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IMPACT OF THE NEW ROAD TRAFFIC SAFETY LAW ON THE NUMBER OF ROAD ACCIDENTS IN SLOVENIA

ABSTRACT

This paper studies the number of traffic accidents (TAs) in which people were killed or/and seriously injured over the period from January 1996 to October 2000 in Slovenia. The aim of this work is to ascertain if the reduction in the increase of the number of TAs after 1 May 1998, when the new road traffic safety law (RTSL) was adopted, is statistically significant.

Assuming that the time series analysed contains also a seasonal component, we found out that the new RTSL had a very positive impact on the number of TAs, especially in the first year (approximately) after adoption. After this period the average increase of the number of TAs rose again, but not as high as before the adoption of the RTSL.

KEY WORDS

road traffic accidents, piecewise linear trend function, seasonal component

1. INTRODUCTION

Road traffic accidents are very negative and undesirable consequences of road traffic. In this paper the number of TAs from January 1996 to October 2000 is analysed. The new RTSL represents of course only a part of the road-safety system. The new RTSL is not analysed in detail in this paper. Let us very briefly describe its main characteristic: two main penalties in the new RTSL are high money fines and imprisonment. Penalty points and driving restrictions are meant to be lateral. Some other Central and Eastern European countries adopted the new road traffic legislation before Slovenia, including Croatia. The new RTSL tries to combine the experiences from these countries.[1]

It was assumed that from the moment it was adopted the new RTSL has had a very strong positive influence on the road traffic participants by penalty points and high fines system.

Monthly data about the number of TAs in Slovenia are presented in Figure 1. The data can be found in Table A in the Appendix. Two main conclusions can be derived from Figure 1. They are:

- the time series contains also a seasonal component. Monthly seasonal index numbers (SI) calculated using the data in years 1996, 1997, 1998 and 1999, are presented in Table 1.

  The number of TAs from May to October is on the average higher in comparison with the average number of TAs per month. The highest number is in June and the lowest in February - there is on average 19.14% more TAs in June, but 34.43% fewer TAs in February, as compared with the average number of TAs per month.
- New RTSL was adopted on 1 May 1998. Figure 1 shows that in the several following months the number of TAs was smaller than one would usually expect, since these were the months with the highest average number of TAs in a year.

These conclusions are the basis of our analysis. We wanted to find out, whether a time period can be established, after adopting the new LTRS, in which the reduction of the number of TAs is statistically significant. It was assumed that the time period from January 1996 to October 2000 can be divided into three sections, each having different characteristics regarding the average increase of the number of TAs.

Table 1 - Monthly seasonal index numbers (SI)

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SI	73.95	65.57	86.40	95.56	106.23	119.14	114.38	113.92	112.37	113.33	99.32	99.82

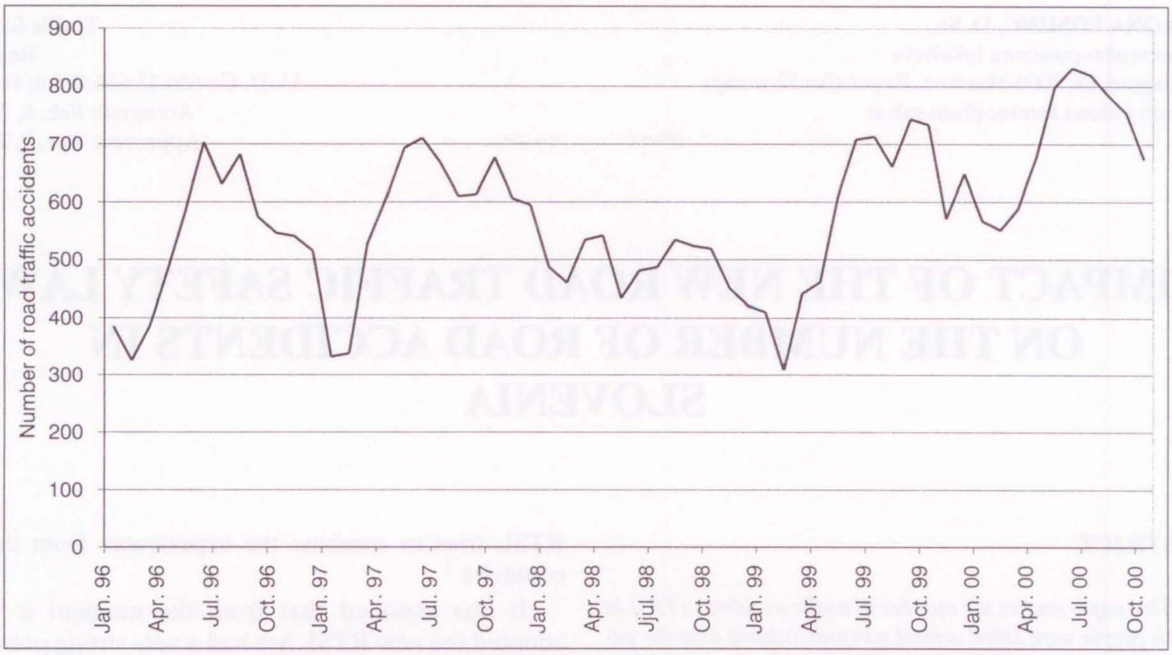

Figure 1 - Road traffic accidents in Slovenia from January 1996 to October 2000

2. TIME SERIES ANALYSIS

There are many cases in which a sample can be divided into two or more sections and where some or all of the location parameters may differ. Common situations include seasonal models, in which explanatory variables have different effects depending on the season of the year; models that allow behavioural differences in geographic regions; models that permit different response coefficients during unusual time periods, such as war years etc.[2]

The methodology used in such situations – parameter variations - has been modelled in two principal ways. The first of the approaches typically allows an infinite number of possible parameter values and random parameter variations. The second approach is the alternative case, in which the number of possible states for the parameter vector is finite and usually very small. Each possible state of the parameter vector is usually named a regime.[3] Functions which are included in such analysis (sometimes named basic functions) are usually of the same shape

The trend component in the time series describing the number of TAs in different time periods, can also be described similarly.

In general, time series consist of a mixture of trend (T_t), seasonal (S_t) and irregular component (e_t). If these components are assumed to be independent and additive, the time series can be written as [4]

$$Y_t = T_t + S_t + e_t \qquad (1)$$

To estimate these components, several decomposition methods can be found in literature, one being the regression method, which is also used in this paper.

Trend component

As already mentioned, it was assumed that the whole time period analysed, could be divided into three time periods. The first time period includes months from January 1996 to the end of April 1998, before the adoption of the new RTSL. In the second time period the reduction of the number of TAs occurred in the months following May 1998. In the third time period the average increase of the number of TAs per month became higher again. The switch between the first and the second time period is set to May 1998, since the new RTSL was assumed to have positive impact on the road safety situations from the moment of its adoption. But it was expected that the impact of the new RTSL would weaken gradually. Therefore, we assumed that the switch between the second and third time period could not be precisely defined.

Let us assume that the linear trend function is appropriate for each of the three time periods. The trend component for the time series can be written as the piecewise linear function

$$\begin{aligned} T_1 &= y_t = a_1 + a_2 \cdot t \quad \text{for} \quad t < t_1 \\ T_2 &= y_t = a_3 + a_4 \cdot t \quad \text{for} \quad t_1 \le t < t_2 \\ T_3 &= y_t = a_5 + a_6 \cdot t \quad \text{for} \quad t \ge t_2 \end{aligned} \qquad (2)$$

where t_1 and t_2 are switches between the first and the second time period and between the second and the third. Therefore $t_1 = 29$ (May 1998) and the value of t_2 is to be defined.

Parameters a_2, a_4 and a_6 indicate an average increase of the number of TAs per month in the corresponding time period.

All function parameters of the three functions (2) can be estimated at the same time by using the dummy 0-1 variables[5]

$$T_t = a_1 + a_2 \cdot t + b_1 \cdot D_1 + b_2 \cdot t \cdot D_1 + b_3 \cdot D_2 + b_4 \cdot t \cdot D_2 \quad (3)$$

where

$D_1 = 0$ if $t < 29$

$D_1 = 1$ if $t \geq 29$

$D_2 = 0$ if $t < t_2$

$D_2 = 1$ if $t \geq t_2$

Parameters a_3, a_4, a_5 and a_6 are obtained using relationships

$$a_3 = a_1 + b_1 \qquad a_5 = a_1 + b_1 + b_3 \quad (4)$$

$$a_4 = a_2 + b_2 \qquad a_6 = a_2 + b_2 + b_4 \quad (5)$$

If also equalities

$$T_1(t_1) = T_2(t_1) \quad \text{in} \quad T_2(t_2) = T_3(t_2) \quad (6)$$

are required, the piecewise linear trend function (2) can be written as the spline function

$$T_t = a_1 + a_2 \cdot t + b_2 \cdot (t - t_1) \cdot D_1 + b_4 \cdot (t - t_2) \cdot D_2$$

in short

$$T_t = a_1 + a_2 \cdot t + b_2 \cdot V_1 + b_4 \cdot V_2$$

where

$$V_1 = \begin{cases} 0 & ; t < t_1 \\ t - t_1 & ; t \geq t_1 \end{cases} \quad \text{in} \quad V_2 = \begin{cases} 0 & ; t < t_2 \\ t - t_2 & ; t \geq t_2 \end{cases}$$

Parameters of functions T_1 and T_2 are obtained by using relationships

$$a_3 = a_1 - b_2 \cdot t_1 \qquad a_5 = a_3 - b_4 \cdot t_2$$

$$a_4 = a_2 + b_2 \qquad a_6 = a_4 + b_4$$

Since the new RTSL caused an immediate »dropping« change, the spline function was not appropriate for the analysis in this case. It is not suitable to require equalities (6), since less precise results are obtained.

When testing model significance we found that a slightly simplified trend function describes the number of TAs better. Equation

$$T_t = a_1 + a_2 \cdot t + b_2 \cdot t \cdot D_1 + b_4 \cdot t \cdot D_2 \quad (7)$$

was used in the analysis instead of equation (3). It means that the intercepts in all three functions in (2) are the same and parameters a_4 and a_6 are obtained by using equations (5).

There is also a seasonal component included in the model (1). Let us assume that the trend component is represented by the piecewise linear function (7). Since the seasonal component S_t can be described by a linear combination of seasonal dummy variables, the model of the time series analysed is as follows

$$Y_t = a_1 + a_2 \cdot t + b_2 \cdot t \cdot D_1 + b_4 \cdot t \cdot D_2 + \sum_{j=1}^{s-1} \gamma_j \cdot U_{jt} \quad (8)$$

Table 2 - Values of R_2 for model (8), and estimates of a_1, a_2, b_2 and b_4 and calculated values of a_4 and a_6, for t_2 =33,34,...,51

t_2	R_2	a_1	a_2	b_2	a_4	b_4	a_6
33	0,807	278,701	6,631	-9,509	-2,878	6,412	3,534
34	0,815	282,137	6,345	-8,728	-2,383	5,858	3,475
35	0,821	285,632	6,055	-8,070	-2,015	5,430	3,415
36	0,829	287,970	5,781	-7,534	-1,753	5,166	3,413
37	0,850	291,928	5,370	-7,151	-1,781	5,165	3,384
38	0,842	289,218	5,457	-6,657	-1,200	4,696	3,496
39	0,858	324,564	5,298	-6,369	-1,071	4,638	3,567
40	0,862	322,952	5,181	-6,000	-0,819	4,454	3,635
41	0,881	324,575	4,899	-5,688	-0,789	4,476	3,687
42	0,884	320,440	5,033	-5,587	-0,554	4,363	3,809
43	0,874	315,138	5,221	-5,431	-0,210	4,130	3,920
44	0,855	309,359	5,435	-5,243	0,192	3,819	4,011
45	0,853	306,378	5,498	-5,098	0,400	3,700	4,100
46	0,820	299,948	5,763	-4,871	0,892	3,255	4,147
47	0,791	294,320	6,000	-4,664	1,336	2,836	4,172
48	0,793	292,914	5,948	-4,528	1,420	2,873	4,293
49	0,776	289,110	6,058	-4,349	1,709	2,653	4,362
50	0,758	282,611	6,363	-4,282	2,081	2,391	4,472
51	0,737	297,099	6,674	-4,206	2,468	2,050	4,518

where s = 12 months and U_{jt} = 1 correspond to the seasonal period j and 0 respectively. Only (s-1) seasonal dummy variables are needed. Therefore γ_2 which corresponds to February (the smallest average number of TAs) is set to 0 so that the parameters γ_j, $j \neq 2$, represent the seasonal effect of the j-th period – month on the number of TAs, as compared with February.

Since the variable t, t = 1,2,...,58; representing the time unit – month, is discrete, the switch between the second and the third time period can be established by comparing the statistical significance of the estimates in model (8) and coefficients of determination R^2, for different values of the switch t_2.

The values of R^2 for model (8), for t_2 =33,34,...,51, estimates of the most important parameters for the analysis: a_1, a_2, b_2 and b_4 and calculated values of a_4 and a_6, using the equation (6), are presented in Table 2. (All other estimates ($\gamma_1, \gamma_3, \ldots, \gamma_{12}$) and corresponding levels of significance can be found in Table B in the Appendix.)

All estimates of a_1, a_2, b_2 and b_4, for all possible values of t_2 in Table 2 are statistically significant at the level $\alpha \leq 0{,}005$. This confirms the expectation, that the switch between the second and the third time period cannot be singly defined. Testing the significance of the switch, namely, represents the same as testing the significance of parameter b_4 at variable $t \cdot D_2$.[5] So, there is no need to perform any other test, for example, the well-known Chow's test of equality between sets of coefficients in two linear regressions [6]. It can be seen from Table 2 that all possible switches for t_2, t_2 = 33,34,...,51 are in fact statistically significant. However, it is interesting to analyse the distribution of estimates of a_2, a_4 and a_6, when different values of t_2 are used. The length of the second time period increases by increasing t_2; when t_2=33, the second time period includes months from May to September 1998. Whereas t_2 = 52, the second time period includes months from May 1998 to March 2000.

Estimates of a_2

Estimates of a_2 (an average increase of the number of TAs per month in the first time period from January 1996 to May 1998) range from the lowest 4,899 (at t_2 = 41) to the highest 6,674 (at t_2 = 51). The mean value of the distribution is 5,737. From January 1996 to May 1998, therefore, the number of TAs per month increased on an average by approximately 5,737. Distributions of estimates of a_2, a_4 and a_6 at different values for t_2 are presented in Figure 2.

Estimates of a_4

Analysing the estimates of a_4 (an average increase of the number of TAs per month in the second time period after the adoption of the new LRTS) it was found that the positive effects of the new RTSL on the

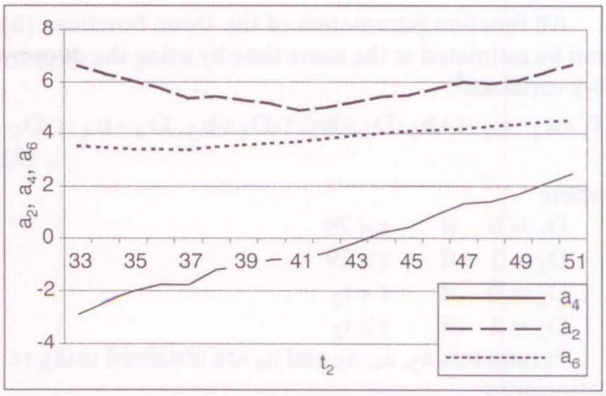

Figure 2 - Estimates of a_2, a_4, and a_6 at different values for t_2

number of TAs evidently became weaker gradually. In the 5-month period after the adoption of the new RTSL, the number of TAs decreased on an average by 2,878 TAs per month (t_2=33). But in the 12-month period after the adoption there was a decrease of only 0,789 TAs per month (t_2 =41). After September 1999 (at t_2=44) the estimate of a_4 again became greater than 0. These characteristics of the estimates of a_4 are presented also in Figure 2.

Estimates of a_6

Estimates of a_6 (an average increase of the number of TAs per month in the third time period) range from the lowest 3,384 (at t_2=37) to the highest 4,518 (at t_2 = 51). This also confirms the assumption that the best effects of the new RTSL were achieved in the first few months after its adoption.

Seasonal effect

The signs and values of the estimates of γ_j, j=1,3,...,12, representing seasonal effects, are as expected, as can be seen in Table B in the Appendix. At t_2 =42 for example, there were on an average 272,389 more TAs in June, but only 43,471 more TAs in January, in comparison with February.

Levels of statistical significance for each estimate are also presented in Table B. All estimates are statistically significant at levels $\alpha \leq 0{,}05$, except the estimates of γ_1 and estimates of γ_3 for some values of t_2. When t_2 = 42, R^2 of the model is the highest and equals 0,884, all estimates are significant at levels $\alpha \leq 0{,}05$, except the estimate of γ_3, which is significant at α= 0,185. Model (7) when t_2 = 42 as a whole therefore best describes the dynamics of the time series.

3. CONCLUSION

Linear piecewise trend function and seasonal component have been analysed in the time series, describing the number of road traffic accidents in which people were killed or seriously injured. It was ascertained that the new RTSL which was adopted on 1 May 1998 had a very positive impact on the number of accidents analysed, especially in the first year (approximately) after the adoption. After this period the average increase of number of TAs became higher again, but not as high as before the adoption of the new RTSL.

The fact, that the number of road traffic accidents may increase because of the increase of traffic participants or may decrease because of different reasons (special police activities, better roads and highways, etc.) was not explicitly taken into account. Since monthly data for a relatively short time period are analysed, this fact cannot affect the results substantially. Also did the black spots on Slovenian roads were not studied, nor the reasons for these numbers of road traffic accidents nor the RTSL itself.

POVZETEK

VPLIV NOVEGA ZAKONA O VARNOSTI CESTNEGA PROMETA NA ŠTEVILO PROMETNIH NESREČ V SLOVENIJI

V prispevku smo analizirali število prometnih nesreč s smrtnim izidom in hujšimi telesnimi poškodbami v času od januarja 1996 do oktobra 2000 v Sloveniji. Pri tem smo želeli ugotoviti, ali je mogoče govoriti o statistično značilnem zmanjšanju prirastka prometnih nesreč po sprejetju novega Zakona o varnosti cestnega prometa, ki je pričel veljati 1. maja 1998. Ob upoštevanju periodičnega značaja opazovanega pojava smo ugotovili, da je novi zakon vplival na zmanjševanje števila prometnih nesreč predvsem v obdobju približno enega leta po sprejetju, nato pa je povprečni prirastek števila prometnih nesreč spet narasel, vendar je nižji kot pa v obdobju pred sprejetjem Zakona.

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APPENDIX

Table A - The number of road traffic accidents with people killed or seriously injured, from January 1996 to October 2000 (Source: Ministry of Interior, RS, December 2000)

Month	The number of road traffic accidents	Month	The number of road traffic accidents
January 1996	385	June 1998	481
February 1996	325	July 1998	487
March 1996	385	August 1998	535
April 1996	481	September 1998	524
May 1996	585	October 1998	519
June 1996	703	November 1998	451
July 1996	630	December 1998	422
August 1996	682	January 1999	411
September 1996	574	February 1999	309
October 1996	546	March 1999	441
November 1996	541	April 1999	461
December 1996	515	May 1999	609
January 1997	332	June 1999	708
February 1997	338	July 1999	713
March 1997	527	August 1999	661
April 1997	603	September 1999	743
May 1997	693	October 1999	733
June 1997	710	November 1999	571
July 1997	668	December 1999	648
August 1997	610	January 2000	567
September 1997	613	February 2000	551
October 1997	677	March 2000	589
November 1997	606	April 2000	678
December 1997	595	May 2000	799
January 1998	487	June 2000	832
February 1998	460	July 2000	820
March 1998	534	August 2000	785
April 1998	542	September 2000	754
May 1998	433	October 2000	673

Table B - Estimates of model parameters (7) and corresponding significance levels

t_2	$\gamma_1(\alpha)$	$\gamma_3(\alpha)$	$\gamma_4(\alpha)$	$\gamma_5(\alpha)$	$\gamma_6(\alpha)$	$\gamma_7(\alpha)$	$\gamma_8(\alpha)$	$\gamma_9(\alpha)$	$\gamma_{10}(\alpha)$	$\gamma_{11}(\alpha)$	$\gamma_{12}(\alpha)$
33	45,192 (0,284)	93,208 (0,031)	145,616 (0,001)	266,178 (0,000)	325,687 (0,000)	298,997 (0,000)	286,506 (0,000)	227,695 (0,000)	210,923 (0,000)	134,738 (0,004)	132,406 (0,005)
34	44,997 (0,277)	93,403 (0,027)	146,005 (0,001)	262,233 (0,000)	321,781 (0,000)	295,129 (0,000)	282,678 (0,000)	266,226 (0,000)	210,941 (0,000)	134,938 (0,003)	132,778 (0,004)
35	44,799 (0,270)	93,601 (0,024)	146,402 (0,001)	259,007 (0,000)	318,622 (0,000)	292,037 (0,000)	279,652 (0,000)	263,267 (0,000)	247,882 (0,000)	135,141 (0,003)	133,156 (0,003)
36	44,634 (0,261)	93,766 (0,021)	146,732 (0,001)	256,396 (0,000)	316,069 (0,000)	289,542 (0,000)	277,215 (0,000)	260,887 (0,000)	245,560 (0,000)	180,376 (0,000)	133,327 (0,003)
37	44,376 (0,234)	94,024 (0,014)	147,248 (0,000)	254,949 (0,000)	314,804 (0,000)	288,458 (0,000)	276,313 (0,000)	260,167 (0,000)	245,021 (0,000)	180,493 (0,000)	180,157 (0,000)
38	79,224 (0,043)	93,927 (0,017)	147,054 (0,000)	251,790 (0,000)	311,449 (0,000)	284,907 (0,000)	272,565 (0,000)	256,224 (0,000)	240,882 (0,000)	176,055 (0,000)	175,502 (0,000)
39	43,476 (0,231)	58,743 (0,111)	111,937 (0,003)	215,073 (0,000)	274,741 (0,000)	248,209 (0,000)	235,877 (0,000)	219,545 (0,000)	204,213 (0,000)	140,109 (0,001)	139,586 (0,001)
40	43,472 (0,224)	94,928 (0,010)	113,420 (0,003)	214,459 (0,000)	274,096 (0,000)	247,533 (0,000)	235,171 (0,000)	218,808 (0,000)	203,445 (0,000)	139,712 (0,001)	139,168 (0,001)
41	43,319 (0,192)	95,081 (0,006)	149,362 (0,000)	212,933 (0,000)	272,657 (0,000)	246,180 (0,000)	233,903 (0,000)	217,627 (0,000)	202,350 (0,000)	139,616 (0,000)	139,192 (0,000)
42	43,471 (0,185)	94,929 (0,005)	149,058 (0,000)	248,592 (0,000)	272,389 (0,000)	245,763 (0,000)	233,337 (0,000)	216,911 (0,000)	201,485 (0,000)	139,118 (0,000)	138,537 (0,000)
43	43,675 (0,201)	94,725 (0,007)	148,650 (0,000)	247,077 (0,000)	307,289 (0,000)	245,783 (0,000)	233,169 (0,000)	216,554 (0,000)	200,940 (0,000)	138,510 (0,000)	137,721 (0,000)
44	43,902 (0,230)	94,498 (0,012)	148,196 (0,000)	245,302 (0,000)	305,248 (0,000)	278,995 (0,000)	233,331 (0,000)	216,513 (0,000)	200,696 (0,000)	137,864 (0,001)	136,845 (0,001)
45	43,999 (0,233)	94,401 (0,013)	148,003 (0,000)	244,173 (0,000)	303,994 (0,000)	277,615 (0,000)	265,436 (0,000)	215,953 (0,000)	200,034 (0,000)	137,465 (0,001)	136,341 (0,001)
46	44,265 (0,277)	94,135 (0,024)	147,469 (0,001)	242,056 (0,000)	301,565 (0,000)	274,874 (0,000)	262,382 (0,000)	245,891 (0,000)	200,457 (0,000)	136,792 (0,003)	135,401 (0,003)
47	44,502 (0,310)	93,898 (0,036)	146,996 (0,002)	240,146 (0,000)	299,377 (0,000)	272,408 (0,000)	259,639 (0,000)	242,869 (0,000)	227,100 (0,000)	136,212 (0,005)	134,585 (0,005)
48	44,511 (0,308)	93,889 (0,035)	146,977 (0,001)	239,327 (0,000)	298,521 (0,000)	271,516 (0,000)	258,710 (0,000)	241,904 (0,000)	226,098 (0,000)	169,669 (0,001)	134,257 (0,005)
49	44,649 (0,326)	93,751 (0,043)	146,702 (0,002)	237,879 (0,000)	296,900 (0,000)	269,721 (0,000)	256,742 (0,000)	239,763 (0,000)	223,784 (0,000)	166,620 (0,001)	165,487 (0,001)
50	68,361 (0,154)	93,471 (0,051)	146,143 (0,003)	236,650 (0,000)	295,378 (0,000)	267,906 (0,000)	254,633 (0,000)	237,361 (0,000)	221,089 (0,000)	162,889 (0,002)	161,417 (0,003)
51	44,792 (0,362)	72,699 (0,146)	125,097 (0,014)	214,892 (0,000)	273,332 (0,000)	245,571 (0,000)	232,011 (0,000)	214,450 (0,000)	197,890 (0,000)	137,825 (0,011)	136,004 (0,012)