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Effects on accidents of technical inspections of heavy goods vehicles in Norway: A re-analysis and a replication

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Abstract

Introduction: This paper presents a re-analysis of a previous study of the effects on accidents of technical inspections of heavy vehicles in Norway and a replication of the study using more recent data. *Method:* Increasing the number of technical inspections is associated with a reduction in the number of accidents. Reducing the number of inspections is associated with an increase in the number of accidents. The relationship between changes in the number of inspections and changes in the number of accidents is well described by means of logarithmic dose–response curves. *Results:* These curves show that inspections had a larger effect on accidents in the recent period (2008–2020) than in the first period (1985–1997). Based on recent data, a 20% increase in the number of inspections is associated with a 4–6% reduction in the number of accidents. A 20% reduction of the number of inspections is associated with a 5–8% increase in the number of accidents.

Previous Next

Keywords

Heavy goods vehicle; Technical inspections; Accidents; Evaluation study

1. Introduction

Heavy goods vehicles that have technical defects have a higher rate of accident involvement than heavy goods vehicles that do not have technical defects. Jones and Stein (1989) found a relative risk of about 1.7, and a population attributable risk of 0.32, meaning that by eliminating technical defects, the number of accidents could be reduced by 32%. Teoh, Carter, Smith, and McCartt (2017) found a relative risk of 3.1 and a population attributable risk of 0.51. Technical defects are therefore an important risk factor for heavy goods vehicles.

In accordance with EU Directive 2014/47, Norway has implemented technical roadside inspections of heavy goods vehicles. Vehicles are inspected by vehicle experts employed by the Public Roads Administration. Vehicles are inspected in roadside inspection stations that have equipment for measuring, for example, vehicle weight and braking performance. Defects are graded as minor, major, or dangerous. A defect graded as dangerous results in vehicle impoundment, that is, the vehicle is out of service until the defect has been repaired.

The number of technical inspections varies from year to year but has been between 0.8 and 1.2 per registered heavy goods vehicle per year in recent years. Thus, on average, a heavy goods vehicle can expect to be inspected about once per year. Elvik (2002) evaluated the effects on accidents of technical inspections carried out in Norway between 1985 and 1997. He found a statistically non-significant association between the number of inspections per vehicle per year and accident rate. The association indicated that by doubling the number of inspections, accident rate would decline by 5–10%.

The statistical technique used by Elvik (2002) was ordinary least-squares linear regression, using various indicators of accident rate as dependent variable. Technical inspections, as well as other variables, were measured in terms of annual percentage changes, that is, increases or decreases from the year before. This approach may have had low statistical power, resulting in non-significant findings.

This paper has two objectives. The first is to re-analyze the 2002-study, using a more appropriate count regression model (negative binomial regression). The second is to replicate the study, by doing a similar analysis of data covering the years from 2008 to 2020.

2. Previous studies

The study published in 2002 (Elvik, 2002) is one of very few studies of the effects on accidents of technical inspections of heavy vehicles. Some studies, notably Jones and Stein, 1989, Moses and Savage, 1992, and Teoh et al. (2017) have estimated the increase in the risk of accidents associated with technical defects. These studies suggest that by eliminating or reducing technical defects, the number of accidents can be reduced. However, the studies say nothing about the type or intensity of technical inspections needed to substantially reduce technical defects.

A Canadian study (Gou, Clément, Birikundavyi, Bellavigna-Ladoux, & Abraham, 1999) estimated that technical defects contributed to about 15% of accidents involving heavy goods vehicles. An American study (Thakuriah, Yanos, Lee, & Sreenivasan, 2001) found a weak tendency for vehicles that had many technical defects when inspected to be more often involved in accidents the following year, compared to vehicles that had no technical defects when inspected. A recent Spanish study (Diaz Lopez, 2019) estimated that periodic motor-vehicle inspections prevent about 7% of all injury accidents. This estimate, however, did not include heavy goods vehicles.

Elvik (2002) estimated that doubling the number of roadside technical inspections per vehicle could reduce the number of accidents involving heavy vehicles (both buses and trucks) by about 7%. This estimate was associated with large uncertainty (95% confidence interval from −18.4% to +5.1%).

3. Re-analysis of previous study

The data used in the study by Elvik (2002) are reproduced in Table 1. The table does not include data on light vehicles, as these are not used in the re-analysis presented in this paper. Heavy vehicles include both buses and trucks.

Table 1. Data used in original study.

Year	Number of Inspections	Accidents involving heavy	Number of vehicles	Million vehicle kilometers	New drivers	All drivers	Inspections per vehicle	New drivers as proportion	Change (%) in GDP/capita
1985	39,134	1180	90,270	2486	9214	304,416	0.434	0.030	5.2
1986	42,940	1232	94,963	2971	9838	317,250	0.452	0.031	3.6
1987	47,708	1202	98,203	3182	10,818	331,992	0.486	0.033	2.0
1988	69,039	1064	98,131	3387	10,631	353,696	0.704	0.030	−0.1
1989	93,490	974	96,587	3475	3805	345,678	0.968	0.011	0.9
1990	113,259	943	95,505	3552	7952	367,262	1.186	0.022	2.0
1991	128,920	1027	95,412	3634	8238	375,938	1.351	0.022	3.1
1992	182,768	995	97,028	3728	7766	383,344	1.884	0.020	3.3
1993	58,310	1008	97,494	3820	7350	389,496	0.598	0.019	2.7
1994	55,990	1046	98,257	3957	6932	395,519	0.570	0.018	5.5
1995	50,143	1074	100,219	4127	7026	400,730	0.500	0.018	3.8
1996	48,340	1082	103,331	4197	11,167	407,403	0.468	0.027	4.9
1997	42,543	1068	107,763	4636	8502	409,593	0.395	0.021	4.7

To estimate the effect of technical inspections on the number of accidents, a negative binomial regression model was developed. The model was fitted in four stages. The first stage included only the constant term and a term for technical inspections. In the next three stages, other variables were added to the model. Estimated coefficients are shown in Table 2.

Table 2. Negative binomial regression of data for 1985–1997. Regression coefficients and standard errors.

Term	Regression coefficients. Standard errors in parentheses. P-value in square brackets			
	Model 1	**Model 2**	**Model 3**	**Model 4**
Constant term	7.061 (0.0196) [0.000]	7.307 (0.0655) [0.000]	6.993 (0.1271) [0.000]	6.978 (0.1153) [0.000]
Inspections per vehicle	−0.115 (0.0227) [0.000]	−0.114 (0.0225) [0.000]	−0.082 (0.0265) [0.002]	−0.070 (0.0251) [0.005]
Million vehicle kilometers		0.000068 (0.000017) [0.000]	0.000029 (0.000023) [0.209]	0.000037 (0.000021) [0.084]
Proportion of new drivers			6.348 (2.1304) [0.003]	6.271 (1.9357) [0.001]
Change in GDP per capita				0.011 (0.0062) [0.082]
Elvik-index of goodness-of-fit				0.9475

The final model (model 4) contained four independent variables. With only 13 units of observation, it was not possible to include more variables.

The coefficient for technical inspections was negative and statistically significant in all model specifications, suggesting that inspections reduce the number of accidents. The final model explained 94.75% of the systematic variation in the number of accidents according to the Elvik-index of goodness-of-fit (Fridstrøm, Ifver, Ingebrigtsen, Kulmala, & Krogsgård Thomsen, 1995). There was no statistically significant autocorrelation of the residual terms for lags from 1 to 11. Fig. 1 shows the data and model predictions.

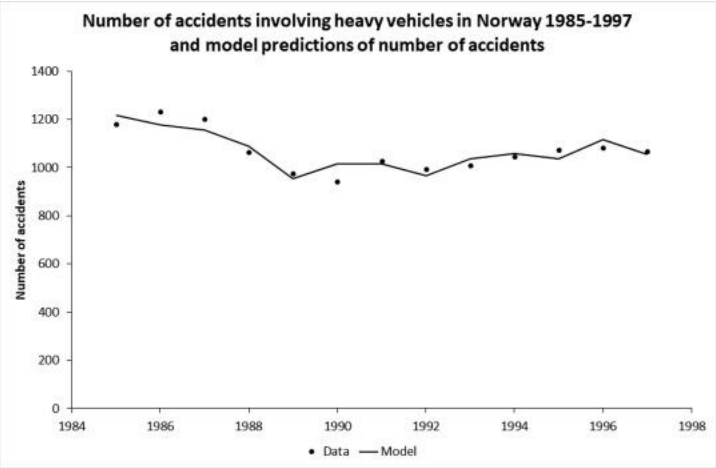

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Fig. 1. Number of accidents involving heavy vehicles in Norway 1985–1997 and model prediction of number of accidents.

There was a downward trend in the number of accidents until about 1990 and a weak upward trend after 1990. To identify the contribution of variations in the number of technical inspections to the annual changes in the number of accidents, annual changes were computed under two conditions: (1) Based on the number of accidents predicted by the model including technical inspections; (2) Based on the number of accidents predicted by a model not including technical inspections. The latter model is intended to establish the counterfactual (i.e., describe the annual changes in the number of accidents that would have occurred if technical inspections did not exist). The differences between the annual differences identifies the contribution to changes in the number of accidents from year N to year N + 1 from changes in the number of technical inspections per vehicle from year N to year N + 1. Table 3 shows these computations.

Table 3. Differences-in-differences estimate of effects on accidents of technical inspections 1985–1997.

Year	Accidents	Predicted with inspections	Predicted without inspections	Annual differences with inspections	Annual differences without inspections	Difference in differences	Relative change in inspections	Relative change in accidents
1985	1180	1216.43	1206.03					
1986	1232	1178.12	1167.28	−38.31	−38.75	0.44	1.043	1.000
1987	1202	1157.34	1146.43	−20.79	−20.85	0.06	1.074	1.000
1988	1064	1088.09	1079.78	−69.25	−66.65	−2.60	1.448	0.998
1989	974	955.27	933.71	−132.82	−146.07	13.25	1.376	1.014
1990	943	1015.13	1035.84	59.86	102.13	−42.27	1.225	0.958

Year	Accidents	Predicted with inspections	Predicted without inspections	Annual differences with inspections	Annual differences without inspections	Difference in differences	Relative change in inspections	Relative change in accidents
1991	1027	1014.28	1053.80	−0.85	17.96	−18.81	1.139	0.981
1992	995	965.88	1039.91	−48.39	−13.89	−34.50	1.394	0.964
1993	1008	1037.29	1015.66	71.40	−24.25	95.65	0.318	1.092
1994	1046	1057.54	1045.61	20.25	29.95	−9.70	0.953	0.991
1995	1074	1036.58	1013.18	−20.96	−32.43	11.47	0.878	1.011
1996	1082	1115.92	1117.06	79.34	103.88	−24.54	0.935	0.978
1997	1068	1056.33	1040.61	−59.59	−76.45	16.86	0.844	1.016

The first column in Table 3 shows the recorded number of accidents. The next two columns show the number of accidents predicted with and without technical inspections. The fourth and fifth columns show the annual differences in the number of accidents as predicted with and without technical inspections. In the sixth column, the differences between differences are computed in order to identify the annual contribution of technical inspections. It is seen that this contribution is sometimes negative (i.e., a reduction of the number of accidents) and sometimes positive (i.e., an increase in the number of accidents).

One would expect an increase in the number of inspections to be associated with a reduction in the number of accidents and a reduction in the number of inspections to be associated with an increase in the number of accidents. The last two columns of Table 3 provide information to assess whether there is such an association. These columns state the relative change in the number of inspections and the relative change in the number of accidents. The latter was computed relative to the predicted number of accidents in the model, including technical inspections. Values above 1 indicate increases, values below 1 indicate decreases.

The data in the two rightmost columns of Table 3 are plotted in Fig. 2. Fig. 2 shows the association between annual changes in the number of technical inspections and annual changes in the number of accidents.

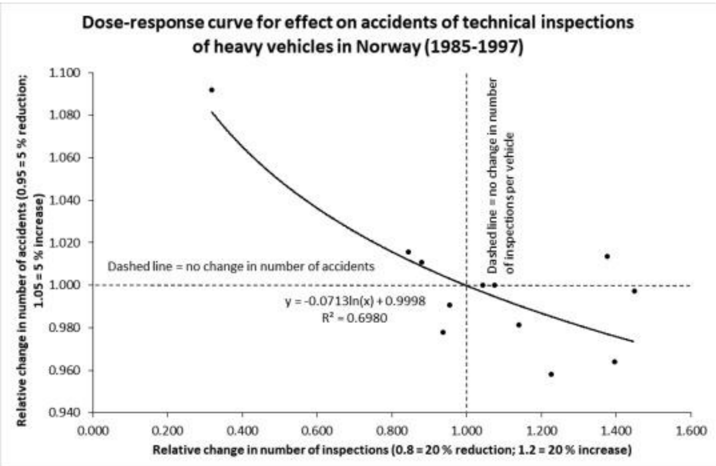

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Fig. 2. Dose-response curve for effect on accidents of technical inspections of heavy vehicles in Norway (1985–1997).

The association between changes in the number of technical inspections and changes in the number of accidents is well described by a logarithmic function. The function passes straight through the equilibrium point for effects of enforcement, that is, no change in enforcement is associated with no change in accidents (Bjørnskau & Elvik, 1992). The standard error of the coefficient for the logarithmic term is 0.015. It is highly statistically significant. A 95% confidence interval for the estimated effect on accidents of a 20% reduction in the number of inspections is (+0.9%; +2.2%). For a 20% increase in the number of inspections, the 95% confidence interval is (−0.8%; −1.8%).

The curve in Fig. 2 is strongly influenced by the data point in the upper left corner. Would the results be different if this data point is omitted? If omitted, there is still a negative relationship between the number of inspections and the number of accidents. The relationship is, however, considerably weaker. The coefficient for the logarithmic function is −0.035 (−0.071 when all data points are included), with a standard error of 0.032.

As the data in Table 1 show, there was a sharp reduction of the number of technical inspections from 1992 to 1993 and an increase in the number of accidents. It is therefore concluded that the data point referring to changes from 1992 to 1993 should be included, although it is located far from the other data points.

4. Replication

The replication copied the re-analysis presented above as far as possible. The data used in the replication are shown in Table 4. The replication included only heavy goods vehicles.

Table 4. Data used in replication study.

Year	Number of vehicles	Million vehicle kilometers	Technical inspections	Inspections per vehicle	Change (%) in GDP/capita	Proportion of young drivers	Accidents involving heavy
2007	84,742	1722			1.0	0.007	786
2008	84,350	1886	82,032	0.973	−0.8	0.007	675
2009	82,694	1737	76,783	0.929	−3.0	0.008	581
2010	81,330	1799	83,784	1.030	−0.5	0.008	602
2011	80,160	1832	68,181	0.851	−0.3	0.012	521
2012	79,857	1938	73,409	0.919	1.4	0.011	551
2013	79,437	1950	69,824	0.879	−0.2	0.014	459
2014	78,668	1909	86,571	1.100	0.8	0.013	384
2015	77,120	1883	70,404	0.913	0.9	0.013	312
2016	75,238	1818	83,160	1.105	0.2	0.014	335
2017	73,808	1855	88,313	1.197	1.5	0.014	327
2018	72,405	1760	82,611	1.141	0.5	0.014	333
2019	72,078	1798	77,734	1.078	0.1	0.014	319
2020	70,670	2035	79,042	1.118	−1.3	0.014	251

The variables of principal interest are the number of accidents and the number of technical inspections per vehicle. The number of technical inspections per vehicle per year fluctuates between about 0.85 and 1.20. This variation is considerably smaller than during 1985–1997.

A negative binomial regression model was developed in four stages, as in the re-analysis. Exploratory analysis found that when kilometers driven was entered, the coefficient for technical inspections indicated an implausibly large effect. Kilometers driven was therefore replaced by number of trucks. Estimated coefficients are presented in Table 5.

Table 5. Negative binomial regression of data for 2008–2020. Regression coefficients and standard errors.

	Regression coefficients. Standard errors in parentheses. P-value in square brackets			
Term	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Constant term	7.841 (0.6459) [0.000]	0.398 (0.5092) [0.435]	3.219 (1.0691) [0.003]	4.058 (1.1768) [0.001]
Inspections per vehicle	−1.752 (0.6316) [0.006]	0.123 (0.1829) [0.502]	−0.208 (0.2136) [0.331]	−0.339 (0.2262) [0.134]
Number of heavy goods vehicles		0.000071 (0.0000047) [0.000]	0.000045 (0.0000099) [0.000]	0.000038 (0.000011) [0.000]
Proportion of young drivers			−38.148 (12.7529) [0.003]	−52.698 (15.3647) [0.001]
Change in GDP per capita				0.027 (0.0157) [0.089]
Elvik-index of goodness-of-fit				0.9421

The coefficient for technical inspections was negative in three of the four models, but was not statistically significant in any of models 2–4. It nevertheless approached statistical significance in model 4. Fig. 3 shows how the model fits the data. There was a large decline in the number of accidents from 2008 to 2020, and the model captures this decline. It explained 94.21% of the systematic variation in the number of accidents (Elvik-index).

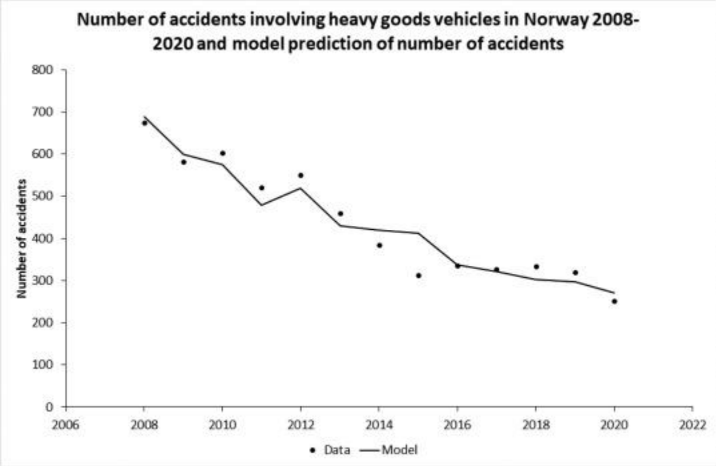

Fig. 3. Number of accidents involving heavy goods vehicles in Norway 2008–2020 and model prediction of number of accidents.

There was some autocorrelation of residual terms. It was statistically significant at the 5% level for lags 4–8, but not for lags 1–3 and 9–11. The contribution of technical inspections to the annual changes in the number of accidents was estimated the same way as in the re-analysis. The number of accidents predicted by models including and not including technical inspections was estimated and annual differences taken. Differences between differences show the annual contribution of changes in the number of technical inspections (see Table 6).

Table 6. Differences-in-differences estimate of effects on accidents of technical inspections 2008–2020.

Year	Accidents	Predicted with inspections	Predicted without inspections	Annual differences with inspections	Annual differences without inspections	Difference in differences	Relative change in inspections	Relative change in accidents
2007	786	688.08	709.23					
2008	675	599.41	596.39	−88.67	−112.84	24.17	0.955	1.040
2009	581	575.62	588.22	−23.79	−8.17	−15.62	1.109	0.973
2010	602	478.18	468.41	−97.44	−119.81	22.37	0.826	1.047
2011	521	519.75	515.47	41.57	47.06	−5.49	1.081	0.989
2012	551	429.39	425.98	−90.36	−89.49	−0.87	0.956	0.998
2013	459	419.32	441.72	−10.07	15.74	−25.81	1.252	0.938
2014	384	411.53	401.01	−7.79	−40.71	32.92	0.830	1.080
2015	312	337.58	344.78	−73.95	−56.23	−17.72	1.211	0.948
2016	335	320.62	333.18	−16.96	−11.60	−5.36	1.083	0.983
2017	327	302.18	302.01	−18.44	−31.17	12.73	0.954	1.042
2018	333	296.68	289.64	−5.50	−12.37	6.87	0.945	1.023
2019	319	271.56	262.72	−25.12	−26.92	1.80	1.037	1.007

The data in the two rightmost columns of Table 6 serve as the basis for the data presented in Fig. 4. Fig. 4 shows a dose–response curve for the association between technical inspections and the number of accidents during 2008–2020.

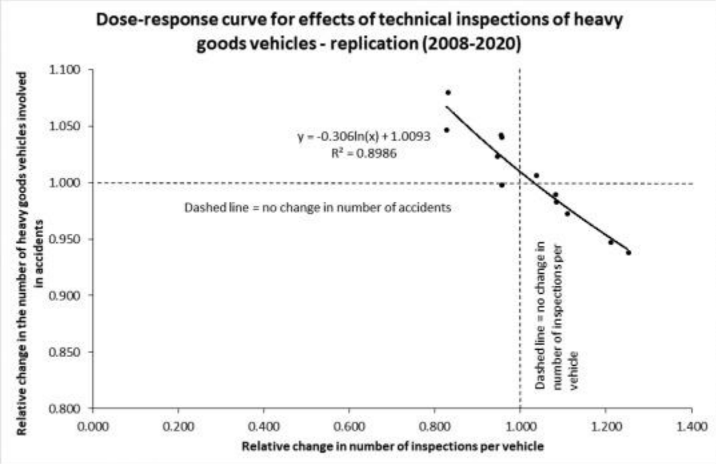

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Fig. 4. Dose-response curve for effects of technical inspections of heavy goods vehicles – replication (2008–2020).

A logarithmic function fits the data well. The curve passes close to the general equilibrium point for effects of enforcement (i.e., the intersection of the lines showing no change in number of inspections and no change in number of accidents). The standard error of the coefficient for the logarithmic term is 0.032. A 95% confidence interval for the estimated effect of a 20% reduction in the number of inspections is (+5.4%; +8.2%). A 95% confidence interval for the estimated effect of a 20% increase in the number of inspections is (−4.4%; −6.3%).

5. Discussion

The re-analysis found a somewhat smaller effect on technical inspections of heavy vehicles than the original study. The original study estimated that doubling the number of inspections would reduce the number of accidents by 6.7% (95% CI: −18.4%; +5.1%). The re-analysis estimated that doubling the number of inspections would reduce the number of accidents by 4.9% (95% CI: −2.9%; −5.0%). The confidence interval is much smaller in the re-analysis than in the original analysis.

The replication indicates a larger effect of technical inspections. According to the replication, doubling the number of inspections would reduce the number of accidents by 21.2% (95% CI: −16.8%; −25.6%). It is reasonable to believe that technical inspections have become more effective in recent years. The roadside inspection stations have been upgraded with more advanced technology for measuring, for example, the performance of braking systems. Leaks and uneven braking forces between axles can be detected more easily than in the past.

Nevertheless, the current level of technical inspections in Norway is insufficient to eliminate technical defects. To achieve a reduction of accidents consistent with an elimination of the risk attributable to technical defects, as indicated by the population attributable risks based on Jones and Stein, 1989, Teoh et al., 2017, the number of inspections would have to increase by a factor of nine. While inspections were at a higher level than now in some years of the first period, they were never close to nine times the current level.

6. Conclusions

Technical inspections of heavy goods vehicles are associated with a reduction in the number of accidents. If inspections did not exist, there would be a higher number of accidents involving heavy goods vehicles. Most years, the number of technical inspections varies within plus or minus 20% from the previous year. Variations in this range are associated with a variation in the number of injury accidents involving heavy goods vehicles of about +8% (for a 20% reduction) to −7% (for a 20% increase).

Credit author statement

The author is the sole author of this paper.

Declaration of conflict of interest

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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