Seasonal adjustment of the daily truck toll mileage index

1 Background

In January 2005, Germany implemented a distance-based toll on trucks with a gross vehicle weight exceeding 12 tonnes. This applied initially to motorways and sections of individual trunk roads, but was gradually extended to include all trunk roads as of July 2018. Furthermore, the tonnage threshold was lowered in October 2015 to a gross vehicle weight of 7.5 tonnes.

The Federal Office for Goods Transport (BAG), which is responsible for the truck toll, has published its aggregated business statistics each month since January 2008 as toll statistics on its website. This shows the mileage of the trucks in kilometres, broken down according to the trucks' country of origin.

In order to make the data from the truck toll more useful for economic analyses, the BAG and the Federal Statistical Office (Destatis) have jointly developed the truck toll mileage index. This is free of the structural breaks resulting from the extensions to the toll and has been published as a monthly indicator in the official short-term statistics since December 2018.[1] The seasonal and calendar adjustment is carried out by Destatis in partnership with the Bundesbank.

The mileage index only takes into account mileage on motorways driven by trucks with at least four axles. Following the last expansion of the toll in July 2018, the index therefore covers around 72% of all tolled mileage.

In addition to the mileage index's high coverage, other positive features of note are its low susceptibility to revision owing to the digital data acquisition via GPS using an on-board unit inside the trucks and the index's early availability. Owing to subsequent transmissions by the trucks' on-board units, there may be slight positive revisions to the truck toll mileage index in the month following the initial publication. No revisions are expected in later months.

Owing to the high demand for quickly available economic data in the wake of the COVID-19 pandemic, the mileage index is additionally published (temporarily for the time being) as a

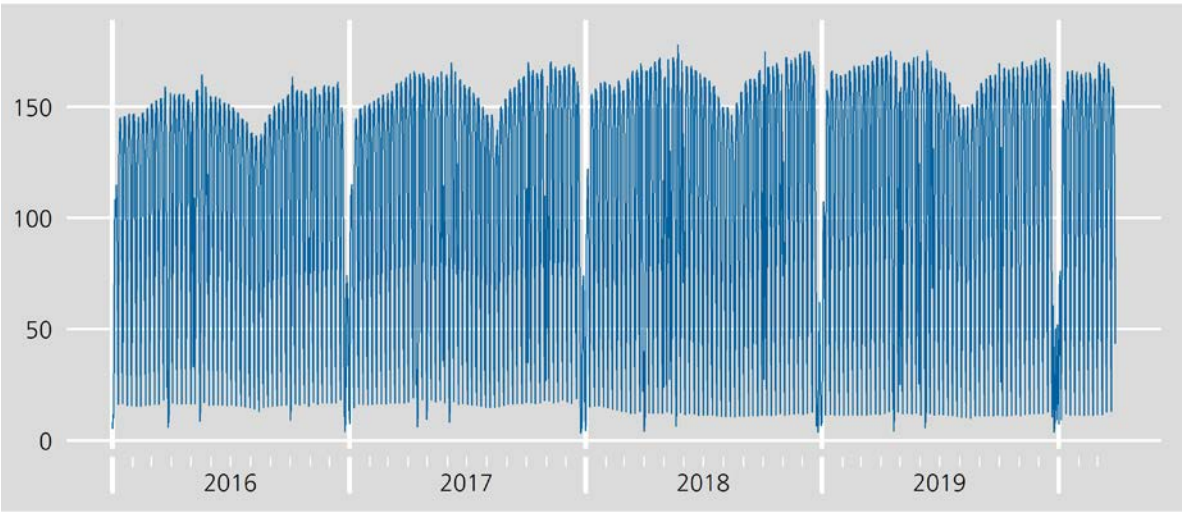
[1] See Cox, M., Berghausen, M., Linz, S., Fries, C., and Völker, J. (2018), Digitale Prozessdaten aus der Lkw-Mauterhebung – Neuer Baustein der Amtlichen Konjunkturstatistiken, Wirtschaft und Statistik 6/2018, 11-32.

daily truck toll mileage index; in short: daily mileage.[2] Chart 1 shows, by way of example, the original values as of January 2016.

Daily truck toll mileage index

Chart 1

2015=100



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The time series is characterised by a pronounced weekday effect. In addition, annually recurring patterns can be seen, such as a funnel-shaped dip in mileage in the third quarter and a brief but deep trough around the turn of the year. A seasonal and calendar adjustment of the daily mileage index therefore appears appropriate, which corresponding statistical tests confirm.

The following section briefly outlines the procedure, identifies possible alternatives and explains the chosen approach.

2 Approaches to the seasonal and calendar adjustment of daily time series

2.1 Overview

Up to now, daily data have tended to be collected on an ad hoc basis as part of official statistics and analysed primarily for the purpose of producing forecasts.[3] By contrast, regular seasonal adjustment and publication of seasonally adjusted daily data for the public

[2] Since the monthly index is calculated on the basis of the aggregated raw data set in relation to 2015, the daily index cannot be aggregated to a monthly index by means of averaging.

[3] See, for example, Koopman, S. J., and Ooms, M. (2003), Time Series Modelling of Daily Tax Revenues, Statistica Neerlandica, 57, 439-469; Koopman, S. J., and Ooms, M. (2006), Forecasting Daily Time Series Using Periodic Unobserved Components Time Series Models, Computational Statistics and Data Analysis, 51, 558-903.

had to date not been envisaged. For this reason, the relevant guidelines[4] do not currently contain any recommendations on modelling or, in particular, seasonal adjustment of daily time series. Nevertheless, there are a number of generally suitable approaches. With regard to the procedures traditionally used in official statistics, these include, in particular:[5]

- An extension of the X-11 approach in combination with regression models containing ARIMA disturbances (RegARIMA model) allows for ex ante adjustment for calendar effects and outliers, followed by a sequential extraction of individual seasonal patterns. This extension is still under development. Its provision in a future version of JDemetra+ is planned.[6]
- A similar extension of JDemetra+, including ex ante adjustment, is envisaged for the ARIMA model-based seasonal adjustment.
- Structural time series models (or their translation into state space models) allow the simultaneous estimation of multiple seasonal patterns as well as calendar effects and effects that can be traced back to outliers.
- The STL procedure[7] also allows a sequential estimation of individual seasonal patterns, but does not initially offer a possibility of ex ante adjustment comparable to the procedures mentioned so far. A corresponding extension is available with the R package "DSA".[8]

The daily mileage index is currently adjusted for seasonal and calendar effects using the enhanced STL approach developed at the Bundesbank. The results were checked for plausibility in a number of test calculations based on the alternative procedures mentioned above.

2.2 The DSA procedure

Daily time series are usually influenced by several overlapping periodic patterns. The three most frequently observed patterns are:

1) Recurring intra-week fluctuations, for example due to differences between workdays and weekend days regarding the behaviour of the time series (day-of-week component).

[4] See, for example, Eurostat (2015), ESS Guidelines on Seasonal Adjustment, Luxembourg: Publications Office of the European Union.

[5] See, for example, Ladiray, D., Palate, J., Mazzi, G. L., and Proietti, T. (2018), Seasonal Adjustment of Daily and Weekly Data, in: Mazzi, G. L., Ladiray, D., and Rieser, D. A. (eds.), Handbook on Seasonal Adjustment, Luxembourg: Publications Office of the European Union, 757-783.

[6] JDemetra+ is a software product that has been developed for the seasonal adjustment of time series. It is publicly available, open source and has been the tool recommended for the seasonal adjustment of official statistics in Europe since 2015. The National Bank of Belgium (NBB), in cooperation with the Deutsche Bundesbank and in line with the recommendations issued by the European Statistical System (ESS) and the European System of Central Banks (ESCB), is responsible for maintaining, revising and updating JDemetra+.

[7] See Cleveland, R. B., Cleveland, W. S., McRae, J. E., and Terpenning, I. (1990), STL: A Seasonal-Trend Decomposition Procedure Based on Loess, Journal of Official Statistics, 6, 3-73.

[8] See Ollech, D. (2018), Seasonal Adjustment of Daily Time Series, Discussion Paper 41/2018, Deutsche Bundesbank.

2) Recurring fluctuations within a month, for example due to differences between mid-month and end-month regarding the behaviour of the time series (day-of-month component).
3) Recurring fluctuations within a year, for example due to differences between winter and summer or fixed holidays such as Christmas regarding the behaviour of the time series (day-of-year component).

The DSA procedure estimates these three seasonal influences sequentially. Any existing interactions between them and also the calendar effects can be identified by means of suitable regressors in a RegARIMA model as part of the calendar adjustment, whichis also used to estimate calendar effects. The most important control options to be set for calendar and seasonal adjustment are:

- Type of decomposition: In order to stabilise the variance of the time series, its logarithm is often calculated prior to adjustment. This corresponds to a multiplicative relationship between the components assumed to be in it. If the logarithm is not calculated, this relationship is additive.
- RegARIMA model: First of all a schedule of parameters can be specified which influences the complexity of the time series model. In a second step, the regressors to be used are defined and transferred. These model the calendar factors as well as all other factors that are to be adjusted.
- Dealing with outliers and extreme values: Exceptional observations which deviate to a particularly large extent from the usual course of the time series must not be allowed to impact the estimation of calendar and seasonal effects. A distorted estimation of seasonal and calendar factors is avoided in two ways. In the RegARIMA model, a (temporary) outlier adjustment is carried out, whereas in the seasonal adjustment loops extreme observations are automatically assigned a lower weight.
- Forecast horizon: In order to obtain forecast seasonal factors, the original values also need to be forecast. For this purpose, a forecast horizon usually lasting 365 days is set in the RegARIMA model.
- Filter length: A reference period is defined for the calculation of each seasonal component. This is used to control how quickly the estimated seasonal effect can change over time.

3 Empirical results

The DSA procedure described above is used for the calendar and seasonal adjustment of the daily mileage index. As a very large number of index values are close to zero, an additive decomposition produces more plausible results. Experience has shown that a multiplicative time series model can lead to extreme seasonal factors in these situations, and thus here as well. Furthermore, short seasonal filters were used to adequately reflect a changing

seasonal pattern. For this empirical evaluation, the daily mileage index was examined from 1 January 2008 to 28 March 2020 with data as at 2 April 2020.

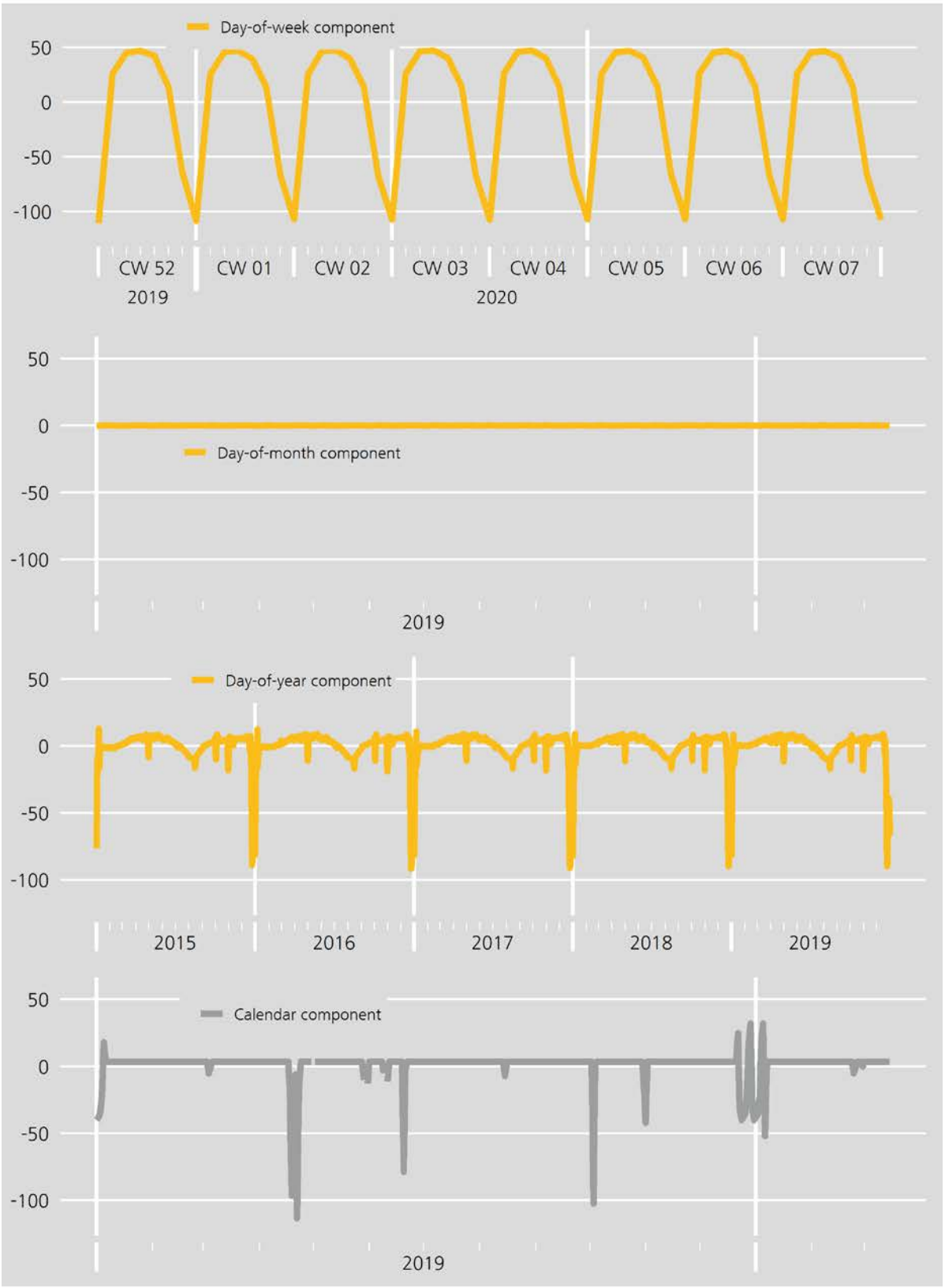
Chart 2 shows the effects of the day of the week, the day of the month and the day of the year. As can be seen, the effect of the day of the week is dominant. Whereas the highest mileage was measured for the days around the middle of the week (Tuesday, Wednesday and Thursday), Sundays show a much lower mileage.[9] The spread between the days of the week amounts to as much as 150 index points. While the day of the month is of no significance for this time series, major differences can be observed for the day of the year. For example, in the summer holiday period there are generally fewer journeys than in the rest of the year. In addition, the day of the year also includes effects attributable to fixed holidays, such as the New Year, Labour Day or the Day of German Unity.

At the same time, it can be observed that the seasonally adjusted series still has exceptionally high fluctuations at these points in time. These are due to cross effects, as mileage on a national holiday is generally roughly as low as on a Sunday. The drop in mileage on a fixed holiday therefore depends on the day of the week on which it falls. For example, the drop in mileage when a fixed holiday falls on a Tuesday or Wednesday is significantly higher than when it falls on a Friday or Saturday. The seasonal filter can only pick up on effects that can be observed at roughly the same level each year. Fixed holidays therefore need to be broken down into a seasonal effect and a calendar effect. These are calculated in RegARIMA models using suitable regressors. This approach is also used to estimate the effects of movable holidays (such as those dependent on Easter).

[9] However, the temporary lifting in mid-March of the Sunday driving ban in the wake of the coronavirus crisis is likely to change the seasonal pattern that has been typical to date.

Calendar and seasonal influences of the truck toll mileage index

Chart 2



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In this analysis, all statutory holidays in Germany were initially examined, regardless of whether they are observed nationwide or only regionally. The table in the annex contains a list of these holidays. In addition, other days which celebrate customs and traditions, such as Shrove Monday, were also examined for possible effects.

On account of the problems described above, a uniform approach for all holidays cannot be applied to modelling. To capture cross effects, fixed holidays were modelled using dummy variables for individual days of the week, which contain a “one” if the holiday in question falls on the specified day of the week and “zero” otherwise. By contrast, movable holidays can be modelled using only one dummy variable, since they always fall on the same day of the week.

But it is not only the holidays themselves that have an impact on mileage. It can also be observed that the days on either side of holidays sometimes exhibit lower mileage. These effects were estimated for movable holidays using additional dummy variables for the days bookending the respective holiday, and for fixed holidays using bridge day regressors. For monthly and quarterly data, adjustment for bridge day effects is not advised.[10] This is mainly due to potential over-adjustment if there is more than one bridge day in a given month, as well as the inability to capture offsets on other days. Since daily data are available, the effects can be quantified more precisely and the existence of potential over-adjustment can be checked. Offsetting effects are also not observable here or, if they are observable, they are minor in comparison to the development of the seasonal pattern. Nonetheless, it seems warranted to hold a consultation on this issue in the wake of the upcoming expansion of European guidelines to include recommendations on the seasonal and calendar adjustment of daily data.

For fixed national holidays, it is evident that the effects differ significantly for the individual days of the week, but the effect is similar across most holidays. If 3 October falls on a Thursday, the mileage observed is similar to that of 1 May if the latter falls on a Thursday. If the regional holidays are weighted, the model can initially be reduced to a holiday regressor for each individual day of the week. Further analyses have shown that the effect is different for a Wednesday prior to 2016 and from 2016 on.

One exception and a particular challenge for calendar and seasonal adjustment is, however, the Christmas period. A reduction in economic activity can be observed here, probably due to the many holidays in quick succession and the fact that a large number of employees take annual leave over this period, and this reduction in economic activity also seems to have an impact on the daily mileage index. The typical weekly pattern, in particular, cannot be observed here. Division into three periods: the pre-Christmas period (21.12 until 23.12), the Christmas period (24.12 until 26.12) and the post-Christmas period (27.12 until 5.1) provides the best results for Saturday and Sunday effects. Furthermore, the effects of the

[10] See Section 2.6, Eurostat (2015), ESS guidelines on seasonal adjustment, ISSN 2315-0815.

individual days of the week from Monday to Friday are additionally captured for the entire period. Table 1 shows the estimated effects.

Estimated calendar effects of fixed holidays **Tab. 1**

Holiday	Day of the week	Coefficient*	Standard deviation	t-value
Fixed holidays (Epiphany, Labour Day, Assumption Day, Day of German Unity, Reformation Day and All Saints' Day)[1]	Mon.	-93.02	2.29	-40.62
	Tues.	-106.11	2.40	-44.21
	Wed. until 2015	-90.16	3.00	-30.05
	Wed. from 2016 on	-126.39	2.83	-44.66
	Thurs.	-106.16	2.29	-46.36
	Fri.	-76.21	2.00	-38.11
	Sat.	-17.46	2.28	-7.66
Reformation Day	2017	-110.01	4.71	-23.36
Bridge days	Labour Day	-17.82	2.54	-7.02
	Day of German Unity	-2.36	2.87	-0.82
	All Saints' Day	-20.51	2.39	-8.58
Christmas Eve	Sat.	13.60	4.30	3.16
	Sun.	41.01	5.08	8.07
Christmas Day	Sat.	25.55	5.82	4.39
	Sun.	58.97	4.28	13.78
Boxing Day	Sat.	20.12	3.71	5.42
	Sun.	31.96	5.82	5.49
Christmas period[2]	Mon.	-33.93	1.82	-18.64
	Tues.	-42.48	1.83	-23.21
	Wed.	-41.00	1.84	-22.28
	Thurs.	-38.18	1.83	-20.86
	Fri.	-24.87	1.82	-13.66
	Sat. before 24 Dec.	1.41	2.65	0.53
	Sat. after 27 Dec.	13.84	1.95	7.10
	Sun. until 23 Dec.	22.75	2.46	9.25
	Sun. from 27 Dec. on	25.79	2.01	12.83

***** For example, the coefficient of -93.02 for fixed holidays on a Monday indicates that these holidays cause an average reduction of 93 index points in the daily mileage index if they fall on a Monday; regional holidays: only on a percentage basis based on their weighting. **1** Regional holidays are weighted as follows: Epiphany 0.2, Assumption Day 0.1, Reformation Day from 2018 on 0.2 and All Saints' Day 0.6. **2** 21 December until 5 January of the following year.

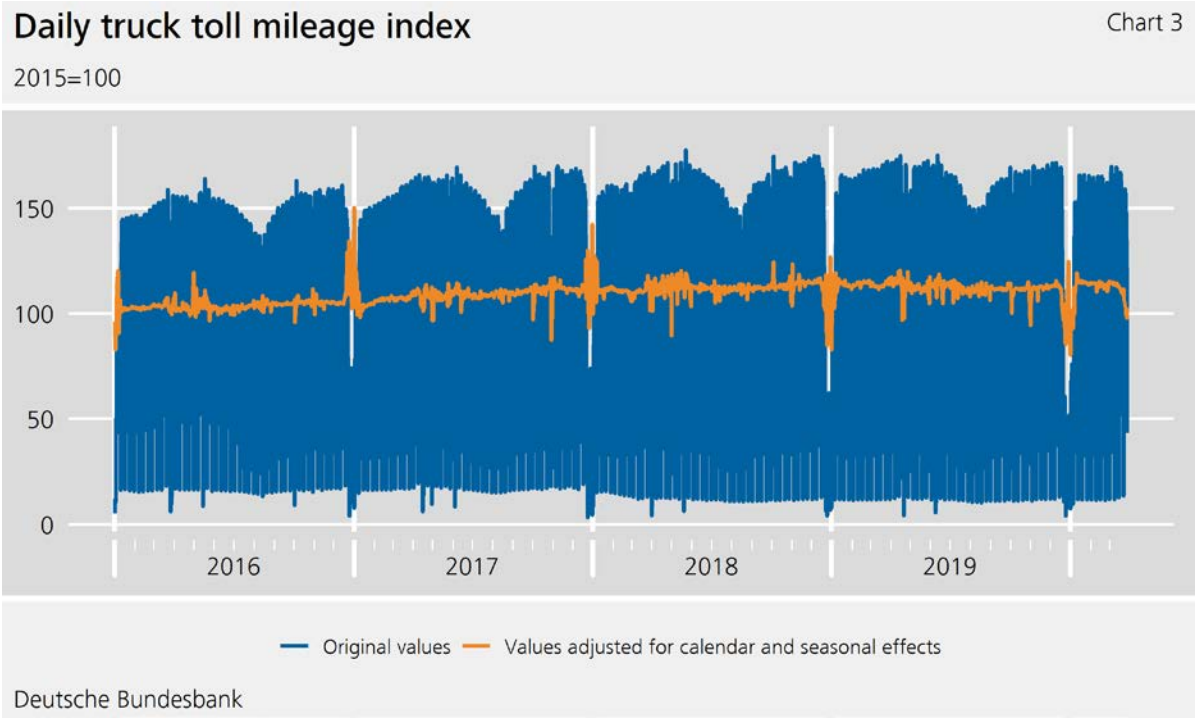
The movable holidays are estimated individually. In the analysis, Shrove Monday and Shrove Tuesday also prove to be significant. Table 2 contains the regression variables with the associated estimated effects.

Estimated calendar effects of movable holidays **Tab. 2**

Festival	Day	Coefficient*	Standard deviation	t-value
Carnival[1]	Shrove Monday	-8.60	1.55	-5.55
	Shrove Tuesday	-4.98	1.55	-3.21
Easter	Maundy Thursday	-19.43	1.64	-11.85
	Good Friday	-100.47	1.98	-50.74
	Holy Saturday	-16.43	2.00	-8.22
	Easter Sunday	-10.56	2.01	-5.25
	Easter Monday	-116.80	1.98	-58.99
	Easter Tuesday	-20.00	1.64	-12.20
Ascension Day	Wednesday before Ascension Day	-13.48	1.61	-8.37
	Ascension Day until 2015	-108.42	2.25	-48.19
	Ascension Day from 2016 on	-128.59	2.71	-47.45
	Friday after Ascension Day	-16.47	1.71	-9.63
Corpus Christi[2]	Wednesday before Corpus Christi	-7.37	1.99	-3.70
	Corpus Christi until 2015	-73.35	2.25	-32.60
	Corpus Christi from 2016 on	-82.34	2.48	-33.20
	Friday after Corpus Christi	-6.82	1.63	-4.18
Whitsun	Whit Sunday	-8.61	1.64	-5.25
	Whit Monday until 2015	-111.99	2.16	-51.85
	Whit Monday from 2016 on	-125.43	2.70	-46.46
	Tuesday after Whitsun	-14.62	1.64	-8.91

***** For example, the coefficient of -8.6 for Shrove Monday indicates that this day causes an average reduction of 8.6 index points in the daily mileage index. **1** Days for the cultivation of customs and traditions. **2** Regional holiday.

After the identifiable periodic and recurring influences are eliminated, the series adjusted for calendar and seasonal effects indicates a considerably lower level of volatility than the corresponding original values (see Chart 3). Relevant statistical tests show that the adjusted series is free from residual seasonality. Like the adjustment of the monthly time series, this permits an easier evaluation of the economic underlying trend, especially at the current end. Over the Christmas and New Year holidays, the irregular components are more pronounced.



4 Conclusion

The present indicator updated on a weekday basis extends the range of economic statistical data in the wake of the COVID-19 pandemic. The calendar and seasonal adjustment of the daily mileage index currently still seen as experimental enables an evaluation, unaffected to the greatest extent possible by periodic effects, of the development of the present indicator with a short time lag, particularly at the current end.

The temporary lifting of the Sunday driving ban is likely to change the current seasonal pattern of the day of the week. This is likely to be associated with increased volatility and higher revisions of seasonally and calendar adjusted data.

An evaluation of the methods used for the adjustment based on experience gained is scheduled to take place in June in the context of an ex post analysis.

Annex

Statutory holidays in Germany

	BW	BY	BE	BB	HB	HH	HE	MV	NI	NW	RP	SL	SN	ST	SH	TH	D
Weighting (%)	20.9	21.4	1.4	1.5	0.8	1.4	6.6	0.9	9	19.3	4.6	1.5	4.2	2	1.9	2.6	100
Holiday																	
New Year	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	1.0
Epiphany	X	X												X			0.4
International Women's Day			X														0.0
Good Friday	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	1.0
Easter Monday	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	1.0
1 May, Labour Day	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	1.0
Ascension Day	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	1.0
Whit Monday	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	1.0
Corpus Christi	X	X					X			X	X	X	X[a]			X[b]	0.7
Assumption Day		X[c]										X					0.2
World Children's Day																X	0.0
Day of German Unity	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	1.0
Reformation Day[#]				X	X	X		X	X				X	X	X	X	0.2
All Saints' Day	X	X								X	X	X					0.7
Day of Prayer and Repentance													X				0.0
Christmas Day	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	1.0
Boxing Day	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	1.0

Moveable holidays are shown in italics. # A one-off public holiday was observed across Germany on 31 October 2017 to mark the 500th anniversary of the beginning of the Reformation. Since then, Bremen, Hamburg, Lower Saxony and Schleswig-Holstein have continued to observe this holiday. **a** Corpus Christi is a statutory holiday in Catholic municipalities in the Sorbian settlement area in the district of Bautzen. **b** Corpus Christi is a statutory holiday in the Eichsfeld district, some municipalities in the Unstrut-Hainich district and the Wartburg district. **c** Assumption Day is a statutory holiday in the, at present, 1,704 municipalities in Bavaria with a predominantly Catholic population (out of a total of 2,056 municipalities).