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In•Stream

Constructing a robust indicator set for sustainable growth? – The quantitative analysis of IN STREAM

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Quantitative research @ IN-STREAM

WP1. COORDINATION

Qualitative Assessment

WP2. Review existing measures in the EU context + ind. selection

Qualitative/Quantitative linking

WP3. Relate existing measures of sust. to economic performances

Quantitative Assessment

WP4. data on key SD targets

WP5. Analyze sustainability in partial equilibrium

WP6. Analyze sustainability in general equilibrium

Integrated Assessment

WP7. Institutional engagement and policy implications

WP8. Recommended approaches and strategies

WP9. DISSEMINATION

Key objectives of INSTREAM quantitative analyses

- ✓ Identifying and estimating the link between mainstream economic indicators and key well-being and sustainability indicators → statistical analyses and econometric techniques.

- ✓ Offering quantitative insight into the synergies and trade-offs implicit in Europe's pursuit of economic growth and environmental sustainability → bottom-up and top-down modelling approaches, EU wide and country analyses.

- ✓ Recommending new approaches to the use of SD indicator (and sets of indicators) based on their robustness, feasibility and suitability to EU policy objectives → role of composite indicators and new uses of existing tools →models.

The idea within INSTREAM

(a) suggesting the coupling of indicators with existing widely used modelling tools → Analizing sustainability and the performance of a composite SI within the framework offered by an economic (CGE) model

Testing with this approach:

- To what extent sustainability could be measured *ex-ante* and not only ex-post.
- the advantages of having different dimensions of sustainability (measurable by the models) "connected" and mutually consistent.
- the advantages to work in a controlled environment where it can be easier to perform quantitative assessments and evaluations (sensitivity).

In addition: if and how much the composite indicator (FSI) moves beyond GDP (even though GDP is certainly one of its components).

The model used: ICES

- ✓ It is a dynamic, multi-regional CGE model of the world economy, based on country and region-specific Social Accounting Matrices (SAM). These describe trade, supply and demand flows to and for all the regions and sectors represented.
- ✓ The model is calibrated in 2001, data are provided by GTAP6 database. The present version offers a detail of 40 countries/macro-regions and 17 economic sectors.
- ✓ It replicates a specific "reference scenario" until 2020 (agreed as common benchmark among INSTREAM partners to allow comparability with other modelling exercises).

Sustainability measured by the composite indicator is assessed in the reference and in the policy scenario (-20% unilateral emission reduction by the EU in 2020 compared to 1990)

Indicator set and composite indicator (FSI)

1. **Selection of indicators**
   Based on the list decided within the INSTREAM research team and compatible with model capabilities.

2. **Construction/calculation of indicators**
   Starting from the output of the ICES model (in the baseline and policy case).

3. **Normalization of indicators**
   Following a policy-oriented benchmarking procedure in order to achieve full comparability of across indicators

4. **Aggregation of indicators**
   Condensing information into a single index using a methodology that accounts for interactions between indicators.

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1. Definition/Calculation of indicators from the CGE model

SD Dimension	INDICATORS	DESCRIPTION
Economic	*GDP per capita*	GDP PPP / population
	Consumption per capita	Consumption expenditure PPP / population
	Relative trade Balance	Trade Balance / market openness *100
	Capital stock per capita	Capital stock PPP/ population
	Capital stock growth rate	(Capital stock(t) - Capital stock(t-1))/ Capital stock(t-1) *100
	Investment as %GDP	Investment / GDP*100
	Terms of trade	Value of export / Value of imports
	Total R&D expenditure as %GDP	R&D expenditure / GDP *100
Environmental	*Energy Intensity*	Energy Use / GDP PPP (Toe/ ml$)
	Greenhouse gases emission per capita	N_2O+CH_4+CO_2 emissions / Population (Tons CO2 eq. per capita)
	Greenhouse gases Intensity	N_2O+CH_4+CO_2 emissions / GDP PPP (Tons CO2 eq/ml $)
	CO_2 intensity	CO_2 emissions / Energy consumption (Tons CO2 eq/ Toe)
	Share of Energy imported	Energy imported/total energy consumption (Toe/Toe)
	Share of Renewable	Renewable energy consumption/ Total energy consumption (Toe/Toe)
	Plant biodiversity	Endangered plants/ total plants*100
	Animal biodiversity	Endangered animals/ total animals*100
	Water	Water use/ water available
Social	*Population growth rate*	Population growth rate
	Food consumption	Food consumption / Private expenditure*100
	Insurance	Insurance expenditure/ GDP *100
	Education	Education expenditure/ GDP *100
	Private health expenditure	Private health expenditure/ Total health expenditure*100
	Total health expenditure	Total health expenditure/GDP*100

2. Normalisation of indicators

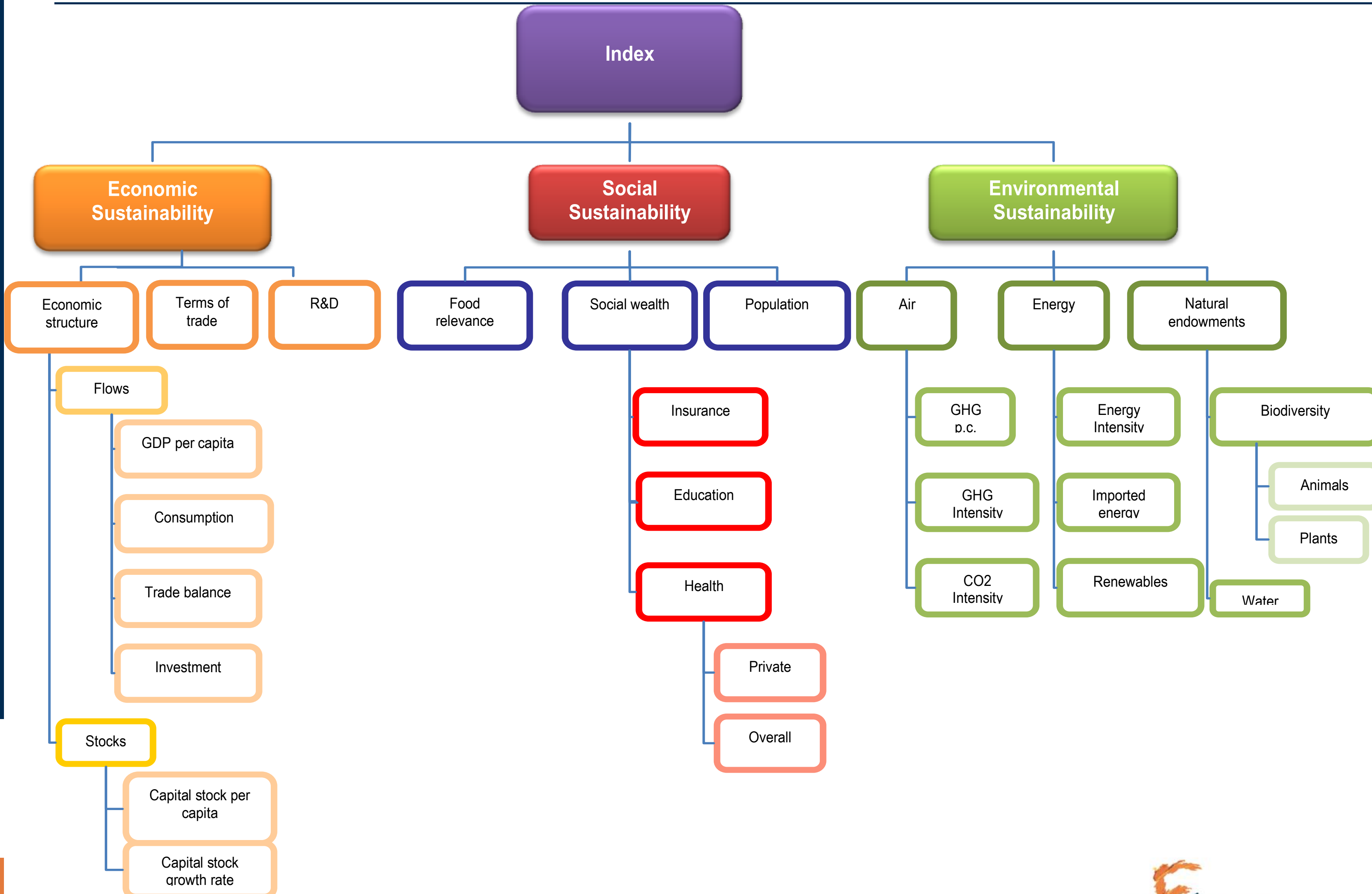
- ✓ Use of a benchmarking normalisation technique → Each indicator is rescaled in the interval 0-1

0	extremely unsustainable situation
0.25	indicator is still not sustainable but not as severely as in the previous case
0.50	a discrete level of sustainability, but still far from target
0.75	satisfactory level in the sustainability, yet not on target
1	target level, fully sustainable

- ✓ Benchmarks are policy-oriented when possible. When not, the threshold values characterizing each interval are calibrated on World performances

- ✓ Each step has been “linearised”, taking the mean values of two subsequent intervals and interpolating, thereby creating a continuous function.

3. Aggregation of indicators



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3. Aggregation of indicators: weighting

Weights are the result of "expert'" evaluations (10 FEEM researchers and 2 external → now on line survey at: https://qtrial.qualtrics.com/SE/?SID=SV_6RmkARfykrii2zy You are very welcome to answer!!!)

The idea is to assign weights trough a procedure which takes into account interactions among indicators → for instance that having two indicators performing well (or badly) together is different from having each of them performing well (or badly). There could be synergies or redundancies.

How to do this?

In technical terms this implies moving from an additive (i.e. a full even though not perfect substitutability) to a non additive approach and then aggregating using the Choquet Integral technique.

In practice this implies asking experts to express weights referred not only to each single indicator, but also to all their possible combinations.

Assume 3 indicators. Additive (standard) weighting => 3 weights; non additive =>2^3=8 weights (if no interactions, non additive boils down to additive)

Contribution of indicators to index

Indicator	Contribution
Food relevance	12.22%
Population	9.72%
R&D	9.21%
Water	8.26%
Terms of trade	5.67%
Energy intensity	4.91%
Renewables	4.26%
Education	4.18%
Imported energy	3.93%
CO2 intensity	3.83%
Plants	3.55%
GHG intensity	3.32%
Capital stock per capita	3.23%
Animals	3.21%
Overall health	3.08%
GHG per capita	3.07%
GDP p.c.	2.69%
Insurance	2.47%
Consumption	2.29%
Capital stock growth rate	2.15%
Investment	1.91%
Private health	1.66%
Relative trade balance	1.18%
Sum	100%

- ✓ The Shapley index describes the relative importance of each indicators or node in the FSI tree
- ✓ It explicits the weights given by the decision makers to each single indicators or node.

Index	Economic Sustainability	28.33%
	Social Sustainability	33.33%
	Environmental Sustainability	38.33%

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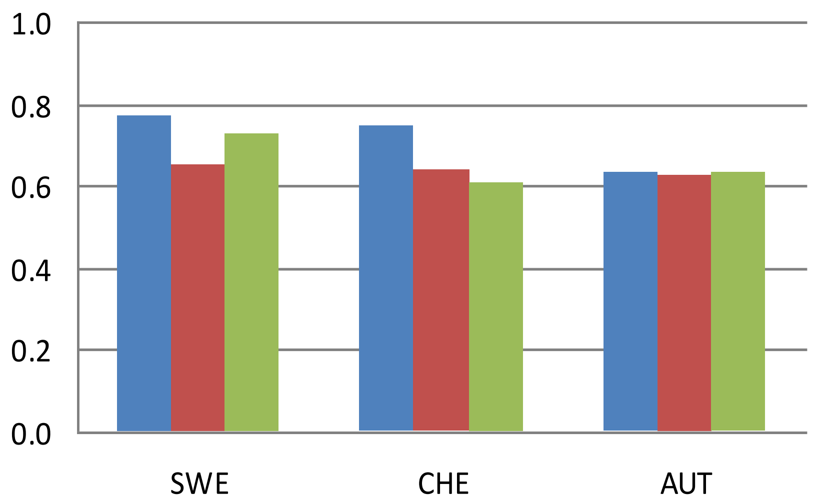
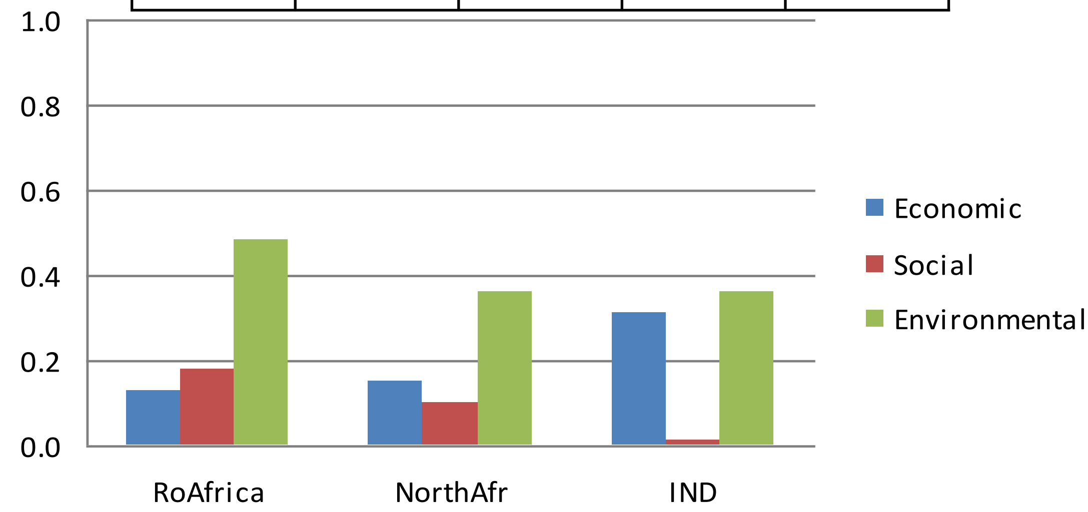
Baseline top 10-3 countries (Left) and bottom 10-3 (Right)

Regions	2010 baseline	Rank	2020 baseline	Regions
SWE	0.684	=	0.685	SWE
CHE	0.632	-1	0.649	AUT
AUT	0.628	1	0.635	CHE
FIN	0.620	=	0.631	FIN
GBR	0.583	=	0.618	GBR
FRA	0.574	=	0.597	FRA
DNK	0.561	-2	0.579	CAN
CAN	0.560	1	0.575	GER
JPN	0.557	-1	0.567	DNK
GER	0.549	2	0.567	JPN

Regions	2010 baseline	Rank	2020 baseline	Regions
POL	0.313	=	0.349	POL
BUL	0.294	=	0.329	BUL
RoLA	0.282	-1	0.318	RoAsia
FSU	0.274	-2	0.313	RoLA
TUR	0.266	5	0.276	CHN
CHN	0.257	1	0.244	FSU
MEast	0.231	=	0.239	MEast
RoAfr.	0.211	=	0.218	RoAfr.
NorthAfr	0.158	=	0.176	NorthAfr
IND	0.143	=	0.154	IND





Comparison among different aggregation methodologies

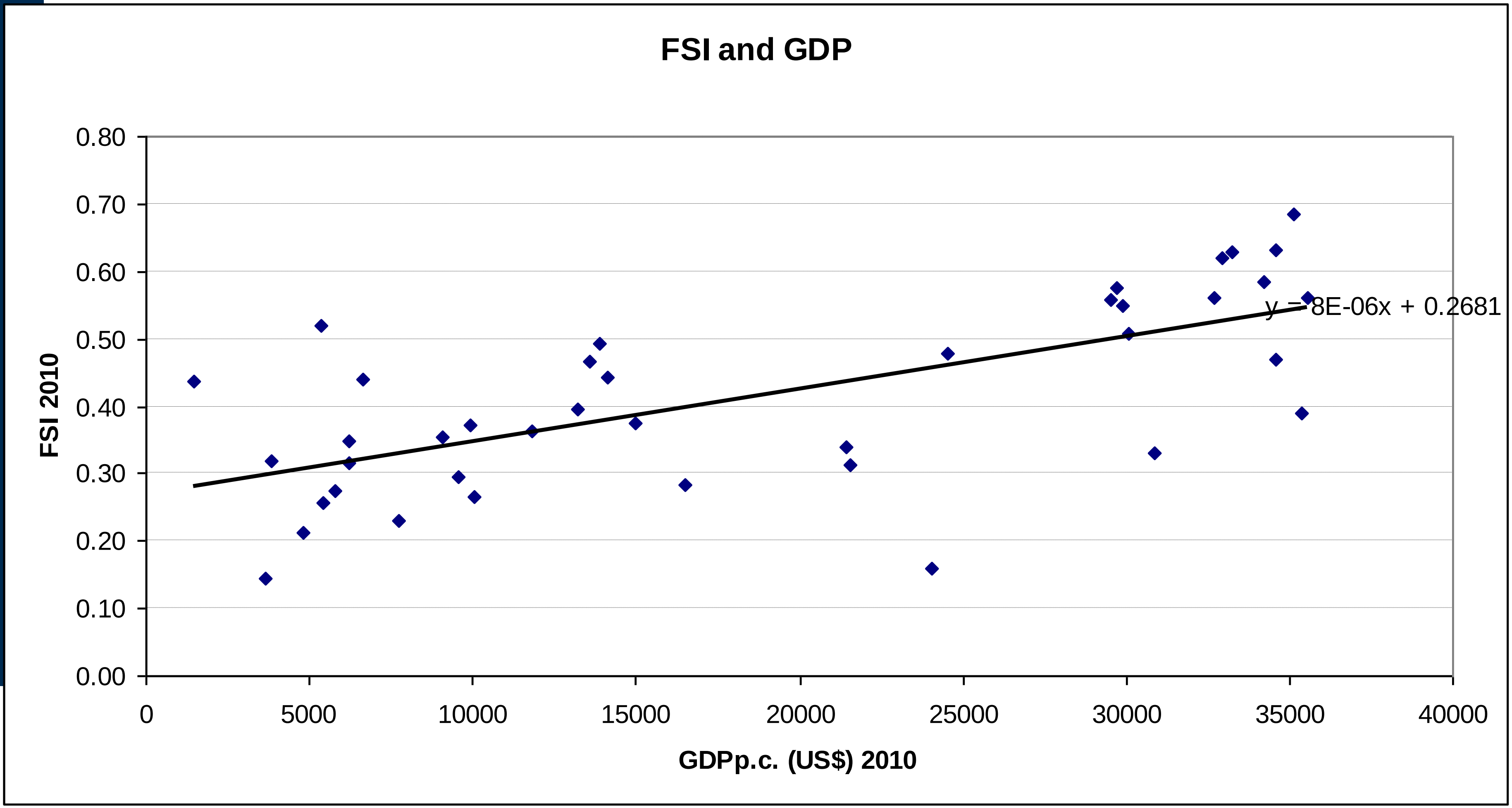
Comparison between the top ten performers in FSI in 2010 with:

- FSI_23 which equally weights all indicators (1/23).
- FSI_3 which equally weights indicators in each node, which implies a weight of 1/3 for each of the three pillars of sustainability and 1/n (n number of indicators in the node) for each node.

Region	FSI		FSI 23	Region
SWE	0.68	=	0.74	SWE
SWZ	0.63	=	0.70	SWZ
AUT	0.63	-3	0.68	FIN
FIN	0.62	1	0.68	DNK
GBR	0.58	-3	0.66	NOR
FRA	0.57	-4	0.65	AUT
DNK	0.56	3	0.64	CAN
CAN	0.56	1	0.64	GBR
JPN	0.56	=	0.64	JPN
GER	0.55	-1	0.62	FRA

Region	FSI		FSI3	Region
SWE	0.68	=	0.76	SWE
SWZ	0.63	-1	0.72	FIN
AUT	0.63	-4	0.72	SWZ
FIN	0.62	2	0.70	DNK
GBR	0.58	-6	0.68	JPN
FRA	0.57	-3	0.66	NOR
DNK	0.56	3	0.65	AUT
CAN	0.56	=	0.65	CAN
JPN	0.56	4	0.63	FRA
GER	0.55	=	0.63	GER

Correlation with GDP



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Sensitivity and robusteness

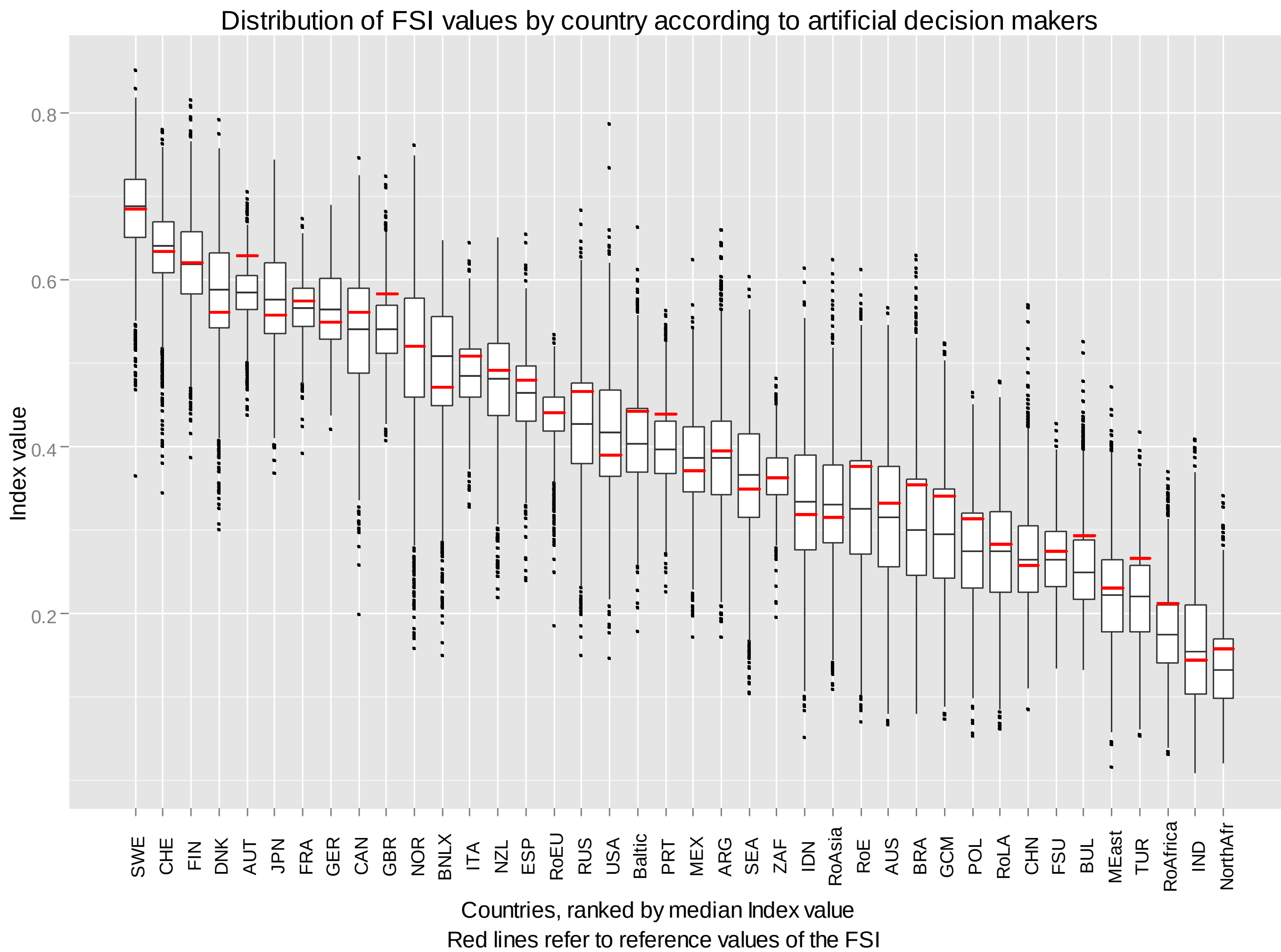
→ To introduce some variability in the determination of subjective weights, a set of 2000 artificial decision makers was generated, in order to simulate the aggregation of the indicators into the FSI using alternative evaluations.

→ Each decision maker provides a set of measures which varies within an interval of +/- 10% with respect to the weights in the original FSI.

→ Variation in the measures set corresponds to a more or less compensative behaviour in terms of willingness to reward lower or higher homogeneous performance of indicators.

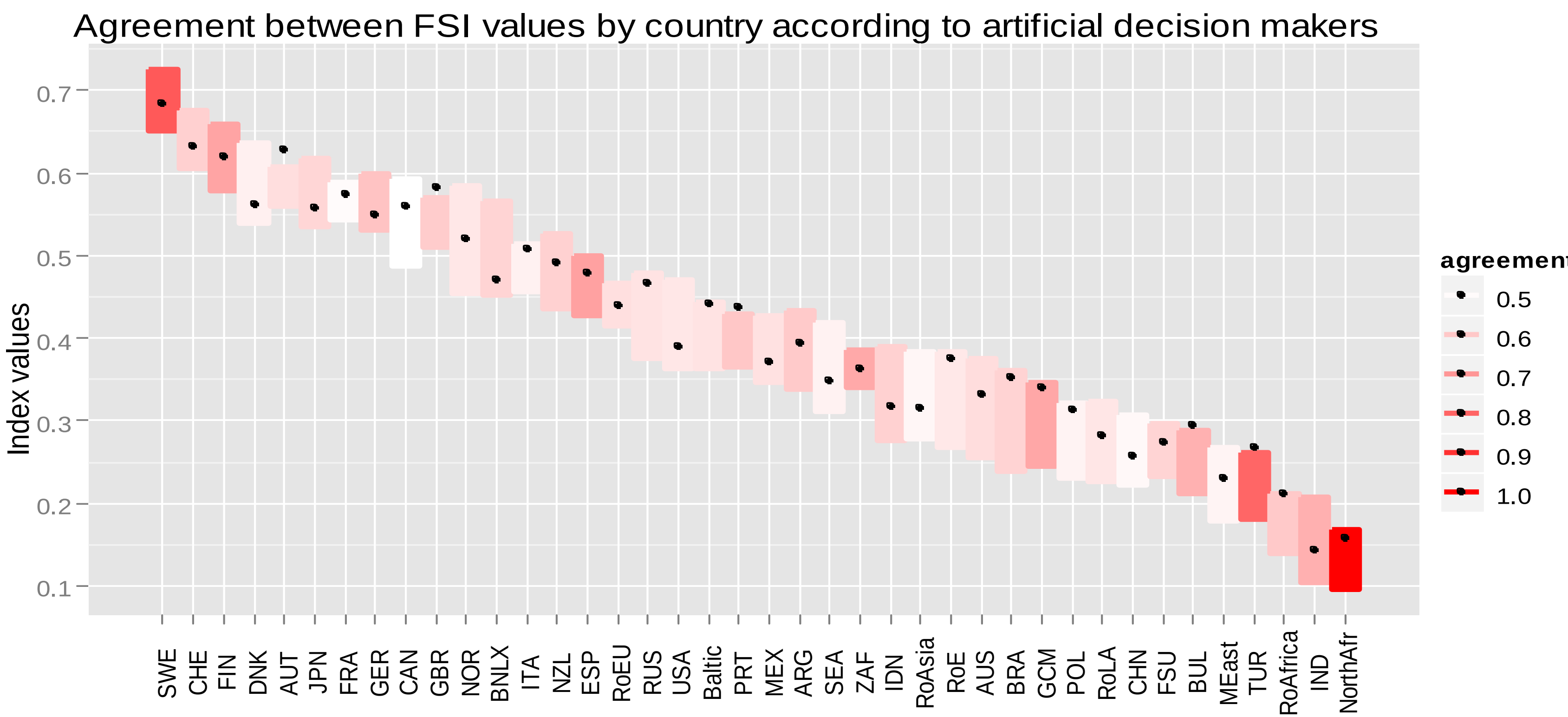
→ Artificial decision makers are given an arbitrarily large freedom in providing unbiased weights of criteria and coalitions of criteria for every node of the FSI tree, while making sure that they supply meaningful and sensible results.

Robustness ranking



Robustness ranking

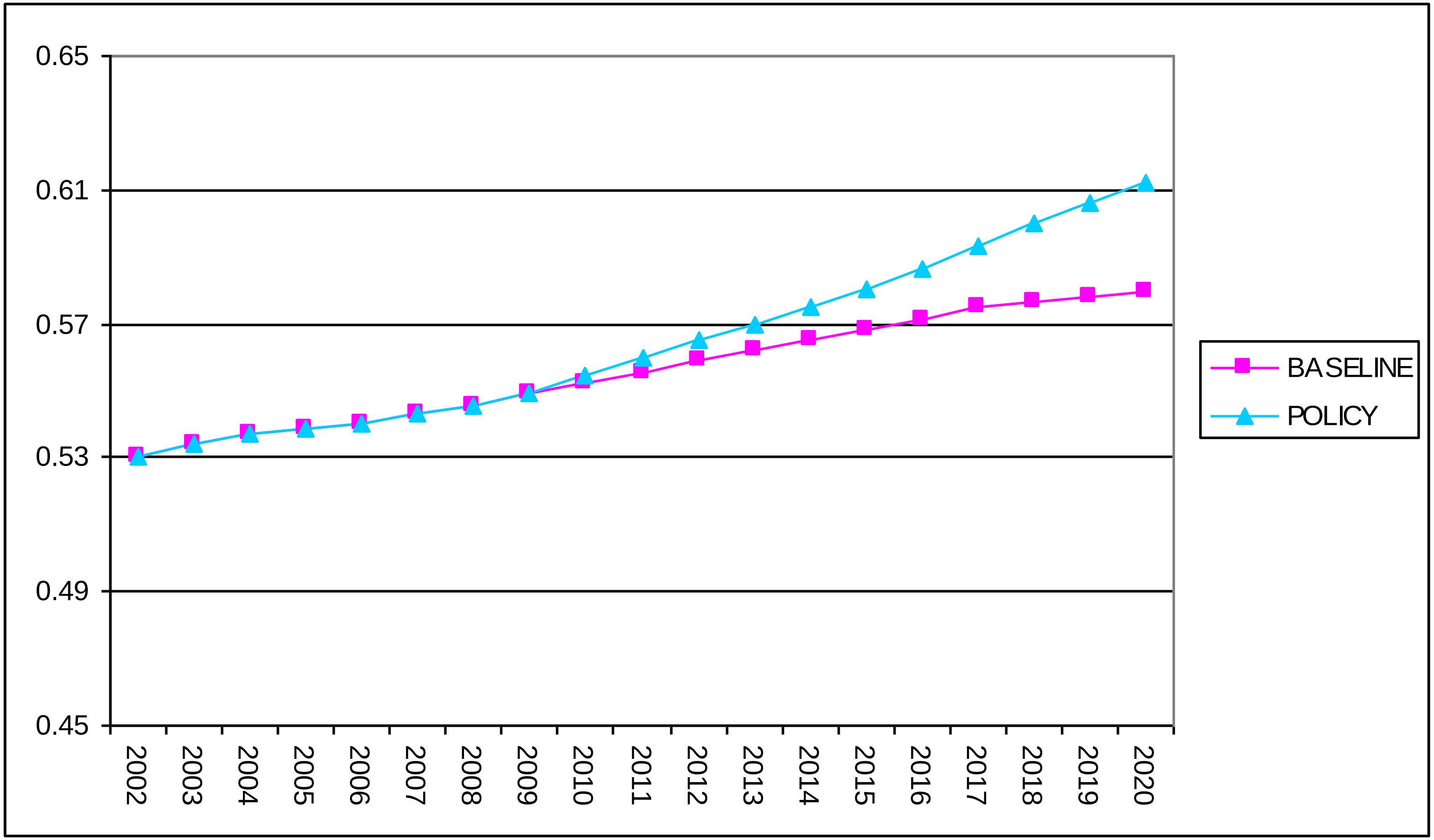
→ The measure of agreement of decision makers with respect to the median ranking is summarized in a single number for each country represented by the share of “artificial experts” agreeing that a country is more sustainable than the next one in the ranking (This measure would take a value of 1 if there is perfect agreement or 0.5 if only 50% of them agree that a given country is better than the next)



Boxplots refer to 50% Confidence intervals around median index value
Black points denote reference FSI values

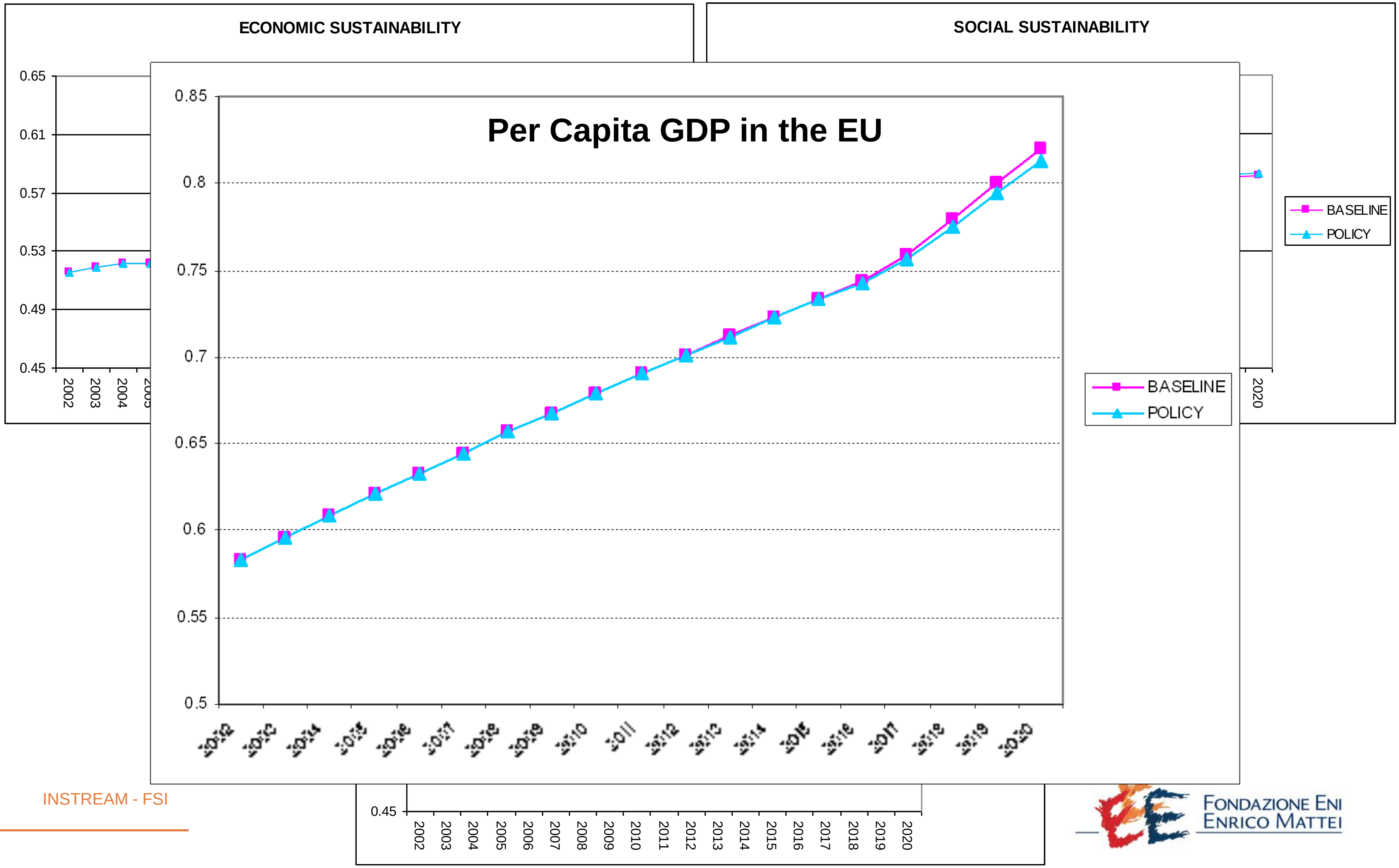
Sustainability implication of mitigation in the EU

FSI in the EU



Sustainability implication of mitigation in the EU

Economic, Social and Environmental pillars in the EU



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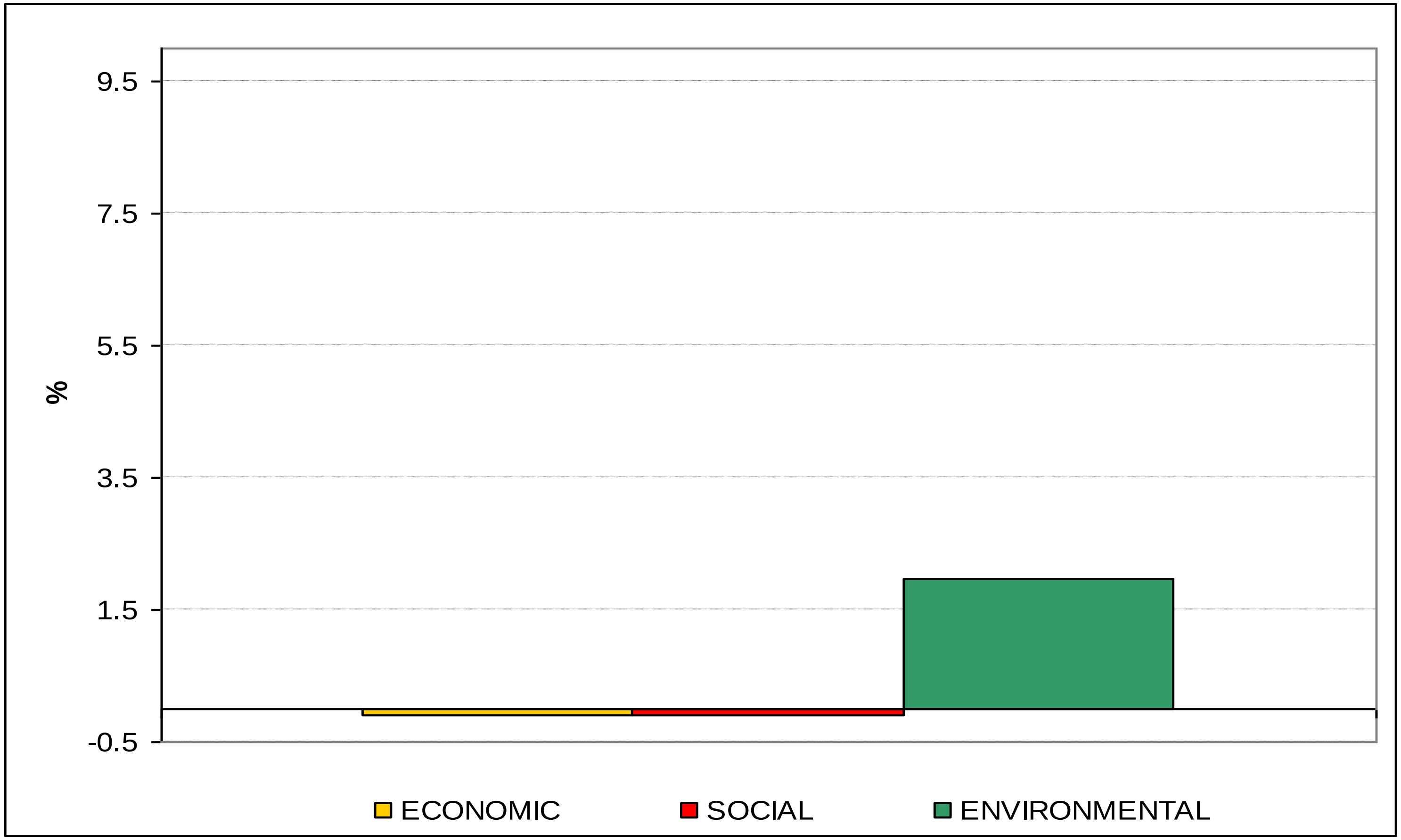
Sustainability implication of mitigation in the EU

Economic, Social and Environmental pillars: World



Conclusions

- Using CGE (but not necessarily only CGE) models to address the issue of sustainability can offer important additional tool to its study and to the evaluation of policy effects on it.

- The most important advantage is probably that of highlighting/measuring non trivial relations between different aspects of sustainability.

- A composite indicator has been also proposed showing that (a) it provides additional/different information from GDP and (b) the NA weighting procedure adopted produces different results than additive weighting.

- However most importantly, and extensible to all Cis, its major contribution is to make perfectly transparent the criteria leading to the synthetic valuation of sustainability. They are powerful communication devices. Weights as important as the final sustainability measure

- All this said it has to be recognized that the weaknesses of sustainability measures (uncertainty + subjectivity) sum up to those of the modelling tools…

Thanks!

Back up slides

FSI ranking 2020 baseline and policy

Region	2020 base	Rank	2020 policy	Region
SWE	0.69	=	0.69	SWE
AUT	0.65	=	0.67	AUT
SWZ	0.64	-1	0.64	FIN
FIN	0.63	1	0.64	SWZ
GBR	0.62	=	0.63	GBR
FRA	0.60	-1	0.60	GER
CAN	0.58	-2	0.60	FRA
GER	0.58	2	0.60	DNK
DNK	0.57	1	0.58	CAN
JPN	0.57	=	0.56	JPN
NOR	0.54	-1	0.55	ITA
ITA	0.54	1	0.54	NOR
NZL	0.51	-2	0.54	BNLX
BNLX	0.51	1	0.53	ESP
ESP	0.50	1	0.51	NZL
RUS	0.50	-1	0.51	RoEU
PRT	0.47	-1	0.50	RUS
Baltic	0.46	-1	0.49	PRT
RoEU	0.45	3	0.46	Baltic
SEA	0.42	-1	0.42	GCM
RoE	0.41	-1	0.41	SEA
GCM	0.40	2	0.40	RoE
USA	0.40	=	0.39	USA
BRA	0.39	=	0.39	BRA
MEX	0.39	=	0.38	MEX
ZAF	0.38	-2	0.38	POL
AUS	0.38	=	0.38	AUS
ARG	0.37	-1	0.37	ZAF
IDN	0.36	-1	0.36	ARG
TUR	0.35	-1	0.36	IDN
POL	0.35	5	0.35	TUR
BUL	0.33	=	0.34	BUL
RoAsia	0.32	=	0.32	RoAsia
RoLA	0.31	=	0.31	RoLA
CHN	0.28	=	0.28	CHN
FSU	0.24	=	0.25	FSU
MEast	0.24	=	0.24	MEast
RoAfrica	0.22	=	0.22	RoAfrica
NorthAfr	0.18	=	0.17	NorthAfr
IND	0.15	=	0.15	IND

4. Aggregation of indicators: weighting

Weights are the result of a "expert'" evaluations (via focus group)

→Expert assigned a weight to all possible combination of indicators in each node satisfing monotonicity

→The Möbius transformation accounts for synergic and redundancy interactions among elements in the coalition. If the Möbius weight is null, no interaction exists among the element of the subset, if it is positive there is a synergy, if negative, a redundancy.

SUSTAINABILITY			Weights	Normalized weights	Möbius transformation
Economic	Social	Environment			
Worst	Worst	Worst	0	0	0
Best	Worst	Worst	20	0.2	0.2
Worst	Best	Worst	50	0.5	0.5
Worst	Worst	Best	30	0.3	0.3
Best	Best	Worst	60	0.6	0.6-(0.2+0.5)=-0.1
Best	Worst	Best	50	0.5	0.5-(0.2+0.3)=0
Worst	Best	Best	90	0.9	0.9-(0.5+0.3)=0.1
Best	Best	Best	100	1	1

→ The Choquet integral, is a generalization of Weighted Average approach, can be directly calculated using the Möbius values as weights.

$$C_m(x_1,\dots,x_n) = \sum_{T \subseteq S} a(T) \cdot \min_{i \in T}(x_i)$$