw a large number of “economic miracles” that had made dramatic changes in the distribution of global economic impact. First of all, we are talking about Japan and the countries of the first wave of newly industrialized economies (NIE's) – "Asian dragons" that received impressive economic development in 50s-60s and 80s respectively. It is no coincidence that the growth of these countries took place

simultaneously when the 4th technological wave with its combustion engine was being changed by the 5th mainly based on microelectronic components. That is why we can make a logical assumption that technological factor and active technology transfer have played a key role in the growth of labor productivity and the rapid development of industries with high added value in these countries. Similarly, now in the process of moving towards to the Fourth industrial revolution we can expect for a new explosion of "economic miracles" " that can alter the ratio of economic power globally. This brings up the question about the possibility of such scenarios implementation and scales of its consequences in the international economy.

Taking into consideration previous industrial revolutions, we can assert that countries with a relatively large amount of capital and production capacity were the first to implement new technologies and inventions and, accordingly, first to receive positive effects from them. That is why it is logical to predict that developed countries with a powerful industrial complex, sufficient amount of capital and developed IT sector will receive greater effects from the new industrial revolution and will continue to dominate the international markets of new high-tech products. However, the development trend of the current economic system is nonlinear which indicates uncertainty of the outputs caused by Industry 4.0 implementation. In our opinion, the future scenario of the international economy development within 6th technological wave can be described by X-model and will include four possible scenarios of development (fig. 2).

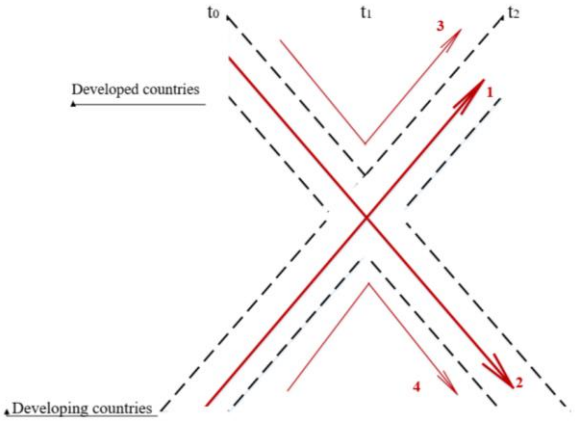

Fig. 2. Probable scenarios of the countries development within Industry 4.0 implementation

1. Developing countries thanks to new technologies will play a leading role in the international economy

Of course, as A. Sbardella et al. fairly noted a new sector is not introduced at random, but only when a productive system has developed the required basket of capabilities, and in this way gradually more and more complex sectors are introduced [6]. However,

transnationalization, international technology transfer, and capital inflows are able to eliminate deep technological gaps and time lags between countries and enable developing countries to implement new technologies relatively quickly with low costs. This scenario was used by Southeastern Asia countries. As a result Japan completely changed global GDP ranking by occupying a position in the top 3 countries at nominal GDP [7], while "Asian dragons" took the lead in various international rankings and indices such as Doing Business, Economic Freedom, Innovation Index, etc.

The case for this scenario:

- economic development nowadays is exponential, which makes the consequences of the Fourth Industrial Revolution introduction unpredictable and radically different from previous revolutions;
- economic agents in developing countries, contrary to developed countries, are ready to take risks and are able to adapt much more quickly to new economic conditions;
- developing countries through technology transfer can quickly and with relatively low cost make work Smart factories and Cyber-Physical Systems which will eliminate the time lag with developed countries.

2. Developed countries will lose competitive advantage

In the majority of developed countries, especially in the EU, we can see increasing risk aversion and lack of the entrepreneurial spirit due to their socio-economic systems are very inertial [8] and people are not able to cope with uncertainty effectively anymore, that is why non-linear trend appears rather than in previous waves of industrial revolutions.

3. Developed countries maintain a leading role in international economy

Based on great industrial potential, IT field, mature capital markets, and developed institutional system, obviously developed countries are the main promoters of the Fourth Industrial Revolution. Moreover, developed countries will be able to get much more positive effects due to the developed system of supporting or adjacent industries to the Forth Industrial Revolution. However, this assumption is true only for those countries that have already begun preparations for the introduction of Industry 4.0. For instance, Japan already launched the initiative Society 5.0 - the 5th Science and Technology Basic Plan (Japan's 5th Science and Technology Basic Plan (2016-2020). Thus, taking into consideration relatively high price for the great majority of resources in developed countries and accordingly, the low price competitiveness of new high-tech goods, the maximization of the effects of the new Industrial Revolution will occur only in the period t_2.

4. Developing countries do not take advantage of Industry 4.0

Without sufficient amount of capital and with weak institutional structure, developing countries cannot fully gain all the opportunities and benefits of a new industrial revolution, further exploiting the resource of price competitiveness of their goods and services.

Finally, the implementation of one of these scenarios will depend on the dominance of one of two factors - existing production and technological base, or the ability to adapt quickly and with minimum costs to the new economic environment since the technology progress is faster than the absorption capacity of the society [9].

The simplest way to determine the probability of some scenarios is the Hardy–Weinberg equilibrium according to which there is one abstract feature – countries' development within Industry 4.0 (table 1). This is determined by two types of alleles-existing industrial and technological complexes, or the ability to take risks and adapt quickly [10] (1). If a significant impact of the IT factor on the level of inequality has been revealed, then it can be predicted how a change in the IT factor will affect the achievement of the level of inequality preferred by society.

$$1=(A+a)^2=A^2+2\ Aa\ +a^2 \quad (1)$$

However, existing studies highlight a deepening of the income divergence between countries because of scientific and technological progress. For instance, Papageorgiou et al. [11] based on IMF research [12] proved that technological progress measured by the share of ICT capital in the total capital stock significantly increase inequality. It is quite obvious because technological development can disproportionately raise the demand for capital labor boosting as a result the premium on skills and then remove many jobs through automation or computerization [11; 13; 14; 15] at least in short-run period. Furthermore, Krueger estimated that employees who directly use computers at work earn a 10 to 15 percent higher wage rate [11].

Table 1. Scenario approach to the development of countries within Industry 4.0 according to the Hardy–Weinberg equilibrium

Model Parameters	Existing industrial and technological complexes	Ability to take risks and adapt quickly
Dominant factor-allele *A*	Scenario 3	Scenario 1
Recessive factor-allele *a*	Scenario 4	Scenario 2
Existing industrial and technological complexes, %	75	90
Ability to take risks and adapt quickly, %	25	10
Probability of dominant strategy	0.5625	0.81
Probability of recessive strategy	0.0625	0.01
Probability of combination	0.375	0.18

Moreover, within Industry 4.0 this gap will just getting deeper because a great part of low-cost jobs will disappear totally even in developed countries – according to the World Bank estimation, automation will put 57% of the jobs in the 35 countries in OECD at risk, including 47% of US jobs and 77% of the jobs in China [8; 11; 16]. Even more, new

technologies and platform industries as one of the examples hide their inner inequality because of its natural characteristics – high connectivity and unregulated growth [17].

The ambiguity of the influence of Industry 4.0 on income distribution in the international economy is also confirmed at macro level. For instance, France, the United Kingdom, and Spain will meet increasing inequality under the influence of the Industry 4.0 while Germany, vice versa, will see a decrease as a result of technological shifts due to the leadership of the Industry 4.0 initiative [11].

There are two main ways to cope with such inequality: tax system to redistribute the gains of machine production or rebuilding of the actual machinery ownership [17]. A necessary condition of obtaining positive effects of Industry 4.0 is choosing an appropriate strategy for the country as a whole. Adapting a corporate approach, we can outline the following variants of strategic management decisions for countries within technological change (fig. 3).

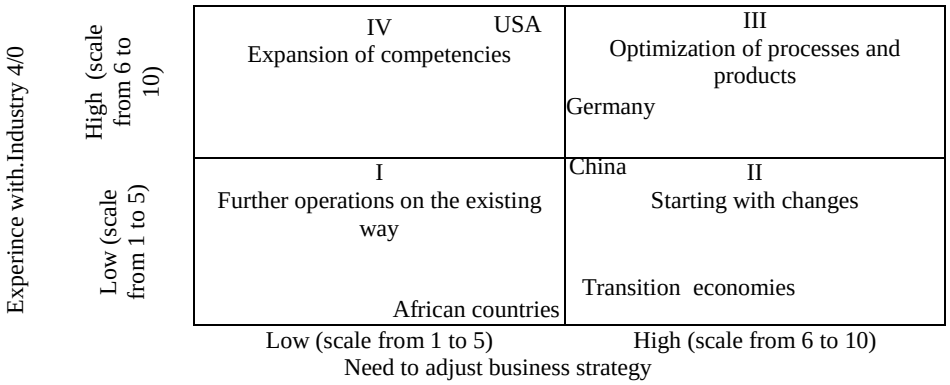

Fig. 3. Positioning of the country according to its strategy of Industry 4.0 [18]

3 Impact of the Industry 4.0 Implementation on Income Inequality

Income inequality depends on many factors, such as land distribution and education, initial levels of inequality, mature of secure property rights and institutional system, social capital, and many others. However, in case of dramatic technological changes caused by Industry 4.0, which will inevitably change economic, managerial and social relations, the greatest attention attracts the connection of technological development of the country and the level of income inequality.

We would like to pose following research question. What impact information technologies and innovations have on social inequality for different countries? One of main index of social inequality is Theil index as a statistic primarily used to measure economic inequality and other economic phenomena.

The Theil T index is defined as

$$T = \frac{1}{N} \cdot \sum_{i=1}^{N} \left(\frac{x_i}{\bar{x}} \cdot ln \frac{x_i}{\bar{x}} \right) \quad (2)$$

where x_i is individual income of i-th country, $\bar{x}$ is average income for the country, and N is the average number of people in the country. If the average incomes of all individuals are equal, then Theil indexes are zero. If the income of the entire population is concentrated in the hands of one individual, then Theil indexes are equal to lnN.

To compare Theil indexes (TI) for different countries we will use weighted average of TI using GDP:

$$TI = \frac{GDP_i}{GDP} \frac{1}{N} \cdot \sum_{i=1}^{N} \left(\frac{x_i}{\bar{x}} \cdot ln \frac{x_i}{\bar{x}} \right) \quad (3)$$

where GDP_i – gross domestic product of country i, $GDP = \sum_{i=1}^{n} GDP_i$ – world GDP.

Among explanatory variables we can use datasets for 2012-2015 years (after introduction of conception Industry 4.0 in 2011):

1) Gross capital formation % of GDP (X_1), which can substitute labor resources [19];
2) Research and development expenditure (% of GDP) (X_2) to create innovations [20];
3) Intellectual property, payments (X_3) to have competitive advantages for know-how [21];
4) High-technology exports (% of manufactured exports) (X_4), which have no domestic analogues [22].

Using software package RStudio requires the following libraries and scripts for 45 countries which have been influenced by explanatory variables:

```
library("dplyr") # data analysis
library("psych") # descriptive statistics
library("lmtest") # test for linear models
library("glmnet") # LASSO + ridge
library("ggplot2") # graphs
library("sjPlot") # significance of parameters

ineqc<-read.csv("_2012.txt", sep="\t", header=TRUE, dec=",")
l<-ineqc
l$countryname <- as.character(l$countryname)
glimpse(l) #
l <- select(l, - Y, -id, -countryname) #
describe(l)
ineqc
cor(l)
```

Correlations between explanatory variables are very low:

```
> cor(l)
            X1          X2          X3          X4
X1  1.00000000 -0.2273892 -0.08686789 -0.1143369
X2 -0.22738920  1.0000000  0.33378478  0.2260948
X3 -0.08686789  0.3337848  1.00000000  0.3401378
X4 -0.11433693  0.2260948  0.34013781  1.0000000
```

It means there are no significant correlations between all explained variables.

To investigate how explanatory variables can impact on countries inequality we will use principal methods after preliminary standardization of variables using data set for Theil index analysis [23] (fig. 4):

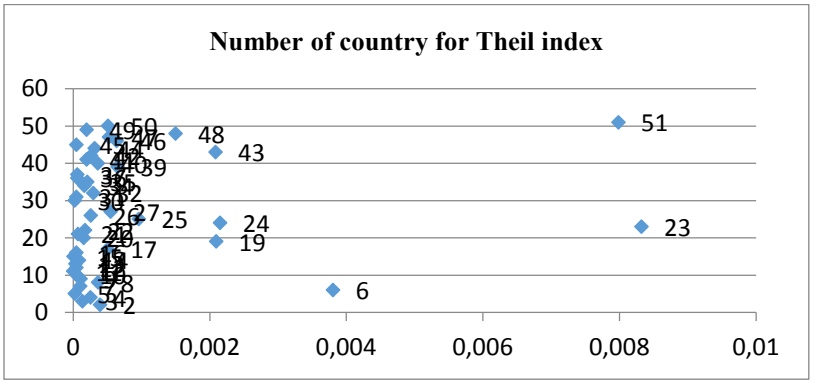

Fig. 4. Country distribution under Theil index (2012)

```
l. pca <- prcomp(l,scale=TRUE)
pca1 <- l.pca$x[,1] # extraction of first principal
component
head(pca1)
tail(pca1)
v1 <- l.pca$rotation[,1] # extraction of the weights with
which the variables belong to the first principal component:
summary(l.pca)
biplot(l.pca, xlim=c(-1,1))
        X1         X2         X3         X4
-0.3378705  0.5519592  0.5628580  0.5141746
```

X_1 decreases level of inequality. At the same time X_2, X_3 and X_4 increase level of inequality. The first two principal components have a sample variance equal to 66,32% of the total sample variance of 4 indicators:

Importance of components:

	PC1	PC2	PC3	PC4
Standard deviation	1.3001	0.9811	0.8633	0.7758
Proportion of Variance	0.4225	0.2407	0.1863	0.1505
Cumulative Proportion	0.4225	**0.6632**	0.8495	1.0000

Cluster 2012

The cluster for original data set in 2012 includes following axes: pc1 – horizontal axis, PC_2 – vertical one (fig. 5).

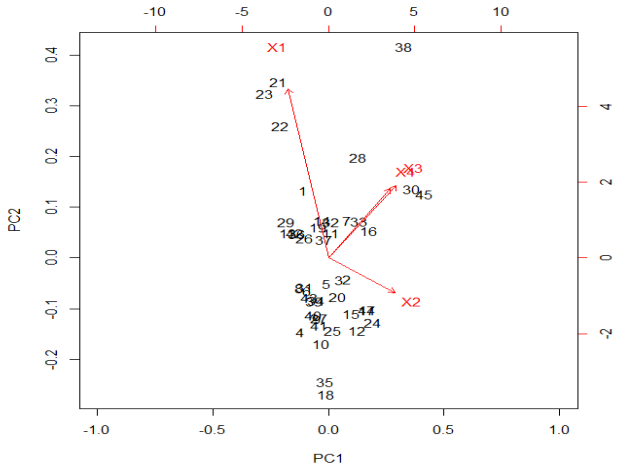

Fig. 5. Four cluster of countries with regard to the level of inequality under the influence of IT (2012)

Cluster 1 (X_1) for countries # 1, 21, 22, 23 inequality in Hong Kong, Hungary and India is formed due to gross capital formation in GDP.

Cluster 2 (X_3, X_4) – countries # 28, 30, 45 intellectual property and high-technology exports creates inequality for Latvia, Malaysia and USA.

Cluster 3 (X_2) – countries # 5, 15, 20, 24, 32, 47 Research and development expenditure form inequality for these countries.

Cluster 4 (0) – other countries. Inequality for these countries (including Ukraine) exists due to other reasons than explanatory variables X_1-X_4.

Cluster 2013

Importance of components:

	PC1	PC2	PC3	PC4
Standard deviation	1.2805	1.0300	0.8555	0.7533
Proportion of Variance	0.4099	0.2652	0.1830	0.1419
Cumulative Proportion	0.4099	**0.6752**	0.8581	1.0000

The clusters for original data set in 2013 is shown in fig. 6.

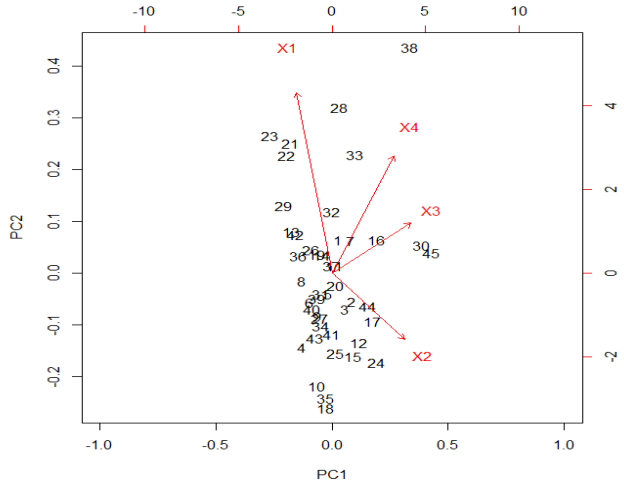

Fig. 6. Five clusters of countries with regard to the level of inequality under the influence of IT (2013)

Cluster 1 (X_1) for countries 21, 22, 23 inequality in Hong Kong, Hungary and India is formed due to gross capital formation in GDP (without changes).

Cluster 2 (X_1 and X_4) for Latvia (28) and Philippines (33) inequality is induced by gross capital formation (% of GDP) and high-technology exports (new cluster).

Cluster 3 (X_3) – 30, 45 intellectual property and High-technology exports creates inequality for Malaysia (30), USA (45) and Estonia (16) (without changes).

Cluster 4 (X_2) – combines countries which have strong impact of research and development expenditure 2, 3, 4, 5, 10, 12, 15, 17, 18, 24, 25, 29, 32, 35, 40, 41, 43, 49 (Ukraine).

Cluster 5 (0) – 8, 36, 26, 37, 39, 20, 8 etc. Inequality exists due to other reasons than Industry 4.0

Cluster 2014

Importance of components:

	PC1	PC2	PC3	PC4
Standard deviation	1.2935	1.0229	0.8176	0.7824
Proportion of Variance	0.4183	0.2616	0.1671	0.1530
Cumulative Proportion	0.4183	**0.6798**	0.8470	1.0000

The clusters for original data set in 2014 is shown in fig. 7.

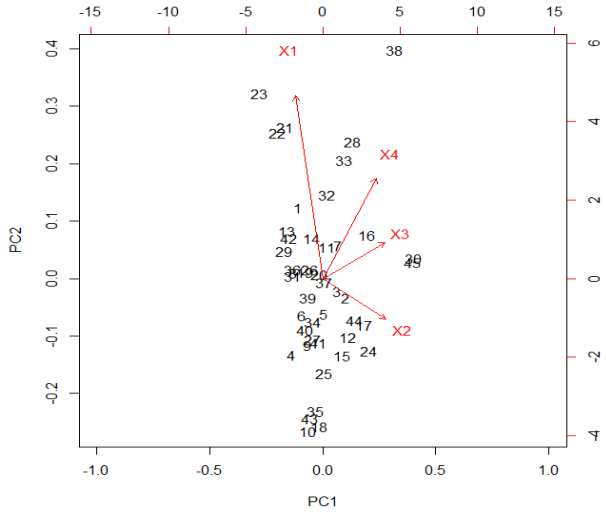

Fig. 7. Two main clusters of countries with regard to the level of inequality under the influence of IT (2014)

There are 2 alternative ways of inequality formation in 2014 and 2015:
Cluster 1 includes countries, which increase X_1, X_4 and X_3 (few countries)
Cluster 2 consist of countries which increase inequality due to X_2 (including Ukraine)

Cluster 2015

Importance of components:

	PC1	PC2	PC3	PC4
Standard deviation	1.2252	1.0404	0.8599	0.8228
Proportion of Variance	0.3753	0.2706	0.1849	0.1692
Cumulative Proportion	0.3753	**0.6459**	0.8308	1.0000

The clusters for original data set in 2015 is shown in fig. 8.

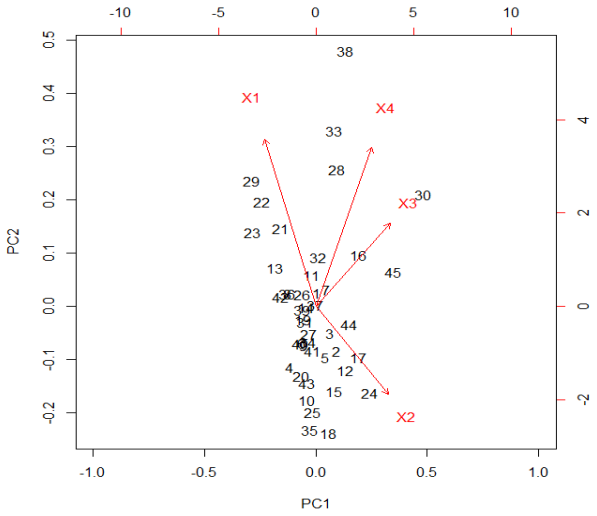

Fig. 8. Two main clusters of countries with regard to the level of inequality under the influence of IT (2015)

There are 3 alternative ways for 2014 and 2015. Cluster 1 consists of countries X_1 (21, 22, 23, 29). Cluster 2 consists of countries that increase inequality due to X_3 and X_4 (16, 30, 45, 28, 33). Cluster 3 includes countries that increase inequality due to X_2 (including Ukraine). At the same time IT factors and Industry 4.0 are not necessarily deleting jobs, but can act as a transformative agent on the nature of jobs (countries in the center of fig. 8). This fact is confirmed for example by authors [24].

Thus 25% of countries create inequality due to gross capital formation, intellectual property, high-technology exports and 75% of countries form inequality as a result of research and development expenditure (radical innovations gives more welfare and different level of living standards).

4 Conclusions

Industry 4.0 creates a new possibility for digitalization, robotics, automation of all business process, creation of modern product and services. It gives competitive advantages to increase export of countries, increasing of the global level of competitiveness but extend the level of frictional and structural unemployment which decrease the level of income for individual and increase the gap of inequality between different segments of inhabitants.

Thus research and development generated more inequality between different countries. Inequality in Ukraine is growing mainly under impact of research and development expenditure during 2012-2015. Intellectual property and high-technology exports changed its impact from same level to different inequality level. Gross capital formation became more significant for other countries than for initial leaders (Hong Kong, Hungary, India). About 44% of all countries had inequality due to other reasons which are not connected with IT development and diffusion of Industry 4.0 which has different speed of expanding for different countries.

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