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The Economic Resilience Index in Pandemic Times: A Case Study for European Countries

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Abstract: The aim of this paper is to compare the economic resilience for 22 European countries for the years 2020 and 2021, and the related verification of important resilience factors. The paper is based on six indicators: i) fiscal surplus, ii) misery index, iii) year-on-year change in public debt, iv) digital economy and society index (DESI), v) trust in government policy, vi) net savings rate. The comparison is based on the economic resilience index (ERI), which is constructed by principal component analysis (PCA). The Nordic countries achieved the highest resilience: Norway, Denmark and Sweden, while the worst performers were Greece, Slovakia and Italy. The authors' conclusions that both the level of digitalization and trust in government policy can be considered important factors in terms of resilience were confirmed. Moreover, it was shown that there is a strong relationship between ERI and gross domestic product (GDP) per capita. Recommendations are made to invest more in digital infrastructure, to build trust in government policy, as well as to learn from each other, especially by exploring best practices, modifying them and applying them in selected economies.

Keywords: principal component analysis; regional resilience; macroeconomic policy; pandemic; economic resilience index

JEL Classification: C38; E62; O47

1. Introduction

The Covid-19 pandemic affected economies around the world when the disease began to spread from the Asian continent to the rest of the world, specifically China, in the spring of 2020. The reactions of individual countries were significant with global closures of local as well as international markets. There was a deep economic slump – almost without exception, 2020 will go down in history as a year of deep economic downturns in individual economies. However, the second half of the year, followed by 2021, was marked by a recovery and an effort to return to pre-pandemic levels as quickly as possible. The recovery of the economies from this extraordinary shock was not, or even could not, proceed without disparity. In this context, the apparent differences between countries or regions can be attributed to differences in the resilience of individual economies to economic and non-economic shocks.

This paper contributes to the existing literature by summarizing several relevant studies in the field of resilience, including a review of various statistical models and methods that can be used to measure regional resilience. Based on PCA, the ERI was constructed in the analytical part, with the choice of variables based on the works of Briguglio et al. (2009) and Fišera (2022). Not only did this index reveal important components of resilience and clarify the relationships between the selected indicators, it also provided an international comparison across the selected countries. Finally, some modifications (extensions) of the index were discussed, as well as indicating possible interventions by economic policy makers leading to the strengthening of the economic resilience of regions in the future.

2. Theoretical Background

The concept of regional economic resilience has over time become an area of interest for many economists around the world. Even so, there are currently only a small number of definitions of economic resilience as a stand-alone concept (Modica & Reggiani, 2015). An interesting perspective on the issue of economic resilience is provided by Martin (2012), who adds adaptive resilience to the existing engineering and ecological resilience. Engineering resilience consists of the speed with which a system returns to an equilibrium state after a shock, ecological resilience is then characterized by the ability to find a new equilibrium state after a shock deflection, and finally adaptive resilience represents a form of reorganization of the system to minimize the impact of a given shock (Martin, 2012). In addition to Martin (2012), Christopherson et al. (2010) also point to the need to view regional resilience in the context of spatial economics, as regions are complex systems in which individual actors, institutions, space and time are dynamically interdependent elements. On the other hand, this very fact manifests itself in considerable difficulty in identifying of a new regional equilibrium (ecological resilience). It is not surprising, then, that most studies in the field of regional economic resilience lean more towards an engineering conception of resilience. Finally, a few definitions can be given, with Foster (2007) defining economic resilience as the ability of a region to anticipate, prepare for and respond to a shock and then recover from it. Rose and Krausmann (2013) note both the static and dynamic aspects of resilience as they argue that economic resilience is on the one hand the ability of a system to maintain its state in the event of a shock (static concept) and at the same time the speed of recovery from that shock (dynamic concept).

The current literature provides many studies that reflect on the choice of appropriate indicators or apply them directly to specific cases. The following table summarises several studies, including the choice of specific indicators, research methods and conclusions.

Based on Table 1, the choice of indicators, or the number of them, can be described as entirely subjective to the needs of the authors. Some limited their research to only one indicator (Martin, 2012; Di Caro, 2014), while Cutter et al. (2008), who developed a model for comparative assessment of resilience to natural disasters (DROP), based their research on as many as 29 indicators.

Particularly when examining resilience to economic shocks, (un)employment can be identified as a crucial indicator, which has been a key indicator in number of studies (Foster, 2007; Cutter et al., 2008; Briguglio et al., 2009; Davies, 2011; Martin, 2012; Di Caro, 2014; Kitsos & Bishop, 2018). In terms of changes in (un)employment, both Martin (2012) and Davies (2011) reached the same conclusions – industrial regions are less resilient to shocks.

Table 1. Literature review of resilience

authors	regions	indicators	methods	conclusions
Foster (2007)	Buffalo-Niagara Falls MA (1970-2000)	change in employment, population change, per capita income, poverty	economic indexes	weak resistance of the investigated region to metropolitan regions, resistance as a four-phase cycle
Cardona et al. (2008)	14 countries in America (2000)	insurance and collateral payments, disaster reserve fund, donations, new taxes, budget reallocation, external loans, international reserves	disaster deficit index	creation of an index that examines the fiscal position and potential loss of countries in the Americas, particularly in the event of extreme disasters
Cutter et al. (2008)	natural disasters	quality of life, transport network, municipal income, wealth creation, demography, employment, etc. (29)	DROP model (composite index)	creation of a model for comparative assessment of resistance to natural disasters
Briguglio et al. (2009)	86 countries	inflation and unemployment, interest rates, external debt, education, fiscal deficit, etc. (13)	composite index, regression analysis	countries' performance is related to their vulnerability and resilience, the resilience index is highly correlated with GDP per capita
Davies (2011)	regions in Europe (2008-2010)	unemployment, GDP per capita, population density, government intervention (business support)	regression and correlation analysis, semi-structured interviews	higher impact of unemployment growth on industrial regions, importance of government support
Martin (2012)	UK regions (1970-2010)	employment	economic indexes	high impact of recession on industrial regions, their low recovery and structural changes
Graziano & Rizzi (2013)	Italian provinces (2007-2011)	bank deposits, loans to companies, total consumption, income per capita (19)	factor analysis (PCA)	higher economic, social and environmental resilience of northern Italian provinces,
Di Caro (2014)	Italian regions (1970-2010)	employment	SUR model, vector error correction model	higher resistance of the northern Italian regions in terms of engineering and ecological resistance
Kitsos & Bishop (2018)	local authority districts of Great Britain (2004-2014)	employment, population density, education, specialization (18)	correlation analysis, linear regression models	higher losses in regions with higher employment rates, especially in the north of the country
Xie et al. (2018)	earthquake in Weunchan (2008-2011)	loss of GDP, sectoral property damage, government investment in recovery	dynamic computable general equilibrium (CGE model)	resilience strategies could significantly reduce GDP losses from 2008-2011 by nearly 50%, the importance of investment in recovery

The evidence came from both Martin (2012), who focused only on UK regions between 1970 and 2010, and Davies (2011), who focused on a few European regions over a much narrower period (2008-2010), i.e. during the financial crisis. Based on these studies, the clear conclusion is that regional policy attention should be primarily focused on regions where there is a higher concentration of manufacturing industry.

The difference at the local scale is noted at the level of Italian regions by Graziano and Rizzi (2013) and Di Caro (2014), who point to significant differences in the resilience of northern and southern regions. Although the northern part of Italy has a smaller population than the south, in the long run the regions in this area have higher GDP per capita. Briguglio et al. (2009) also highlighted the importance of this indicator as an important indicator of regional resilience. Graziano and Rizzi (2013), using PCA, constructed indexes that fully demonstrated that northern Italian regions have higher resilience in the long run, and moreover in all areas of sustainable development (economic, social and environmental).

3. Data and Methodology

For the construction of the index, data for 22 selected countries were collected from the OECD, Eurostat and the European Commission's websites for the years 2020 and 2021, by taking the average of these two years. The selection of countries was made according to the availability of data for each indicator, namely: i) fiscal surplus (in % of GDP), ii) misery index (in %), iii) year-on-year change in public debt (in % of GDP), iv) digital economy and society index (DESI, 0-100), v) trust in government policy (in %), vi) net savings rate (in % of GDP).

3.1. Selection of Indicators and Hypothesis

The first trio of indicators is based on the work of Briguglio et al. (2009), who constructed a resilience index for 86 different countries. This index was based on four core areas (macroeconomic stability, microeconomic stability, good governance and social development), and for the purposes of this paper only the macroeconomic stability dimension was considered. However, there is some modification compared to this study – instead of fiscal deficit, fiscal surplus is considered, misery index is modified and expanded to include real economic growth, and instead of external public debt, year-on-year change in public debt to GDP is considered. The misery index is expanded by real economic growth to better reflect the state of the economy and, as in the previous case, the reverse is considered, i.e. the sum of unemployment and inflation is subtracted from economic growth. Finally, the level of external public debt has been replaced by the dynamics of the reduction of public debt to GDP, with the same purpose that a positive value determines the desired state – a reduction of public debt.

Based on the conclusions of Fišera (2022), DESI was considered as an additional indicator to reflect the digital maturity of EU countries. The author is of the opinion that higher investment in digital infrastructure will allow to better withstand similar shocks in the future. For some countries in particular, Sweden being a case in point, it has been shown that trust in government policy can be an important metric, not only in times when society has been called upon to comply with epidemic measures, but especially in times of rising debt, when understanding in the event of higher taxation or reduced public spending will be important. The inclusion of these 'new' indicators leads to the following hypothesis:

- H_1: Digitalization and trust in government policy are important resilience factors.

The last indicator relates to the potential of the economy, particularly in the recovery phase, namely the net savings-to-GDP ratio. This indicator was chosen because savings play a key role in the economy and their level significantly affects future consumption and investment activity.

Furthermore, as Briguglio et al. (2009) have shown, the resilience index is positively correlated with GDP per capita, so this hypothesis is also tested here beyond the construction of the index:

- H_2: There is a significant relationship between the resilience index and GDP per capita.

3.2. Principal Component Analysis

The economic resilience index was constructed through PCA, like Graziano and Rizzi (2013). This multivariate statistical method aims to transform the original number of variables into a lower number of new variables, called components, which have more appropriate properties than the original variables – they are lower in number, explain almost all of the original variability, are uncorrelated with each other and are a linear combination of the original variables (Karamizadeh et al., 2013). The method is based on a source data matrix where the rows represent *n* objects and the columns represent *p* features (variables). The source matrix has the form:

$$\boldsymbol{X}(n\ x\ p) = \begin{bmatrix} X_{11} & \cdots & X_{1p} \\ \vdots & \ddots & \vdots \\ X_{n1} & \cdots & X_{np} \end{bmatrix} \tag{1}$$

The essence of this method is the approximation of a source data matrix *X* containing *n* measurements for *p** principal components. Typically, a correlation matrix is first constructed by examining the correlation between the variables based on the respective correlation coefficients r_{jk} (for j, k = 1, ..., p), which can take the values $-1 \leq r_{jk} \leq 1$:

$$(p\ x\ p) = \begin{bmatrix} 1 & \cdots & r_{1p} \\ \vdots & \ddots & \vdots \\ r_{p1} & \cdots & 1 \end{bmatrix} \tag{2}$$

In the next step, it is recommended to use two tests – the Kaiser-Meyer-Olkin test designed to check whether the application of PCA to the data set makes sense, and the Bartlett's test to check for homoskedasticity, i.e. whether all random variables have the same finite variance. The first test follows the so-called Kaiser-Meyer-Olkin criterion, which can take values between 0 and 1:

$$KMO = \frac{\sum\sum_{j\neq k} r_{jk}^2}{\sum\sum_{j\neq k} r_{jk}^2 + \sum\sum_{j\neq k} p_{jk}^2} \tag{3}$$

where r_{jk} are the relevant correlations (see equation 2) and p_{jk} define the so-called partial correlations. The value of this criterion should be at least 0.5, otherwise the use of this method cannot be considered acceptable. The Bartlett's test is based on the following equation:

$$K\chi^2 = \frac{(N-k)\, ln\left(S_p^2\right) - \sum_{i=1}^{k}(n_i - 1) ln\left(S_p^2\right)}{1 + \frac{1}{3(k-1)}\left(\sum_{i=1}^{k}\left(\frac{1}{n_i - 1}\right) - \frac{1}{N-k}\right)} \tag{4}$$

where $N = \sum_{i=1}^{k} n_i$ a $S_p^2 = \frac{1}{N-k}\sum_i (n_i - 1) S_i^2$ are the pooled variance estimates. This test has approximately a χ_{k-1}^2 distribution. The null hypothesis is rejected if $\chi^2 > \chi_{k-1,\alpha}^2$. If the null hypothesis is rejected, the data must be standardized. Standardization occurs even if the random variables are expressed in different units. Standardization is determined by the following equation:

$$\begin{aligned} Z_1 &= \frac{(X_1 - \mu_1)}{\sqrt{\sigma_{11}}} \\ &\vdots \\ Z_p &= \frac{(X_1 - \mu_1)}{\sqrt{\sigma_{pp}}} \end{aligned} \tag{5}$$

where μ is the vector of means and σ is the corresponding standard deviation. The standardization of the original variables can also be written in matrix form:

$$Z = (V^{\frac{1}{2}})^{-1}\,(X - \mu) \tag{6}$$

Where

$$V^{\frac{1}{2}}(p\ x\ p) = \begin{bmatrix} \sqrt{\sigma_{11}} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \sqrt{\sigma_{pp}} \end{bmatrix} \tag{7}$$

For the i-th principal component obtained as a linear combination of standardized variables:

$$Y_i = \omega_i^T z = \omega_1^T\,(V^{\frac{1}{2}})^{-1}\,(X - \mu) \tag{8}$$

where ω represents the eigenvectors. These determine the weight of each of the principal components. The principal components are ordered such that the first component (PC_1) explains the largest variability in the original data. Further, the following components are uncorrelated with the previous components. As for the appropriate number of principal components, this choice depends to some extent on the subjective view of the author. However, Kaiser (1960) recommends number of principal components for which the eigenvalue is at least 1. A more detailed description and construction of PCA is developed in Johnson and Wichern (2007).

Mathematical and statistical calculations in the application of this method were performed exclusively in STATISTICA 12, SPSS and Microsoft EXCEL software.

4. Results

A sample correlation matrix was first constructed from a matrix of original data averaged over 2020 and 2021 across the indicators (see Table 2).

Table 2. Correlation matrix

indicators	DESI	trust in government	net savings rate	fiscal surplus	misery index	reduction of public debt
DESI	1					
trust in government	0.80	1				
net savings rate	0.70	0.54	1			
fiscal surplus	0.68	0.66	0.72	1		
misery index	0.34	0.29	0.61	0.52	1	
reduction of public debt	0.02	0.23	-0.14	0.05	-0.05	1

The correlation matrix shows significant relationships between the variables, and a correlation of at least 0.5 can be considered a relevant relationship. Net savings rate (0.72), DESI (0.68) and trust in government (0.66) are the most strongly correlated with this indicator.

The next step tested the significance of applying PCA to the original dataset or checking the agreement of variances for possible data standardization.

Table 3. Assessing the suitability of applying PCA and testing for homoscedasticity

The Kaiser Meyer Olkin test	Bartlett's test	
0.750	value of the testing criteria	61.624
	p-value	0.000

Table 3 shows the results of The Kaiser Meyer Olkin test when the use of PCA was recommended, as the value of 0.750 was well above the allowable limit of 0.5. As for the Bartlett's test, the null hypothesis of agreement of variances was rejected at any level of significance, as shown by the null p-value (for the purpose of this paper, a standard *p*-value of 0.05 was considered). Before the necessary standardization, the principal components were determined based on the eigenvalue (see Table 4).

Table 4. Eigenvalues of the principal components

components	eigenvalues	the % of overall variance	cumulative share in %
1	3.379	56.310	56.310
2	1.154	19.233	75.542
3	0.759	12.656	88.198
4	0.298	4.965	93.163
5	0.268	4.463	97.626
6	0.142	2.374	100.000

The first two principal components reach an eigenvalue greater than 1, with the former explaining more than half of the original variability in the data (56.310%) and the latter 19.233%, cumulatively explaining 75.542% of the original variability. From the point of view of further progress, this proportion can be found to be sufficient.

Table 5. Standardized correlation matrix of indicators and components

indicators	comp_1	comp_2	comp_3	comp_4	comp_5	comp_6
DESI	0.475	0.106	-0.393	0.299	0.234	0.681
trust in government	0.445	0.350	-0.292	0.356	-0.407	-0.550
net savings rate	0.473	-0.254	0.066	-0.144	0.707	-0.431
fiscal surplus	0.480	0.001	0.035	-0.771	-0.386	0.157
misery index	0.349	-0.314	0.733	0.402	-0.249	0.137
reduction of public debt	0.028	0.839	0.466	-0.079	0.262	0.063

Table 5 already presents a standardized matrix of indicators and principal components. Attention has been focused exclusively on the first two components. For the first component, we can observe more significant positive relationships approaching 0.5 for DESI (0.475), trust in government (0.445), net savings rate (0.473), fiscal surplus (0.480) and already slightly more distant misery index (0.349). However, there is no doubt that this component is affected by these indicators in a positive sense, as evidenced by the positive values. The remaining indicator (reduction of public debt) is explained by the second component (0.839), again in a positive sense. Based on these findings, the Economic Resilience Index (ERI) can be calculated using the following equation:

$$ERI = 0.563 \cdot COMP\_1 + 0.192 \cdot COMP\_2 \tag{9}$$

The Economic Resilience Index was determined sequentially for all 22 selected countries, with index values ranging between -0.88 and 1.26 (see Appendix). It is true that a larger value within the index indicates a higher resilience of a country to the Covid-19 pandemic for the years 2020 and 2021.

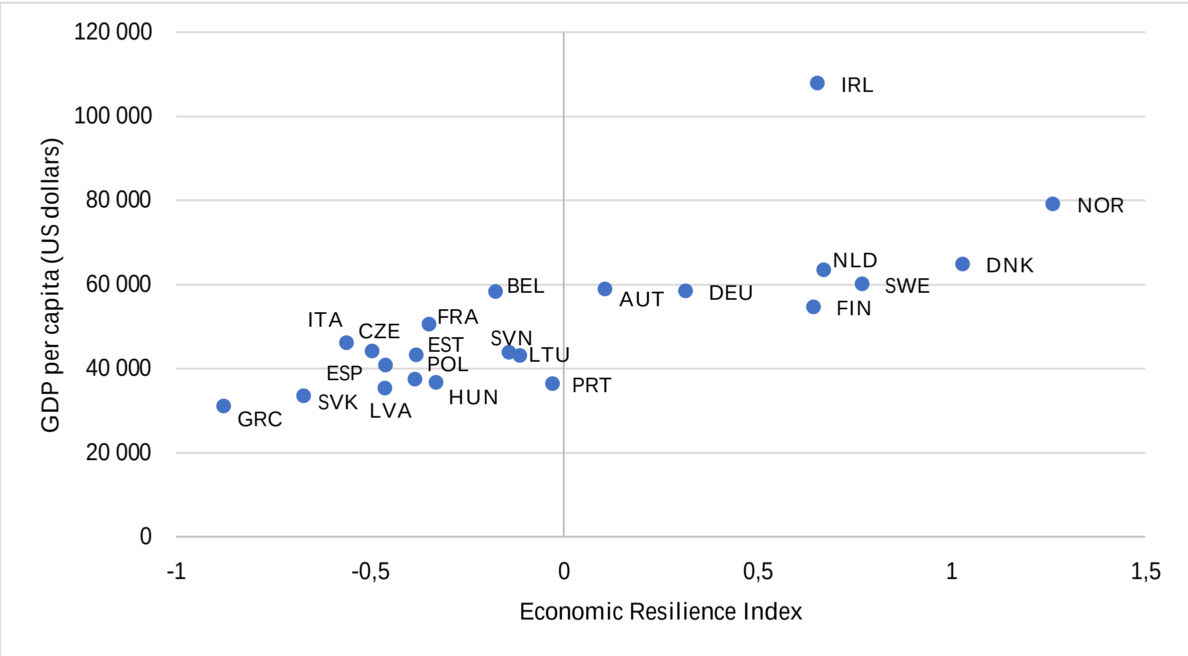

Figure 1. GDP per capita in 2021 and Economic Resilience Index (own processing based on OECD (2022))

The ERI values were then used in a regression analysis with GDP per capita to test the hypothesis of whether a significant relationship can be seen between regional resilience and this important macroeconomic indicator.

Figure 1 clearly shows that there is a strong relationship between ERI and GDP per capita, with countries with higher GDP per capita generally also achieve higher ERI values. Despite the outlier for Ireland, the correlation between the indicators reaches 0.767, which explains the relatively strong correlation.

5. Discussion

There is no disputing that the Covid-19 pandemic was an unexpected shock that caused significant losses to economies around the world. On the other hand, there have been significant differences between countries in terms of their economic downturn and their now gradual return to their pre-pandemic trajectory. The ERI values constructed in this study clearly show which countries, based on selected indicators, have performed more resiliently over 2020 and 2021, and conversely which countries have experienced greater economic downturns. The highest ERI values are generally achieved by the Nordic countries, namely Norway (1.26), Denmark (1.03), Sweden (0.77). In contrast, the least resilient countries are Greece (-0.88), Slovakia (-0.67) and Italy (-0.56), and others (see Appendix).

The correlation analysis showed a significant relationship between fiscal surplus (deficit) and trust in government policy as well as the level of digitalization (DESI), satisfying the first hypothesis H1. At the same time, the findings of Fišera (2022) that countries with higher levels of digitalization and higher trust in government policy were more resilient in times of pandemics were confirmed. Countries such as Norway, Denmark and Sweden can be characterized as digitally advanced countries with high trust in government policy, which is undoubtedly reflected in the low deficits or even surpluses in public finances in recent years. Of course, more detailed conclusions would require deeper investigation into the actual setup of the processes taking place in these economies.

The Economic Resilience Index constructed in this study through PCA was able to explain more than 75% of the original data variability across countries and variables in 2020 and 2021 using only 2 principal components. In addition, a positive correlation between ERI and GDP per capita was confirmed across countries (Figure 1), thus satisfying the second hypothesis H2. It should be added that although different crises were assessed - the financial crisis examined in Briguglio et al. (2009) and Covid-19 in this study - and a different set of indicators were partly chosen, the relationship between resilience and GDP per capita remained.

In future research, it would be useful to extend the conclusions drawn to a longer time horizon, e.g. to include the period between the financial and pandemic crises. The fact that economies are still recovering from the pandemic and are currently facing an energy crisis and other negative effects also leads to considerations of a longer time horizon. There are also suggestions to expand the ERI to include other dimensions of resilience, such as social and environmental, which Graziano and Rizzi (2013) have previously included in their studies. A larger number of indicators would allow for a more comprehensive view of country resilience in the future. Furthermore, the possibility of removing outliers can be discussed.

6. Conclusions

The aim of this paper was to compare the resilience of 22 European countries for the years 2020 and 2021 and to test two related hypotheses. The Economic Resilience Index allowed a comparison of individual European countries in terms of their resilience in a pandemic. It showed that the Nordic countries are outperforming the rest of Europe on this measure, which should evoke an increased interest in examining economic policies in these countries and then applying proven principles and processes, of course, taking into account the limits and differences between countries. Clearly, economic policy makers should conclude the increasing importance of investment in digital infrastructure as well as the much more difficult task of building greater trust in government policy, both of which have been shown in this study to have a significant impact on country resilience. In addition, a strong positive correlation between resilience and GDP per capita has been demonstrated, with better performing economies better able to absorb shocks and more easily bounce back. Finally, in applying the index, it was recommended to consider including a longer time horizon, a higher number of indicators, expanding the index to include social and environmental dimensions, or eliminating outliers.

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Appendix

Table A1. Average Values of Variables for Selected Countries (2020, 2021), Economic Resilience Index

country	DESI	trust in government	net savings rate	fiscal surplus	misery index	reduction of public debt	ERI	rank
Austria	55.60	61.84	8.73	-6.97	-9.14	-0.08	0.10	8
Belgium	56.20	38.40	6.12	-7.27	-7.25	-0.06	-0.18	12
Czech Republic	49.10	30.17	5.75	-5.44	-7.18	-0.19	-0.50	19
Denmark	69.60	68.38	14.21	1.92	-5.05	-0.06	1.03	2
Estonia	60.40	49.21	12.25	-3.94	-4.80	-0.57	-0.38	15
Finland	69.70	76.12	5.97	-4.11	-8.54	-0.06	0.64	6
France	51.40	42.20	3.16	-7.76	-9.56	-0.08	-0.35	14
Germany	55.10	62.95	10.44	-4.03	-6.18	-0.08	0.31	7
Greece	37.30	39.96	-6.82	-8.69	-16.54	-0.04	-0.88	22
Hungary	44.35	42.27	8.94	-7.34	-7.01	-0.09	-0.33	13
Ireland	61.05	60.58	10.34	-3.35	2.43	0.02	0.65	5
Italy	44.55	36.44	3.53	-8.36	-11.50	-0.07	-0.56	20
Latvia	50.10	30.07	1.29	-5.66	-8.63	-0.10	-0.46	18
Lithuania	52.85	38.89	8.51	-4.01	-7.76	-0.12	-0.12	10
Netherlands	66.40	68.27	10.47	-3.16	-6.01	-0.05	0.67	4
Norway	66.35	80.14	16.65	3.65	-5.39	-0.04	1.26	1
Poland	43.00	26.62	9.10	-4.38	-5.15	-0.10	-0.38	16
Portugal	49.70	59.55	-0.97	-4.36	-8.88	-0.05	-0.03	9
Slovak Republic	44.20	26.16	1.78	-5.41	-9.49	-0.15	-0.67	21
Slovenia	52.00	39.61	7.95	-6.20	-3.86	-0.08	-0.14	11
Spain	57.45	37.68	4.16	-8.50	-19.45	-0.11	-0.46	17
Sweden	67.90	65.23	13.63	-1.43	-8.75	-0.05	0.77	3