ORIGINAL PAPER

STATISTICAL ANALYSIS OF INTERNET OF THINGS (IoT) PENETRATION IN INDIVIDUAL CONSUMPTION IN EU COUNTRIES

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Abstract. *The interest that Internet of Things (IoT) enjoys is particular not only from a technical point of view, but also through the lens of the special contribution in terms of economic competitiveness or development of public services. As a result, at the European level, IoT development is a goal for both companies and individual users. In our study, we aimed to analyze from a statistical point of view what is the situation of equipping private homes with IoT devices, the factors that exert an influence on invididual behavior and the extent to which Member States differ from each other, as a premise for future public measures that will be adopted in this field.*

Keywords: *EU; barriers; individual consumption; Internet of Things (IoT).*

1. INTRODUCTION

The Internet of Things (IoT) is a relatively recent concept, as it was first mentioned in 1998 by Kevin Ashton. Its essential principle that of connecting several objectcs through the Internet ensured it, from the very beginning, a series of peculiarities that constitute technical advatages: distributiveness, interoperability, scalability, limited necessary ressources, security [1].

The advantages of IoT have paved the way for its applcability in different fields, creating new opportunities, atend that will continue in 2023 [2]. At the same time, at the level of European Union, IoT is seen as an asset for the competitiveness of some economic sectors, but also as a factor supporting the orientation towards the green economy and digitalization [3]. As a result, a series of programmatic documents were adopted (such as Towards a vibrant EU IoT ecosystem and RoadMap for IoT Research, Innovation and Deployment in Europe 2021-2027 [4]), being supported by European programs dedicated to the expansion of this field (within Horizon Europe, such as: NEMO, NebulOus, ICOS, FluiDOS, aeRos, NEPHELE, within Digital Europe, as well as programs to achieve Green Deal objectives) [5].

Regarding the studies carried out relative to the use of IoT, it belongs to the technical approach, intended to explain the concepts, the process, the applicability of IoT (such as [6]), to the economic approach, which highlights the advantages through the prism of productivity gain, the revitalization of some economic branches, the change in the behavior of consumption, but also sustainable development [7]. A problem that creates increasingly

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intense debates is that of securing the use of these devices, in close connection with data protection [8].

2. STUDY METHODOLOGY

Taking into account the vast applicability of IoT, as well as its usefulness in both public and private space, we set out to study, from a statistical point of view, the degree of use of IoT devices in the private homes of individual consumers, aiming to answer to the following questions:

a) Are there differences between the member countries of the European Union?

and further,

Are these differences so great that we can consider that there are several stages of penetration in consumption at the EU level?

b) What are the factors that influence the degree of use of IoT devices in homes and how do they manifest themselves: does their intensity differ from country to country, from one devices category to another?

To answer these questions, we based our analysis on primary statistical data provided by Eurostat and available online for the years 2020 and 2022. These are the data series on *The use of IoT* [9] and those on *The barriers to the use of IoT devices* [10], which we called "influence factors".

In a first step, we analyzed the differences regarding the degree of device use between EU27 members. The application of the coefficient of variation allowed us to study wether the data indicated for the EU countries express a common tendency or are sufficiently heterogenous to be able to state that the differences between the countries are major. Then, the same approach to analyze the homogeneity of the series was applied to the statistical data on the factors that influence the use of IoT devices at the individual level in the European states. In the paper, to simplify the presentation, we have always used the internationally recognized country codes [11].

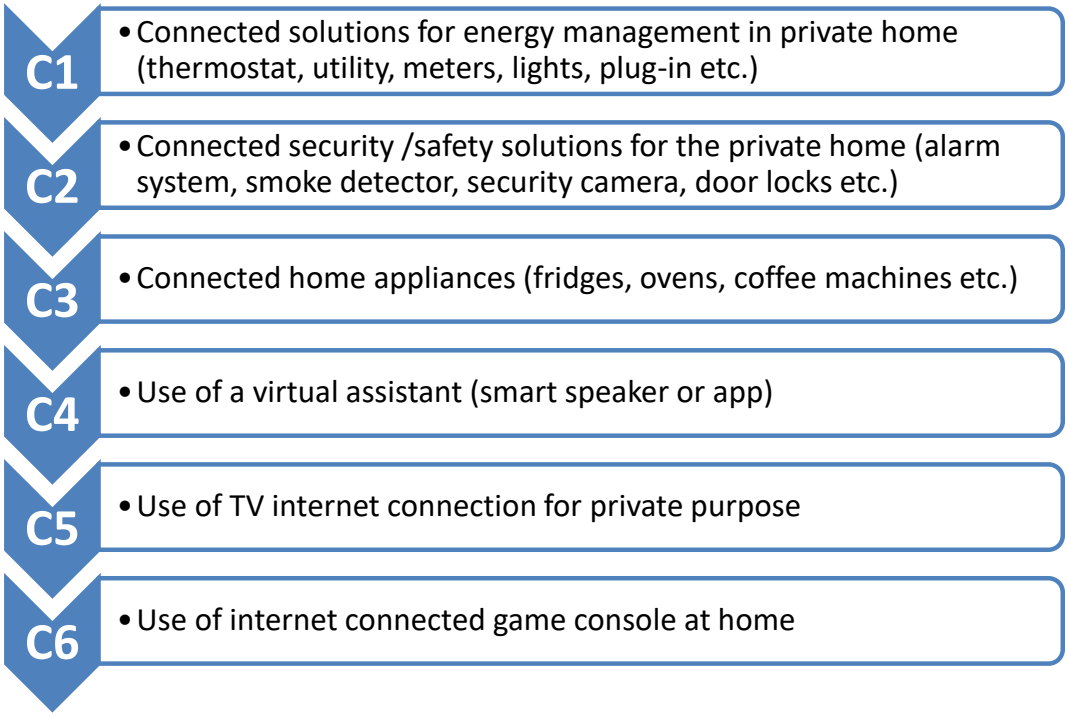

Figure 1. IoT device categories by utility.

In a second step, we analyzed the relationship between the factors that influence the use of IoT devices and the degree of household use of these devices, to determine how strong this influence is on each category of devices. In this sense, the Pearson linear correlation coefcicient was chosen as an indicator, taking into account the distribution mode of the individual values of the series.

The analysis of the degree of use of IoT devices was carried out on the six categories of devices, as they were established at the European level and highlighted in Fig. 1. Regarding the influencing factors on their use, the nine categories established at the European level are indicated in the paragraph no. 4.

3. DIFFERENCES IN THE DEGREE OF PENETRATION OF IoT IN THE PRIVATE HOMES OF CITIZENS IN EUROPEAN COUNTRIES

Fig. 2 shows the percentage of presence in EU27 households of the six categories of IoT devices and the evolution of the situation in 2022 compared to 2020. It can be seen that, at EU27 average level, endowment with IoT devices increased in the two years in all categories, however the rate of growth is different: + 9% in the C5 category (the highest increase), +4% in the C3 category, + 3% in the C6 category, +3% in the C2 category, +2% in the C4 category and +1.9% in the C1 category (the weakest increase).

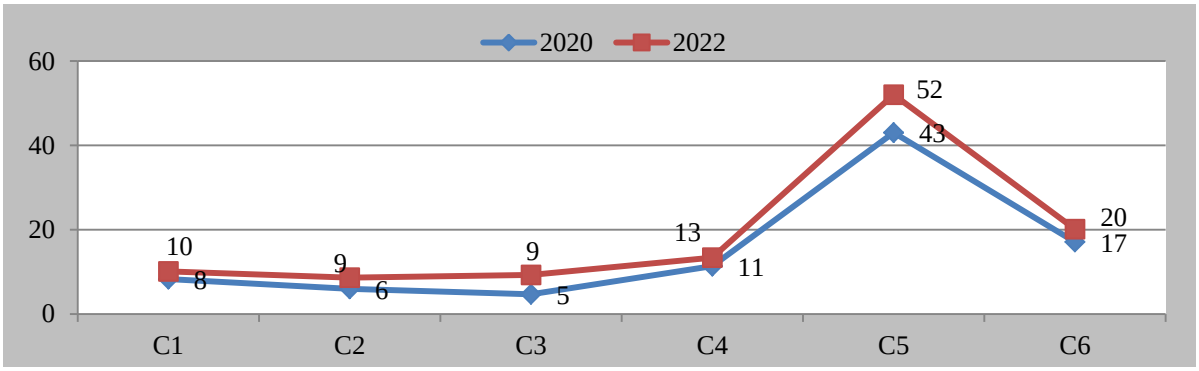

Figure 2. The degree of penetration of IoT in personal homes, in EU member countries (%).
Note: EU27 data for 2020 are estimates for C1, C4, C5 and C6.
Source: processed by the authors according to Eurostat.

Regarding the situation of IoT device provision of private homes in each EU country, the statistical data show quite large differences, as can be seen from Tables 1and 2.

Table 1. The degree of penetration into personal homes of IoT devices, in EU member countries in 2020 (%).

	C1	C2	C3	C4	C5	C6
EU 27	8.28	5.97	4.69	11.36	43.02	17.09
BE	10.25	12.14	3.57	8.84	NA	NA
BG	2.08	2.06	1.06	0.83	23.19	3.62
CZ	2.85	4.78	2.39	3.86	36.20	12.48
DK	11.45	14.53	12.05	19.35	62.50	27.39
DE	8.06	3.87	5.25	16.56	50.71	19.51
EE	14.79	9.21	8.45	6.18	41.37	15.54
IE	16.63	12.96	3.95	17.74	37.58	23.34
EL	1.70	4.43	2.27	0.75	29.37	7.79
ES	7.85	8.88	10.09	16.86	66.39	30.22

	C1	C2	C3	C4	C5	C6
FR	NA	NA	NA	NA	NA	NA
HR	3.52	3.90	4.36	8.23	44.96	25.1
IT	1.63	5.37	1.93	11.8	29.54	10.37
CY	1.07	11.11	0.85	4.31	48.14	8.79
LV	3.44	4.27	3.39	4.02	46.43	10.53
LT	2.45	4.86	4.50	1.7	31.24	6.43
LU	12.39	13.15	7.99	12.12	57.02	28.73
HU	4.44	5.67	3.86	3.82	37.71	12.47
MT	8.25	13.11	11.34	16.79	72.19	33.67
NL	68.72	11.52	5.72	19.51	56.57	28.23
AT	5.46	4.28	4.80	17.49	45.91	21.02
PL	2.27	2.42	3.26	1.75	30.87	10.48
PT	4,00	5.19	4.42	7.62	43.85	23.04
RO	0.66	1.65	0.93	0.9	24.92	6.51
SI	10.03	6.01	13.91	14.32	40.86	10.9
SK	2.53	4.24	4.06	3.56	42.96	13.46
FI	7.78	10.27	4.09	17.41	53.41	9.16
SE	13.30	16.81	6.53	18.85	62.27	28.07

Note: NA = data not available. *Source: Eurostat.*

Table 2. The degree of penetration into personal homes of IoT devices, in EU member countries in 2022 (%).

	C1	C2	C3	C4	C5	C6
EU 27	10.11	8.62	9.27	13.37	52.01	20.12
BE	14.13	12.67	9.56	6.46	51.16	23.04
BG	1.15	2.26	4.29	0.82	30.12	3.69
CZ	5.13	7.81	6.75	5.99	47.85	13.45
DK	14.57	16.61	19.72	21.68	65.51	25.11
DE	7.11	4.32	7.08	14.94	49.15	17.26
EE	16.07	15.72	18.02	6.35	51.76	16.81
IE	21.41	15.96	5.78	38.89	67.64	35.28
EL	3.65	5.85	5.84	1.11	38.62	10.55
ES	11.77	11.48	16.34	23.51	69.34	27.25
FR	10.88	11.39	13.79	15.69	53.84	30.75
HR	5.58	5.87	7.46	2.98	34.71	22.55
IT	4.38	9.13	4.19	15.09	49.05	17.02
CY	6.59	10.62	10.25	5.44	65.67	11.26
LV	4.69	5.40	8.60	2.33	48.59	6.37
LT	5.31	8.08	12.12	3.03	42.66	10.52
LU	10.74	14.81	12.19	14.59	60.98	26.07
HU	5.18	6.54	6.53	3.02	49.04	11.71
MT	8.67	13.95	19.80	16.92	77.76	34.91
NL	65.69	22.68	15.05	24.85	64.13	30.7
AT	14.57	7.33	9.33	18.67	60.03	27.48
PL	3.33	3.01	5.73	2.09	37.55	9.73
PT	3.34	5.85	8.71	7.33	52.43	25.35
RO	2.09	3.30	3.79	1.41	39.75	7.42
SI	9.28	8.45	17.54	13.88	49.29	12.37
SK	3.94	6.26	11.89	4.32	59.37	15.07
FI	12.35	11.97	8.55	15.02	64.17	20.71
SE	15.94	18.23	12.65	18.93	67.96	25.85

Source: Eurostat.

To analyze how big the differences are between the 27 states, we used the coefficient of variation, a statistical indicator able to demostrate the dispersion that exists in a group of statistical data. The lower its level, the more homogenous the data, the 35% level being considered a reference threshold for the homogeneity of the series. The coefficient of variation is calculated based on the average value of the data ($\bar{x}$) and the standard deviation (σ) [12]. For the average value we used the data indicated by Eurostat at EU27 level in the two years (2020 and 2022). In the case of the standard deviation, we use the calculation formula based on dispersion (σ^2):

$$\sigma = \sqrt{\sigma^2} \tag{1}$$

The formula for calculating dispersion is:

$$\sigma^2 = \frac{\sum_1^n (x_i - \bar{x})^2}{n} \tag{2}$$

where n = the number of member states

After calculating the standard deviation, the coeficient of variation (v) was determined by applying the formula:

$$v = \frac{\sigma}{\bar{x}} * 100 \tag{3}$$

The data obtained are presented in the following table.

Table 3. Calculation of the coefficient of variation regarding endowment of private homes with IoT devices in EU countries (years 2020 and 2022) (%)

	2020			2022		
	$\bar{x}$	σ	v	$\bar{x}$	σ	v
C1	8.28	12.8309	154.963	10.11	11.9354	118.055
C2	5.97	4.5783	76.6884	8.62	5.2251	60.616
C3	4.69	3.4551	73.6695	9.27	4.88828	52.7323
C4	11.4	6.93534	61.0506	13.4	9.4213	70.466
C5	43.02	13.0098	30.2413	52.01	11.8567	22.7969
C6	17.1	8.8252	51.6397	20.1	8.8898	44.1839

Source: authors, based on Eurostat data.

As can be seen from Table 3, the coefficient of variation has values greater than 35% in all cases, except for devices in category C5 (Use of TV internet connection for private purpose) where v_{2020} = 30.24% and v_{2022} =22.79%. In other words, only for this category of devices the level of equipment of private homes is homogenous in the case of EU27 group of countries, while for the rest of the categories of devices the differences are large enough for the group to be considered heterogenous from a statistical point of view and the average level calculated at EU27 not to be statistically relevant. As a result, in terms of consumer penetration of IoT devices, in private homes, it is recommended that the 27 states be included in more statistically homogenous categories or classes.

Table 4. Grouping of EU countries according to the degree of use of IoT devices in private home

		Very low (<5%)	Low (5%-10%)	Medium (10%-20%)	High (20%-40%)	Very high (>40%)
C1	2020	BG, CZ, EL, HR, IT, CY, LV, LT, HU, PL, PT, SK, RO, SK	DE, ES, MT, AT, FI	BE, DK, EE, IE, LU, SI, SE		NL
	2022	BG, EL, IT, LV, PL, PT, RO, SK	CZ, DE, HR, CY, LT, HU, SI	BE, DK, EE, ES, FR, LU, MT, AT, FI, SE	IE	NL
C2	2020	BG, CZ, DE, EL, HR, LV, LT, AT, PL, RO, SK	EE, ES, IT, HU, PT, SI	BE, DK, IE, CY, LU, MT, NL, FI, SE		
	2022	BG, DE, PL, RO	CZ, EL, HR, IT, LV, LT, HU, AT, PT, SI, SK	BE, DK, EE, IE, ES, FR, CY, LU, MT, FI, SE	NL	
C3	2020	BE, BG, CZ, DE, IE, EL, HR, IT, CY, LV, LT, HU, AT, PL, PT, RO, SK, FI	EE, ES, LU, NL, SE	DK, MT, SI		
	2022	BG, IT, RO	BE, CZ, DE, IE, EL, HR, LV, HU, PL, PT, FI	DK, EE, ES, FR, CY, LT, LU, MT, NL, AT, SI, SK, SE		
C4	2020	BG, CZ, EL, CY, LV, LT, HU, PL, PT, RO, SK	BE, EE, HR	DK, DE, IE, ES, IT, LU, MT, NL, AT, SI, FI, SE	NL	
	2022	BG, EL, HR, LV, LT, HU, PL, RO, SK	BE, CZ, EE, CY, PT	DE, FR, IT, LU, MT, AT, SI, SE	DK, IE, ES	
C5	2020				BG, CZ, IE, EL, IT, LT, HU, PL, PT, RO	DK, DE, EE, ES, HR, CY, LV, LU, MT, NL, AT, SI, SK, FI, SE
	2022				BG, EL, HR, PL, RO	BE, CZ, DK, DE, EE, IE, ES, FR, IT, CY, LV, LT, LU, HU, MT, NL, AT, PT, SI, SK, SE
C6	2020	BG	EL, CY, LT, RO	CZ, DE, EE, IT, LV, HU, PL, PT, SI, SK, FI	DK, IE, ES, HR, LU, MT, NL, AT, SE	
	2022	BG	LV, PL, RO	CZ, DE, EE, EL, IT, CY, LT, HU, SI, SK	BE, DK, IE, ES, FR, HR, LU, MT, NL, AT, PT, FI, SE	

Source: authors, based on Eurostat data.

A grouping solution that we propose is that in five classes, depending on the degree of endowment with IoT devices, as shown in Table 4. According to this grouping proposed, the degree of penetration of IoT devices in individual consumption in 20222 is presented as follows:

- Category C1 : very low level (below 5%) for 8 EU countries, low level (between 5% and 10%) for 7 EU coutries and medium level (10%-20%) for other 7 countries ;
- Category C2 : very low level (below 5%) for 4 EU coutries, low level (between 5% and 10%) for 11 EU countries and medium level (10%-20%) for other 11 countries;
- Category C3 : very low level (below 5%) for 3 EU countries, low level (between 5% and 10%) for 11 EU coutries and medium level (10%-20%) for other 13 countries ;
- Category C4 : very low level (below 5%) for 9 EU countries, low level (between 5% and 10%) for 5 EU countries, medium level (10%-20%) for 8 countries, while 3 countries can be included in the group with a high degree of penetration (20%-40%) ;
- Category C5, unlike the previous ones, has only two groups of countries, with high penetration (20%-40%) – 5 countries and very high penetration (over 40%) – 21 countries ;
- Category C6: low level (between 5% and 10%) for 3 EU countries, medium level (10%-20%) for 10 countries and high level (20%-40%) for 13 EU countries.

In addition to greater homogeneity of data within each of these classes, grouping allows observing the evolution of each country, as well as the evolution of the degree of endowment in each category of devices. For example, between 2020 and 2022, for category C1, the number of countries with a „very low" level of use decreased from 14 to 8, the number of those with a „low" level of use increased (from 5 to 7), of those with „medium" level of use (from 7 to 10) and of those with „high" level of use (from 0 to 1).

4. FACTORS INHIBITING THE GROWTH OF IoT USAGE IN PRIVATE HOMES

Regarding the brakes on the use of IoT by individual users in their private homes, European statistics [10] provide comparable data for five categories of factors, namely:

- Lack of information regarding the existence of the respective devices;
- Lack of a need;
- Too high costs invloved;
- The incompatibility of these devices with those commonly used;
- Low ability to use such devices;
- Fears related to the protection of privacy and personal data;
- Fears related to the security of the respective devices;
- Concerns regarding the impact on safety and health;
- Other reasons.

Next, the nine categories of brakes will be analyzed according to the coding that we represented in the figure beow (Fig. 3).

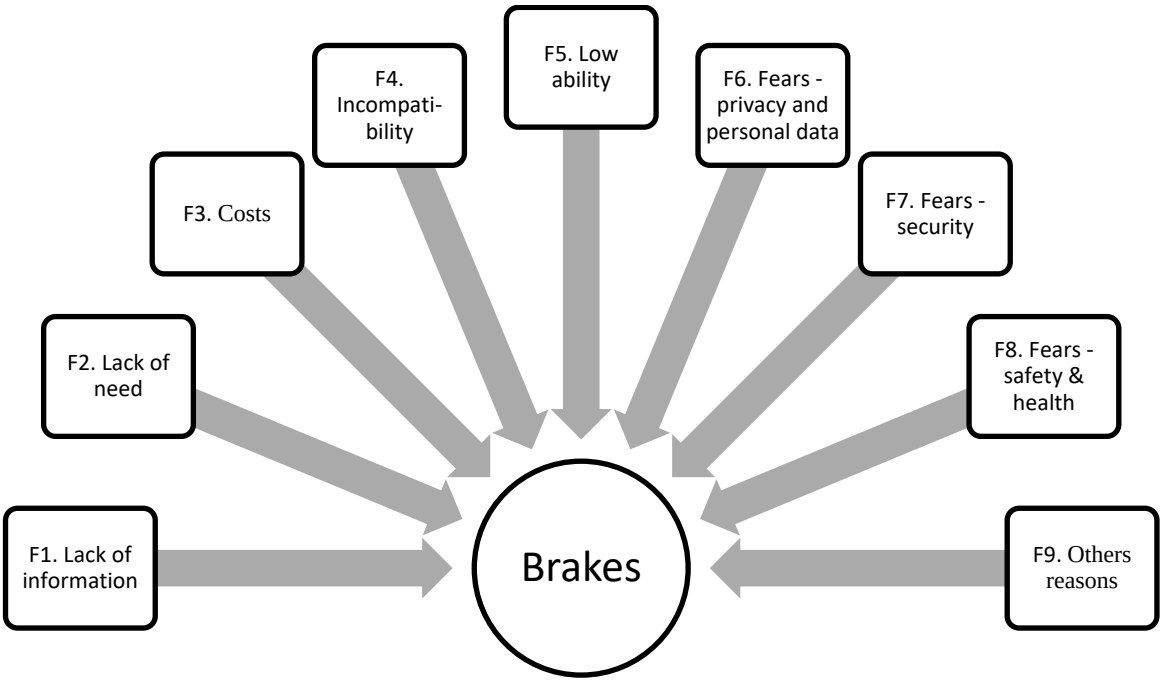

Figure 3. Categories of brakes in the use of IoT devices by individual consumers in European countries

Fig. 4 highlights the nine categories of barriers to the use of IoT devices by residents of EU member countries. This is the average at EU27 level and, according to this indicator, it can be seen that the biggest brake is represented by category F2 – "lack of need", i.e. the population has not identified those needs that justify the purchase of IoT devices. The weight of this category is decreasing, from 43% to 41% which may be the result of information campaigns regarding the role of IoT devices. In second place as a brake on the use of IoT devices, but far from the first category of brakes, is the cost of IoT devices (11.4% in 2020, 10.2% in 2022).

At the opposite pole, concerns about the safety and health of users (category F8) and incompatibility between IoT devices in relation to other devices (category F4) are the least expressed brakes among people in EU member countries. It should also be noted that in the case of all categories of barriers to the use of IoT devices, the weight is decreasing in 2022 compared to 2020.

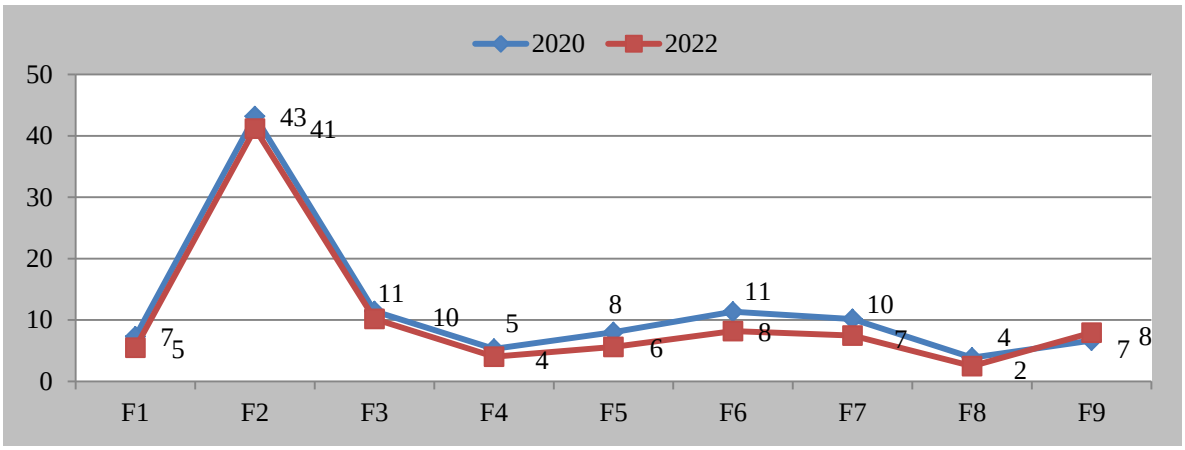

Figure 4. Categories of brakes manifested in EU countries regarding the provision of private homes with IoT devices (%)

Note: EU27 data for 2020 are estimates.

Source: processed by the authors according to Eurostat.

5. ANALYSIS OF THE DIFFERENCES BETWEEN EU STATES REGARDING THE FACTORS THAT INHIBIT THE USE OF IoT DEVICES IN PRIVATE HOMES

Regarding the differences between EU member states with respect to the factors that discourage the use of IoT devices in private homes, we analyzed the degree of dispersion of the values recorded in the years 2020 and 2022 to see if the average level established for the EU27 is representative for this group of states.

For this purpose, we used the coefficient of variation, the method of calculation of which is already presented in paragraph 3. The values used to determine the coeffcieint of variation are indicated in Tables 5 and 6.

Table 5. Differences regarding the intensity of factors inhibiting the use of IoT devices, in EU member countries in 2020 (%)

	F1	F2	F3	F4	F5	F6	F7	F8	F9
EU 27	7.31	43.20	11.43	5.31	8.01	11.35	10.15	3.86	6.65
BE	3.98	21.80	19.24	13.40	14.50	12.91	13.57	3.15	13.87
BG	9.96	35.81	7.40	2.81	3.92	1.11	0.94	0.58	8.22
CZ	4.70	60.31	9.06	0.80	3.75	1.42	1.63	0.12	4.58
DK	4.02	37.37	15.49	2.56	8.59	13.22	11.63	2.31	12.04
DE	1.25	60.37	11.62	1.16	11.09	24.67	20.23	5.92	1.20
EE	2.99	52.40	6.95	0.95	3.19	2.33	2.75	1.14	2.31
IE	4.48	11.25	3.91	2.04	4.22	6.11	5.72	3.58	27.04
EL	10.26	40.49	13.57	12.83	7.04	1.82	2.29	0.91	5.50
ES	14.21	37.41	19.36	10.84	12.82	17.82	17.79	10.54	10.57
FR	NA	NA	NA	NA	NA	NA	NA	NA	NA
HR	18.29	25.58	22.69	1.08	11.38	17.35	19.12	0.67	6.01
IT	3.65	34.63	5.51	4.95	6.14	2.46	2.05	0.49	8.05
CY	9.77	52.91	37.49	16.65	10.56	20.40	17.,04	14.92	0.05
LV	6.67	54.04	9.27	16.15	7.45	4.41	2.97	1.61	1.57
LT	2.35	62.07	15.77	3.97	8.20	2.81	3.00	2.16	0.95
LU	5.43	41.58	9.19	3.24	9.59	15.10	14.29	4.40	10.67
HU	3.45	61.70	4.84	3.15	3.53	1.77	2.09	0.50	3.00
MT	22.36	25.44	7.28	6.68	7.68	8.90	9.39	6.68	5.12
NL	1.67	14.32	5.56	0.64	0.95	4.08	3.28	1.01	2.50
AT	4.31	52.77	7.69	10.43	10.84	30.52	26.66	8.35	4.38
PL	4.69	55.63	8.20	5.29	4.20	1.50	1.29	0.77	6.42
PT	20.56	37.09	21.29	16.58	14.43	21.66	21.19	14.04	5.47
RO	30.14	27.14	15.22	3.80	3.05	0.85	1.07	0.53	5.24
SI	25.28	26.42	6.43	0.79	2.44	2.80	2.35	1.35	3.24
SK	10.72	28.43	13.54	5.87	8.44	3.81	2.75	1.64	22.90
FI	11.62	50.17	13.77	12.30	9.53	21.69	21.93	4.30	22.34
SE	7.35	37.28	10.51	2.35	5.32	7.92	6.90	2.19	8.55

Note: NA = data not available, estimated data for EU27 (2020). Source: Eurostat.

Table 6. Differences regarding the intensity of factors inhibiting the use of IoT devices, in EU member countries in 2022 (%)

	F1	F2	F3	F4	F5	F6	F7	F8	F9
EU 27	5.48	41.19	10.18	4.02	5.62	8.20	7.46	2.49	7.93
BE	3.20	20.17	16.74	10.39	12.87	13.09	12.43	1.80	15.33
BG	6.72	39.41	13.93	2.17	6.03	0.27	1.59	0.70	12.10
CZ	2.15	60.73	7.94	0.33	3.39	0.79	0.83	0.05	3.68
DK	2.06	31.59	9.82	1.10	4.80	8.99	6.14	1.19	8.68
DE	1.42	51.47	6.63	0.55	3.94	8.75	8.00	2.82	4.52

	F1	F2	F3	F4	F5	F6	F7	F8	F9
EE	1.96	48.00	6.41	1.04	2.78	3.29	3.04	1.52	1.82
IE	1.79	31.16	6.77	1.33	2.88	9.10	6.54	1.36	4.14
EL	10.47	37.26	9.90	16.86	5.62	0.93	1.23	0.51	3.95
ES	12.47	32.30	14.98	7.77	9.95	19.66	17.89	0.52	10.35
FR	1.27	41.50	10.03	1.12	5.07	9.79	8.68	1.57	8.24
HR	11.85	33.08	22.68	0.01	12.98	21.10	20.39	3.11	1.59
IT	3.12	36.71	5.73	2.83	4.68	2.03	1.02	0.35	11.74
CY	4.62	44.05	20.15	11.74	7.90	11.66	12.53	13.11	15.25
LV	6.30	50.69	7.00	16.90	4.36	1.75	1.41	0.64	1.67
LT	0.71	61.49	14.82	3.53	6.77	1.64	1.26	0.67	0.44
LU	4.92	39.86	10.01	4.32	8.78	11.99	11.33	3.11	4.16
HU	4.75	41.88	9.36	5.32	5.58	2.49	2.10	0.60	14.83
MT	18.34	24.84	5.40	4.28	6.64	4.79	5.21	3.51	5.47
NL	1.70	16.15	4.69	0.81	1.06	4.49	3.94	0.42	1.86
AT	7.15	48.05	16.00	4.78	8.22	28.50	27.13	6.87	8.90
PL	3.54	58.03	8.19	6.30	4.27	1.07	0.98	0.44	5.40
PT	14.44	43.98	25.41	17.18	13.07	19.14	20.08	11.62	4.50
RO	27.30	30.49	19.94	4.98	4.39	0.90	1.03	0.46	4.86
SI	20.21	31.27	7.84	1.74	3.31	2.55	2.17	1.31	4.35
SK	8.95	29.42	7.81	3.67	6.49	3.09	2.66	1.22	19.78
FI	8.62	50.77	16.81	13.45	8.85	24.16	23.36	3.57	27.91
SE	3.22	31.11	8.56	1.98	5.03	6.76	7.01	1.40	10.83

Note: NA = data not available. *Source: Eurostat.*

The result of the calculations performed regarding the standard deviation and the coefficient of variation are presented in the Table 7. It is observed that only in the case of factor F2 – "lack of a need" the coefficient of variation is below the level of 35%, i.e. the data series is homogenous. For the other factors, the calculated coefficients are higher than 35%, and the higher the level, the more heterogenous the data series corresponding to that factor, in other words, there are significant differences between countries.

It should also be noted that between 20202 and 2022 the differences between Member States increased: the coefficient of variation augmented for all factors, except F3 ("cost of IoT devices") and F9 ("others reasons").

Table 7. Calculation of the coefficient of variation regarding factors inhibiting the use of IoT devices in EU coutries (years 2020 and 2022) (%)

	2020			2022		
	$\bar{x}$	σ	v	$\bar{x}$	σ	v
F1	7.31	7.9975	109.40	5.48	6.7254	122.73
F2	43.20	11.7191	27.1275	41.19	11.6147	28.1979
F3	11.43	7.2849	63.7349	10.18	5.7969	56.9440
F4	5.31	5.4281	102.2241	4.02	5.4951	136.694
F5	8.01	3.7816	47.2110	5.62	3.1814	56.6085
F6	11.35	8.8594	78.0564	8.20	7.8844	96.1512
F7	10.15	8.119	79.9901	7.46	7.6466	102.5013
F8	3.86	4.0705	105.4534	2.49	3.1756	127.5341
F9	6.65	6.951	104.5263	7.93	6.3057	75.5170

Source: authors, based on Eurostat data.

6. ANALYSIS OF THE INTENSITY OF THE CONNECTION BETWEEN THE DEGREE OF USE OF IOT DEVICES AND THE DEGREE OF MANIFESTATION OF THE INFLUENCING FACTORS

The question is to what extent each of the nine categories of barriers to the use of IoT devices influence the behavior of individual users. To answer this question we used the correlation coefficient, applied to the data series corresponding to the EU member states (as presented in Tables 1, 2, 5, and 6).

The correlation coefficient allows us to measure the degree of association between two variables [13], in our case one of the variables being the degree of use of IoT devices, and the other – the factor considered as a brake on the way of using the devices. Since there are six categories of devices and nine types of brakes, according to the statistical data, the correlation coefficient was calculated for each combination of the two variables, and the resuls are shown in Table 8.

Formula for correlation coefficient is:

$$r_{y/x} = \frac{n\sum xy - \sum x \sum y}{\sqrt{[n\sum x^2 - (\sum x)^2]\,[n\sum y^2 - (\sum y)^2]}} \tag{4}$$

For the interpretation of the results, we consider that the sign (+) indicated a positive correlation and the sign (-) a negative correlation. Also, taking into account the fact that this coefficient can have values from -1 to +1, the intensity of the correlation increases as the value of the coefficient approaches one of the extremes and decreases as it approaches the value 0. Thus, a coefficient between 0.00 – 0.10 means „negligible correlation", between 0.10 – 0.39, „weak correlation", between 0.40 – 0.69 „moderate correlation", between 0.70 – 0.89 „strong correlation" and between 0.90 – 1.00 „very strong correlation" [14].

Table 8. Values of the correlation coefficient between the degree of use of IoT devices (y) and the factors inhibiting the use of devices (x) in EU27 member countries (2020, 2022)

$r_{y/e}$	F1	F2	F3	F4	F5	F6	F7	F8	F9
C1									
2020	-0.257	-0.430	-0.281	-0.301	-0.332	-0.065	-0.076	-0.116	-0.012
2022	-0.302	-0.420	-0.235	-0.238	-0.278	0.015	0.003	-0.061	0.043
C2									
2020	-0.19	-0.328	0.053	-0.022	0.092	0.188	0.199	0.213	0.317
2022	-0.28	-0.389	-0.122	-0.195	-0.121	0.054	0.063	0.051	0.228
C3									
2020	0.184	-0.198	-0.200	-0.274	0.011	0.119	0.131	0.079	-0.008
2022	0.079	-0.165	0.010	-0.124	0.039	0.095	0.099	0.181	-0.075
C4									
2020	-0.095	-0.344	-0.201	-0.167	0.141	0.488	0.476	0.236	0.279
2022	-0.173	-0.437	-0.278	-0.211	-0.02	0.286	0.267	0.211	0.432
C5									
2020	0.011	-0.155	0.137	0.097	0.389	0.503	0.508	0.421	0.095
2022	-0.057	-0.233	0.037	0.143	0.185	0.375	0.356	0.483	0.332
C6									
2020	-0.001	-0.404	-0.048	-0.154	0.305	0.305	0.434	0.305	0.140
2022	-0.046	-0.496	-0.092	-0.063	0.281	0.281	0.482	0.339	0.374

Source: authors, based on Eurostat data.

The results obtained by applying the correlation coefficient (Table 8) show us the following associations between the two categories of analyzed variables:

- Moderate, negative correlation between the use of devices C1 – "Connected solutions for energy management" and "Lack of need for such devices" (F2). The influence of other factors on C1 category devices is weak or negligible.
- In the case of C2 devices – "Connected security/safety solutions" and C3 – "Connected home appliances" the values obtained show weak or negligible correlations in the case of all factors analyzed.
- In the case of devices C4 – "Use of virtual assistant", in 2020 a weak: negative influence of factor F2 ("lack of need") and a moderate, positive influence of factors F6 ("Fears related to protecting private life and of personal data") and F7 ("Fears related to the security of the respective devices"). Two years later, in 2022, it is observed that the influence of factors F6 and F7 has decreased, while the influence of factors F2 has increased slightly, but corresponding to the level of "moderate correlation" and negative.
- Regarding the use of devices in category C5 – "Use of TV internet connection", in 2020 it can be noted the influence of factors F5 ("Low ability to use such devices") – weak, direct correlation, F6 ("Fears related to protecting private life and of personal data") – moderate, direct correlation, F7 ("Fears related to the security of the respective devices") – moderate, direct correlation, F8 ("Fears regarding the influence on safety and health") – moderate, direct correlation. In 2022, only the F8 factor maintains the same level of influence (moderate, positive), while the influence of the other factors decreased.
- With regard to the devices in category C6 – "Internet connected game console", we note the moderate, negative influence of F2 ("Lack of need") and the moderate, positive influence of F7 ("Fears related to the security of the respective devices") in both years analyzed.

7. CONCLUSIONS

The statistical analysis carried out highlights the large differences between EU countries in terms of the degree of retention in the use of IoT devices in private homes. The endowment of IoT devices increased across the EU27 between 2020 and 2022 for all device categories, but the level of growth was different between the 6 categories.

The grouping of EU contries according to the degree of penetration of IoT devices in individual consumption, in addition to ensuring greater statistical homogeneity of the formed groups, allows us to more easily follow how the level of penetration in consumption evolves over time for each category of device. It also helps us to observe the situation of a country for each of the categories of devices and so we can identify which ones require greater stimulation in terms of consumption.

The main reasons why IoT devices are not used are: first, lack of need (41.2% of people in 2022, down from 43.2% in 2020), followed by a long distance by the cost of the devices. The data indicate a decreased at EU27 level in the influence of all categoris of analyzed factors.

Within the EU, the degree of use of IoT is very different for all categories of devices except for category C5 („Use of TV internet connection for private purpose"), the only one where the analysis highlighted the homogeneity of the data for all 27 EU states. Also, the analysis of the factors that influence the use of IoT devices indicates large differences in

intensity between the member states, the only factor in which a homogeneity is observed between the 27 states is „lack of need"; moreover, the result regarding the coefficient of variation highlights an accentuation of the differences between member countries regarding the manifestation of different barriers to the use of IoT.

Although the factors that influence the use of IoT devices are numerous, their influence differs from one category to another of the devices, and the correlation „influence factor" – „degree of device use" is at most in the „moderate" level. Thus, „lack of need" is the factor that has a „moderate" influence regarding devices in the categories „Connected solutions for energy management" (C1), „Use of virtual assistant" (C4) and „Internet connected game console" (C6). Concerns related to protecting privacy and personal data (F6) devices security (F7) and influence on safety and health (F8) had a moderate influence on the use of devices in the categories „Virtual assistant" (C4), „TV internet connection" (C5) and „Internet connected game console" (C6).

Our analysis does not refer to the use of IoT devices at the level of companies and which factors influence their use to legal entities, but such a study is also necessary and can complement the situation presented by us.

Knowing the differences regarding the degree of use of IoT devices, as well as relative to the factors that influence the use, is important for understanding the behavior of European consumers, but also for the premises of public policies in this area. Taking into account the major differences observed between countries, we belive that the development of the consumption of these devices requires strategic decisions and promoting actions adapted to specifics of each country.

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