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Safety Inspectorates and Safety Perforance: A Tentative Analysis for Aviation and Rail in Norway

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Abstract: Safety inspectorates have been established for all modes of transport in Norway. This paper explores whether establishing a safety inspectorate is related to safety performance. Long-term trends in safety in aviation and rail were compared before and after safety inspectorates were established for these modes of transport. In aviation, there have been no passenger fatalities after the safety inspectorate was established. The number of (non-fatal) accidents in scheduled and charter flights has been between zero and five per year, which is higher than predicted according to the long-term trend in the period before the safety inspectorate was created. In rail, both the number of accidents and the number of passenger fatalities have been lower after the creation of the safety inspectorate than predicted according to long-term trends in the before-period. The paper shows statistical relationships indicating that safety performance has improved, at least in rail transport. A causal interpretation of these relationships is not possible on the basis of the analyses in this paper. Establishing safety inspectorates may improve transport safety, but showing this rigorously is extremely difficult.

Keywords: transport safety; accident rates; long-term trends; aviation; railways; governance

1. Introduction

Safety management in transport has changed substantially in the past 15–20 years. A wave of deregulation started around 1980 [1]. Subsequently, the organization of transport policy agencies has changed in many countries, in particular by establishing separate organizations for: (1) the development and maintenance of infrastructure; (2) regulation of transport operators; (3) safety management. As an example, the mainline railways in Norway used to be operated as a vertically integrated state monopoly (Norwegian State Railways, abbreviated NSB in Norwegian). The NSB was in charge of everything that had to do with railways. In 1996, the NSB was split into three organizations:

1. The National Rail Administration, which manages infrastructure (tracks, signals, stations) and issues permissions to operate trains.
2. The Norwegian Railway Authority, which issues safety regulations, approves rolling stock and infrastructure, and performs safety inspections.
3. The Norwegian State Railways, which operates trains on a commercial basis. It no longer has a monopoly and although it remains dominant, several companies now operate trains in Norway.

The Norwegian Railway Authority is a safety inspectorate; *i.e.*, it drafts and enforces safety regulations, issues type approvals of rolling stock and infrastructure, performs safety inspections, receives incident reports, and keeps accident statistics. Before it was established, these functions were either not performed at all (incident reporting), or performed "in-house" by the Norwegian State Railways, usually without any publicity or external review. An independent accident investigation board, now responsible for investigating accidents in all modes of transport was established in 1989. It originally investigated aviation accidents only, but its mandate was extended to rail accidents in 2002.

There has been concern that deregulation and privatization of aviation and rail transport may harm safety [2–5]. It has been argued that competition may induce cost-cutting that reduces safety margins, for example, by using planes and rolling stock more intensely or by cutting staff to the minimum and prolonging working hours. One measure that can be taken to maintain or improve safety under these circumstances is the creation of a safety inspectorate with powers to issue safety instructions to transport operators.

The objective of this paper is to assess whether the creation of independent safety inspectorates in Norway, in particular in aviation and rail, is associated with changes in the long-term trends in safety in these modes of transport. Long-term trends in accident rates were determined for the period before the safety inspectorates were established. These trends were then projected to the period after the safety inspectorates were created. The projected trends were then compared to actual accident rates in the period after the safety inspectorates were created. This approach to analysis is identical to the approach taken in studies of the privatization of railways [6,7].

It should be noted that for rail, the changes made in 1996 included more than just establishing a safety inspectorate. Therefore, the paper can only evaluate the whole package of reforms. However, competition between train operators was very limited until 2006.

2. Background and Literature Review

Independent safety inspectorates in transport are a comparatively recent phenomenon in Norway. By contrast, Evans [6] reports that Great Britain has had a Railway Inspectorate since 1840. Table 1 gives an overview of safety inspectorates in transport in Norway as of 2015 [8].

Table 1. Transport safety inspectorates in Norway.

Sector	Established	Approximate Number of Employees	Parent Body	Location
Aviation	2000	180	Ministry of Transport and Communications	Bodø
Rail	1996	50	Ministry of Transport and Communications	Oslo
Maritime	1962	330	Ministry of Trade, Industry and Fisheries	Haugesund
Road	2012	10	Road Directorate	Voss

There are safety inspectorates for all modes of transport. The most recently established inspectorate is for roads. It was created in 2012, which is too recent to assess any potential safety effects. The maritime safety inspectorate, which is both a regulatory body and an inspectorate, was established in 1962. This is too long ago to meaningfully reconstruct data for a before-period. Thus, the only inspectorates for which there are sufficiently long before- and after-periods to study long-term changes in safety are the inspectorates for aviation and rail.

An attempt was made to locate previous studies of the effects of creating safety inspectorates by searching for studies in Sciencedirect using "safety inspectorate" and "safety management" as keywords. Based on this literature search, there seem to be few, if any, previous studies that have evaluated safety inspectorates. Hedlund [9] evaluated the effects on fatal and disabling injuries of a voluntary five-star occupational health and safety management system developed in South Africa. It was found that companies with a high star rating had a better safety performance than those with a low star rating or companies that did not use the star-rating system. Mooren *et al.* [10] reviewed the literature on safety management for heavy vehicle transport. The study identified elements of safety management that were associated with a superior safety performance. Some of these elements, such as management commitment to safety and the use of risk analysis to identify hazards, could perhaps be stimulated by regular safety inspections.

3. Data and Analysis

3.1. Aviation

Data were obtained on accidents, traffic volume, and transport volume for aviation and railways in Norway. Detailed accident statistics for the period from 1970 to 2012 were obtained from the Civil Aviation Authority. These statistics list the number of accidents, identified as either fatal or non-fatal, and the number of fatalities each year from 1970 to 2012. Five types of commercial operations are identified: (1) scheduled flights; (2) charter flights; (3) air taxi; (4) aerial work; and (5) instruction flights. Only two indicators of exposure are available for the entire period: (1) kilometers flown, which comprises only scheduled flights and charter flights; and (2) passenger kilometers of travel. Long-term trends in safety were therefore described by means of the following two estimators:

1. Accidents involving scheduled or charter flights per million flight kilometers;
2. Passenger fatalities per billion passenger kilometers.

The data that were used in the analyses are shown in Tables A1 and A2 in the Appendix to the paper. Changes over time in these two estimators are shown in Figures 1 and 2. Figure 1 shows the annual accident rate for scheduled and charter flights per million kilometers flown. The rate includes all reported accidents, both fatal and non-fatal. It is seen that the rate has declined sharply over time.

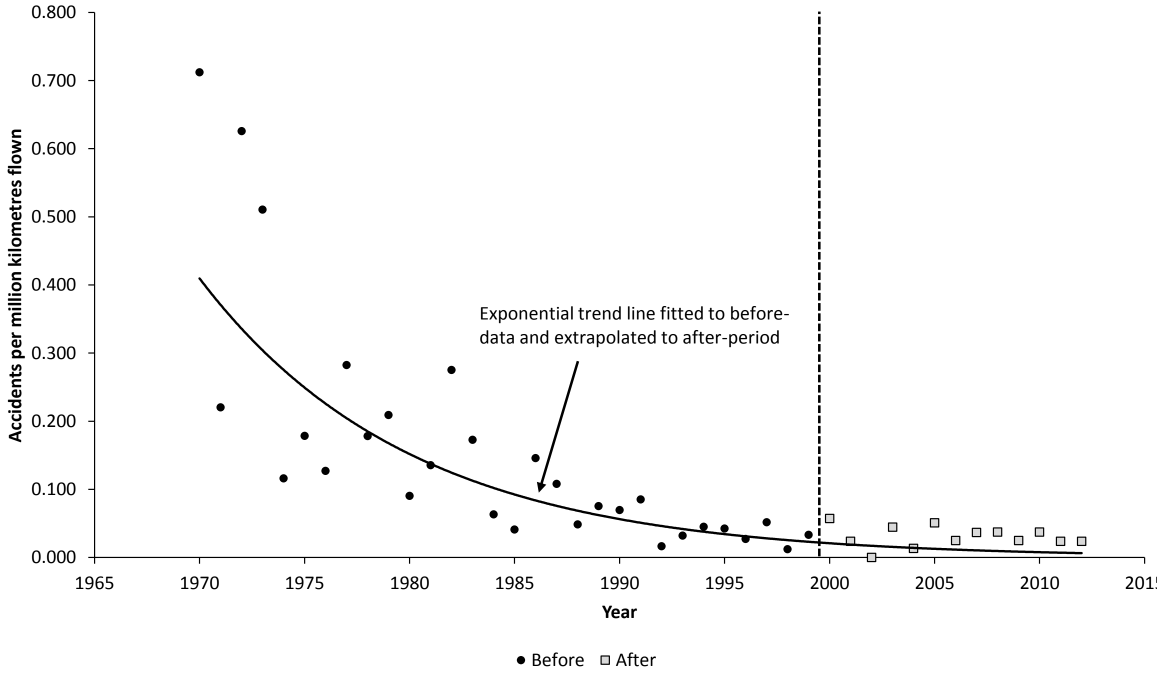

Figure 1. Accident rates in commercial civil aviation in Norway before and after safety inspectorate was established.

An exponential trend line has been fitted to the data points for the before-period (1970–1999) and extrapolated to the after-period (2000–2012). The extrapolated part of the trend line is intended as an estimate of what the accident rate would have been if a safety inspectorate had not been created and the long-term trend had remained unchanged from the before-period. The squared correlation coefficient for the trend line is 0.742. It is particularly important that the trend line fits the data well for the end of the before-period. If, for example, the trend line is located below most of the data points close to the end of the before-period, extrapolating it may produce biased (*i.e.*, too low) estimates of the accident rate expected in the after-period. The trend line in Figure 1 runs right in the middle of the data points. There is no statistically significant autocorrelation of the residuals, which indicates that there are no strings of adjacent data points that consistently are above or below the trend line.

The number of passenger fatalities is low. Estimates of the long-term trend have therefore been based on periods of ten years (1970–79, 1980–89, and 1990–99). As shown in Figure 2, the fatality rate declined sharply during this period, in particular in the third decade (1990–99). There have not been any passenger fatalities after 1997.

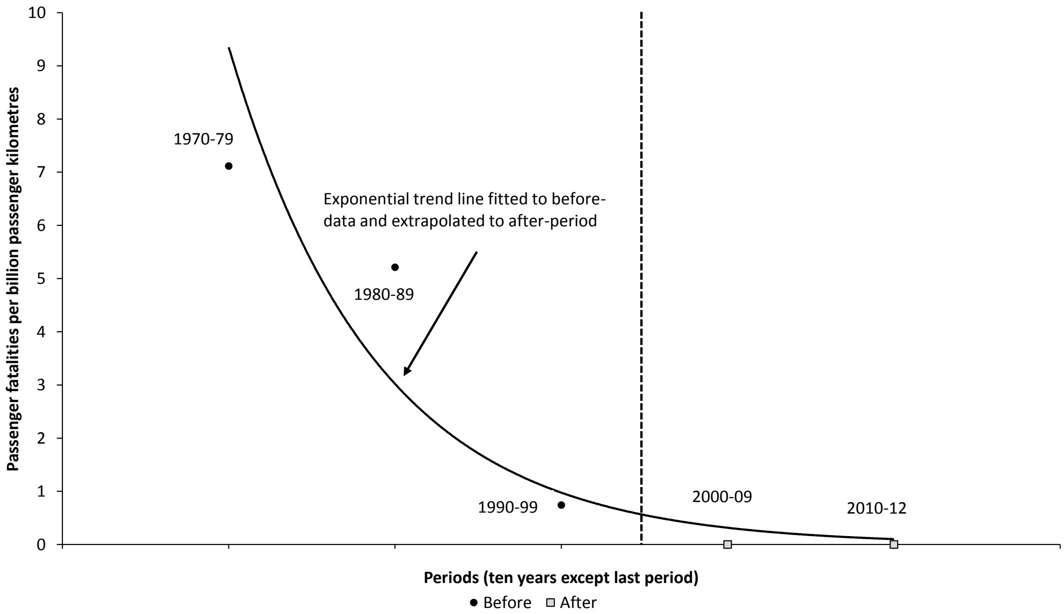

Figure 2. Passenger fatalities per billion passenger kilometers in civil aviation in Norway 1970–2012.

3.2. Railways

A comprehensive data set for railways was developed in a previous study [11]. That data set ended in 2011 and data for the years 2012 and 2013 have been added. Two estimators of the long-term trends in safety have been developed:

1. The total annual number of accidents per million train kilometers;
2. Passenger fatalities per billion passenger kilometers.

The data that were used in the analyses are shown in Tables A3 and A4 in the Appendix to the paper. Figure 3 shows the trend in the first of these estimators. The trend line fits the data points quite well (R^2 = 0.713; no significant autocorrelation in residual terms). The four last data points in the before-period (1962–1996) are located below the trend line, but the extrapolation of the trend line passes through the data points in the after-period until 2004. All data points after 2004 are located below the extrapolated trend line.

Figure 4 shows the long-term trend in the passenger fatality rate. Passenger fatalities include all passengers on board a train as well as those who are boarding or alighting a train. Events where no train was involved are not included. Data have been aggregated into five-year periods. Even so, there is great variation. The period 1972–76 is an outlier, attributable to a large train accident in 1975 with 27 victims. The trend line passes close to the data points for the periods 1977–81, 1982–86, 1987–91, and 1992–96. The first data point in the after-period is again somewhat of an outlier (although not as extreme as the 1972–76 data point) due to a major accident in 2000 (16 passengers and three train staff were killed).

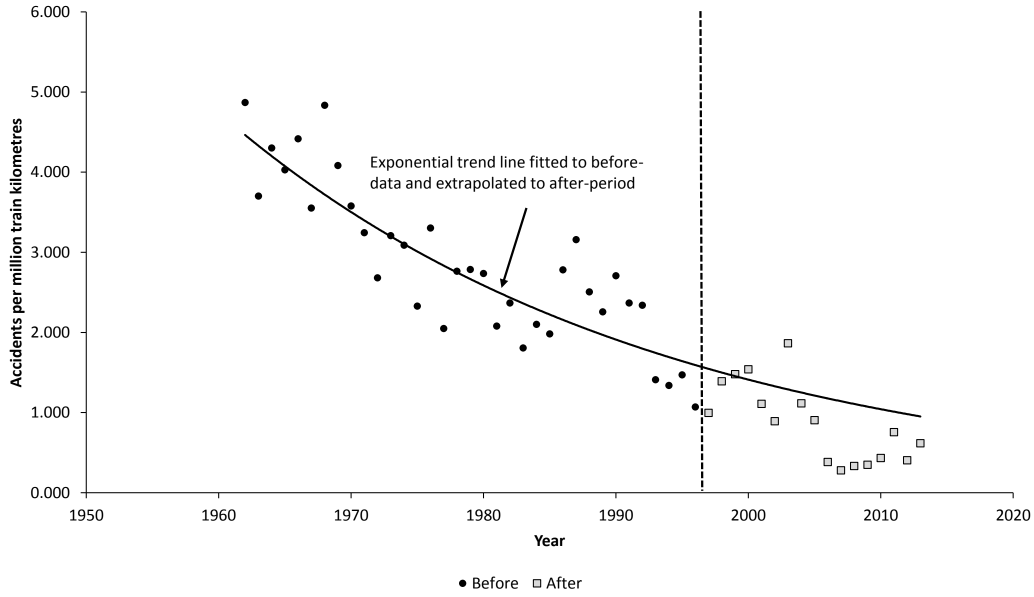

Figure 3. Trends in the risk of train accidents in Norway before and after safety inspectorate was established.

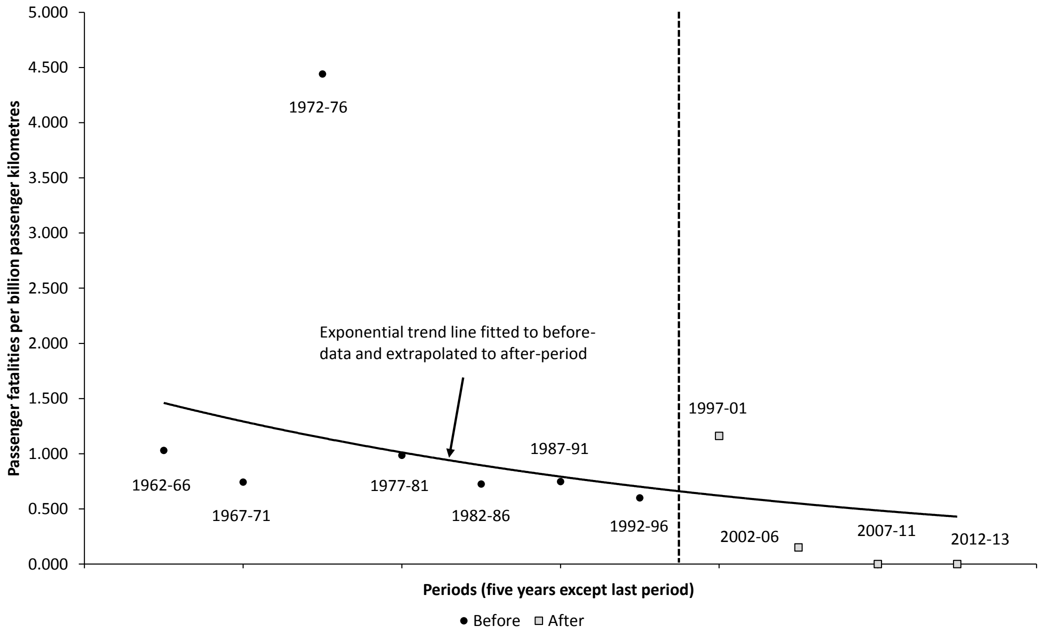

Figure 4. Passenger fatality rate for Norwegian mainline railways 1962–2013.

3.3. Statistical Analysis

The statistical analysis consisted of the following steps:

1. Using the trend lines, an expected number of accidents or fatalities was estimated for the after-period.
2. The standard error of the expected number of accidents was estimated.
3. The recorded number of accidents in the after-period was compared to the expected number.
4. The difference between the recorded and expected number of accidents and the standard error of the difference were determined.

These steps will be illustrated using aviation accidents as an example. The trend line was fitted by means of a function of the form:

$$\text{Trend line } = \alpha \cdot e^{\lambda \cdot t} \tag{1}$$

where, α is a constant term, e is the exponential function, and λ is a parameter showing the percentage change in accident rate from one period to the next. The period is one year in analyses relying on annual data, 10 years in the analysis of air passenger fatalities, and five years in the analysis of rail passenger fatalities. Years were numbered from 1 to n when fitting the function. For accidents in commercial civil aviation in Norway (Figure 1), the parameter λ was estimated to a value of −0.099 with a standard error of 0.011. Thus, for the first year in the after-period (year 31) , the expected number of accidents was estimated as the product of fitted accident rate ($0.452 \cdot e^{(31\ \cdot\ -0.099)}$) and million flight kilometers flown that year (87.331):

$$\text{Expected number of accidents} = 0.452 \cdot e^{(31\ \cdot\ -0.099)} \cdot 87.331 = 1.83 \tag{2}$$

The exponential function gives the expected accident rate. Multiplying this with million flight kilometers (87.331) gives the expected number of accidents. Similar estimates were made for each year in the after-period; these estimates were then summed in order to determine the total expected number of accidents. Using this method, the total expected number of accidents was determined to be 12.88. The standard error of this number was estimated as: 12.88 · (0.011/0.099) = 1.43.

The recorded number of accidents in the after-period was 32. The recorded number of accidents was assumed to be Poisson-distributed. Hence, the standard error is the square root of the number, or 5.66. The difference between the recorded and expected number of accidents is 32 − 12.88 = 19.12. The standard error of this difference is equal to:

$$\text{Standard error of difference} = \sqrt{SE_{expected}^2 + SE_{recorded}^2} \tag{3}$$

where SE is standard error; expected is the expected number of accidents; and recorded is the recorded number of accidents. In the numerical example, this becomes 5.83. The difference between the recorded and expected number of accidents is therefore statistically significant at the 5% level. The accident modification factor is estimated as 32/12.88 = 2.48. The standard error of the accident modification factor is:

$$\text{Standard error of accident modification factor} = \sqrt{\left(\frac{SE_{recorded}}{Expected}\right)^2 + \left(\left(\frac{Recorded}{Expected^2}\right) \cdot SE_{expected}\right)^2} \tag{4}$$

where SE is standard error; expected is the expected number of accidents; and recorded is the recorded number of accidents. The standard error of the accident modification factor becomes 0.519 in the present numerical example.

4. Results

Results are presented in Table 2. The results are somewhat mixed, in particular for aviation. For accidents, the accident modification factor suggests an increase of 148 percent. For passenger fatalities, the predicted number for the years 2000–2012 (thirteen years) is 14.8. The recorded number of fatalities was zero. Nominally, therefore, the number of passenger fatalities has been reduced by 100 percent. The standard error of the accident modification factor for fatalities (0.00) cannot be estimated.

It is unlikely that the long-term expected number of passenger fatalities in commercial aviation in Norway is zero. However, until the time of writing this paper (January 2016), no fatalities had been recorded after 1997. The largest number of fatalities ever recorded in an aviation accident in Norway was 55. Even if an accident involving this number of fatalities were to occur in the near future, the mean number of passenger fatalities per year for all years after 2000 (15 years) would be only 3.7.

The annual mean number of passenger fatalities was 7.4 during 1970–79, 10.6 during 1980–89 and 2.6 during 1990–99. It is therefore likely that passenger safety has improved after 2000.

Table 2. Estimated changes in number of accidents and passenger fatalities from before to after safety inspectorates were established.

Estimators of Effect (Standard Error)	Aviation		Railways	
	All Accidents	Passenger Fatalities	All Accidents	Passenger Fatalities
Constant term of trend	0.452 (0.089)	28.956 (29.585)	4.601 (0.318)	1.651 (0.955)
Annual term	−0.099 (0.011)	−1.130 (0.473)	−0.030 (0.003)	−0.122 (0.129)
Predicted number of accidents or fatalities	12.9 (1.4)	14.8 (6.2)	869.4 (86.9)	26.1 (27.6)
Recorded number of accidents or fatalities	32 (5.7)	0 (0.0)	511 (22.6)	18 (4.2)
Accident modification factor	2.48 (0.52)	0.00 (0.00)	0.59 (0.06)	0.69 (0.75)

Results for railways are more consistent. The number of accidents was about 40 percent lower than predicted, if the trend before the safety inspectorate was created had continued. The reduction in the number of accidents was statistically highly significant. The number of fatalities was about 30 percent lower, but this decline was not statistically significant.

5. Discussion

The deregulation of transport that started around 1980 was intended to stimulate competition, in the belief that increased competition would lead to improved service and lower fares. This has certainly been the case for aviation in Norway. A new main airport opened in 1998. Initially, competition between airlines did not change much. In 2003, however, the airline Norwegian started a rapid growth of service and a fierce competition with the flag carrier, Scandinavian Airlines. Fares have been reduced and the number of flights and destinations served have increased.

There are, to be sure, worries about safety and about the working conditions of airline employees [5]. As far as safety is concerned, these worries have so far proved groundless, at least if one judges safety in terms of accidents and fatalities. The analyses presented in this paper do not indicate that the creation of a safety inspectorate for aviation in 2000 has been associated with a reduction of the number of non-fatal accidents in scheduled and charter flights. One may wonder, however, if it really is possible to further reduce the number of accidents. The mean annual number of accidents in the thirteen years from 2000 to 2012 was 2.46. The annual recorded numbers varied between zero and five and did not differ significantly from a Poisson-distribution, suggesting that the accidents occur at random. All the accidents were property-damage-only accidents.

The fact that aviation accidents occur at random should not be taken to imply that they cannot be prevented. It is a misunderstanding to think that randomness in accident occurrence means that the accidents are unpreventable. Randomness over time simply means that the mean number of accidents has not changed during the study period. However, the mean number of accidents can often be reduced by introducing new technology or new procedures. It is, perhaps, more a matter of a lack of interest in trying to further improve safety if the number of accidents per years gets as low as two or three.

It is a fact that the Civil Aviation Authority has had a troubled history. When created in 2000, it was located in Oslo. In 2003, the government proposed to relocate it to the city of Bodø in northern Norway. This decision was very unpopular among employees of the authority and was resisted. In 2005, however, the government forced the director of the authority to resign and gave employees the choice between quitting or moving to Bodø. A very large number quit and new staff had to be hired after the agency opened its new main office in Bodø in 2008. This turbulence may have reduced the efficiency of the agency, although quantifying its efficiency is beyond the scope of this paper.

The railways in Norway are no longer a state monopoly, although competition is much more limited than in aviation. The National Rail Administration, created in 1996, initially had the same managing director as the state railway company. This arrangement ended in 1999. On 4 January 2000 a major train accident with 19 fatalities in total occurred. This lead to extensive investigations and, perhaps as an unintended by-product, made the Norwegian Railway Authority a key organization in matters related to safety. The relationship between the Railway Authority and the National Rail Administration was at first uneasy, but has gradually improved [8]. It seems clear that railway safety has improved after the inspectorate was created, although claiming a causal relationship is not possible, based on the analyses reported in this paper.

The basic limitation of the analyses presented in this paper is the absence of a comparison group. Thus, the only manner in which the paper can answer the question 'What would have happened if the safety inspectorates had not been created?' is simply to assume that before-period trends in accident rates would have continued. While this is sometimes a quite reasonable assumption, there is no way of showing how reasonable it is. Clearly, it is never entirely satisfactory to rely on an assumption whose accuracy cannot be demonstrated.

6. Conclusions

The main results of the study presented in this paper can be summarized as follows:

1. Following the creation of a safety inspectorate for aviation in 2000, there have been no passenger fatalities in civil aviation in Norway. The number of accidents (all non-fatal) has varied between zero and five per year, which is higher than predicted according to the long-term trend before the safety inspectorate was established.
2. The number of railway accidents has been about 40 percent lower than predicted from trends before the National Railway Authority was established. The number of fatalities has been about 30 percent lower than predicted on the basis of prior trends.
3. The findings in this paper show statistical associations only and cannot be interpreted as causal relationships. However, a statistical relationship is generally regarded as a necessary condition for a causal relationship.

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Author Contributions: Rune Elvik designed the study and performed the statistical analyses. Beate Elvebakk collected data on safety inspectorates and described their function. Both authors contributed to writing the paper, with Elvik as principal author.

Conflicts of Interest: The funding agencies had no role in the design of the study; in the collection, analyses and interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

Appendix: Data Used in the Study

The tables in this appendix list the data that were used in the analyses presented in the paper.

Table A1. Total aircraft accidents in scheduled and charter operation per million flight kilometers.

Year	Before (0) or after (1) Safety Inspectorate	Number of Accidents	Million Flight Kilometers	Accidents per Million Flight Kilometer
1970	0	13	18.250	0.712
1971	0	5	22.697	0.220
1972	0	15	23.963	0.626
1973	0	13	25.459	0.511
1974	0	3	25.813	0.116
1975	0	5	28.023	0.178
1976	0	4	31.466	0.127
1977	0	10	35.419	0.282
1978	0	7	39.308	0.178
1979	0	9	43.046	0.209
1980	0	4	44.221	0.090

Table A1. *Cont.*

Year	Before (0) or after (1) Safety Inspectorate	Number of Accidents	Million Flight Kilometers	Accidents per Million Flight Kilometer
1981	0	6	44.256	0.136
1982	0	13	47.235	0.275
1983	0	8	46.352	0.173
1984	0	3	47.448	0.063
1985	0	2	48.851	0.041
1986	0	9	61.733	0.146
1987	0	6	55.565	0.108
1988	0	3	61.869	0.048
1989	0	4	53.095	0.075
1990	0	4	57.343	0.070
1991	0	5	58.579	0.085
1992	0	1	60.403	0.017
1993	0	2	62.255	0.032
1994	0	3	66.493	0.045
1995	0	3	70.468	0.043
1996	0	2	73.482	0.027
1997	0	4	77.334	0.052
1998	0	1	82.138	0.012
1999	0	3	90.418	0.033
2000	1	5	87.331	0.057
2001	1	2	84.794	0.024
2002	1	0	75.131	0.000
2003	1	3	67.505	0.044
2004	1	1	74.989	0.013
2005	1	4	78.860	0.051
2006	1	2	80.484	0.025
2007	1	3	81.748	0.037
2008	1	3	80.554	0.037
2009	1	2	80.039	0.025
2010	1	3	80.630	0.037
2011	1	2	84.471	0.024
2012	1	2	84.781	0.024

Table A2. Passenger fatalities per million passenger kilometers flown – by decades.

Years	Before (0) or after (1) Safety Inspectorate	Number of Fatalities	Million Passenger Kilometers	Accidents per Million Passenger Kilometer
1970–1979	0	74	10.399	7.116
1980–1989	0	106	20.332	5.213
1990–1999	0	26	35.029	0.742
2000–2009	1	0	42.405	0.000
2010–2012	1	0	14.068	0.000

Table A3. Total railway accidents per million train kilometer.

Year	Before (0) or after (1) Safety Inspectorate	Number of Accidents	Million Train Kilometers	Accidents per Million Train Kilometer
1962	0	169	34.703	4.870
1963	0	124	33.493	3.702
1964	0	147	34.164	4.303
1965	0	130	32.265	4.029
1966	0	144	32.598	4.417
1967	0	117	32.934	3.553
1968	0	160	33.093	4.835
1969	0	132	32.337	4.082
1970	0	115	32.131	3.579
1971	0	104	32.055	3.244
1972	0	85	31.708	2.681
1973	0	100	31.173	3.208

Table A3. *Cont.*

Year	Before (0) or after (1) Safety Inspectorate	Number of Accidents	Million Train Kilometers	Accidents per Million Train Kilometer
1974	0	100	32.369	3.089
1975	0	77	33.073	2.328
1976	0	112	33.912	3.303
1977	0	70	34.174	2.048
1978	0	94	34.022	2.763
1979	0	95	34.098	2.786
1980	0	95	34.733	2.735
1981	0	72	34.610	2.080
1982	0	81	34.206	2.368
1983	0	60	33.210	1.807
1984	0	69	32.837	2.101
1985	0	65	32.794	1.982
1986	0	93	33.441	2.781
1987	0	104	32.939	3.157
1988	0	79	31.535	2.505
1989	0	70	31.022	2.256
1990	0	88	32.504	2.707
1991	0	79	33.358	2.368
1992	0	80	34.208	2.339
1993	0	49	34.754	1.410
1994	0	50	37.342	1.339
1995	0	54	36.712	1.471
1996	0	40	37.364	1.071
1997	1	37	37.103	0.997
1998	1	52	37.417	1.390
1999	1	56	37.871	1.479
2000	1	59	38.325	1.539
2001	1	43	38.779	1.109
2002	1	35	39.223	0.892
2003	1	74	39.686	1.865
2004	1	46	41.217	1.116
2005	1	37	40.853	0.906
2006	1	16	41.828	0.383
2007	1	12	42.904	0.280
2008	1	14	42.025	0.333
2009	1	15	43.064	0.348
2010	1	20	46.097	0.434
2011	1	35	46.306	0.756
2012	1	19	46.765	0.406
2013	1	30	48.518	0.618

Table A4. Passenger fatalities per million passenger kilometers in trains—by five-year periods.

Years	Before (0) or after (1) Safety Inspectorate	Number of Fatalities	Million Passenger Kilometers	Fatalities per Billion Passenger Kilometer
1962–1966	0	9	8.740	1.030
1967–1971	0	6	8.070	0.743
1972–1976	0	40	9.006	4.441
1977–1981	0	11	11.169	0.985
1982–1986	0	8	11.035	0.725
1987–1991	0	8	10.698	0.748
1992–1996	0	7	11.676	0.600
1997–2001	1	16	13.779	1.161
2002–2006	1	2	13.278	0.151
2007–2011	1	0	15.306	0.000
2012–2013	1	0	6.337	0.000

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