# ESPON 2.1.1

## Cohesion Impacts

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# ESPON 2.1.1.
# Territorial Impact of EU Transport and TEN Policies

## Cohesion Impacts

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# Foreword

This report contains supplementary material to the Final Report of ESPON 2.1.1 'Territorial Impact of EU Transport and TEN Policies'. This supplementary material concerns the results of an analysis of the cohesion impacts of the EU Transport and TEN policies on the basis of the effects of these policies as computed by the SASI, CGE and STIMA models.

In order to increase the accessibility of the results of the analyses presented here, we have included section 3.5 of the ESPON 2.1.1 final report as chapter 2. In this chapter the various measures of inequality that are used for the analysis of the SASI, CGEurope and STIMA models are introduced.

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# 1 Introduction

A basic question to be asked about cohesion indicators is: why do we need them? The models that are used in ESPON 2.1.1 make forecasts about the effects of various TEN scenarios on the level of European regions (NUTS2 or NUTS3). These forecasts contain detailed information about the expected effects of the policy measures that is valuable. Some of this information is inevitably thrown away if it is summarised in cohesion indicators. The answer to the basic question is, however, that cohesion indicators allow one to summarise the most useful aspects of the model output with respect to cohesion in a few numbers. It is impossible to deal with all the information in a direct way. For instance, there are 1321 NUTS3 regions and the human brain is unable to deal with such a large number of figures. Summary measures are therefore necessary. In order to compute the cohesion indicators that we will use, all the detailed information is needed. The function of the indicators is to concentrate one of its aspects into a single figure.

The basic material that we use refers to the regions of the fifteen original (before 2004) EU countries, the twelve former candidate countries that are now new members and the regions of Switzerland and Norway. The SASI and CGE models use the NUTS3 level (1321 regions), while the STIMA model uses the NUTS2 level (282 regions).

When computing the indicators we have throughout taken the point of view that the basic units to which we refer are persons. That means, for instance, that if we compute an average effect of a policy measure, it refers to the average person in the original member states, the new member states, et cetera. Since the basic material produced by the models refers to regions, this means that we had to weigh with the regional population size.

# 2 Cohesion indicators

## 2.1 Introduction

This chapter contains a general discussion of the cohesion indicators that will be used in the next chapter. The discussion will be informal, in the sense that no mathematical formulas will be presented. These are relegated to the final subsection.

## 2.2 Indicators referring to the effects themselves

In the present subsections we discuss a number of indicators that are computed on the effects of the various policy measures themselves, without relating them to other variables.

*Averages*

The first thing one presumably wants to know about the effects of policy measure is: what is their size? The conventional way of summarising a number of figures is by computing an average. The output of the various models refers to the per capita gross domestic product (gdp) of each region and in order to compute an average we should weight these figures with the population size of each region. By weighting in this way, we find the average effect of the policy measures over the inhabitants of the set of regions concerned.

Sometimes we are not interested so much in the absolute size of an effect, but in its size in comparison to another variable. In the present context, it is natural to relate the change in per capita gdp to the original value of that variable. The ratio between the effect of a policy measure and the original value of per capita gdp will be referred to as the relative effect of the policy measure. In order to compute the relative effect per inhabitant, regional figures must also here be weighted by regional population sizes.

Averages do not in themselves inform us about the distribution of the effects. However, the comparison of average effects for different groups of regions gives valuable information about the distribution of the effects over these groups and in this way average play a very useful role in the analysis of cohesion impacts.

*Distribution of the effects*

There are other indicators that focus especially on the distribution of the effects within a group of regions. Two will be used in this study: the standard deviation and the coefficient of variation. The standard deviation is closely related to a third indicator, namely the variance of a distribution. The variance is the mean of the squared difference between the value of the effect for a particular region and the average of that effect. The difference is squared, since the average of the untransformed difference would be zero, and is therefore not informative. In order to facilitate interpretation, the square root of the variance is often taken. This can be interpreted loosely as the expected absolute value of the difference between the actual and average effects. This square root is known as the standard deviation and this name refers to the interpretation just discussed.

It is often useful to relate the standard deviation of a variable to its average. A given value of the standard deviation will be interpreted differently when it refers to a variable that has a mean close to zero (implying that actual values may be of a different sign than the average) or a means that is large in comparison to the standard deviation. For this reason one often uses the so-called coefficient of variation, which gives the ratio between the standard deviation and the average value of the variable to which is refers.

A third measure that informs us about the distribution of policy effects is the share of the population for which this effect is negative. Clearly, a policy is more attractive when (almost) everyone experiences a positive effect than when a large fraction of the population suffers from its execution, even if in the latter case the average effect as large as in the former.

### 2.3 Correlation of policy effects with gdp

Per capita gdp is generally considered to be an important (if not the single most important) indicator of welfare. It is therefore of some interest to investigate the relation between the effects of policy measures and this indicator. A movement towards cohesion is generally associated with a movement towards more equality in per capita gdp. It is therefore of some interest to investigate the relationship between the effects of the various policy scenarios and regional gdp. If these effects tend to be large in regions that have a high per capita gdp, the policy contributes less to cohesion than in the case when the effects tend to be large in regions with a low per capita gdp.

A useful measure for the association between two variables is the correlation coefficient. If larger-than-average effects of the policy are often realised in regions with a larger than average per capita gdp, this coefficient will be positive. In the reverse case, it will be negative. The coefficient takes values between –1 and 1 and the extremes correspond with situations in which the relation between the policy effects and per capita gdp is exactly a straight line. When the coefficient has the value 0 there is no relation between the policy effects and per capita gdp.

It has been discussed above that one may be interested in the absolute as well as in the relative values of the policy effects. For both cases one can compute a correlation coefficients. The one referring to absolute figures informs us about the relation between the size of the policy effects measured in euros and gdp, while the other informs us about the relation between the policy effects measured as a percentage of gdp and gdp.

## 2.4 Policy effects on inequality in per capita gdp

Still another way of looking at the cohesion effects of transport policy starts from summary measures of inequality in per capita gdp and asks by how much these measures change because of the policy. The change in the inequality measure can be interpreted as the effect of the policy on cohesion.

A large number of inequality measures have been developed over time and we have already met some of them when discussing the distribution of the policy effects. Just as we can summarise the distribution of the policy effects by means of the standard deviation of the coefficient of variation, we can summarise the distribution of per capita gdp by the same measures.

If regional per capita gdp changes as a result of transport policy, in general the distribution of this variable will also change. A decrease in the standard deviation and the coefficient of variation of per capita gdp may be interpreted as a movement towards more cohesion. Note that changes in the standard deviation and the coefficient of variation always have the same sign, because of the relation between the two measures. When studying the distribution of incomes (or directly related variables such as gdp) the coefficient of variation is often the preferred indicator. The reason is that it easier to compare inequality among groups of regions that differ in average income with this coefficient because it is dimensionless.

Apart from these two statistical measures of inequality, which are of general applicability, measures have been developed that refer especially to income inequality. One is the Gini coefficient, which measures the sum of the differences between the incomes of all units (inhabitants of European regions, in our case) and scales the result so as to obtain a figure between 0 and 1. A value 0 corresponds to complete equality, a value 1 to complete inequality.

The Gini-coefficient is related to the Lorenz curve, which gives a graphical measure of income inequality. The Lorenz curve can be constructed by ordering all subjects (individuals) on the basis of their income, with the one with the lowest income first. One can then determine the share of total income that is earned by the 10% of the population with the lowest incomes, by the 20% of the population with then lowest incomes, et cetera. These shares can be plotted and the result is the Lorenz curve. The Lorenz curve is always below the $45^0$ line, and the difference between the two lines can be regarded as an indicator on inequality. The Gini-coefficient measures the area between these two lines, and multiplies it by 2 so as two obtain a value that is between 0 and 1. The latter value corresponds to complete inequality: a single individual earns all income. The former corresponds to complete equality: all individuals earn the average income.

An alternative indicator of income inequality can be defined as 1 minus the ratio between the geometric and the arithmetic averages of the individual incomes. The geometric average is never lower than the arithmetic average and the two are equal only when all incomes are equal. The ratio can therefore be interpreted as an indicator of equality, and the difference between this indicator and 1 as an indicator of inequality.

## 2.5 Welfare and inequality

The inequality measures that have been discussed in the previous subsection were formulated on the basis of their mathematical properties. They were not derived from a particular concept of social welfare. There is another approach to the measurement of inequality that is closely linked to economic theory. It links the measurement of inequality to the formulation of a social welfare function. This approach was pioneered by Atkinson (1970) who defined a whole class of inequality measures on the basis of this approach.

It must, however, be noted that the two approaches are not contradictory, but must rather be seen as complementary. For instance, Atkinson stresses the importance of the principle of transfers, which says that inequality should decrease if a person transfers some of his or her income to someone with a lower income.[1] This principle gives a desirable property of an indicator of inequality, which is closely related to economic analysis. The principle of transfers can also be applied to social welfare function and then it requires that social welfare must increase if such a transfer takes place.

Atkinson concentrated attention on the class of social welfare functions that define this welfare as the sum of a power function of income. We will not consider this general class here, but concentrate on the special case for which welfare is defined as the sum of the logarithms of the individual incomes. It can be shown that this welfare function can alternatively be written as the sum of the logarithm of average income and the logarithm of

[1] The transfer should leave their relative positions unchanged.

the ratio between the geometric and the arithmetic means of the individual incomes. The significance of this result is that average income can be regarded as an indicator of welfare that ignores distributional issues, while the ratio of the two means is an indicator of equality as was discussed in the previous subsection. Welfare is therefore interpreted as the sum of two terms that refer to different aspect of the welfare concept: efficiency and equity. Since the ratio of the two means is always smaller than 1, its logarithm is negative and we can therefore interpret the second term as the ‘cost’ associated with inequality.

A welfare indicator that is even easier to interpret results when one exponentiates the logarithmic indicator just discussed. The result can again be interpreted as a welfare indicator, but now welfare is defined as the product of two terms: the first is equal to average income, and the second is the ratio of the geometric and arithmetic means. This second term has a value between 0 and 1 represents the negative effect of inequality on social welfare.

## 2.6 Decomposition of (in)equality

One important advantage of the logarithmic welfare indicator is that it allows the researcher to decompose total inequality into inequality between groups of regions and inequality within groups of regions. For instance, one might want to know how much of the total inequality of the extended EU (15 original members plus twelve new ones) is due to differences between the two groups and how much to differences between the groups. The logarithmic welfare indicator can be written as the sum of (1) the logarithm of average income in the extended EU, (2) a negative term referring to inequality between the two groups of member states, and (3) a term that is a weighted (arithmetic) average of the inequality with the two groups of member states. The second term is the logarithm of the geometric average of average income in the two groups of member states. The inequality within each of these two groups is the geometric average of the average incomes of the members belonging to that group.

This rewritten welfare function can also be exponentiated to give welfare as the product of three terms, the first of which is equal to average income, while the second and third are corrections referring to inequality between and within the groups, respectively.

This decomposition is especially relevant if one is interested in the effect of transport policies on particular groups of regions, such as objective 1 regions or lagging regions.

## 2.7 Technical appendix

### Averages

*1 Average absolute effects*

A first indicator is the average change in per capita gdp that occurs because of the project. This indicator is defined as:

$$aae = \frac{\sum_{i \in G} b_i \Delta_i}{\sum_{i \in G} b_i},$$

where $b_i$ denotes the population of region *i* and $D_i$ the effect of a scenario on per capita gdp in region *i*. Note that weighting with the regional population implies that we compute an average per capita effect.

*2 Average relative effects*

A second indicator is the average percentage change in per capita gdp that occurs because of the project. This indicator is defined as:

$$are = \frac{\sum_{i \in G} b_i (\Delta_i / y)}{\sum_{i \in G} b_i},$$

where *y* denotes per capita gdp in region *i*.

These two measures are (strictly speaking) not referring to cohesion, since they give no information about the distribution of the effects. Average effects are, nevertheless, important for the analysis of inequality. Comparison of average effects for different groups of regions gives an idea of the inequality of the effects. Moreover, average effects are used as an ingredient in the computation of more advanced indicators of inequality.

### Distribution of the effects

*3 The standard deviation of the effects*

This is defined for the absolute effect as:

$$sdae = \sqrt{\frac{\sum_{i \in G} b_i \left(\Delta_i - aae\right)^2}{\sum_{i \in G} b_i}}$$

The standard deviation gives an indication of the typical difference between the effect for a specific and the average effect.

*4 Coefficient of variation*

This indicator is closely related to the standard deviation and defined as:

$$cvae = \frac{sdae}{aae}$$

It gives the ratio between that standard deviation and the average effect. It indicates the typical percentage difference between the effect for a particular person and the average effect.

*5 Percentage of the population in regions with negative effects*

Perhaps the most important aspect is: will a region benefit from the measure or not? In order to find the answer to this question we have computed the share of the people living in regions that experience a negative change in per capita gdp in the various scenario's.

Then we have determined for some groups *G* of regions:

$$\frac{\sum_{i \in G} b_i I(\Delta_i < 0)}{\sum_{i \in G} b_i}$$

where $I(.)$ is an indicator variable that is equal to 1 if the statement that appears at the place of the dot between the braces is true, and zero otherwise.

**Correlation between effects and gdp**

*6 Correlation of absolute effects*

In order to compute this we first define the variance of the absolute effects as:

$$vae = \frac{\sum_{i \in G} b_i (\Delta_i - aae)^2}{\sum_{i \in G} b_i}$$

and the variance of per capita gdp as:

$$vy = \frac{\sum_{i \in G} b_i (y_i - ay)^2}{\sum_{i \in G} b_i},$$

where *ay* denotes the average of per capita gdp for the group *G*.

The correlation coefficient is:

$$caey = \frac{\sum_{i\in G} b_i (\Delta_i - aae)(y_i - ay) \Big/ \sum_{i\in G} b_i}{\sqrt{vae\, vy}}$$

*6 Correlation of relative effects*

In order to compute this we first define the variance of the absolute effects as:

$$vre = \frac{\sum_{i\in G} b_i (\Delta_i - are)^2}{\sum_{i\in G} b_i}$$

The variance of per capita gdp has already been defined above.

The correlation coefficient is:

$$caey = \frac{\sum_{i\in G} b_i (\Delta_i - are)(y_i - ay) \Big/ \sum_{i\in G} b_i}{\sqrt{vre\, vy}}$$

## Inequality measures

We compute the change in the (in)equality of per capita gdp on the basis of the following indicators:

*7 Coefficient of variation of income*

The computation is based on average income:

$$ay = \frac{\sum_{i\in G} b_i y_i}{\sum_{i\in G} b_i},$$

and the standard deviations of income:

$$sdy = \sqrt{\frac{\sum_{i\in G} b_i (y_i - ay)^2}{\sum_{i\in G} b_i}}$$

The coefficient of variation is the ratio of these two variables:

$$cvy = \frac{sdy}{ay}$$

The coefficient of variation can be regarded as a summary measure of relative inequality. The effect of the various policy scenarios on this measure can be determined as follows. We can distinguish the various possibilities by means of a superscript $j$. For the base scenario $j=0$, whereas for the others $j$=A1,A2,A3,B1,... . The base scenario refers to the year 2001 for the A-scenarios and to 2021 for the others. The effect of a policy scenario is:

$$
\begin{aligned}
ecvy^{j} &= cvy^{j} - cvy^{0} \\
&= \frac{sdy^{j}}{ay^{j}} - \frac{sdy^{0}}{ay^{0}}
\end{aligned}
$$

*8 Gini coefficient*

This coefficient is defined as:

$$
gc = \frac{\sum_{i\in G}\sum_{k\in G} b_i b_j \left| y_i - y_k \right|}{2\left(\sum_{i\in G} b_i\right)^2 ay}
$$

Changes in this coefficient that occur as a consequence of the TEN scenarios can be determined in the same way as for the coefficient of variation.

*9 Ratio between the geometric and arithmetic mean*

This coefficient is defined as:

$$
\begin{aligned}
rgay &= \frac{\exp\left(\sum_{i\in G} b_i \ln y_i \Big/ \sum_{i\in G} b_i\right)}{\sum_{i\in G} b_i y_i \Big/ \sum_{i\in G} b_i} \\
&= \frac{\exp\left(\sum_{i\in G} b_i \ln y_i \Big/ \sum_{i\in G} b_i\right)}{ay}
\end{aligned}
$$

The value of *rgay* is positive and smaller or equal to 1. A larger value indicates more equality. The corresponding inequality measure can be found by subtracting *rgay* from 1. And again, the changes in this measure that occur as a consequence of the TEN scenarios can be computed on the basis of this indicator in the same way.

## Welfare and decomposition of inequality

*10 Welfare function*

The economic approach to project evaluation makes use of a social welfare function. One particular form of this function is the average of the logarithm of per capita gdp:

$$
W = \sum_{i\in G} b_i \ln y_i \Big/ \sum_{i\in G} b_i
$$

This function can be rewritten as:

$$
\begin{aligned}
W &= \ln ay + \frac{\sum_{i\in G} b_i \ln y_i \Big/ \sum_{i\in G} b_i}{\ln ay} \\
&= \ln ay + \ln rgay
\end{aligned}
$$

This equation shows that welfare is defined as the sum of the logarithm of average income and the logarithm of the inequality measure *rgay* discussed above. It says that we can interpret welfare as the utility at average income, plus a correction for inequality.

If we exponentiate welfare, we get an alternative welfare measure, that is equal to the product of average per capita gdp and the ratio between the geometric and arithmetic average of regional gdp. The latter functions as a correction term for inequality that takes on a value between 0 and 1:

$$W' = \exp W = ay * rgay \qquad *$$

This alternative welfare measure is easier to interpret than the original one.

*11 Decomposition*

The welfare indicator discussed above has the attractive property that it can be decomposed so as to show the contribution of average incomes and inequality for groups of regions (see Bourguignon, 1979 for a general analysis of decomposable inequality measures). To see this, assume that we have to such groups, denoted as *G* and *H*. Each region belongs either to *G* or to *H*. Welfare is defined as:

$$
\begin{aligned}
W &= \left(\sum_{u\in G} b_i \ln y_i + \sum_{i\in H} b_i \ln y_i\right) \Bigg/ \left(\sum_{i\in G} b_i + \sum_{i\in H} b_i\right) \\
&= w_G\left(\sum_{u\in G} b_i \ln y_i / \sum_{i\in G} b_i\right) + w_H\left(\sum_{u\in H} b_i \ln y_i / \sum_{i\in H} b_i\right) \\
&= w_G\left(\ln ay_G + \ln rgay_G\right) + w_H\left(\ln ay_H + \ln rgay_H\right) \\
&= \left(w_G \ln ag_G + w_H \ln ay_H\right) + \left(w_G \ln rgay_G + w_H \ln rgay_H\right)
\end{aligned}
$$

where $w_G$ is the share of the population in *G* in the total population[2] and $w_H$ the share of the population in *H*. The second line shows that total welfare is a weighted average of the regional welfares, with the weights equal to the population shares. The third line writes regional welfare as the difference between a term referring to average income and inequality, as we did above for total welfare. In the fourth line this expression is again rewritten as the sum of a term referring to average regional incomes and another referring to regional inequality. The first of these terms can be further elaborated to

[2] That is $w_G = S_{i\hat{I}G} b_i / (S_{i\hat{I}G} b_i + S_{i\hat{I}H} b_i)$.

show that is is the difference between a term referring to total average income and inequality within regions:

$$w_G \ln ay_G + w_H \ln ay_H = \ln ay + \frac{(b_G \ln ay_G + b_H \ln ay_H)/(b_G + b_H)}{\ln ay}$$

where $b_G$ is the total population in the regions belonging to group $G$ and $b_H$ that in the regions belonging to group $H$. The second term on the right-hand-side of this equation is the logarithm of the ratio of the geometric and arithmetic means of the regional average incomes.

We can interpret the expression in the last equation as a partial welfare measure that ignores inequality within the two groups of regions and reflects only equality between these groups.

This decomposition can easily be generalised to an arbitrary number of regions. Total welfare can be written as the sum of (1) the logarithm of average income in all regions, (2) inequality between the average regional incomes, and (3) a weighted average of inequality within the regions. The second term on the right-hand-side can be regarded as the logarithm of a multiplicative correction factor that refers only to inequality between the two groups of regions.

If we exponentiate this welfare measure we get the following expression:

$$W' = \exp W = ay * rgay_{between} * rgay_{within} .$$

The first term on the right-hand-side is average income. The second is the ratio between the geometric and artihmetic averages of the average incomes in the groups. The third term is a geometric average of the ration between the geometric and arithmetic averages of income within the groups. The product of the latter two terms is – by definition – equal to $rgay$ in the equation marked with an asterix (*) above.

# 3 Cohesion Impacts

## 3.1 Introduction

In this section we present the results of the cohesion analysis. The indicators that will be used were introduced in chapter 2 above. Here we apply them to the results of the three models.

This section is organised as follows. We start with a brief discussion of the general setting in which transport policies take place. Then the results of the SASI model, CGEurope and the STIMA model are summarised by means of the cohesion indicators. Some brief conclusions follow.

## 3.2 The general setting

The background of the policy effects studied here is the economic development of the European Union and its neighbours Switzerland and Norway. It is therefore useful first to consider the background against which these effects should be placed. We do so in this subsection by means of a brief discussion of the development of per capita GDP in the period 2001-2021 that is used as a reference scenario in the SASI model.

Table 1 shows the average value of per capita GDP in all 1321 NUTS3 regions considered and in three groups: the 15 original EU countries (EU15), the 12 new member states (NM12) and Switzerland and Norway (SN). The table shows that there are clear differences between the various parts of Europe. Norway and Switzerland are among the wealthiest countries on the continent, while the new member states belong to the poorest countries, at least in relative terms.

**Table 1 Per capita gdp**

| | 2001 | 2021 |
|---|---|---|
| All | 18.10 | 32.03 |
| EU15 | 21.20 | 36.88 |
| NM12 | 4.38 | 7.84 |
| SN | 36.48 | 63.58 |

There are substantial differences between the various regions that belong to the same group. For instance, among the original member states are countries as wealthy as Norway and Switzerland, but also some with a per capita gdp that is comparable with that of some new member states.

It is apparent from chapter 1 that inequality in per capita gdp can be measured in various ways. Table 2 lists three possibilities: the coefficients of variation, the GINI-coefficient and 1 minus the ratio of the geometric and arithmetic mean. A higher value of these measures indicates more inequality. When there is complete equality (per capita income in all regions is identical) they all take on the value 0. The table shows that according to all three indicators inequality is decreasing in all groups of regions except Switzerland and Norway, where there is a modest increase. The changes in inequality are in general very small.

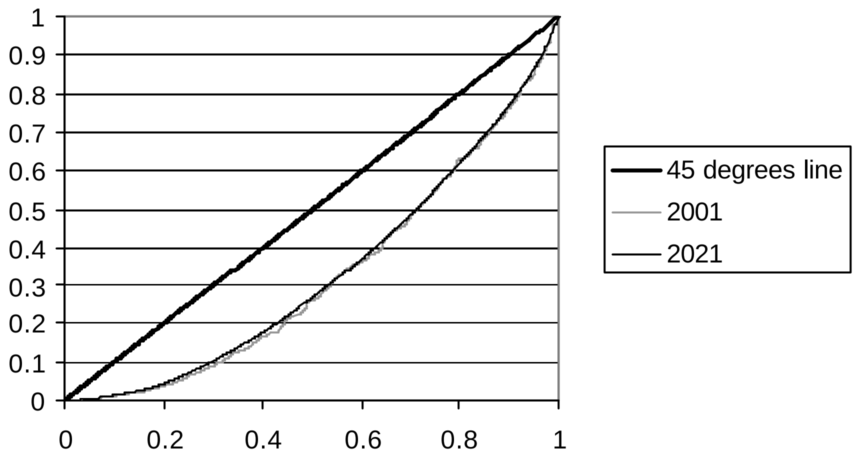
**Table 2 Inequality measures**

| | Coefficient of variation | | | Gini-coefficient | | | 1-ratio of geometric and arithmetic average | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2001 | 2021 | Dif.[1] | 2001 | 2021 | Dif.[1] | 2001 | 2021 | Dif.[1] |
| All | 0.624 | 0.610 | 0.014 | 0.335 | 0.326 | 0.009 | 0.227 | 0.215 | 0.012 |
| EU15 | 0.448 | 0.446 | 0.002 | 0.226 | 0.225 | 0.001 | 0.081 | 0.080 | 0.001 |
| NM12 | 0.812 | 0.878 | -0.066 | 0.329 | 0.334 | -0.005 | 0.170 | 0.174 | -0.004 |
| SN | 0.194 | 0.196 | -0.002 | 0.107 | 0.108 | -0.001 | 0.175 | 0.178 | -0.003 |

[1] Dif denotes the difference between the value of the inequality indicator in 2001 and 2021.

The inequality of an income distribution can be pictured by means of the so-called Lorenz curve. To derive this curve all individuals should be ordered on the basis of their income, with the lowest income first. The cumulative share of the income of each fraction of the population is then put on the vertical axis, while the fraction of the population is put on the vertical axis. Figure 1 shows the Lorenz curves of the income (=gdp per capita) distribution of Europe as whole for 2001 and 2021.

**Figure 1 The Lorenz curve in 2001 and 2021**



When there is complete equality of incomes, the Lorenz curve is equal to the 45$^o$ line. The area between the actual curve and this line can be regarded as a measure of inequality and is in fact equal to the Gini coefficient.

It has been shown by Atkinson (1970) that a Lorenz curve that lies completely above another one corresponds to a more equal income distribution if one accepts the principle of transfers. The principle of transfers says that inequality decreases if person gives some of his income to a person with a lower income (provided that the transfer is not so large that their relative positions change). The inequality of income distributions whose Lorenz curves cross cannot be compared on the basis of this principle alone.

The figure shows that the income distribution in 2021 is not necessarily more equal than that of 2001, even though the Lorenz curve of the more recent year is mostly above that of 2001.

The average value of gdp and inequality can be regarded as two aspects of social welfare. A social welfare function should integrate them into a single welfare measure. Many social welfare functions have proposed, but the class suggested by Atkinson (1970) is generally regarded as attractive. Here we take one member of this class, that defines social welfare as the product of average per capita gdp and a measure of equality. The measure of equality is the ratio of the geometric and the arithmetic mean. This ratio was already used in the third inequality measure listed in Table 2 above. This welfare measure is shown in Table 3. The figure in this table should be compared with those in Table 1, which shows average per capita gdp. The relatively small inequality in Switzerland and Norway is reflected in the small difference between welfare and per capita gdp for this group of regions. The relatively large inequality in the new member states appears from the large (in relative terms) difference for that group.

**Table 3 Welfare**

| | 2001 | 2021 |
|---|---|---|
| All | 13.99 | 25.14 |
| EU15 | 19.49 | 33.94 |
| NM12 | 3.63 | 6.48 |
| SN | 35.85 | 62.45 |

The ratio of welfare and per capita income is a multiplicative indicator of equality. The associated inequality indictor can be found as 1 minus the equality indicator.

Because of the decomposition property of our welfare function we can write the equality indicator as the product of two sub-indicators, one referring to equality between groups of regions and the other referring to equality within the groups of regions. Associated with these sub-indicators of equality are sub-indicators of inequality. Table 4 shows the two sub-indicators for inequality when the groups are the objective 1 or 2 regions and all other regions. The table shows that inequality within the groups is more substantial than that between the groups.

**Table 4 Decomposition of welfare for various groups of regions**

| | Av. Gdp Obj regions | Av. Gdp $0^{th}$er regions | Inequality between | Inequality within |
|---|---|---|---|---|
| Obj 1 | 8.92 | 23.53 | 0.088 | 0.153 |
| Obj 2 | 21.92 | 15.46 | 0.073 | 0.166 |

### 3.3 The results of the SASI model

We start with a summary of the results of the SASI model. Columns 2 to 5 of Table 5 give the average effect of the various policy scenarios on average per capita income for all regions, the 15 original EU members, the 12 new member states, and Switzerland and Norway, respectively. These effects vary between –1100 and 1500 euros per year. At first sight, one may be tempted to conclude that these are not very large amounts of money. However, it should be noted that they refer to per annual capita gdp, which means that every person in the area concerned experiences this change (on average) and that they are in principle permanent. The benefits of investments in infrastructure will be realised in every year, provided that sufficient maintenance takes place. It should be observed that a proper interpretation of these effects requires a comparison between costs and benefits, and the Table shows only one of these two.

The effects tend to be largest for the Switzerland and Norway and smallest for the new members, while the existing members take an intermediate position. Since the new members are in general poorer than the other regions, this is not too surprising. The benefits of infrastructure are large when demand for transportation is large and a higher GDP usually implies more transportation demand. However, it seems at first sight like the policy measures have undesirable consequences for inequality.

The picture is different when we focus on the relative effects, that is, on the ratio between the absolute effects and total per capita gdp. We have computed these effects on the basis of the reference scenario, that was discussed in section 3.2 above.

The relative effects are shown in the last four columns of Table 5. The order of magnitude of the policy effects varies between –2 and 2.5 %. The differences between the relative effects in the various groups of member states are much smaller than the differences in the absolute effects, which suggests that the effects of the investments are more or less proportional to the level of gdp. In some scenarios the new member states now appear to be the ones that experience the largest benefit or experience the smallest cost, of the policy measures.

**Table 5 Absolute and relative effects of TEN scenarios (SASI model)**

| | Absolute effects (euros) | | | | Relative effects (percentage points) | | | |
|---|---|---|---|---|---|---|---|---|
| | All | EU15 | NM12 | SN | All | EU15 | NM12 | SN |
| A1 | 81 | 96 | 19 | 146 | 0.44 | 0.44 | 0.45 | 0.40 |
| A2 | 37 | 44 | 9 | 76 | 0.20 | 0.20 | 0.19 | 0.20 |
| A3 | 114 | 134 | 28 | 214 | 0.62 | 0.62 | 0.62 | 0.59 |
| | | | | | | | | |
| B1 | 514 | 607 | 92 | 799 | 1.59 | 1.70 | 1.17 | 1.24 |
| B2 | 841 | 965 | 240 | 1521 | 2.73 | 2.67 | 3.04 | 2.40 |
| B3 | 756 | 879 | 171 | 1331 | 2.39 | 2.45 | 2.18 | 2.10 |
| B4 | 209 | 233 | 91 | 324 | 0.73 | 0.64 | 1.15 | 0.50 |
| B5 | 149 | 163 | 93 | 134 | 0.62 | 0.49 | 1.21 | 0.21 |
| | | | | | | | | |
| C1 | 161 | 189 | 22 | 336 | 0.46 | 0.50 | 0.29 | 0.53 |
| C2 | -132 | -153 | -27 | -247 | -0.39 | -0.40 | -0.36 | -0.39 |
| C3 | -456 | -526 | -79 | -1114 | -1.35 | -1.43 | -0.93 | -1.77 |
| | | | | | | | | |
| D1 | 46 | 67 | 11 | -320 | 0.21 | 0.23 | 0.22 | -0.54 |
| D2 | 372 | 422 | 161 | -408 | 1.35 | 1.20 | 2.10 | 0.62 |

The differences between the average absolute effects for the various groups of regions show that there is some variation between the groups. Within the groups of regions there is further variation and Table 6 gives two summary measures of this phenomenon. The first is the standard deviation, which can be interpreted (somewhat loosely) as the expected value of the difference between the actual effect and the average effect for the group of regions. For instance, the number 392 that emerges in the second column of Table 8 in the row referring to scenario B1 indicates that the effect of this policy scenario for a particular region differs typically from the average effect by 392 euros. Since the average effect (reported in Table 1) was 514 euros, there appears to be quite some variation in the effects for specific regions. Within all three groups of member states the standard deviation is smaller, mostly so in the new members. Indeed, Table 2 suggests that for groups of regions where the average effect is larger, the standard deviation is also larger.

This is confirmed by the last four columns of Table 6, which give the coefficient of variation. This coefficient is the ratio of the standard deviation and the average absolute effect.[3] For the group of new member states it is usually larger than for the original member, while it is often smallest for Switzerland and Norway.

**Table 6 Variation in absolute effects (SASI model)**

| | Standard deviation (euros) | | | | Coefficient of variation | | | |
|---|---|---|---|---|---|---|---|---|
| | All | EU15 | NM12 | SN | All | EU15 | NM12 | SN |
| A1 | 64 | 63 | 16 | 42 | 0.79 | 0.65 | 0.83 | 0.29 |
| A2 | 39 | 39 | 12 | 37 | 1.04 | 0.90 | 1.35 | 0.49 |
| A3 | 90 | 86 | 25 | 54 | 0.78 | 0.64 | 0.92 | 0.25 |
| | | | | | | | | |
| B1 | 392 | 368 | 116 | 256 | 0.76 | 0.61 | 1.27 | 0.32 |
| B2 | 566 | 520 | 250 | 360 | 0.67 | 0.54 | 1.04 | 0.24 |
| B3 | 519 | 472 | 182 | 314 | 0.69 | 0.54 | 1.06 | 0.24 |
| B4 | 165 | 164 | 98 | 186 | 0.79 | 0.70 | 1.08 | 0.57 |
| B5 | 131 | 138 | 85 | 59 | 0.88 | 0.85 | 0.90 | 0.44 |
| | | | | | | | | |
| C1 | 122 | 110 | 26 | 78 | 0.76 | 0.58 | 1.18 | 0.23 |
| C2 | 95 | 88 | 30 | 62 | 0.72 | 0.57 | 1.08 | 0.25 |
| C3 | 328 | 275 | 105 | 404 | 0.72 | 0.52 | 1.33 | 0.36 |
| | | | | | | | | |
| D1 | 249 | 255 | 85 | 464 | 5.42 | 3.82 | 7.71 | 1.45 |
| D2 | 336 | 337 | 181 | 538 | 0.90 | 0.80 | 1.13 | 1.32 |

Because of the relatively large variation in the effects, it is of some importance to look at the distribution of their signs. We have therefore computed the percentage of the population that lives in a region that experiences a negative effect from the policy measures. For the A, B and C scenarios the sign of the effect is identical for all regions: if the average effect is positive (negative), all regions experience a positive (negative) effect. For the D-scenarios this is not the case. For these scenarios 40% and 9% of the inhabitants of the total area considered lives in a region with a negative effect, in scenarios D1 and D2, respectively. In the new member states the percentage of the population that experiences negative effects is smaller (32% in D1 and 1% in D2) whereas in Norway and Switzerland 67% experiences negative effects under D1 and 29% under D2.

[3] The table reports absolute values of the coefficient of variation.

Table 7 shows the correlation between the absolute effects and per capita gdp. We observed above that the average effect is larger in the regions with high gdp, suggesting that this relation is positive. Columns 2-5 of this Table confirm this. Except for scenario D1 the correlation coefficients are rather large. The last four columns of Table 7 show that the correlation between the relative effects and per capita gdp is much weaker. In a relatively large number of cases the coefficients switches sign if we consider relative instead of absolute effects.

**Table 7 Correlation between absolute effects and per capita gdp (SASI model)**

| | Absolute effects (euros) | | | | Relative effects | | | |
|---|---|---|---|---|---|---|---|---|
| | All | EU15 | NM12 | SN | All | EU15 | NM12 | SN |
| A1 | 0.84 | 0.79 | 0.86 | 0.54 | 0.06 | 0.15 | -0.11 | -0.10 |
| A2 | 0.61 | 0.50 | 0.85 | 0.41 | 0.06 | 0.02 | 0.25 | -0.02 |
| A3 | 0.84 | 0.77 | 0.92 | 0.69 | 0.08 | 0.12 | 0.06 | -0.09 |
| B1 | 0.76 | 0.65 | 0.89 | 0.76 | 0.04 | -0.13 | 0.00 | 0.17 |
| B2 | 0.85 | 0.77 | 0.97 | 0.78 | -0.18 | -0.11 | 0.06 | -0.04 |
| B3 | 0.84 | 0.75 | 0.94 | 0.74 | -0.05 | -0.13 | 0.01 | -0.08 |
| B4 | 0.68 | 0.62 | 0.93 | 0.45 | -0.31 | -0.03 | 0.03 | 0.15 |
| B5 | 0.42 | 0.39 | 0.81 | 0.38 | -0.46 | -0.23 | -0.04 | -0.03 |
| C1 | 0.91 | 0.86 | 0.89 | 0.72 | 0.42 | 0.19 | -0.20 | -0.12 |
| C2 | -0.91 | -0.87 | -0.96 | -0.69 | -0.23 | -0.21 | 0.10 | 0.09 |
| C3 | -0.89 | -0.85 | -0.87 | -0.40 | -0.29 | 0.06 | -0.31 | 0.18 |
| D1 | -0.02 | -0.02 | 0.13 | 0.07 | -0.12 | -0.12 | -0.17 | 0.20 |
| D2 | 0.53 | 0.47 | 0.82 | 0.21 | -0.31 | -0.11 | -0.10 | 0.10 |

The effects of the policy scenarios on the values of the coefficient of variation and the Gini coefficient for per capita gdp are shown in Table 8. Given the small change in these measures over the whole period 2001-2021, it comes as no surprise that these effects are very small. In some cases the changes in inequality measured by the two indicators are different. This is in accordance with the fact that the Lorenz curves constructed for the cases with the effects of the policy measures included cross that referring to the situation without these effects. An unambiguous ordering of the inequality in the situation with and without the policy effect on the basis of the principle of transfers is therefore not possible. The coefficient of variation and the Gini coefficient can be interpreted as originating from different preferences with respect to inequality. The Gini concentrates on the absolute value of the differences in per capita gdp, whereas the coefficient of variation squares these differences and therefore attaches a higher weight to large differences.

**Table 8 Effects of policy scenarios on two inequality measures (SASI model)**

| | Change in coefficient of variation (x100) | | | | Change in Gini coefficient (x100) | | | |
|---|---|---|---|---|---|---|---|---|
| | All | EU15 | NM12 | SN | All | EU15 | NM12 | SN |
| A1 | 0.019 | 0.030 | -0.042 | -0.015 | 0.011 | 0.018 | -0.023 | -0.001 |
| A2 | 0.002 | 0.001 | 0.072 | 0.002 | 0.005 | 0.008 | 0.019 | -0.003 |
| A3 | 0.022 | 0.032 | 0.023 | -0.013 | 0.016 | 0.024 | -0.004 | -0.004 |
| | | | | | | | | |
| B1 | -0.043 | -0.080 | -0.304 | 0.062 | -0.027 | -0.054 | -0.014 | 0.027 |
| B2 | -0.091 | -0.070 | 0.414 | -0.025 | -0.057 | -0.043 | 0.029 | -0.006 |
| B3 | -0.074 | -0.097 | 0.276 | -0.042 | -0.043 | -0.061 | -0.013 | -0.010 |
| B4 | -0.046 | -0.006 | 0.156 | 0.033 | -0.027 | 0.001 | 0.018 | 0.021 |
| B5 | -0.108 | -0.050 | -0.153 | -0.006 | -0.078 | -0.049 | -0.047 | -0.002 |
| | | | | | | | | |
| C1 | 0.039 | 0.028 | 0.046 | -0.015 | 0.023 | 0.016 | -0.013 | -0.003 |
| C2 | -0.020 | -0.021 | -0.055 | 0.009 | -0.015 | -0.018 | -0.003 | 0.005 |
| C3 | -0.048 | 0.003 | -0.271 | 0.095 | -0.023 | 0.010 | -0.085 | 0.074 |
| | | | | | | | | |
| D1 | -0.100 | -0.090 | 0.038 | 0.161 | -0.055 | -0.051 | -0.096 | 0.101 |
| D2 | -0.147 | -0.077 | 0.144 | 0.071 | -0.085 | -0.040 | -0.044 | 0.064 |

In Table 9 we present the effects of the various policy measures on our welfare measure. The figures in that table can be interpreted as changes in gdp that have been corrected for the inequality in the group of regions concerned. In regions with relatively much inequality (such as the new member states) a given increase in average per capita gdp therefore contributes less to welfare than in regions with less inequality (such as Switzerland and Norway). When we consider the whole area, the ordering of the scenarios on the basis of welfare is very similar to that based on the average effect on per capita GDP. The efficiency effect dominates the inequality effect. This conclusion would, of course, be different if we adopted a welfare functions with a larger coefficient of inequality aversion.

**Table 9 Effects of TEN scenarios on welfare (SASI model)**

| | Absolute effects (euros) | | | |
|---|---|---|---|---|
| | All | EU15 | NM12 | SN |
| A1 | 62 | 86 | 17 | 144 |
| A2 | 28 | 40 | 7 | 75 |
| A3 | 87 | 121 | 23 | 211 |
| | | | | |
| B1 | 398 | 575 | 75 | 778 |
| B2 | 686 | 904 | 197 | 1495 |
| B3 | 599 | 828 | 141 | 1310 |
| B4 | 184 | 216 | 75 | 314 |
| B5 | 156 | 166 | 79 | 131 |
| | | | | |
| C1 | 115 | 169 | 19 | 331 |
| C2 | -99 | -137 | -23 | -243 |
| C3 | -339 | -487 | -60 | -1108 |
| | | | | |
| D1 | 50 | 76 | 14 | -335 |
| D2 | 338 | 403 | 136 | 388 |

The welfare measure we use allows us to decompose total welfare into a first part referring to average per capita gdp, a second part referring to inequality between groups of regions and a third part referring to inequality within these groups of regions. This opens the possibility to study the effects of the various policy measures for the inequality between a group of regions that is of special interest for policy purposes and other regions. Table 11 shows the results of such an analysis for objective 1 and objective 2 regions. The first column of this table gives the average absolute impact for the group of regions for which these types are defined (the original member states plus the new member states except Bulgaria and Rumania). The next three columns give the average absolute effects of the policies for the objective 1 regions and the other regions, and the change in the multiplicative term that corrects for inequality, respectively. The last three columns of the table do the same for objective 2 regions.

**Table 10 Effects of policy scenarios on objective 1 and objective 2 regions (SASI model)**

| | Change in av. Gdp p.c. | Objective 1 regions | | | Objective 2 regions | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 0 | | 1 | 0 | |
| A1 | 84 | 40 | 107 | -0.004 | 106 | 65 | .0004 |
| A2 | 38 | 17 | 49 | -0.001 | 48 | 29 | .0000 |
| A3 | 118 | 55 | 150 | -0.006 | 148 | 91 | .0003 |
| | | | | | | | |
| B1 | 535 | 279 | 657 | -0.018 | 652 | 425 | -.0004 |
| B2 | 861 | 503 | 1031 | -0.047 | 1015 | 709 | -.0024 |
| B3 | 779 | 444 | 939 | -0.039 | 930 | 633 | -.0011 |
| B4 | 212 | 123 | 255 | -0.012 | 256 | 171 | -.0004 |
| B5 | 156 | 164 | 153 | -0.034 | 136 | 170 | -.0063 |
| | | | | | | | |
| C1 | 165 | 66 | 212 | 0.001 | 206 | 126 | .0009 |
| C2 | -135 | -59 | -171 | 0.000 | -161 | -109 | -.0003 |
| C3 | -461 | -236 | -586 | 0.014 | -540 | -383 | .0015 |
| | | | | | | | |
| D1 | 60 | 40 | 70 | -0.005 | 95 | 33 | .0007 |
| D2 | 384 | -265 | 442 | -0.035 | 454 | 317 | -.0015 |

The table shows that there are indeed differences in the impacts of the various policy scenarios on the objective 1 and 2 regions and the other regions. The equality between obj1 regions and other regions decreases as a result of the policy measures, except for the C scenarios. The equality between obj2 regions and other regions increases in the A scenarios and in C1,C3 and D1, while it decreases in the B scenarios and in C2 and D2. (Recall that an increase in equality is a decrease in inequality and vice versa.) It should, however, be noted that the effects on inequality are small.

### 3.4 The results of the CGEurope model

The results for CGEurope have been reported in terms of equivalent variations in income. For ease of interpretation we deal with these changes as if they referred to GDP. Since the difference is small, the error involved will typically be negligible.

This subsection is organised in the same way as the previous one, which referred to the SASI model. We start by summarizing the basic results. Columns 2 to 5 of Table 11 give the average effect of the various policy scenarios on average per capita income for all regions, the 15 original EU members, the 12 new member states and Switzerland and Norway, respectively. These effects are typically smaller than 100 euros per year.

The effects tend to be largest for Switzerland and Norway and smallest for the new members.

**Table 11 Absolute and relative effects of TEN scenarios (CGEurope)**

| | Absolute effects (euros) | | | | Relative effects (percentage points) | | | |
|---|---|---|---|---|---|---|---|---|
| | All | EU15 | NM12 | SN | All | EU15 | NM12 | SN |
| A1 | 8 | 10 | 1 | 12 | 0.05 | 0.05 | 0.04 | 0.04 |
| A2 | 19 | 23 | 3 | 37 | 0.12 | 0.12 | 0.10 | 0.14 |
| A3 | 25 | 31 | 4 | 46 | 0.16 | 0.17 | 0.13 | 0.17 |
| B1 | 23 | 28 | 5 | 32 | 0.16 | 0.16 | 0.16 | 0.12 |
| B2 | 42 | 49 | 15 | 57 | 0.33 | 0.28 | 0.51 | 0.21 |
| B3 | 38 | 45 | 11 | 51 | 0.28 | 0.26 | 0.36 | 0.19 |
| B4 | 7 | 7 | 4 | 9 | 0.06 | 0.04 | 0.14 | 0.03 |
| B5 | 9 | 9 | 10 | 3 | 0.11 | 0.06 | 0.30 | 0.01 |
| C1 | 8 | 10 | 1 | 14 | 0.05 | 0.05 | 0.03 | 0.05 |
| C2 | -46 | -56 | -8 | -70 | -0.29 | -0.30 | -0.29 | -0.25 |
| C3 | -58 | -71 | -10 | 98 | -0.37 | -0.38 | -0.35 | -0.35 |
| D1 | -34 | -41 | -5 | -66 | -0.21 | -0.21 | -0.18 | -0.24 |
| D2 | -15 | -20 | 5 | -40 | -0.03 | -0.09 | 0.17 | -0.14 |

The CGEurope model does not work with a reference scenario for 2021. The policy effects it computes should be interpreted as referring to the actual (2001) situation and we have therefore computed the relative effects as the ratio between the policy effect and the per capita GDP figures for 2001 that have been used in this model. These relative effects are shown in the last four columns of Table 11 and the picture that emerges from these figures differs from that of the absolute effects. The new member states are in general the ones that benefit most, or experience the smallest cost, of the policy measures.

The differences between the average absolute effects for the various groups of regions show that there is some variation in their size. Within the groups of regions there is further variation and Table 12 gives two summary measures: the standard deviation and the coefficient of variation.

**Table 12 Variation in absolute effects (CGEurope)**

| | Standard deviation (euros) | | | | Coefficient of variation | | | |
|---|---|---|---|---|---|---|---|---|
| | All | EU15 | NM12 | SN | All | EU15 | NM12 | SN |
| A1 | 7 | 7 | 1 | 6 | 0.92 | 0.75 | 0.99 | 0.47 |
| A2 | 35 | 37 | 3 | 52 | 1.86 | 1.66 | 1.08 | 1.42 |
| A3 | 36 | 38 | 4 | 51 | 1.40 | 1.23 | 0.86 | 1.10 |
| | | | | | | | | |
| B1 | 26 | 28 | 5 | 26 | 1.14 | 0.99 | 0.97 | 0.82 |
| B2 | 31 | 30 | 11 | 31 | 0.74 | 0.62 | 0.69 | 0.54 |
| B3 | 30 | 30 | 8 | 27 | 0.79 | 0.66 | 0.75 | 0.54 |
| B4 | 6 | 6 | 4 | 6 | 0.87 | 0.83 | 0.87 | 0.71 |
| B5 | 15 | 16 | 9 | 2 | 1.63 | 1.79 | 0.91 | 0.77 |
| | | | | | | | | |
| C1 | 6 | 6 | 1 | 10 | 0.83 | 0.62 | 1.15 | 0.70 |
| C2 | 27 | 21 | 5 | 14 | 0.59 | 0.38 | 0.59 | 0.20 |
| C3 | 34 | 26 | 6 | 29 | 0.59 | 0.36 | 0.61 | 0.29 |
| | | | | | | | | |
| D1 | 31 | 30 | 5 | 22 | 0.91 | 0.73 | 0.99 | 0.34 |
| D2 | 28 | 29 | 7 | 17 | 1.87 | 1.46 | 1.25 | 0.43 |

Table 12 shows that the standard deviation is of the same order of magnitude as the average size of the policy effect for the groups of regions.

The last four columns of Table 12 give the coefficient of variation. For the new member states this coefficient is of the same order of magnitude as for the other regions. Scenarios A2 and D2 have relatively large coefficients of variation.

We have also computed the percentage of the population that lives in a region that experiences a negative effect from the policy measures. For the A, B and C scenarios the sign of the effect is in almost all cases identical for all regions. The D-scenarios are an exception. For D1 93% the population in the total study area lives in a region experiencing a negative effect, for D2 this is 70%. For scenario D2 there is a much smaller percentage in the new member states that experiences negative effects, while 100% of the Swiss and Norwegian this is 100%.

Table 13 shows the correlation between the absolute effects and per capita gdp. There is substantial positive correlation between the size of the effects and per capita gdp. However, the correlation between the relative effects and per capita gdp is generally negative and in some cases also substantial.

**Table 13 Correlation between absolute effects and per capita gdp (CGEurope)**

| | Absolute effects (euros) | | | | Relative effects | | | |
|---|---|---|---|---|---|---|---|---|
| | All | EU15 | NM12 | SN | All | EU15 | NM12 | SN |
| A1 | 0.61 | 0.45 | 0.73 | 0.12 | -0.05 | -0.15 | 0.20 | -0.36 |
| A2 | 0.30 | 0.20 | 0.54 | 0.08 | 0.00 | -0.06 | 0.01 | -0.19 |
| A3 | 0.40 | 0.27 | 0.74 | 0.10 | -0.01 | -0.10 | 0.08 | -0.22 |
| | | | | | | | | |
| B1 | 0.39 | 0.21 | 0.59 | 0.15 | -0.14 | -0.20 | 0.09 | -0.31 |
| B2 | 0.46 | 0.22 | 0.81 | 0.07 | -0.48 | -0.32 | -0.08 | -0.46 |
| B3 | 0.45 | 0.20 | 0.76 | 0.08 | -0.35 | -0.32 | 0.04 | -0.47 |
| B4 | 0.33 | 0.22 | 0.68 | 0.06 | -0.50 | -0.24 | -0.12 | -0.31 |
| B5 | -0.14 | -0.18 | 0.65 | 0.09 | -0.48 | -0.29 | 0.20 | -0.15 |
| | | | | | | | | |
| C1 | 0.64 | 0.47 | 0.77 | -0.11 | 0.01 | -0.21 | 0.34 | -0.42 |
| C2 | -0.92 | -0.85 | -0.81 | -0.54 | 0.27 | 0.37 | 0.35 | 0.64 |
| C3 | -0.91 | -0.85 | -0.94 | -0.15 | 0.19 | 0.41 | 0.24 | 0.59 |
| | | | | | | | | |
| D1 | -0.66 | -0.51 | -0.57 | -0.02 | -0.06 | -0.03 | 0.21 | 0.47 |
| D2 | -0.59 | -0.49 | 0.44 | -0.10 | -0.46 | -0.20 | 0.02 | 0.32 |

The effects of the policy scenarios on the values of the coefficient of variation and the Gini coefficient for per capita gdp are shown in Table 14. Given the relatively small size of the policy effects, it comes as no surprise that the effects on the inequality indicators are very small. In some cases the changes in inequality measured by the two indicators are different.

In Table 15 we present the effects of the various policy measures on our welfare measure. The figures in that table can be interpreted as changes in gdp that have been corrected for the inequality in the group of regions concerned. In regions with relatively much inequality (such as the new member states) a given increase in average per capita gdp therefore contributes less to welfare than in regions with less inequality (such as Switzerland and Norway).

**Table 14 Effects of policy scenarios on two inequality measures (CGEurope)**

| | Change in coefficient of variation (x100) | | | | Change in Gini coefficient (x100) | | | |
|---|---|---|---|---|---|---|---|---|
| | All | EU15 | NM12 | SN | All | EU15 | NM12 | SN |
| A1 | -0.00 | -0.01 | 0.00 | -0.01 | -0.003 | -0.004 | 0.003 | -0.005 |
| A2 | -0.01 | -0.01 | -0.01 | -0.02 | -0.001 | -0.002 | 0.002 | -0.025 |
| A3 | -0.01 | -0.02 | -0.00 | -0.02 | -0.004 | -0.006 | 0.005 | -0.029 |
| | | | | | | | | |
| B1 | -0.03 | -0.03 | -0.01 | -0.01 | -0.017 | -0.022 | 0.005 | -0.019 |
| B2 | -0.08 | -0.08 | -0.04 | -0.04 | -0.041 | -0.040 | -0.009 | -0.036 |
| B3 | -0.07 | -0.07 | -0.03 | -0.04 | -0.035 | -0.039 | -0.001 | -0.032 |
| B4 | -0.02 | -0.01 | -0.01 | -0.01 | -0.008 | -0.005 | -0.002 | -0.005 |
| B5 | -0.05 | -0.04 | -0.02 | -0.00 | -0.028 | -0.023 | 0.018 | -0.001 |
| | | | | | | | | |
| C1 | -0.01 | -0.01 | 0.01 | -0.02 | -0.003 | -0.004 | 0.003 | -0.011 |
| C2 | 0.03 | 0.04 | 0.05 | 0.04 | 0.011 | 0.014 | 0.011 | 0.023 |
| C3 | 0.04 | 0.05 | 0.02 | 0.07 | 0.016 | 0.022 | 0.007 | 0.051 |
| | | | | | | | | |
| D1 | 0.01 | 0.02 | 0.01 | 0.06 | -0.002 | -0.000 | 0.013 | 0.032 |
| D2 | -0.04 | -0.03 | -0.02 | 0.03 | -0.026 | -0.019 | 0.001 | 0.015 |

**Table 15 Effects of TEN scenarios on welfare (CGEUrope)**

| | Absolute effects (euros) | | | |
|---|---|---|---|---|
| | All | EU15 | NM12 | SN |
| A1 | 6 | 9 | 1 | 13 |
| A2 | 14 | 22 | 2 | 39 |
| A3 | 19 | 30 | 3 | 48 |
| | | | | |
| B1 | 19 | 29 | 4 | 33 |
| B2 | 39 | 51 | 13 | 60 |
| B3 | 33 | 47 | 9 | 53 |
| B4 | 8 | 8 | 4 | 9 |
| B5 | 13 | 12 | 8 | 3 |
| | | | | |
| C1 | 6 | 9 | 1 | 15 |
| C2 | -35 | -53 | -7 | -70 |
| C3 | -44 | -68 | -9 | -100 |
| | | | | |
| D1 | -25 | -38 | -5 | -67 |
| D2 | -4 | -16 | 4 | -40 |

Table 16 shows the results of a decomposition analysis for objective 1 and objective 2 regions. The first column of this table gives the average absolute impact for the group of regions for which these types are defined (the original member states plus the new member states except Bulgaria and Rumania). The next three columns give the average absolute effects of the policies for the objective 1 regions and the other regions, and the change in the multiplicative term that corrects for inequality, respectively. The last three columns of the table do the same for objective 2 regions.

**Table 16 Effects of policy scenarios on objective 1 and objective 2 regions (CGEurope)**

| | Change in av. Gdp p.c. | Objective 1 regions | | | Objective 2 regions | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 0 | | 1 | 0 | |
| A1 | 8 | 5 | 10 | -0.002 | 10 | 7 | -0.000 |
| A2 | 19 | 10 | 24 | -0.002 | 27 | 14 | 0.000 |
| A3 | 27 | 15 | 33 | -0.004 | 35 | 20 | -0.000 |
| | | | | | | | |
| B1 | 24 | 19 | 27 | -0.009 | 28 | 21 | -0.001 |
| B2 | 44 | 36 | 48 | -0.017 | 51 | 37 | -0.002 |
| B3 | 40 | 33 | 43 | -0.015 | 47 | 34 | -0.002 |
| B4 | 7 | 5 | 8 | -0.002 | 8 | 6 | -0.000 |
| B5 | 10 | 18 | 5 | -0.013 | 5 | 13 | -0.003 |
| | | | | | | | |
| C1 | 8 | 5 | 10 | -0.002 | 10 | 7 | -0.000 |
| C2 | -47 | -25 | -60 | 0.006 | -58 | -39 | 0.001 |
| C3 | -60 | -34 | -75 | 0.009 | -73 | -50 | 0.002 |
| | | | | | | | |
| D1 | -36 | -15 | -46 | 0.000 | -44 | -28 | 0.000 |
| D2 | -16 | 2 | -25 | -0.008 | -20 | -11 | -0.001 |

The table shows that there are indeed differences in the impacts of the various policy scenarios on the objective 1 and 2 regions and the other regions. The equality between obj1 regions and other regions increases as a result of the policy measures, except for scenarios C2 and C3. The equality between obj2 regions and other regions increases in all policy scenarios, but it must be noted that the effects are small.

### 3.5 Results from the STIMA model

The results for the STIMA model have been reported in terms of changes in GDP growth rates. We have transformed them here into the implied changes in per capita gdp in the first year. We interpret these figures in the same way as those resulting from the CGEurope model.

The STIMA model uses the NUTS2 level of regional detail. For a number of regions (BE1, DED, DK, ES63, FR83, GR13, GR21-22, GR41-43, IT12, PT14-15) no results have been reported. The figures below refer to the 186 remaining regions.

We start by summarising the results of STIMA. Table 17 gives the average effect of the three policy scenarios on average per capita income. Just as for SASI and CGEurope, these effects are typically smaller than 100 euros per year.

**Table 17 Absolute and relative effects of TEN scenarios**

| | Absolute | Relative |
|---|---|---|
| A | 64 | 0.32 |
| B | 62 | 0.27 |
| C | 41 | 0.19 |

**Table 18 Variation in absolute effects**

| | St. dev. | Coeff. Of var. |
|---|---|---|
| A | 200 | 3.15 |
| B | 215 | 3.46 |
| C | 163 | 3.99 |

Table 18 shows that there is a lot of variation in the regional effects of ICT policies. The standard deviation is much larger than for the CGEurope model (which concerned, it should be kept in mind, different policy scenarios) and the standard deviation is more than three times the size of the average effect. This shows that there is a large amount of regional variation in the predicted effects of ICT policies.

Even though the variation in the size of the effects is relatively large, it is nowhere negative. For each region the policy effect is forecasted to be either 0 or positive. The large variation that is apparent from Table 18 is caused entirely by outliers for which the effect is very large in comparison to that of other regions.

Table 19 shows the correlation between the absolute and relative effects and per capita gdp. The effects of ICT policies are in two of the three cases negatively correlated with per capita gdp. For policy C the reason is, of course, that it was designed so as to help especially or exclusively the backward regions. Table 19 suggests that it is successful in this respect. However, the effects of policy A, which does not discriminate between regions on the basis of economic indicators are even more negatively correlated with per capita gdp.

**Table 19 Correlation between absolute effects and per capita gdp**

| | Abs. | Rel. |
|---|---|---|
| A | -0.045 | -0.133 |
| B | 0.112 | 0.024 |
| C | -0.023 | -0.041 |

This is confirmed by Table 20, which shows the effects of the policy scenarios on the values of the coefficient of variation and the Gini coefficient for per capita gdp are shown.

**Table 20 Effects of policy scenarios on two inequality measures**

| | Change in coefficient of variation (x100) | Change in Gini coefficient (x100) |
|---|---|---|
| A | -0.105 | -0.053 |
| B | 0.045 | 0.025 |
| C | -0.058 | -0.017 |

In Table 21 we present the effects of the various policy measures on our welfare measure. As discussed in section 3.5, the figures in that table can be interpreted as changes in gdp that have been corrected for the inequality in the group of regions concerned. A remarkable aspect of Table 1 is that for scenario A the welfare effect exceeds the effect on average income. The reason is the relatively large increase in equality that is associated with this scenario. For scenario C the welfare effect is marginally smaller than the effect on average income.

**Table 21 Effects of ICT policy scenarios on welfare**

| | Absolute effects (euros) |
|---|---|
| | All |
| A | 68 |
| B | 58 |
| C | 41 |

# 4 Conclusions

The results of the ESPON 2.1.1 project with respect to cohesion can be found in the final report. The conclusion formulated in the final report are based on the results of the analysis presented in the previous chapters as well as on other analyses. Rather then formulate a set of separate conclusions here, we refer the reader to that final report. We conclude the present report with a number of general remarks with respect to cohesion analysis.

1 The cohesion impacts of the various policy scenarios can be studied from various perspectives and a number of indicators have been developed. Each indicator summarises one aspect of the model results. Since the concept of cohesion has so many different aspects, it should come as no surprise that the size or even the sign of the policy effects differs, depending on the indicator that has been used. Inequality measures can be interpreted as value judgements that have been made explicit and the weight attached to such judgements may differ from person to person.

2 In order to sketch the general context in which the various transport and ICT policies should be placed, we have used the reference scenario for the year 2021 that is used in the SASI model. According to this scenario, there will be a substantial increase in average per capita income, and a more modest decrease in inequality. Apart from transportation policy there are others that attempt to decrease inequality. Moreover, the enlargement of the European Union may itself be expected to give an important impulse towards more cohesion in the whole European area. If the result of all these efforts is just a modest decrease in inequality, this suggests that one should not expect to much from transportation policy in this respect. On the other hand, one should realise that the importance that is usually attached to cohesion issues and the apparent difficulties that exist in improving cohesion make even more important to study the cohesion impacts of transport policies.

3 The results of the SASI and CGEurope models suggest that the effects of the various transportation policies are positively correlated with the size of per capita income. However, if one looks at the relative effects, the correlation is substantially smaller and in some cases negative. The percentage change in per capita income is more important than the absolute size of the effects in many cohesion indicators. This is the reason that in many cases we find a positive impact of the various policies on cohesion. With respect to the results of IVT policies the STIMA models suggests that they may have relatively large cohesion impacts. It appears, somewhat surprisingly, that a policy that does not discriminate on the basis of per

capita income or similar measures has better results than one explicitly directed towards improvement of objective 1 regions. This is illustrative for the difference that may potentially exist between intentions and results. Moreover, it shows the importance of measuring the effectiveness of policy measures.

4 It must be kept in mind that the policy impacts that have been studied refer to one side of the cost-benefit balance only. Investments require funds to be realised and the way these funds are raised may have regional impacts that may counteract or reinforce the effects of the investments themselves. Also, the introduction of pricing measures should be expected to generate means that can be spend in many different ways, with potentially significant cohesion impacts. The D-scenarios that combine pricing measures and investments may come close to self-financing, implying that a complete picture of their regional impacts has been given. However, even in these scenarios the budget is probably not exactly balanced.

## References

Atkinson, A.B. (1970) On the Measurement of Inequality, *Journal of Economic Theory*, **2**, 244-263.

Bourguignon, F. (1979) Decomposable Inequality Measures, *Econometrica*, **47**, 901-920.

These two articles, referenced in the text, have been important in the development of the economic literature on inequality. A recent comprehensive review of this literature can be found in:

Atkinson, A.B. and F. Bourguignon (eds.) (2000) *Handbook of Income Distribution*, Amsterdam, Elsevier.