Wegman F, Allsop R, Antoniou C, Bergel-Hayat R, Elvik R, Lassarre S, Lloyd D, Wijnen W.
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Accident Analysis & Prevention. 102 (May), 2017, 51-59. 0001-4575

The article has been published in final form by Elsevier at

http://dx.doi.org/10.1016/j.aap.2017.01.022

The final publication is available in: Accident Analysis and Prevention, 102, 2017, 51-59.

10.1016/j.aap.2017.01.022

How did the economic recession (2008-2010) influence traffic fatalities in OECD-countries?

Fred Wegman, Richard Allsop, Constantinos Antoniou, Ruth Bergel-Hayat, Rune Elvik, Sylvain Lassarre, Daryl Lloyd, Wim Wijnen

ABSTRACT

This paper presents analyses of how the economic recession that started in 2008 has influenced the number of traffic fatalities in OECD countries. Previous studies of the relationship between economic recessions and changes in the number of traffic fatalities are reviewed. Based on these studies, a causal diagram of the relationship between changes of the business cycle and changes in the number of traffic fatalities is proposed. This causal model is tested empirically by means of multivariate analyses and analyses of accident statistics for Great Britain and Sweden. Economic recession, as indicated both by slower growth of, or decline of gross national product, and by increased unemployment is associated with an accelerated decline in the number of traffic fatalities, i.e. a larger decline than the long-term trend that is normal in OECD countries. The principal mechanisms bringing this about are a disproportionate reduction of driving among high-risk drivers, in particular young drivers and a reduction of fatality rate per kilometre of travel, probably attributable to changes in road user behaviour that are only partly observable. The total number of vehicle kilometres of travel did not change very much as a result of the recession. The paper is based on an ITF-report that presents the analyses in greater detail.

Key words: economic recession; traffic fatalities; literature review; multivariate analyses

1 BACKGROUND AND RESEARCH PROBLEM

The observation that the number of traffic fatalities tends to decline during an economic recession was first made many years ago, see, for example Wagenaar (1984) for an early analysis. By now, several studies, reviewed in the next section of the paper, have reported an association between fluctuations of the business cycle and fluctuations in the number of traffic fatalities. Most studies have found that during an economic recession, the number of traffic fatalities is reduced, or a long-term decline is reinforced. The main objectives of this paper are: (1) to assess the robustness of the statistical relationship between economic recession and the number of traffic fatalities, and (2) to identify mechanisms producing this relationship. The paper is based on an ITF-report (ITF/IRTAD 2015) consisting of six independent studies of the relationship between economic recession and changes in the number of traffic fatalities together with an overview (Allsop 2015). The OECD defines a recession as at least two successive quarters during which there is a decline in gross domestic product. In this paper, the term recession will also refer to periods during which unemployment increases.

One of these studies (Wijnen and Rietveld 2015) is a review of previous studies. One study is a combination of a review of previous studies and statistical analyses of data for 14 OECD-countries (Elvik 2015). The third (Antoniou et al. 2015) and fourth (Bergel-Hayat et al. 2015) are econometric analyses of the relationship between recessions and traffic fatalities. The fifth (Forsman et al. 2015) and sixth (Noble et al. 2015) studies examine accident statistics for Sweden and Great Britain in order to identify mechanisms that underlie the relationship between economic recession and change in the number of traffic fatalities. The overview (Allsop 2015) draws together a number of the findings. All studies were completed during 2014. The studies were conducted independently of each other. They differ in several aspects of methodology and may therefore be used as a basis for assessing the robustness of the relationship between economic recessions and changes in the number of traffic fatalities. If the results of the studies are similar, that indicates a more robust relationship than if the findings are inconsistent.

2 REVIEW OF PREVIOUS STUDIES

Wijnen and Rietveld (2015) identified 41 studies that were included in their review. The studies are listed in Table 1. Some of the studies contained more than one estimate of the relationship between recessions and road safety; hence the total number of estimates extracted from the studies was 49. Summarising the findings of all studies by means of meta-analysis was not feasible, because the studies were too heterogeneous and did not consistently report the information needed for inclusion in a meta-analysis. Elvik (2015), see below, performed a meta-analysis of a subset of studies. The studies reviewed by Elvik are marked by an asterisk in Table 1.

Table 1 about here

A majority of the studies were made in the United States. There are also several studies from Australia. The data used in the studies span from 1947 to 2008. None of the studies include the great financial crisis and recession that started in 2008. There are 49 estimates of the relationship between economic changes and changes in the number of casualties (fatalities or injuries). 34 of the 49 estimates indicate a statistically significant positive relationship between the economic variables and the number of casualties. This means that when there is growth in gross domestic product (GDP) per capita, or growth in employment (i.e. decline in unemployment), there is also growth in the number of traffic casualties. 10 of the 49 estimates indicate a statistically significant negative relationship the economic variables and the number of traffic casualties, and 5 estimates indicate no statistically significant relationship.

There were 19 estimates using accident rate (number of accidents per vehicle kilometre of travel) as dependent variable. A positive relationship (growing income and growing employment is associated with an increase in accident rate) was found in 58 percent of the cases, a negative relationship in 37 percent of the cases and no clear relationship in 6 percent of the cases.

By far the two most common indicators of economic changes used in the studies are unemployment and GDP per capita. There is a recession when unemployment increases or when there are at least two consecutive quarters (periods of three months) without real growth in GDP per capita. When unemployment increases, the number of traffic casualties declines in 79 percent of the cases (N = 28), and accident rate declines in 78 percent of the cases (N = 9). Changes in GDP per capita have a less clear relationship with road safety. There is positive relationship (both variables increase) with the number of casualties in 53 percent of the cases (N = 15), and with accident rate in 50 percent of the cases (N = 6).

Change in unemployment thus seems to be the stronger predictor of change in the number of traffic casualties: When unemployment goes up, there will in most cases be a decline in traffic casualties. Is it, on the basis of the studies reviewed, possible to say anything about the strength of the relationship? Elvik (2015) extracted 21 estimates of the elasticity of the number of traffic casualties (mostly fatalities) with respect to unemployment and summarised these by means of an inverse-variance meta-analysis (i.e. each estimate of elasticity was weighted by $1/SE^2$; SE = standard error of estimate). The summary estimate of the elasticity was between -0.024 and -0.060, depending on the model of analysis. This means that if unemployment increases by 1 percent, one may expect a reduction of the number of traffic casualties of between 0.024 and 0.060 percent (given that the size of the labour force is constant).

This may seem like a minor effect. However, in the 14 OECD-countries included in the statistical analyses reported by Elvik (2015; see next section of the paper for further details), mean unemployment rate increased from 5.2 percent in 2008 to 7.3 percent in 2010. This is an increase of 40 percent, but only of 2.1 percentage points. Based on studies made before the financial crisis, one would expect such an increase in unemployment to be associated with a reduction in traffic casualties of between 1 and 2.4 percent.

In their review, Wijnen and Rietveld (2015) included a discussion of mechanisms that may generate the relationship between changes in the business cycle and changes in road safety. Based on that discussion, they proposed the model shown in Figure 1.

Figure 1 about here

Economic changes primarily take the form of changes in GDP per capita and changes in unemployment. These changes may influence road safety through a number of pathways. In a recession, vehicle kilometres of travel may be reduced or grow more slowly than usual. This may in turn influence both the number of traffic casualties and accident rate, since accident rate usually depends on traffic volume (Hauer 1995). Changes in traffic composition, in particular a reduction in the amount of driving among young drivers has been discussed in many studies. If high-risk drivers are more sensitive to recessions than low-risk drivers, there may be a reduction of accident rate. Road user behaviour may change during a recession. Several studies (listed by Wijnen and Rietveld) have mentioned that drinking and driving may be reduced in a recession as people may not afford to go to bars or restaurants as often as during an economic boom. Such a change in road user behaviour would most likely be associated with a reduction of accident rate.

Finally, safety investments may be influenced by a recession. It seems likely that the renewal of the car fleet will slow down, as sales of new cars may be reduced. Public expenditures on safety programmes, on the other hand, could either increase as part of a stimulus package or be reduced if austerity policies are pursued.

Any model like the one shown in Figure 1 is a gross simplification. There are complex interactions between macro-economic conditions, travel behaviour and risk factors (Noland 2013). These interactions are only partly understood and any statistical model intended to estimate the relationships (arrows) shown in Figure 1 is likely to omit potentially important variables. It is therefore difficult to argue that a particular statistical model is the only correct one. In view of this, several models have been developed, based on different data sets. These models are compared in the next section of the paper.

3 STATISTICAL ANALYSES OF THE RELATIONSHIP BETWEEN THE ECONOMIC RECESSION AND TRAFFIC FATALITIES

All studies reviewed by Wijnen and Rietveld (2015) and all except one reviewed by Elvik (2015) were based on data before the financial crisis and recession started in 2008. The three studies presented below are based on data up to 2012.

3.1 Antoniou et al. 2015

The most comprehensive of the analyses presented in the ITF-report was made by Antoniou et al. (2015). It included 30 European countries with data for 37 years (1975-2011). GDP per capita was used as indicator of economic changes. GDP per capita was stated in US dollars, fixed prices (2011), adjusted to purchasing power parity. The study made a distinction between short term changes in GDP per capita (year-to-year changes) and long term changes. The following model was estimated for the relationship between annual changes in GDP per capita and annual changes in the number of traffic fatalities in the countries i (short-term changes):

$$Ln(Fat_{it}) - \ln\left(Fat_{i(t-1)}\right) = \alpha + \beta_1\left[\ln(GDP_{it}) - \ln(GDP_{i(t-1)})\right] + \beta_2 Country\ Group_{it} + \varepsilon_{it}$$

Countries were classified in three groups: northern Europe, eastern Europe and southern Europe. The model was fitted separately for each group of countries. Table 2 reports the results of analysis.

Table 2 about here

The constant term indicates a declining trend in traffic fatalities in all groups of countries. The estimated decline is between 0.96 and 1.75 percent per year. A growth in GDP per capita of one percent in fixed prices is associated with an increase in the number of traffic fatalities of between 0.42 and 0.66 percent. A decline in GDP per capita of one percent is associated with a decline in traffic fatalities of between 0.15 and 0.75 percent. During most years covered by the analysis, GDP per capita has increased. It should be noted that the coefficients estimated for a 1 % increase and a 1 % decrease in GDP per capita were not statistically significantly different, despite having opposite signs.

Separate estimates for each country found a positive elasticity for GDP in most countries, controlling for the long-term declining trend in the number of fatalities in most countries. There was a negative relationship between the annual trend in traffic fatalities and the estimated elasticity of traffic fatalities with respect to changes in GDP per capita. This relationship is shown in Figure 2.

Figure 2 about here

Countries in which there is a strong negative trend in the number of traffic fatalities appear to be more vulnerable to changes in GDP per capita than countries with a weaker negative trend in the number of traffic fatalities. Reasons for this are unknown. One may perhaps suggest that a strong negative trend indicates an effective road safety policy. To the extent an effective road safety policy reduces the importance of well-known risk factors, such as drinking and driving, non-use of protective devices or speeding, the relative importance of other risk factors may grow. This is speculation only, but it will be examined in a little more detail in the analyses using unemployment as an indicator of the business cycle.

The models developed for long-term changes in GDP per capita found a mean positive elasticity of the number of fatalities with respect to GDP per capita of 0.63.

Variables representing road safety interventions had then been added to the model. The long-term trend was negative, but the term for year squared was not statistically significant. One possible interpretation of this is that the turning point in the number of traffic fatalities may to some extent have been brought about by more effective road safety interventions and was not simply a mathematical necessity resulting from a slowdown of traffic growth combined with a declining fatality rate per kilometre of travel.

3.2 Elvik 2015

The second statistical analysis of the relationship between economic changes and changes in traffic fatalities was reported by Elvik (2015). The analysis was based on data for 14 OECD countries covering the period 1970-2010. An additional data set covering the period 1995-2010 specified the age of traffic fatalities, thus permitting an analysis of whether young people are more strongly affected by a recession than other age groups. Unemployment stated as a percentage of the labour force was used as indicator of a recession. GDP per capita, stated in US dollars 2005-prices, adjusted to purchasing power parity was also included as an independent variable. Analyses were made separately for each country. In these analyses, three types of models were developed. The first type of model was a negative binomial regression model, specified as follows:

Number of traffic fatalities =

$$e^{(\alpha+\beta_1 Year+\ \beta_2 \ln(GDP\ per\ capita)+\ \beta_3 \ln(unemployment\ rate))}$$

In this model, estimated coefficients can be interpreted as elasticities. A major problem in fitting such a model is the very strong correlation between year and GDP per capita. Unemployment is less correlated with year. To reduce this problem, a model based on annual differences was also developed:

ΔNumber of traffic fatalities = $\alpha + \beta_1$Year + $\beta_2\Delta$GDP per capita + $\beta_3\Delta$Unemployment rate

The letter Δ denotes change from one year to the next. All changes were stated in natural units; no conversions of the variables were made. Thus, for the United States, the number of fatalities changed from 52,627 in 1970 to 52,542 in 1971. This was a reduction of 85, stated as -85 in the models developed. Gross domestic product per capita increased from 20,544 dollars in 1970 to 20,988 dollars in 1971, stated in the model as 444. Finally, unemployment increased from 4.9 percent in 1970 to 5.9 percent in 1971, stated in the model as 1.0.

The final form of model was similar to the model used by Antoniou et al. (2015). It was specified as follows:

$\text{Ln}(\text{Fatalities}_{t+1}) - \ln(\text{Fatalities}_t) = \alpha + \beta_1\text{Year} + \beta_2[\ln(\text{GDP}_{t+1}) - \ln(\text{GDP}_t)] + \beta_3[\ln(\text{Unemployment}_{t+1}) - \ln(\text{Unemployment}_t)]$

The models were assessed in terms of several criteria: (1) the overall goodness-of-fit in terms of the percentage of the systematic variation in the number of fatalities explained by the model; (2) unbiasedness of predictions: models should not systematically predict too few or too many fatalities; (3) whether standardised residuals were normally distributed; (4) homoscedasticity of residual terms. i.e. residuals should not have uneven variance; (5) autocorrelation of residual terms, i.e. there should not be strings of positive or negative residual terms. None of the models were judged as perfect in terms of all these criteria, but on the whole, the model based on differences between natural logarithms (a mixed linear model) was judged as best.

With 14 countries, two data sets (1970-2010 and 1995-2010) and three models, a large number of coefficients was estimated ($14 \cdot 2 \cdot 3 = 84$) for each variable. It is judged as not very informative to present all these coefficient estimates for all variables. Based on estimated coefficients, a series of diagrams were developed showing the estimated relationship between percentage points of change in unemployment and percent change in the number of fatalities. Figure 3 shows an example of such a diagram.

Figure 3 about here

The points are estimates based on the models. Thus, the black circular points are estimates based on negative binomial regression, the grey square points are based on linear differences and the black triangles based on the mixed linear model (differences between logarithms). Trend lines have been fitted to the estimated data points for each model. As can be seen, these trend lines do not fit equally well to the points. A weighted mean of the trend lines was estimated by weighting each line in inverse proportion to its residual variance. Thus, the weight assigned to the trend line for the negative binomial regression model in Figure 3 becomes $1/0.8729 = 1.1456$. The thick black trend line in Figure 3 is a weighted mean of the three trend lines. Similar figures were developed for all 14 countries and are summarised in Figure 4.

Figure 4 about here

A negative relationship was found between changes in unemployment and changes in the number of traffic fatalities in all countries included in the study, although the strength of the relationship varies, as indicated by the varying slopes of the lines.

3.3 Bergel-Hayat et al. 2015

The third study of the relationship between economic recession and traffic fatalities was reported by Bergel-Hayat et al. (2015). The study consisted of two analyses. The first was a study of long-term trends in the number of traffic fatalities in five European countries. This study did not address fluctuations of the business cycle and will therefore not be further discussed. The second analysis used monthly values of the unemployment rate in three European countries as indicator of recession. State-space time series analysis was applied. A 0.1 percentage point increase in unemployment was found to be associated with a 0.3 percent decline in the number of fatalities. Results were similar for France and Spain, but not statistically significant for Greece.

Thus, the results of the three studies are highly consistent. Economic recession is found to be associated with a decline in the number of traffic fatalities, controlling for the long-term trend towards fewer fatalities. This applies irrespective of whether analyses were based on groups of countries or made separately for each country, and irrespective of whether the data referred to a period of 40 years or a shorter period. The results were also consistent for all statistical models employed in the analyses.

3.4 Stability over time in the association between recessions and road safety

However, as mentioned above, the analysis reported by Antoniou et al. (2015) gave an indication that the relationship between economic recession and changes in the number of traffic fatalities may not be stable over time, but that recent recessions have been associated with larger reductions in the number of fatalities than past recessions. To assess whether there is such a tendency, data for the fourteen countries analysed by Elvik (2015) were used. For each country, a recession was defined as a period of at least two years during which unemployment increased. Figure 5 shows how periods of recession were identified for Ireland according to this criterion.

Figure 5 about here

Periods of recession are marked by rectangles. It is seen that the most recent recession was deeper than the earlier recessions, in the sense that there was a sharper increase in the unemployment rate. The association between increase in unemployment and changes in the number of traffic fatalities can be described in terms of the percent decline in the number of traffic fatalities per percentage point increase in unemployment, adjusted for the long-term trend in the number of fatalities. Thus, in the most recent recession in Ireland, unemployment increased from 4.4 to 13.9 percent, or by 9.5 percentage points. Traffic fatalities declined from 396 to 212, a decline of 46.5 percent. The decline expected according to the long-term trend was from 343 to 314 fatalities. Thus, the adjusted decline was (212/396)/(314/343) = 0.586 or 41.4 percent. The reduction in traffic fatalities per percentage point increase in unemployment was 41.4/9.5 = 4.36 percent. Similar estimates have been developed for all fourteen countries and are shown in Figure 6.

Figure 6 about here

The decline in fatalities has been plotted as a positive number. It is seen that an increase in unemployment is not always associated with a decline in the number of traffic fatalities. The mean value of the decline, per percentage point increase in unemployment, shows a weak tendency to increase towards the end of the period. However, the data points are widely scattered and suggest that any model-based prediction of the change in the number of traffic fatalities to be expected if there is a new recession would most likely have large error terms.

4 STUDIES OF MECHANISMS THROUGH WHICH TRAFFIC FATALITIES ARE INFLUENCED

The data set for the period 1995-2010 used by Elvik (2015) specified road users aged 18-24 and included data on vehicle kilometres of travel. Based on estimated coefficients and long-term trends, Elvik reported a rough decomposition of the decline in traffic fatalities in 14 OECD countries from 2008 to 2010 into the following contributing factors:

1. Lower traffic volume or slower growth than prior trends: 179
2. Fewer fatalities involving young (18-24) road users: 487
3. Reduced fatality rate below historical trends 4 181
4. Other factors (continuation of pre-recession trends) 2 620

Total reduction of fatalities was 7467. It is seen that a sharper than usual decline in fatality rate per vehicle kilometre of travel made the largest contribution.

Forsman et al. (2015) compared changes in the number of traffic fatalities in Sweden from the 4-month periods December-March ending in 2006, 2007 and 2008 (before recession) to the corresponding period ending in 2009 (during recession). Among the main findings were: There was a larger decline in traffic fatalities in the evening (18-23 hours) than during the rest of the day, which may indicate a reduction of leisure driving in the evening. Accidents involving at least one driver testing positive for alcohol or drugs were reduced more (47 percent) than accidents not involving such drivers (32 percent), indicating less drinking-and-driving. Fatal accidents involving unlicensed drivers increased by 35 percent, whereas other fatal accidents were reduced by 43 percent. This may indicate an increase in the number of drivers who could not afford a licence and took the chance of driving without one. Of the factors surveyed by Forsman et al., only the possible reduction of driving in the evening and in drinking-and-driving would contribute to explaining the decline in fatalities during the recession.

Noble et al. (2015) reported a more extensive study for Great Britain. They found a modest reduction of vehicle kilometres of travel of about 3.5 percent. The decline in fatalities from 2007 to 2010, 37.2 percent, was considerably greater than the decline vehicle kilometres of travel, suggesting that factors influencing fatality rate made the largest contribution to the decline.

Between 2007 and 2009, vehicle kilometres performed by heavy goods vehicles declined 8 percent, but the number of fatalities involving heavy goods vehicles declined by 39 percent. There was a larger decline in fatal accidents involving drivers aged between 17 and 24 than involving other drivers. Fatal accidents involving drinking drivers also declined more than other fatal accidents. Speeding declined slightly on all types of road. In addition to these factors, unusually cold winters in 2009 and 2010 are believed to have contributed to the decline in traffic fatalities in Great Britain from 2007 to 2010 (Noble et al. 2015). Lloyd et al. (2015) conclude that the recession in Great Britain was associated with a reduction in driving by young males, a reduction in speeding and a reduction drinking-and-driving.

5 DISCUSSION

The findings of studies of the association between economic recessions and road safety made before the recent recession were somewhat mixed. Although a clear majority of studies indicated that economic recessions were associated with a reduction of the number and rate of traffic fatalities, findings were not perfectly consistent. The studies presented in the IFT-report (ITF/IRTAD 2015) and summarised in this paper are perfectly consistent. In all countries that were studied, it was found that economic recession, irrespective of whether GDP per capita or unemployment was used to indicate it, was associated with a greater decline in the number of traffic fatalities than past trends would imply. The ITF-studies were completed in 2014. Do recent studies, published after 2014, confirm the findings of the ITF-studies?

He (2016) tried to uncover the mechanisms underlying the large reduction in traffic fatalities in the United States between 2007 and 2010. She used data for 50 states (all states except the District of Columbia) from 2003 to 2013. She decomposed the decline in fatalities into the contribution from a reduction in vehicle kilometres of travel and reduced fatality rate per kilometre of travel. She found that reduced fatality rate accounted for 88 percent of the reduction in fatalities. This is consistent with the rough estimates made by Elvik (2015), which indicated that decline in the amount of travel contributes little to the decline in fatalities. She furthermore found that recession was associated with disproportionately large reductions in large truck fatalities, accidents involving speeding, and accidents involving drivers who had been drinking. These results are highly consistent with those found in Great Britain (Lloyd et al. 2015).

Maheshri and Winston (2016) ask if the Great Recession kept bad drivers off the road. They used detailed data for the state of Ohio and found that total vehicle kilometres of travel did not change very much during the recession (their data are from August 2009 to September 2013). They found that drivers who were classified as high-risk (e.g. drivers who filed a claim to the insurance company between August 2009 and September 2013) reduced their driving more during the recession than drivers who were classified as low-risk.

Noland and Zhou (2017) reported an analysis which in many ways was similar to the analysis presented by He (2016). They used data from 50 states of the United States from 1984 to 2013. They found that reduction in median income from 2006 to 2014 was associated with a reduction of the number of fatalities. In one model a reduction of median income of 3.19 % was associated with an estimated reduction of the number of fatalities of 454 (95 % CI: 265; 642). In another model, a 5.20 % reduction of median income was associated with an estimated decline in traffic fatalities of 508 (95 % CI: 297; 718). The largest contributor in their analysis was a reduction of rural interstate vehicle kilometres of travel, which was associated with a reduction of the number of fatalities of some 3370 to 3820. This result contrasts with what He found, which was that the reduction in the amount of travel made only a small contribution. It should be noted, however, that the two analyses did not include the same variables, and that the total effect of all variables as estimated by Noland and Zhou amounted to a fatality reduction of 1840 from 2006 to 2014, which explains only a small part of the actual reduction from 2006 to 2014, which was 9964. The fact that the net decline in fatalities was smaller than the decline in fatalities attributed to a reduction of rural interstate travel is explained by the fact that other factors, in particular population growth, were estimated to have contributed to an increase in fatalities.

Is the relationship between economic recession and reduction in traffic fatalities causal? One should obviously be cautious about claiming that it is, but some characteristics of the relationship support a causal interpretation:

1. The direction of the relationship seems clear: Changes in economic performance can be a cause of changes in road safety, but the opposite is highly implausible.
2. The findings of recent studies are highly consistent.
3. There is a dose-response relationship: The more severe a recession, the greater the decline in traffic fatalities.
4. The relationship between economic variables and traffic fatalities holds up when potential confounders are controlled for.
5. Some plausible mechanisms underlying the relationship have been identified.

Despite these systematic tendencies, it is clear that the relationship between economic recessions and road safety is noisy and has been imprecisely estimated in all available studies. Although the relationship is likely to be causal, that does not mean it can be predicted with great accuracy.

6 CONCLUSIONS

The main conclusions of the research presented in this paper can be summarised as follows:

1. Most studies of the relationship between economic recessions and road safety made before the recession that started in 2007-2008 found that a recession was associated with a decline in traffic casualties.
2. A set of new studies, all including the recession starting in 2007-2008 consistently find that it was associated with a larger reduction in traffic fatalities in OECD-countries than implied by prior trends.
3. This main finding is highly consistent for all countries that have been analysed.
4. Economic recessions appear to be associated with less driving among young drivers, less drinking-and-driving and less speeding. It is not clear if these changes fully explain the larger decline in the number of fatalities.

ACKNOWLEDGEMENT

The research presented in this paper was partly funded by the Organization for Economic Cooperation and Evelopment (OECD)

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LIST OF FIGURES AND TABLES

Table 2:

Coefficients in models estimated by Antoniou et al.

Table 1:

Study	Publication year	Country or region	Period covered by data
Peltzman	1975	United States	1947-1972
Eshler	1977	United States	1949-1976
Hoxie et al.	1984	United States	1975-1982
Jocksch	1984	United States	1930-1982
Partyka	1984	United States	1960-1984
Wagenaar (*)	1984	United States (Michigan)	1972-1983
Zlatoper	1984	United States	1947-1980
Hoxie and Skinner	1985	United States	1975-1983
Mercer (*)	1987	Canada (British Columbia)	1978-1984
Evans and Graham (*)	1988	United States	1946-1985, 1975-1984
Saffer and Chaloupka	1989	United States	1980-1985
Wagenaar and Streff	1989	United States	1976-1985
McCarthy and Ziliak	1990	United States (Californian cities)	1982-1985
Wagenaar et al.	1990	United States	1978-1988
Zlatoper	1991	United States	1987
Reinfurt et al. (*)	1991	United States	1960-1986
Leigh and Waldon (*)	1991	United States (District of Columbia)	1976-1980
Partyka (*)	1991	United States	1960-1989
Pettitt et al.	1992	Australia (Victoria)	1981-1991
McCarthy	1993	United States (Indiana counties)	1981-1989
Haque (*)	1993	Australia (Victoria)	1966-1990, 1985-1990
Keeler	1994	United States	1970, 1980

Table 1:

Study	Publication year	Country or region	Period covered by data
McCarthy	1994	United States (Californian counties)	1981-1989
Ruhm	1995	United States	1975-1988
Loeb	1995	United States (Texas)	1982-1987
Ruhm	1996	United States	1982-1988
Johansson	1996	Sweden (7 counties)	1982-1991
Robertson	1996	United States	1975-1991
Wilde and Simonet (*)	1996	Switzerland	1963-1993
Farmer (*)	1997	United States	1975-1995
Newstead et al. (*)	1998	Australia (Victoria)	1983-1996
Fridstrøm (*)	1999	Norway	1973-1994
Ruhm (*)	2000	United States	1972-1991
Scuffham (*)	2003	New Zealand	1970-1994
Tay (*)	2003	Australia (Victoria)	1983-1992
Neumayer (*)	2004	Germany	1990-2000
Van den Bossche et al. (*)	2005	Belgium	1990-2001
Hermans et al. (*)	2006	Belgium	1974-1999
Garcia-Ferrer et al. (*)	2007	Spain	1975-2003
Hu et al.	2008	China	1985-2005
Wiklund et al. (*)	2011	Sweden	1981-2008

(*) The study was included in the review of Elvik (2015), which in addition included the studies of Scuffham and Langley (2002), Kweon (2011) and Yannis et al. (2014)

Figure 1:

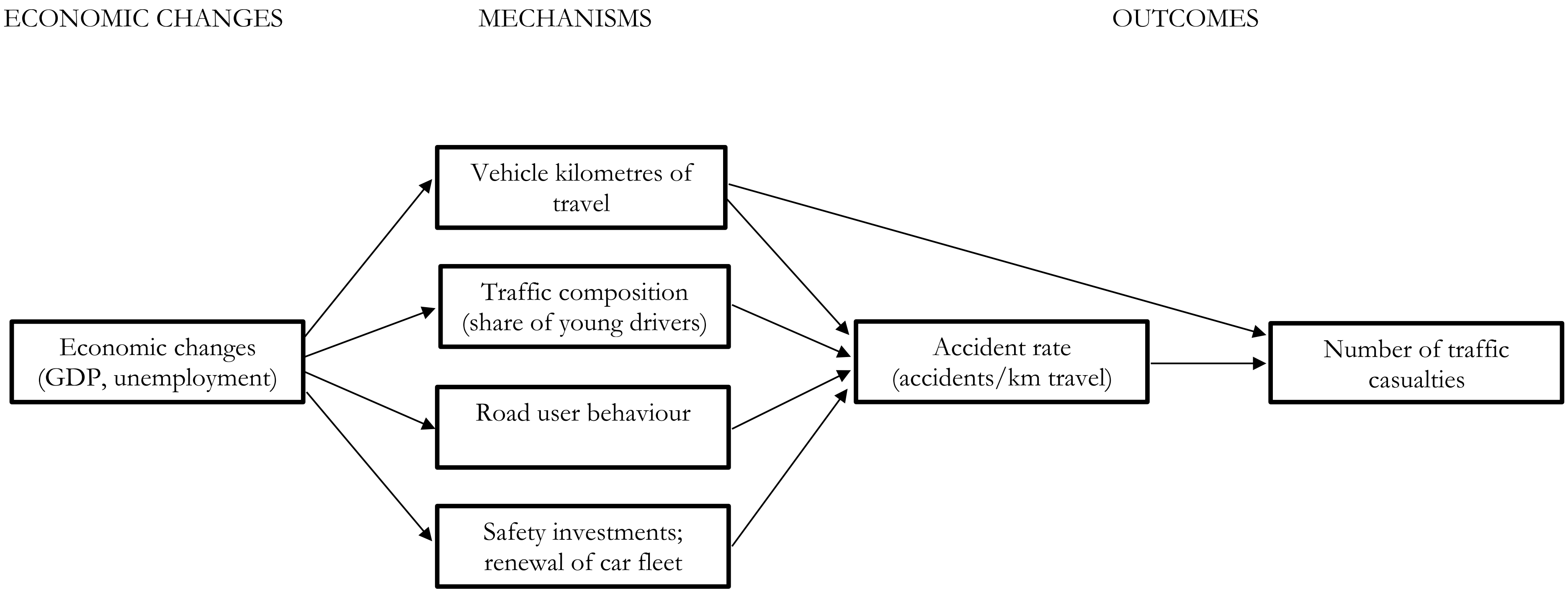

ECONOMIC CHANGES
MECHANISMS
OUTCOMES
Economic changes (GDP, unemployment)
Vehicle kilometres of travel
Traffic composition (share of young drivers)
Road user behaviour
Safety investments; renewal of car fleet
Accident rate (accidents/km travel)
Number of traffic casualties

Table 2:

	Group of countries		
	Northern	**Eastern**	**Southern**
Mean annual change (%)	-1.25	-0.96	-1.75
Effect of 1 percent increase in GDP per capita	0.66 (**)	0.42 (*)	0.45 (**)
Effect of 1 percent decrease in GDP per capita	-0.75 (**)	-0.60 (NS)	-0.15 (**)
Rho	-0.29 (**)	0.34 (**)	-0.04 (NS)

** = significant at 5 % level; * = significant at 10 % level; NS = not significant

Figure 2:

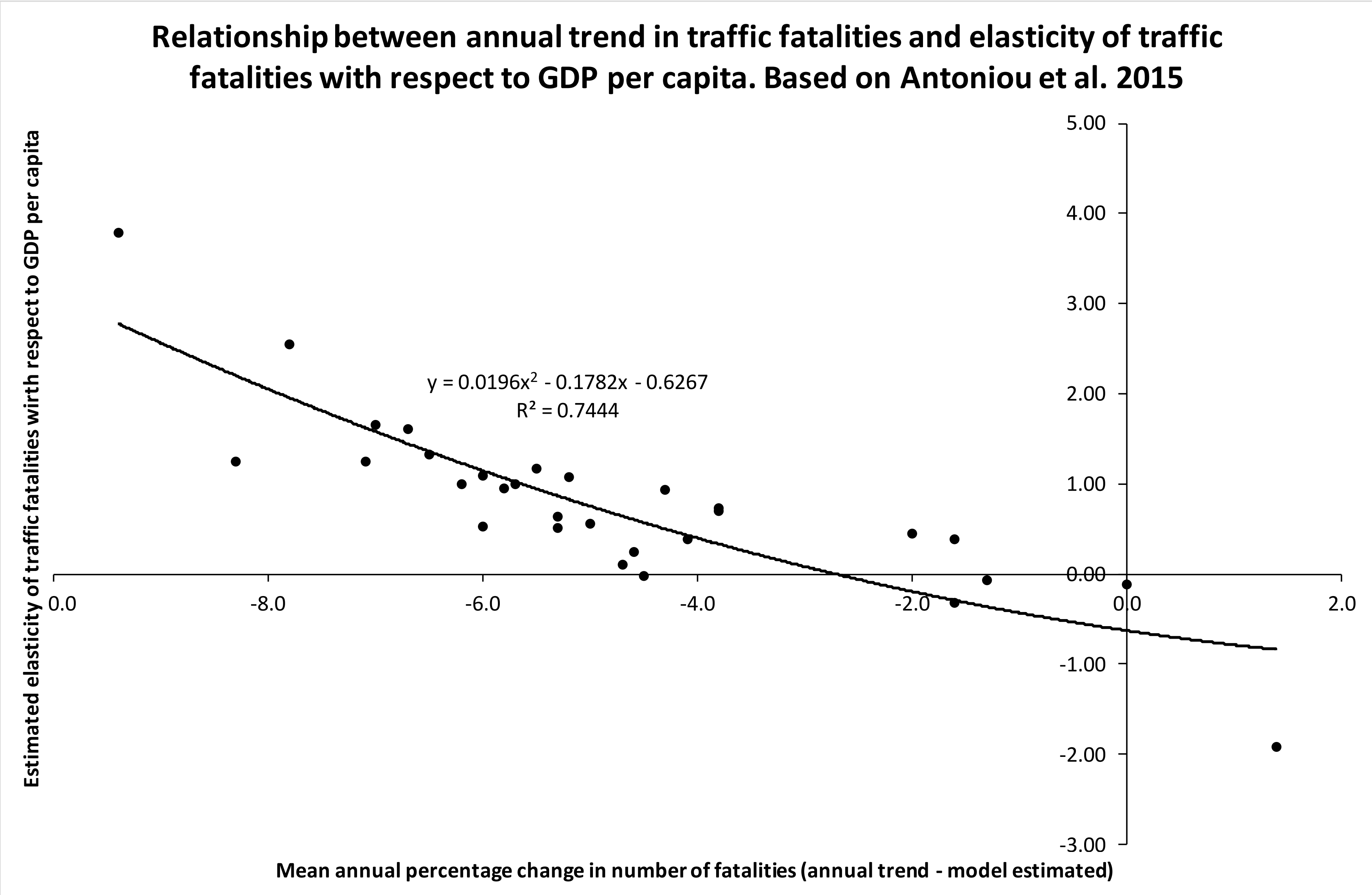

Relationship between annual trend in traffic fatalities and elasticity of traffic fatalities with respect to GDP per capita. Based on Antoniou et al. 2015
y = 0.0196x² - 0.1782x - 0.6267
R² = 0.7444
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
0.0
-8.0
-6.0
-4.0
-2.0
0.0
2.0
Estimated elasticity of traffic fatalities wirth respect to GDP per capita
Mean annual percentage change in number of fatalities (annual trend - model estimated)

Figure 3:

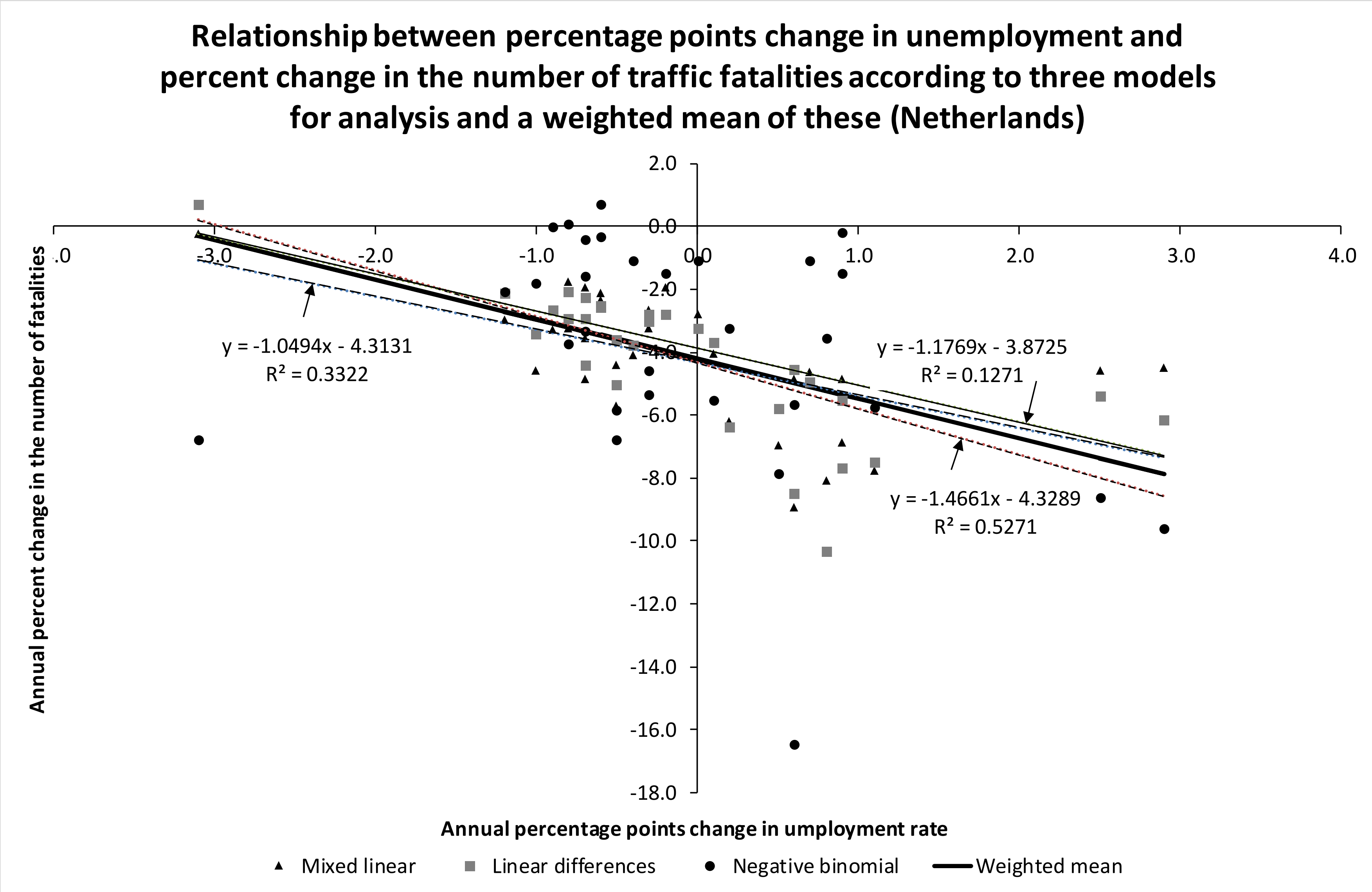

Relationship between percentage points change in unemployment and percent change in the number of traffic fatalities according to three models for analysis and a weighted mean of these (Netherlands)
2.0
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
-12.0
-14.0
-16.0
-18.0
.0
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
y = -1.0494x - 4.3131
R² = 0.3322
y = -1.1769x - 3.8725
R² = 0.1271
y = -1.4661x - 4.3289
R² = 0.5271
Annual percent change in the number of fatalities
Annual percentage points change in umployment rate
Mixed linear
Linear differences
Negative binomial
Weighted mean

Figure 4:

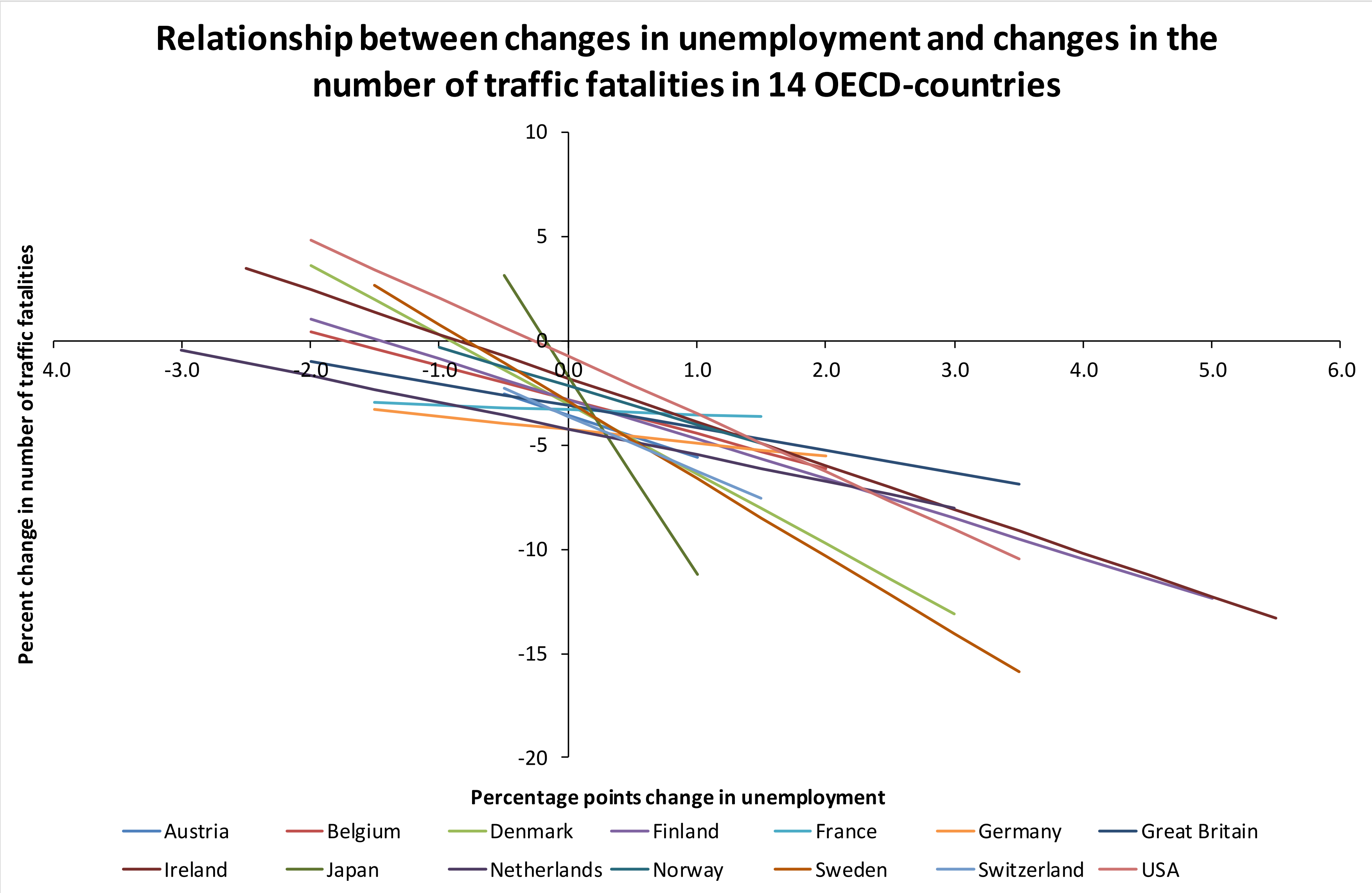

Relationship between changes in unemployment and changes in the number of traffic fatalities in 14 OECD-countries
10
5
0
-5
-10
-15
-20
-4.0
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
Percent change in number of traffic fatalities
Percentage points change in unemployment
Austria
Belgium
Denmark
Finland
France
Germany
Great Britain
Ireland
Japan
Netherlands
Norway
Sweden
Switzerland
USA

Figure 5:

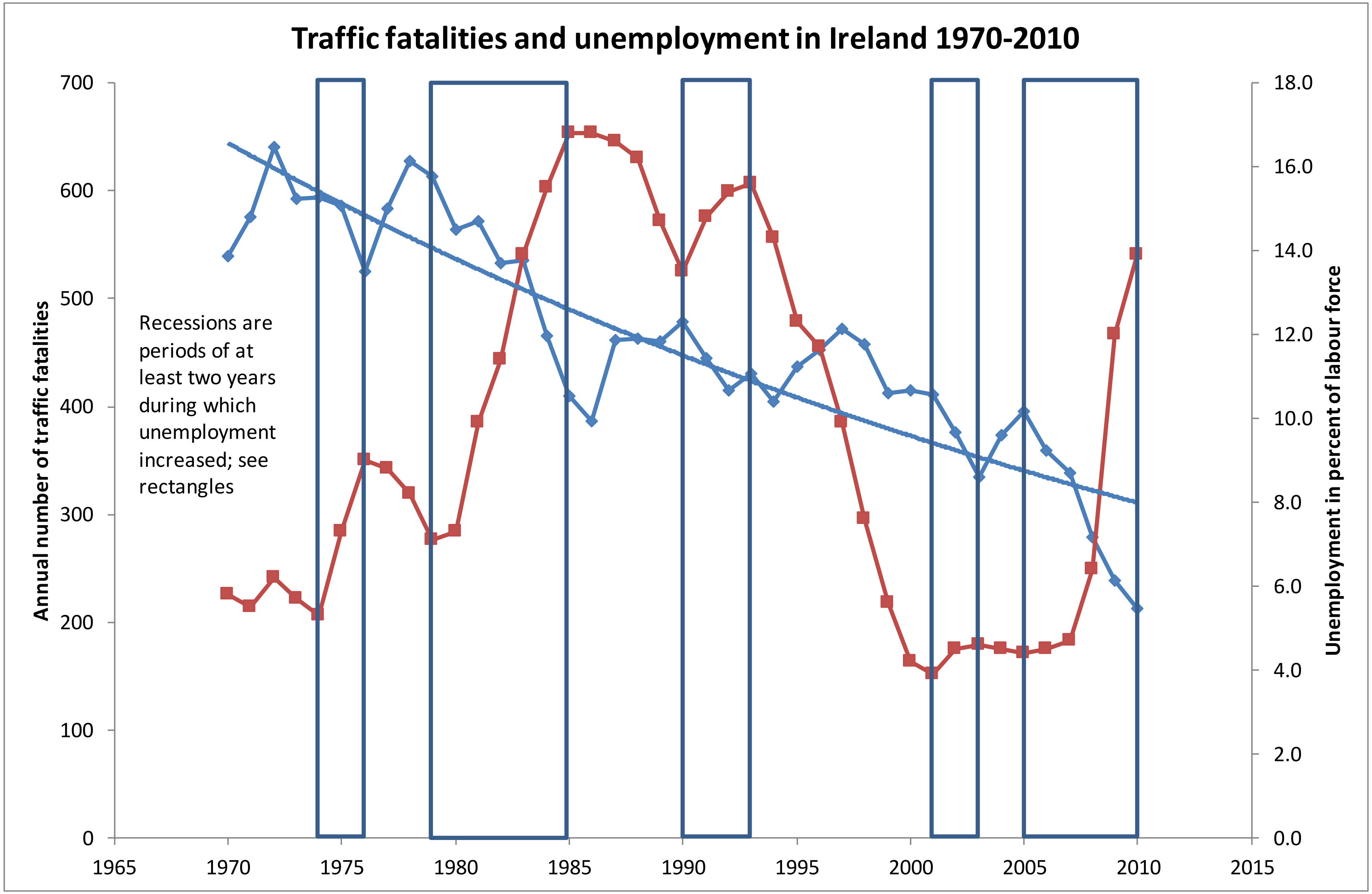
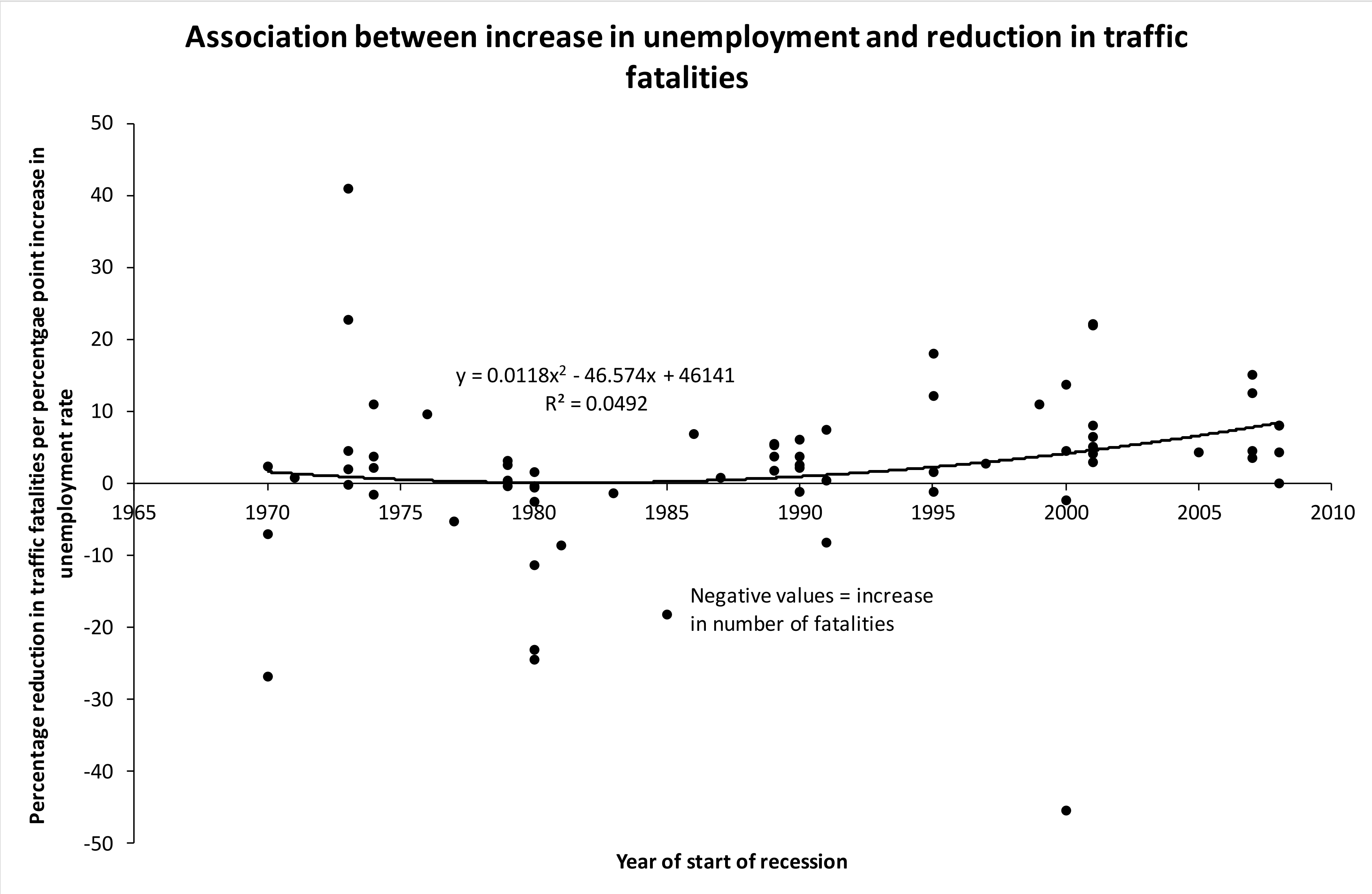

Traffic fatalities and unemployment in Ireland 1970-2010
Annual number of traffic fatalities
Unemployment in percent of labour force
Recessions are periods of at least two years during which unemployment increased; see rectangles
0
100
200
300
400
500
600
700
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015

Figure 6:



Association between increase in unemployment and reduction in traffic fatalities
y = 0.0118x² - 46.574x + 46141
R² = 0.0492
Negative values = increase in number of fatalities
Percentage reduction in traffic fatalities per percentgae point increase in unemployment rate
Year of start of recession
50
40
30
20
10
0
-10
-20
-30
-40
-50
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010