# Effect of GDP changes on road traffic fatalities

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## Abstract

Road safety developments are correlated with mobility developments, which are in turn affected by socioeconomic factors (level of motorization, economic growth etc.). During the last few years, road traffic fatalities exhibit important annual reductions in several developed countries; these reductions cannot be justified by policy efforts alone, and are partly attributed to the global economic recession affecting most countries' economy and mobility. The present research aims to associate annual Gross Domestic Product (GDP) changes with the related annual changes in road traffic mortality rates. Mortality rates and GDP per capita data for the period 1975-2011 are used from 27 European countries, for the development of mixed linear models. The results suggest that an annual increase of GDP per capita leads to an annual increase of mortality rates, whereas an annual decrease of GDP per capita leads to an annual decrease of mortality rates. These effects are statistically significant overall, and in different groups of countries (Northern / Western, Central / Eastern and Southern). A one-year lagged effect of annual GDP decrease was found to be significant in Northern / Western countries. These effects may capture annual GDP increases from the improvement in the prosperity level of most European countries, as well as occasional annual GDP decreases as a result of socioeconomic events (e.g. economic recessions, political changes in Central / Eastern European countries in the early nineties etc.). The models proposed in this paper are able to characterize the short-term dynamics of the examined variables, but not their long-run relationships.

**Key-words**: road fatalities; GDP per capita; annual changes; mixed regression models.

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## 1. Background and objectives

Road traffic fatalities and related injuries present a constantly decreasing trend during the last decades in most developed countries, as a result of systematic efforts at national and international level. Nevertheless, the total number of road fatalities in several countries and as a whole is still considered to be unacceptable, and more efforts are required for achieving the ambitious road safety targets adopted by most countries (ETSC, 2012). Within this context, the analysis and understanding of past developments is critical for the identification and quantification not only of efficient road safety interventions and good practice examples, but also of the effects of underlying or external factors that may affect these developments (IRTAD, 2011).

Road crash risk developments over time are typically correlated with mobility developments, as expressed in the amount of vehicle-kilometres. These mobility estimates are in turn affected by socioeconomic factors, reflecting the level of motorization in a country, the economic growth and the level of prosperity overall. The hypothesis that economic growth leads to increased vehicle ownership and increased amount of travel, affecting the road safety level, has been tested and confirmed by several macroscopic studies, dating since Smeed (1968).

More recently, Page (2001) presented a statistical model to compare road mortality in OECD (Organisation for Economic Co-operation and Development) countries, and showed that, the higher the GDP per capita, the higher the vehicle ownership in each country, whereas road fatalities per registered vehicles tend to decrease over time as GDP increases. Another study (Lassarre, 2001) applied the local linear trend model to ten European countries and used the estimated trend and elasticities to make inference about the relationship between traffic flow and number of fatalities. Another study (vanBeeck et al., 2000) examined the association between prosperity and traffic accident mortality in industrialized countries in a long-term perspective (1962-1990) and found that the long-term relation between prosperity and traffic accident mortality appears to be non-linear. More recently, (Kopits &Cropper, 2005) researchers used linear and log-linear forms to model region specific trends of traffic fatality risk per income growth, using panel data from 1963 to 1999 for 88 countries. In another study (Yannis et al. 2011) piece-wise linear regression models were fitted to identify critical changes in macroscopic road accident trends in European countries, and the results suggested that the maximum fatality rates experienced in various countries over time lied within a relatively short range of vehicle ownership, namely around 200-300 vehicles per 1000 inhabitants, a point at which the fatality rates switched from an increasing trend to a decreasing one.

On the other hand, microscopic or occasional changes in economic and social factors, interrupting the smooth macroscopic trends, were also proved to be associated with road safety changes. The global petrol crisis in the early seventies has been studied (Tihansky, 1974), concluding that the reduced speed limits introduced by the authorities and the more cautious driving by an energy-conscious public have contributed to striking declines in the highway death toll.

The economic recession of the early eighties has been studied by several researchers with respect to its effects on road traffic fatalities. A significant concurrent inverse relationship between the rate of unemployment and the frequency of crash involvement was revealed (Wagenaar, 1984), as well as a significant positive one-year lagged effect between these two variables. In the same context (Hedlund et al., 1984), several factors were found to have contributed to the 1982 changes in road traffic fatalities in the USA, including demographic shifts, economic conditions, and travel patterns. Another study examined the effects of that recession within a broader scope, by associating unemployment rates with road fatalities, suicides and homicides (Reinfurt et al., 1991); the results revealed that unemployment rates do not appear to improve short-term forecasts of road fatalities.

During the last few years, road traffic fatalities exhibit important reductions in several countries; these reductions cannot be justified by the considerable policy efforts alone, and are already partly attributed to the global economic recession affecting most countries' economy and thus mobility. More specifically, a number of possible effects of economic recession are suspected to contribute to this impressive reduction, however they have not been substantiated so far (IRTAD, 2011). A recent study (Kweon, 2011) examined the 2008 reduction in traffic fatalities in the US using historical annual data and found that annual changes in unemployment rate and CPI (Consumer Price Index) were strongly associated with annual changes in road safety outcomes.

The objective of the present research is the analysis of the effect of changes in Gross Domestic Product (GDP) on mortality rates. More specifically, the present research aims to associate annual GDP changes with the related annual changes in mortality rates in Europe, unlike most existing studies which focus on the long-term relation between these two. This type of short term analysis is expected to shed some light on how the ongoing economic growth has resulted in constant decrease in fatalities overall, and - most importantly - how temporary economic recessions, especially the current one, may affect road safety beyond the expected effects. For that purpose, economic and road safety data from 27 European countries are used for the development of mixed effects models. It is therefore underlined that the models proposed may be able to characterize the short-term dynamics of the variables but not their long-run relationships.

## 2. Methodology and data

### 2.1. Time series data of road fatalities and GDP

In the present research, countries have been grouped according to their geographical location, while taking into account both the level of prosperity and the road safety development. Therefore, three groups of European countries were created, as follows:

- Northwest countries: Belgium (BE), Denmark (DK), Germany (DE), Ireland (IE), France (FR), Luxembourg (LU), Netherlands (NL), Austria (AT), Finland (FI), Sweden (SE) and United Kingdom (UK)
- Southern countries: Greece (EL), Spain (ES), Italy (IT) and Portugal (PT)
- Central/Eastern countries: Bulgaria (BG), Czech Republic (CZ), Estonia (EE), Latvia (LV), Lithuania (LT), Hungary (HU), Poland (PL), Romania (RO) and Slovenia (SI)

Indeed, Northwest countries are more prosperous with the average GDP per capita be over 25.000$, followed by Southern countries whose average GDP per capita ranges between 12.000$ and 25.000$ and Central/Eastern countries with an average GDP per capita less than 12.000$. As regards the road safety development over time, countries of each group exhibit similar patterns, as it is described in detail below.

Figure 1 shows the developments of road traffic mortality rates (F/P i.e. fatalities per population) and GDP per capita in a representative sample of eight European countries, including four Northwestern countries (the Netherlands, Germany, Finland and the United Kingdom), two Central-eastern countries (Hungary and Estonia) and two Southern countries (Spain and Greece), for the period 1975-2011. The mortality rate is a popular indicator for risk performance assessment at international level, especially since vehicle-kilometres or other traffic data are not available or comparable at international level. However, this indicator does not take into account the level of motorization, and its value can be low not only in case of high level road safety but in also case of low motorization level (Papadimitriou et al., 2013).

In Northern-Western countries, the mortality rate presents a constantly decreasing trend during the last decades, however in Southern and Central-Eastern countries an increasing trend was initially observed within the examined period, with more fluctuations overall. It has been argued that Southern and central-Eastern countries have reached the level of motorization at which fatalities start to decrease later than Northern and Western countries (Yannis et al., 2011). In all countries, the GDP per capita shows a seemingly constantly increasing trend, with the effect of the current economic recession, as well as of the economic recession of the early eighties, being visible in almost all countries at the end and in the middle of the time series respectively.

***Figure 1 to be inserted here***

Moreover, a clear regional pattern is identifiable (see Figure 2): in Northwestern countries, the decreasing trend in the mortality rate spans the entire period, while in Southern countries the decrease started somewhat later, following an increasing trend that was initially observed within that period. In Central and Eastern countries, the mortality rate shows more fluctuation, and the effect of the changes in political regimes that took place in the early nineties is striking.

***Figure 2 to be inserted here***

The overall picture of Figure 1 appears to confirm the negative relationship between economic growth and road safety found in several macroscopic studies. However, when examining the annual percentage changes in mortality rates and GDP per capita in the same sample of countries for the same period (see Figure 3), another pattern is observed. More specifically, it appears that annual changes in mortality rates are positively correlated with annual changes in GDP per capita, i.e. annual GDP increases coincide with annual mortality rate increases and vice versa, i.e. annual GDP decreases coincide with annual mortality rate decreases. This pattern is more identifiable in Central-Eastern and in Southern countries. Furthermore, a lagged effect is also detectable, suggesting that annual GDP changes, especially larger ones, may be positively correlated with next year's mortality rate changes i.e. an important annual drop in GDP per capita may result in an important annual drop of mortality rate one year later. The data from year 2008 onwards seem to suggest such a pattern in particular.

***Figure 3 to be inserted here***

On the basis of the above, the present research aims to explore these patterns, by associating annual GDP changes with annual mortality rate changes. Data for 27 European countries have been extracted from different data sources for the period 1975-2011. More specifically, data on fatalities have been extracted from the IRTAD database of the OECD/International Transport Forum, population data come from the European Statistical Office (Eurostat) and GDP per capita data have been obtained from USDA's Economic Research Service. To account for differences in purchasing power across countries and allow for comparisons over time, the economic factor is measured by Real GDP per capita in 2005 dollars. Then, a mixed effects modeling technique is applied.

### 2.2. Mixed effects model

In the present analysis, the dependent variable is the annual percentage change in the mortality rate per population, and the main explanatory variable is the annual percentage change of GDP per capita. These are estimated on the basis of the time series data of mortality rates and GDP per capita for the period 1975-2011 for the 27 European countries.

Mortality rates are expected to be serially correlated, as is typically the case with time series data. Annual mortality rate changes, however, are expected to be less or not at all serially correlated, compared to the mortality rates, as their calculation is equivalent to a differencing of the series. This was confirmed by means of the autocorrelations of the mortality rate annual changes in each country. It was observed that in all countries, the mortality rates are indeed autocorrelated, whereas the mortality rate annual changes are not always autocorrelated. Nevertheless, another source of possible covariation in the data is the fact that the measurement of mortality and GDP changes are "nested" in countries, possibly sharing thus unobserved attributes, as is often the case for repeated measurements in panel data.

This type of data can be modeled on the basis of mixed effects models (Harville, 1976; McLean et al. 1991). Mixed effects models expand general linear models, so that the error terms and random effects are permitted to exhibit correlated and non-constant variability. They can be written according to the following general formulation, in matrix notation:

$$Y_i = X_i\beta + Z_i\gamma_i + \varepsilon_i \qquad (1)$$

Where $X_i$ and $Z_i$ are the fixed and random design matrices, respectivey, $\beta$ is a vector of unknown fixed effects and $\varepsilon_i$ is the unknown random error. Moreover, $\beta$ represents parameters that are the same for all subjects and $\gamma$ represents parameters that are allowed to vary over subjects. It is assumed that random effects are normally distributed with:

$$E\begin{bmatrix}\gamma \\ \varepsilon\end{bmatrix} = \begin{bmatrix}0 \\ 0\end{bmatrix}, \text{ and } \operatorname{Var}\begin{bmatrix}\gamma \\ \varepsilon\end{bmatrix} = \begin{bmatrix}G & 0 \\ 0 & R\end{bmatrix}$$

Given these assumptions, the variance of Y is given by $V = ZGZ^T + R$, consequently the random part of the model is fit by specifying the terms that define the random design matrix Z, and by specifying the covariance structures of G and R.

In this research, a logarithmic form of the model was opted for, namely the natural logarithm of the dependent variable as is typically the case for road fatality data. Population data were used in order to model the annual changes in the mortality rates rather than in the fatality counts. Moreover, annual GDP changes and country group (i.e. northern / western, central / eastern, southern) are considered as fixed effects.

As regards random effects, time effects are considered as a random variation of 1st order autoregressive nature (AR-1) in the unknown random error ε, to express the continuous repeated measurements (time series) over the examined countries.

Therefore, in (1) $Y_i$ is the annual change in the logarithm of the mortality rate, $\beta_i$ are fixed effects of the regressors (annual change in the logarithm of GDP, country group) in $X_i$, and random errors $\varepsilon_i$ are assigned a 1st order autoregressive covariance structure. Equation (1) can be thus written as follows:

$$\log FAT_{it} - \log FAT_{i(t-1)} = \alpha + \beta_1[\log GDP_{it} - \log GDP_{i(t-1)}] + \beta_2 CountryGroup_{it} + \varepsilon_{it} \qquad (2)$$

With $E(\varepsilon_{it}) = 0$ and $\operatorname{Var}(\varepsilon_{it}) = R = \sigma_t^2 \begin{bmatrix} 1 & \rho & \rho^2 & \rho^3 \\ \rho & 1 & \rho & \rho^2 \\ \rho^2 & \rho & 1 & \rho \\ \rho^3 & \rho^2 & \rho & 1 \end{bmatrix}$

Where α is a fixed intercept, $\sigma_t^2$ is the between-country variance of the measurement at particular year t and ρ is the correlation between measurements taken at successive years. According to this structure, the correlation of measurements taken over successive years are stronger than the correlations of measurements taken further apart. It is also noted that homogenous country variances are considered and no other random effect expressing variation over countries is assumed.

As mentioned above (see Figure 2), three distinct groups of countries are identified as regards the trends of the mortality rates. Therefore, two types of models are considered, first a global model for annual mortality rate changes and annual GDP changes in all countries, and then a set of separate models for each group of countries. Moreover, two distinct effects are examined as regards the effect of GDP changes; GDP increases and decreases are entered in the models separately - on the basis of their absolute values - as two distinct variables, as it was revealed in early modeling attempts that a single linear effect of GDP change could not describe the related changes in fatalities. Consequently, two variables were defined: “GDP increase” as the absolute value of annual GDP increases, with value 0 if no increase took place, and “GDP decrease”, respectively.

## 3. Results

### 3.1. Modelling all countries

Linear Mixed Models are used to estimate the effect of different annual GDP changes on mortality rate changes, while adjusting for correlation due to repeated observations on each country over the 35 year period. Table 1 shows the best fitting model for all countries, with fixed effects for each group of countries and each type of annual GDP change (i.e. increase or decrease), as well as their interactions, and random effects for the autoregressive covariance structure expected in the model residuals.

As regards the fixed effects, the regional pattern suggested by previous studies was confirmed in the present study, i.e. central and eastern countries present higher annual changes in mortality rates, Southern countries have somewhat lower annual changes in mortality rates and Northwestern countries have the lowest annual changes in mortality rates.

***Table 1 to be inserted here***

Moreover, an annual increase of GDP per capita leads to an annual increase of mortality rates, whereas an annual decrease of GDP per capita leads to an annual decrease in mortality rates; these effects are statistically significant. It is thereby indicated that, although an inversely proportional macroscopic relationship between mortality rates and GDP may exist (i.e. while GDP increases over time fatalities decrease in all countries), there is a short-term effect of GDP annual changes on fatality annual changes. When looking into the interactions of country group with GDP changes, it is observed that annual GDP increases or decreases significantly affect mortality rate annual changes only in Central / Eastern countries, whereas these effects are not significant in the other groups of countries.

Lagged effects of annual GDP increase and decrease were also tested, in order to examine whether the annual GDP change affects not only the change in the mortality rate of that year, but also of the next year, but they were not found to be significant.

Not all parameters of the covariance structure considered (AR-1) were found to be statistically significant. In fact, the between-country variation $\sigma_t^2$ was found to be significant, whereas the autocorrelation ρ (rho) was not found to be significant. For completeness, the same model has been tested allowing for:
(i) heterogenous variances (i.e. a different country variance $\sigma_{it}^2$ at each year of observation), instead of fixed country group effects. The results indicated that indeed the different variances were significant, however the modelling results were not significantly different.
(ii) heterogenous variances and heterogenous correlations (i.e. a different country variance $\sigma_{it}^2$ at each year of observation and different autocorrelations $\rho_t$ between

successive years). The results indicated that the different variances were significant, but the different autocorrelations were not. Again, the modelling results were not significantly different in terms of the sign and statistical significance of the parameter estimates.
Given that both models included a large number of parameters (40 and 74 respectively), without offering substantial improvement to the results, we opted for keeping the original more parsimonious model of Table 1 with homogenous variances.

### 3.2. Modelling groups of countries

In order to further investigate the effect of annual GDP changes on annual mortality rate changes, separate models were developed for each group of countries. This was attempted because the data exploration revealed quite different patterns of mortality rate and GDP changes in the different groups of countries, leading to the assumption that the effect of annual GDP changes on annual fatalities changes may differ in different groups of countries. The results of the total model (Table 1) also indicated a different relationship in different groups of countries.

The three separate models fitted for Northern / Western, Central / Eastern and Southern European countries are presented in Table 2.

Annual GDP increases were found to lead to annual mortality rate increases, and vice versa, in all groups of countries, a regional effect which was not identifiable when examining all countries together. These effects are statistically significant at 95% in all groups of countries, and only in Southern countries the annual GDP decrease is significant at 87%, which may be considered as marginally acceptable.

***Table 2 to be inserted here***

Lagged effects were also tested, according to which, the annual GDP change affects not only the change in the mortality rate of that year, but also of the next year (expressed by the lagged variables GDPincrease-lagged1, GDPdecrease-lagged1). This lagged effect was found to be significant only in Northern / Western countries, and only as regards annual GDP decrease. This may be explained by the fact that GDP in Northern / Western countries has presented a smoother trend over the examined period, with smaller (although not necessarily fewer) fluctuations over the years, compared to the rest of Europe. The increased economic reliability of these countries is likely to result in a larger GDP decrease being experienced as a striking change, affecting thus mortality rates to a slightly longer term.

In almost all cases, the random effects representing the autoregressive structure of the model residuals were found to be significant, which was also not identifiable when examining all countries together. More specifically, the correlations between successive measurements of mortality rate annual changes are significant in Northern and Southern countries, but non significant in Eastern countries.

It is interesting to notice that, in Northern countries a negative $\rho$ is estimated, suggesting that an annual mortality rate increase is typically associated with a decrease in the next year, and vice versa. This may reflect the fact that in these countries, fluctuations in mortality rate changes were relatively small and 'recoverable'. On the other hand, in Southern countries a positive $\rho$ is estimated, suggesting that an annual increase in mortality rate is typically associated with an increase in the next year as well - the same is the case for annual decreases in these countries. This may reflect larger and less 'recoverable' fluctuations in the mortality rate.

## 4. Discussion

From the above results, it is suggested that a relationship exists between annual mortality rate changes and annual GDP changes. More specifically, a statistically significant relationship between annual GDP increase and mortality rate increase was established, as well as a statistically significant relationship between annual GDP decrease and mortality rate decrease. Particularly in Northern / Western European countries, annual GDP decrease is associated with mortality rate decrease on the same year, as well as on one year later.

This effect was identified throughout a long period of related data, and is therefore likely to capture all sorts of annual effects, from systematic annual GDP increases, as a result of the overall improvement in the prosperity level of most European countries, to occasional annual GDP decreases that have been observed as a result of socioeconomic events (e.g. economic recessions, as those of the early eighties and from 2008 onwards, the political changes in Central / Eastern European countries of the early nineties etc.). In each case, annual fluctuations in the mortality rates appear to "follow" the related annual fluctuations in GDP.

Within this context, it may be useful to examine more closely the situation related to the current economic recession in the examined European countries. Table 3 shows the mortality and GDP per capita figures in several European countries from 2007 onwards, including the most recent (although often provisional) data for 2011.

***Table 3 to be inserted here***

It is noticed that, from 2007 onwards, a smaller or bigger decrease in GDP per capita took place in all the countries, as a results of the global economic recession. At the same time, fatalities decreased to a significant degree, mainly as a result of decrease in mobility due to the recession. However, it is interesting to notice the most recent developments, i.e. in the last couple of years.

In several countries, GDP started to increase again after year 2009. In most of these countries, an increase in fatalities is observed, mostly not at the exact same year (2010), but one year later (i.e. after two consecutive annual GDP increases) – see for instance Belgium, Germany, Estonia, Italy, Finland, Sweden and the UK. In a couple of cases (e.g. Italy, Belgium) the GDP increase on 2010 was very small and thus the increase of fatalities on 2011 is also very small, yet detectable.

In other countries, mostly in Southern ones but also in Ireland, GDP per capita continues to decrease during the examined period, and fatalities continue to decrease – see for instance Greece, Ireland, Spain, and Portugal. It is therefore quite likely that, once these economies start to recover, fatalities increase again.

There are a few countries whose economy has recurred from the recession, but their fatality figures appear to be less affected. More specifically, there are countries for which GDP started increasing again after 2009, but the fatality figures continue to decrease – see for instance Austria, the Netherlands, Hungary and the Czech Republic. It is possible that an increase in fatalities takes place in the very near future, reflecting a longer lagged effect in these countries. On the other hand, it is also possible that the overall decreasing trend of the traffic fatalities in these countries may not suffer the effect of recent GDP increases as in the other countries. The monitoring of future developments in these countries (growth and safety measures) will certainly provide further insight in the nature of these effects.

In a few years, where more data will be available, it will be possible to fully assess the effects of the current economic recession on road safety, and test whether it fits the global pattern suggested by the results of the present research. The new data should be exploited for further improvement of the proposed models.

The present research focused on the short-term relationship between the differenced GDP and mortality rate series. The long-term relationship between these two measures also warrants further investigation, especially with respect to panel data (i.e. European countries). In this case, appropriate statistical techniques should be implemented to account for possible cointegration between the two series. The Error Correction Model in particular (Engle & Granger, 1987; Eberhart, 2010), allows for a combined analysis of long- and short-term dynamics, and appears to be the most promising - although particularly demanding - analysis technique.

## 5. Conclusions

Despite the few exceptions discussed above, the most recent fatality and GDP data appear to reveal a systematic relationship between GDP annual fluctuations and mortality rates annual fluctuations. The short-term dynamics of the relationship empirically identified on the basis of the data have been tested, quantified and statistically substantiated for the first time by the models presented in the previous sections. The model was built upon the data of not only the recent economic recession, but also on previous related socioeconomic events in many different European countries.

Overall, it is expected that, although traffic fatality trends will continue to decrease over time, as the overall level of prosperity of European countries and the road safety awareness, culture and policy efforts increase, at periods of economic recession there may be important road safety additional “benefits”. These “benefits” may be due to a number of potential impacts of economic recession that are suspected to contribute to the impressive reductions in fatalities, such as:

- Less vehicle-kilometers because of increased fuel prices, decrease of recreation mobility, less heavy goods traffic;
- Less speeding and more economical and environment friendly driving, due to increased fuel prices; less speeding possibly also due to low drivers’ morale, depression etc.;

- Less risky or impaired driving behaviours, as fewer young, inexperienced or elderly drivers may afford vehicle ownership and travel – to a different extent and for different reasons.

Nevertheless, it is also expected that, once the socioeconomic conditions improve, road traffic fatalities will temporarily increase, “correcting” for the effect of these external factors.

On the other hand, one might consider other impacts of economic recession that might contribute to an increase in road traffic fatalities rather than a decrease, such as: poorer level of vehicle fleet with more older cars on the roads and fewer applications of passive and active safety-related devices; more pedestrians, bicyclists and motorcyclists on the roads thus increasing the share of vulnerable road users; slowing down of the infrastructure improvements on the roads; more risky driver behavior due to stress, depression, or higher alcohol consumption, etc. Within this complicated system of possible positive and negative impacts of the economic recession on road safety, the mobility reduction may be the most critical determinant of the final road safety outcomes.

Conventional macroscopic models relating socioeconomic factors with road safety may by nature fail to capture the effect of local phenomena within the time series of the examined developments. Such phenomena may temporarily yet heavily affect road traffic fatalities, although the road safety situation may eventually recur close - although not exactly - to the overall trend. Consequently, the monitoring and quantification of the effect of short-term, circumstantial effects of economic growth on road safety may assist in the prompt identification of such situations, the interpretation of road safety improvements or deteriorations beyond the expected road safety policy outcomes, and the adjustment of expectations as regards future developments.

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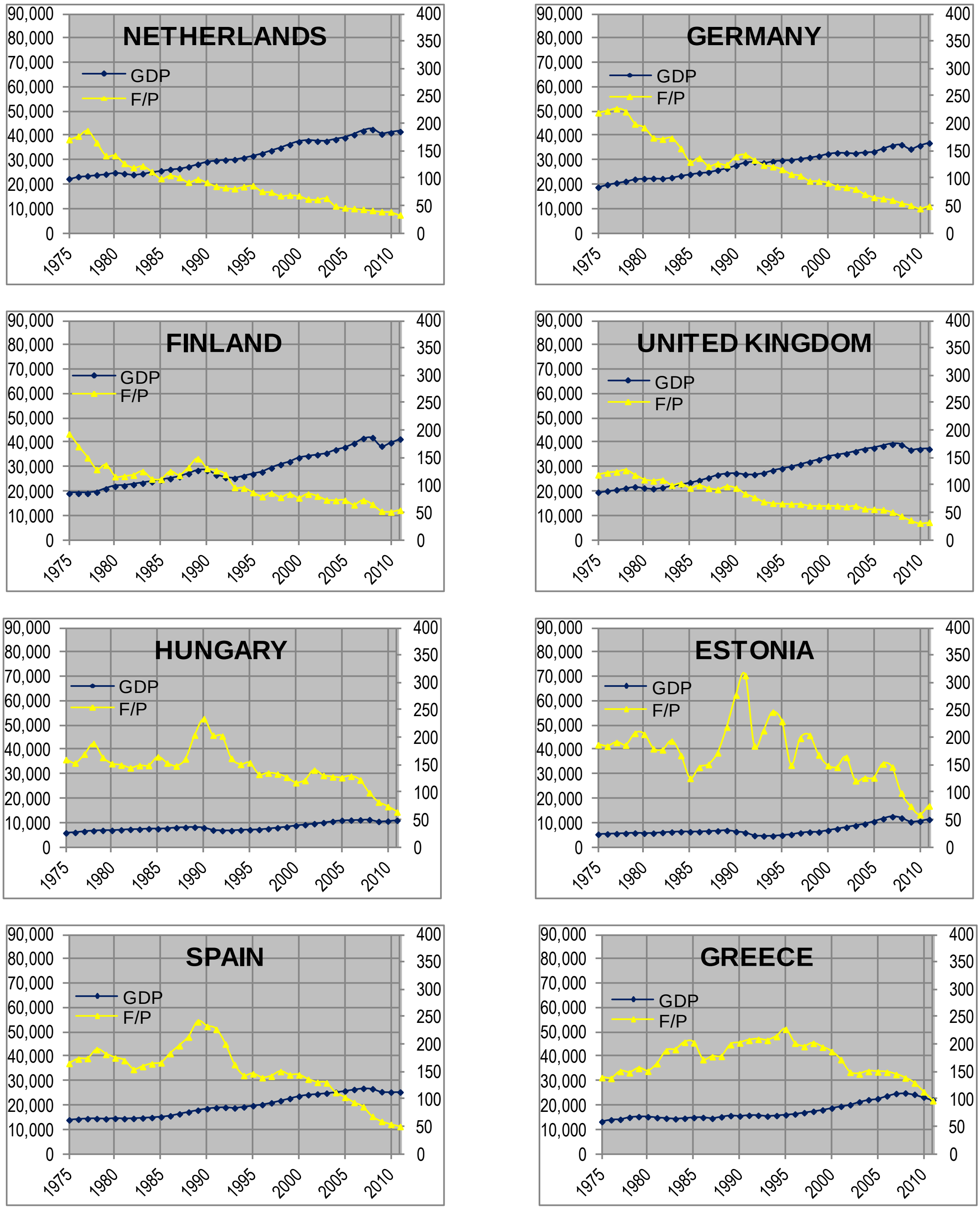


**Figure 1.** Time series of fatalities per population (F/P) and GDP per capita 1975-2011 for eight countries

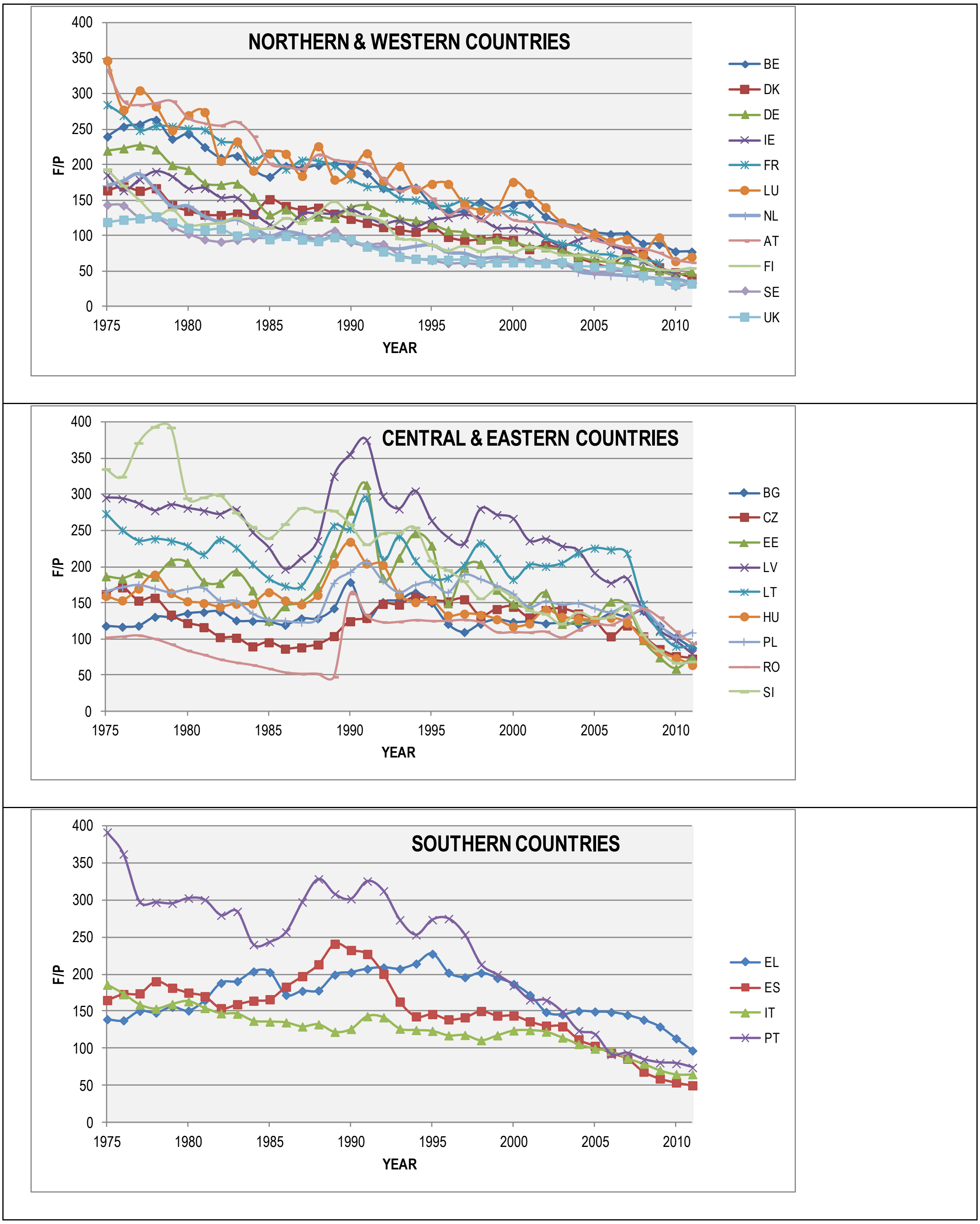


**Figure 2.** Time series of fatalities per population (F/P) per group of country 1975-2011 (Northern / Western – top panel, Central / Eastern – middle panel, Southern – bottom panel)

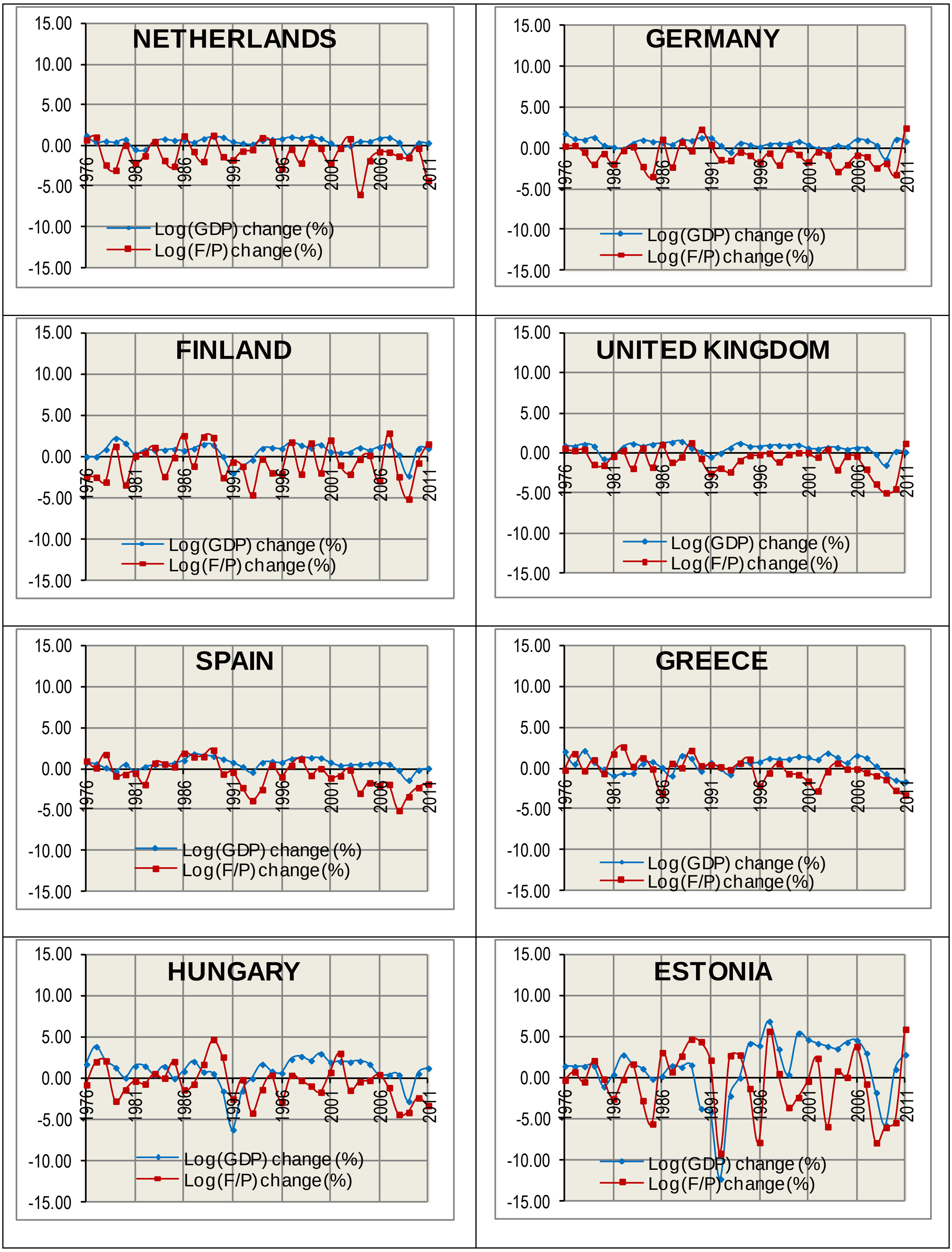


**Figure 3.** Time series of mortality rate annual percentage change [Log(F/P) change (%)] and GDP annual percentage change [Log(GDP) change (%)] 1975-2011 for eight countries

**Table 1.** Linear mixed effects model for mortality rate annual changes in all countries

| **Fixed effects** | Estimate | t | p-value |
|---|---|---|---|
| Intercept | -1.322 | -6.746 | 0.000 |
| [Country group=Eastern] | 0.667 | 2.360 | 0.019 |
| [Country group=Southern] | 0.426 | 1.127 | 0.260 |
| [Country group=Northern] | $0^a$ | . | . |
| Log[GDPincrease] | 0.763 | 3.516 | 0.000 |
| Log[GDPdecrease] | -0.857 | -2.141 | 0.033 |
| [Country group=Eastern] *Log[GDPdecrease] | 0.752 | 1.862 | 0.063 |
| [Country group=Southern] *Log[GDPdecrease] | 0.073 | 0.099 | 0.921 |
| [Country group=Northern] * Log[GDPdecrease] | $0^a$ | . | . |
| [Country group=Eastern] * Log[GDPincrease] | -0.612 | -2.679 | 0.008 |
| [Country group=Southern] * Log[GDPincrease] | -0.239 | -0.641 | 0.522 |
| [Country group=Northern] * Log[GDPincrease] | $0^a$ | . | . |
| **Covariance parameters** | | | |
| AR1 diagonal ($\sigma^2$) | 5.085 | 20.670 | |
| AR1 rho ($\rho$) | -0.032 | -0.900 | |
| **Likelihood Ratio Test** | 3862.375 | | |
| Degrees of freedom | 10 | | |

**Table 2.** Linear mixed effects models for mortality rate annual changes in groups of countries (Northern / Western – left panel, Central / Eastern – middle panel, Southern – right panel)

| | Northern countries | | | Southern countries | | | Eastern countries | | |
|---|---|---|---|---|---|---|---|---|---|
| **Fixed effects** | Estimate | t | p-value | Estimate | t | p-value | Estimate | t | p-value |
| Intercept | -1.250 | -8.832 | 0.000 | -0.964 | -3.215 | 0.002 | -1.752 | -5.273 | 0.000 |
| Log[GDPincrease] | 0.657 | 3.663 | 0.000 | 0.417 | 1.914 | 0.058 | 0.445 | 3.760 | 0.000 |
| Log[GDPdecrease] | -0.751 | -2.422 | 0.016 | -0.599 | -1.522 | 0.130 | -0.147 | -2.245 | 0.026 |
| Log[GDPincrease]-lag1 | 0.114 | 0.639 | 0.524 | 0.196 | 0.919 | 0.360 | -0.050 | -0.448 | 0.655 |
| Log[GDPdecrease]-lag1 | -1.125 | -3.637 | 0.000 | -0.281 | -0.698 | 0.486 | 0.096 | 1.469 | 0.144 |
| **Covariance parameters** | | | | | | | | | |
| AR1 diagonal ($\sigma^2$) | 3.210 | 12.841 | | 2.075 | 7.437 | | 5.516 | 9.59253 | |
| AR1 rho ($\rho$) | -0.291 | -5.813 | | 0.337 | 4.158 | | -0.035 | -0.43868 | |
| **Likelihood Ratio Test** | 1555.316 | | | 496.398 | | | 868.652 | | |
| Degrees of freedom | 6 | | | 6 | | | 6 | | |

**Table 3.** Fatalities (30-days definition) and GDP per capita (USD, 2005) development 2007-2011 per country

| | Fatalities | | | | | GDP per capita | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2007 | 2008 | 2009 | 2010 | 2011 | 2007 | 2008 | 2009 | 2010 | 2011 |
| Belgium | 1071 | 944 | 942 | 840 | 843 | 38.27 | 38.61 | 37.51 | 38.29 | 39.14 |
| Czech Republic | 1221 | 1076 | 901 | 802 | 769 | 13.80 | 14.15 | 13.58 | 13.91 | 14.29 |
| Germany | 4949 | 4477 | 4152 | 3648 | 4006 | 35.83 | 36.30 | 34.53 | 35.89 | 37.01 |
| Estonia | 196 | 132 | 100 | 79 | 101 | 12.48 | 11.92 | 10.33 | 10.58 | 11.31 |
| Ireland | 338 | 280 | 238 | 212 | 188 | 50.80 | 47.94 | 43.70 | 42.84 | 41.98 |
| Greece | 1612 | 1553 | 1456 | 1281 | 1100 | 24.79 | 25.01 | 24.46 | 23.34 | 22.16 |
| Spain | 3823 | 3100 | 2714 | 2478 | 2298 | 26.92 | 26.74 | 25.53 | 25.38 | 25.41 |
| France | 4620 | 4275 | 4273 | 3992 | 3969 | 35.11 | 34.88 | 33.73 | 34.05 | 34.42 |
| Italy | 5131 | 4725 | 4237 | 3934 | 3941 | 30.95 | 30.31 | 28.55 | 28.78 | 28.86 |
| Lithuania | 740 | 499 | 370 | 300 | 299 | 8.61 | 8.88 | 7.60 | 7.72 | 8.15 |
| Hungary | 1232 | 996 | 822 | 739 | 639 | 11.15 | 11.26 | 10.52 | 10.66 | 10.97 |
| Netherlands | 709 | 677 | 644 | 640 | 550 | 41.92 | 42.55 | 40.69 | 41.20 | 41.71 |
| Austria | 691 | 679 | 633 | 552 | 521 | 39.70 | 40.54 | 38.94 | 39.69 | 40.62 |
| Poland | 5583 | 5437 | 4572 | 3907 | 4164 | 8.95 | 9.41 | 9.57 | 9.94 | 10.36 |
| Portugal | 974 | 885 | 840 | 845 | 782 | 18.72 | 18.66 | 18.14 | 18.34 | 17.97 |
| Finland | 380 | 344 | 279 | 272 | 290 | 41.69 | 42.05 | 38.55 | 39.92 | 41.44 |
| Sweden | 471 | 397 | 358 | 266 | 311 | 44.22 | 43.87 | 41.47 | 43.70 | 45.55 |
| United Kingdom | 3059 | 2645 | 2222 | 1905 | 1998 | 39.29 | 39.02 | 36.90 | 37.15 | 37.32 |