

THE IMPACT OF THE CLOCK BUG ON ABSENTEEISM: AN ANALYSIS FOR THE EDITION OF ENEM 2019¹

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This study aims to assess the impact of the bug on clocks, caused by the end of daylight saving time, on absenteeism in the National High School Exam (Enem) of 2019. To achieve this goal, we use quasi-experimental methods of regression discontinuity design and difference-in-differences. The results found indicate that failures in digital devices contributed significantly to the reduction of absenteeism, making Enem 2019 to obtain the lowest abstention since 2001. In addition, the results indicate that the most benefited socioeconomic group were students with family monthly income up to a minimum wage, whose mother's education are no higher than complete elementary school.

Keywords: Enem; absenteeism; quasi-experimental methods.

O IMPACTO DO *BUG* DO RELÓGIO NO ABSENTEÍSMO: UMA ANÁLISE PARA A EDIÇÃO DO ENEM 2019

Este estudo tem como objetivo avaliar o impacto do *bug* nos relógios, causado pelo fim do horário de verão, sobre o absentismo no Exame Nacional do Ensino Médio (Enem) de 2019. Para atingir esse objetivo, utilizamos métodos quase-experimentais de desenho de regressão descontínua e diferença-em-diferenças. Os resultados encontrados indicam que as falhas nos dispositivos digitais contribuíram significativamente para a redução do absentismo, fazendo com que o Enem 2019 obtivesse a menor abstenção desde 2001. Além disso, os resultados indicam que o grupo socioeconômico mais beneficiado foram os alunos com renda mensal familiar de até um salário mínimo, cuja educação da mãe não ultrapassa o ensino fundamental completo.

Palavras-chave: Enem; absentismo; métodos quase-experimentais.

EL IMPACTO DEL *BUG* DEL RELOJ EN EL AUSENTISMO: UN ANÁLISIS PARA LA EDICIÓN DE LA ENEM 2019

Este estudio tiene como objetivo evaluar el impacto del error en los relojes, causado por el final del horario de verano, sobre el absentismo en el Examen Nacional de Bachillerato (Enem) de 2019. Para lograr este objetivo, utilizamos métodos cuasiexperimentales de regresión discontinua.

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diseño y diferencia en diferencias. Los resultados encontrados indican que las fallas en dispositivos digitales contribuyeron significativamente a la reducción del absentismo, haciendo que Enem 2019 obtenga la menor abstención desde 2001. Además, los resultados indican que el grupo socioeconómico más beneficiado fueron los estudiantes con ingresos familiares mensuales hasta un mínimo salario, cuya educación de la madre no exceda la escuela primaria completa.

Palabras clave: Enem; absentismo; métodos cuasiexperimentales.

JEL: A21; I21; C21.

1 INTRODUCTION

In its 22 years of existence, the National High School Examination (Enem) has consolidated itself as the main gateway to University education in Brazil. According to the Ministry of Education and Culture (MEC), in 2015 Enem became the second highest assessment of access to higher education in the world, behind only the Gaokao exam, from China (A segunda..., 2015). According to statistics from the National Institute of Studies and Educational Research Anísio Teixeira (Inep), the exam went from 157 thousand students enrolled in its first edition, which happened in 1998, to around 5.8 million enrolled in 2020 (Exame..., 2015; Inep, 2020a).

Initially, Enem aimed to evaluate the learning acquired during basic education,⁶ providing information to assist the government in the elaboration of public policies towards education. However, the growing number of institutions that adopted their results as a selection tool for their students encouraged the MEC to institute the University for All Program (Prouni), which linked the granting of scholarships to private higher education institutions to the results of Enem (Inep, 2015a).

In this context, currently around 130 public institutions use Enem scores as a method of full or partial entry. In addition, candidates can use the exam results to obtain student funding through the Student Financing Fund (Fies). It is worth mentioning that Enem is also accepted in several institutions outside Brazil, as in Portugal, where 50 institutions admit the individual results of Enem in their selection processes (Inep, 2020b).

Since the first edition of Enem, there has been a concern with the democratization of access to the exam. Within this perspective, in 2001 it was established that students graduating from high school in public schools would be guaranteed exemption from paying the registration fee. Over the years, additional exemption rules have been created, consolidating that between 2013 and 2020, approximately 70% of participants were benefited with the exemption (Inep, 2019). However, one concern of the MEC is the absenteeism on the exam day.

6. According to Law No. 9,394/1996 that establishes the guidelines of Brazilian education, basic education is debt in three stages: Early Childhood Education (Nursery School: age of up to 3 years old; Preschool: age group between 4 and 5 years old); Elementary School with duration of 9 years (age group between 6 and 14 years of age) and High School with duration of 3 years (age group between 15 and 18 years of age).

The growing number of candidates was followed by high rates of abstention. Thus, since 2011 Inep had been studying mechanisms to reduce the number of absences (Saldaña and Palhares, 2015). According to Inep, between the 2013 and 2017 editions, there was a financial loss of R\$ 962 million,⁷ coming from participants who signed up, but did not attend the tests (MEC, 2018). Therefore, in 2017, the MEC established that exempt candidates who abstained should justify their absence to be entitled to a new exemption the following year. According to the MEC, this measure aims to discourage absenteeism, promote greater efficiency in the management of expenses, so that the amount saved is applied in the expansion of security resources (Inep, 2018b).

In this perspective, with accumulated losses and high abstention rates, the numbers from the 2019 Enem exam were well-regarded, given that it showed the lowest absenteeism rates ever recorded in the exam for the second day of tests. However, a fact that really caught the attention of the media was the failure of clocks due to the end of daylight saving time.

In this scenario, in a brief context, daylight saving time has been in effect every year since 1985. In its last change, in 2017, the federal government established that the daylight saving time (DST) would start at 00:00 am on the first Sunday of November every year. Coincidentally, the new date for the clocks' change would happen on November 4 of 2018, which was on the same day of application of the first day of tests of Enem 2018. This fact motivated a request by MEC for the postponement of the start of the DST, so as not to prejudice candidates (Nascimento, 2018).

In 2019, the federal government, through Decree No. 9,772, of April 25 of 2019, extinguished the DST. However, many electronic devices, especially cell phones, were previously programmed to shift their clocks forward by one hour on the first Sunday of November, a date that would again fall on the first day of Enem 2019 tests. The automatic change in clocks caught many candidates by surprise, although the possibility of changing the clocks was foreseen by some large mobile companies such as Motorola and Google, that alerted their users to the possible change in time (Celulares..., 2019; Trabalhando..., 2019).

In view of these considerations, using the empirical strategy of regression discontinuity design and difference-in-differences, we assessed the impact of the clock bug caused by the end of the daylight saving time on abstentions in Enem 2019. The results found indicate that a failure of the devices negatively affected absenteeism, contributing to the exam to obtain the lowest abstention rate since 2001. In terms of magnitudes, the bug may have contributed to a reduction of up to 85 thousand absences, avoiding a financial waste of around R\$ 8.9 million.⁸

7. On May 2018, the exchange rate between the Brazilian Real and the US Dollar was 3.73 R\$/US\$.

8. On November 2019, the exchange rate between the Brazilian Real and the US Dollar was 3.99 R\$/US\$.

The article is structured in 6 sections. Shortly after this introduction, in sections 2 and 3, brief historical surveys of Enem and daylight saving time are made, respectively. In section 4, data and descriptive statistics are presented. In section 5, the empirical strategy is exposed. In section 6, the results are presented. Finally, in section 7, the final considerations are made.

2 ENEM

In 1998, the Federal Government of Brazil, through Inep, created Enem. Until 2008, the main objective was to assess the education competencies and skills developed during basic schooling (Inep, 2015b). In 2004, the Ministry of Education and Culture instituted Prouni and linked the granting of scholarships to private institutions of higher education based on the results of Enem. The growing number of university institutions that also started to adopt their results to select their students made Enem gain more and more importance in the national scenario.

Within this perspective, Enem was reformulated in 2009, becoming one of the main educational entrance examinations to federal universities in the country. The changes covered the evaluation format, which started to be carried out in two consecutive days of tests and also the Item Response Theory (IRT)⁹ started to be used (Inep, 2011).

Since its first editions, Enem proved to be an inclusive exam, guaranteeing the exemption from the registration fee for public school students. In 2001, the federal government formalized the exemption for all students coming from public schools and for candidates who completed their studies through Youth and Adult Education (EJA) twelve months prior to the registration period. This way, high school graduates and graduates in any of the modalities who declared themselves unable to pay the registration fee were also benefited. The registration fee exemption in the cases described resulted in a total of 82.6% of exempt candidates, increasing the number of applicants from 352,487 registered in 2000 to 1,200,883 in 2001 (Inep, 2001).

As of 2007, new criteria for exemption were established. In addition to high school graduates from public schools, low-income family members, enrolled in the Federal Government's unique registry for social programs, were also exempt from the registration fee, pursuant to Decree No. 6,135, of June 26, 2007.¹⁰ Thus, the growing number of subscribers was also followed by high abstention rates.

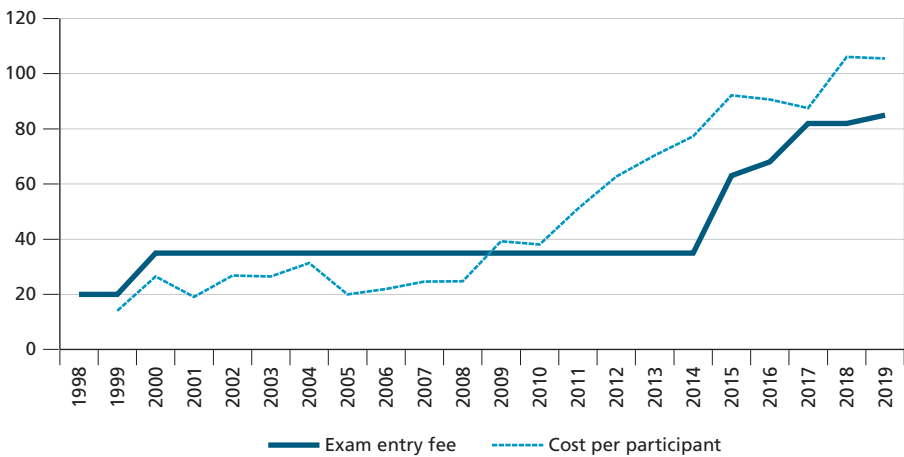
9. The IRT is a statistical tool that qualifies the responses, allowing the comparison between candidates from the same population who have undergone different tests. The IRT is also used for other exams, such as: The Test of English as a Foreign Language (Toefl), Basic Education Assessment (Saeb), National Exam for Certification of Competences for Youth and Adults (Encceja) and in the Prova Brasil.

10. Candidates with per capita monthly family income of up to half a minimum wage, or who have a monthly family income of up to three minimum wages. See more at: <<https://bit.ly/3Z9KW5R>>.

In this context, the federal government sought several alternatives to combat the high rates of absenteeism. Since 2011, Inep has been studying mechanisms to reduce the high number of absences. According to Inep, between the 2013 and 2017 editions, there was a loss of R\$ 962 million¹¹ coming from absent participants (MEC, 2018). Using the information available from abstentions and average cost of evidence for the period 2009-2019, we estimate approximately R\$ 1.84 billion¹² in losses, when adjusted by the Broad National Consumer Price Index (IPCA) for July 2020. In view of this reality, as an attempt to reduce abstentions, in 2017 MEC established that exempt candidates who abstained should justify their absence in order to receive a new exemption the following year (Inep, 2018b).

It should be noted that the losses due to abstentions do not fall exclusively on exempt candidates, since the tests have been subsidized since 2009. That is, from the moment that Enem started to have the format of two days of tests, the registration fee did not cover the average cost of the exam (Inep, 2017; 2018c; 2020c). In figure 1, it is possible to observe how the registration fee values evolved and the average cost of the tests.

FIGURE 1
Registration fee versus cost per participant (1998-2019)
 (In R\$)



Source: Inep (2013; 2017; 2018a; 2018b; 2018c; 2019; 2020a; 2020c) and Último... (2019).
 Authors' elaboration.

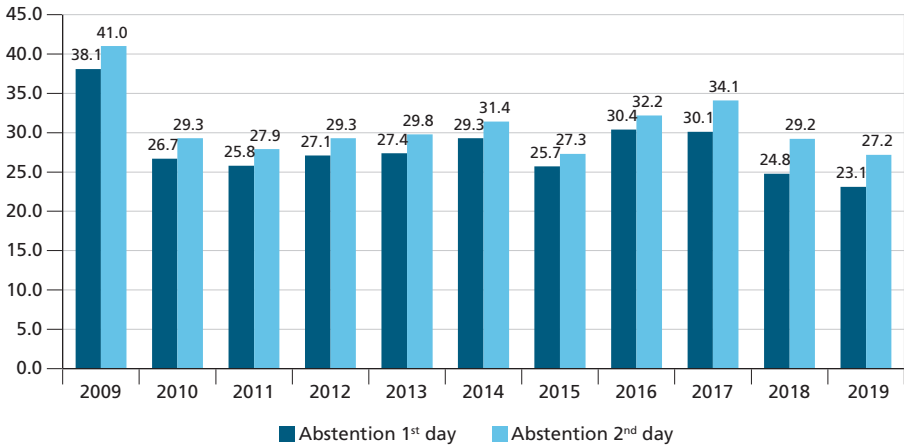
11. On May 2018, the exchange rate between the Brazilian Real and the US Dollar was 3.73 R\$/US\$.

12. On July 2020, the exchange rate between the Brazilian Real and the US Dollar was 5.20 R\$/US\$.

Between 2000 and 2014, the registration fee was maintained at R\$ 35.00, despite constant variations in market prices and inflationary adjustments. After 10 years, in 2015, the rate was adjusted by 80%. Even with the increases that occurred in the following years, the rates remained below average costs (Inep, 2017; 2020c). The most recent plan from MEC to reduce the costs of applying the tests would be the digital Enem. According to Inep, in addition to reducing costs, the digital version has the potential to reduce the abstentions of students taking the test in places far from where they live (Tokarnia, 2019).

In view of the reality of accumulated losses and high abstention rates, in 2019 Enem obtained the lowest absenteeism rates since 2001 and the lowest abstention rate on the second day of tests of the entire exam. Figure 2 shows the evolution of absenteeism rates in the exam since 2009.

FIGURE 2
Absenteeism at Enem (2009-2019)
(In %)



Source: Inep (2013; 2017; 2018a; 2018b; 2018c; 2019; 2020a; 2020c) and Último... (2019).
Authors' elaboration.

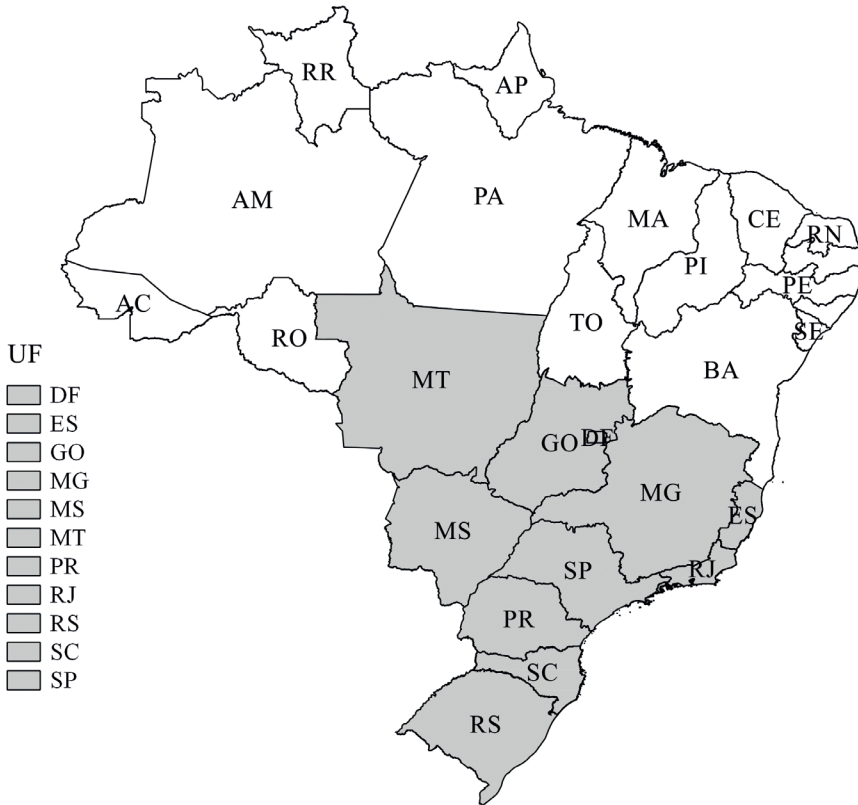
The decree that terminated daylight saving time marked the edition of Enem 2019 with the bug caused in the time of electronic devices. This fact will be discussed in the next section.

3 DAYLIGHT SAVING TIME AND WATCH BUGS

Daylight saving time (DST) represents a change in the time zone, which aims to take advantage of the longer days that spring and summer nights provide. The first country to adopt it was Germany, in 1916, and was followed by several countries afterwards. In Brazil, there had been several attempts to adopt daylight saving time.

In the period from 1931 to 1985, DST was used 11 times. Due to the scarcity of water and overload of the Brazilian electrical system, daylight saving time started to be used annually since 1985, covering the entire national territory. Over the years, its geographical area of effect has been reduced, since the states¹³ of the north and northeast regions stopped adopting it (Montalvão, 2005).

MAP 1
Map of the federative units covered by daylight saving time



Authors' elaboration.

Obs.: 1. The gray region represents daylight saving time coverage in 2018.

2. Map whose layout and texts could not be formatted due to the technical characteristics of the original files (Publisher's note).

In Brazil, the dates that define the period of daylight saving time are determined by a presidential decree. In 2017, through Decree No. 9,242, of December 15, it was established that daylight saving time would start from 00:00 a.m. of the

13. Until extinct, the summer time was in effect for the states of Rio Grande do Sul (RS), Santa Catarina (SC), Paraná (PR), São Paulo (SP), Rio de Janeiro (RJ), Espírito Santo (ES), Minas Gerais (MG), Goiás (GO), Mato Grosso (MT), Mato Grosso do Sul (MS) and the Distrito Federal (DF), covering 3,326 municipalities out of a total of 5,570.

first Sunday of the month of November every year, until 00:00 a.m. of the third Sunday of February on the subsequent year. This change made the start of daylight saving time to coincide with the first day of tests of Enem 2018.

It is well known in the literature that setting watches for the DST can impair both cognitive ability and attention, plus mood changes due to altered sleep quality. In addition, daylight saving time has the potential to negatively impact student performance (Schneider and Randler, 2009; Gaski and Sagarin, 2011; Medina et al., 2015; Sun et al., 2019; Jin and Ziebarth, 2020). In view of this situation and the possibility of candidates' delays, the MEC filed a request for the postponement of the start of daylight saving time. At first, the government complied with the request, but reversed and revoked the decision, maintaining the start of DST to 00:00 a.m. of the first day of exams 2018 (Brandão, 2018).

In 2019, based on technical studies by the Ministry of Mines and Energy, which indicated that daylight saving time did not produce the expected results in reducing electricity consumption, the new president in office extinguished daylight saving time, through the Decree No. 9,772, of April 25, 2019.¹⁴ However, many electronic devices were still programmed by Decree No. 9,242/2017, to adjust their clocks by one hour forward on the first Sunday of November, a date that again coincided with the first day of tests at Enem 2019. Automatic change on watches mainly affected Android phones, computers, and street clocks.

The possible automatic change on devices was already foreseen by cellphone manufacturers such as Motorola and Google, which released a note explaining that some mobiles may not have the information necessary to prevent the schedule from being changed automatically, given that the government measure could affect the Internet's Assigned Numbers Authority (Iana) global database, a tool used by electronic devices to ensure the right time (Celulares..., 2019; Trabalhando..., 2019). According to the National Union of Telephone Companies and Mobile Cellular and Personal Services (SindiTelebrasil), the failure was not caused by telephone operators, but by the devices that updated the time automatically as previously scheduled (Gusmão, 2018).

The automatic change in cellphone clocks caught many candidates by surprise, which ended up arriving an hour in advance. The fact resonated on social media, reaching the Trending Topics of the social network Twitter.¹⁵ It is worth noting that, according to the Enem 2019 microdata, approximately 97.8% of candidates claim to have at least one cellphone at home.

14. Available at: <<http://bit.ly/3J7DVLH>>. Accessed on: Aug. 23, 2020.

15. See more in: <<https://bit.ly/3VIYK4n>>.

4 DATA

The main data set used is the Enem 2019 microdata, made available by Inep. Furthermore, data from the fleet of buses and minibuses collected from the Ministry of Infrastructure (MI) were used, estimated population obtained from the Brazilian Institute of Geography and Statistics (IBGE); and precipitation level data for the two days of exam obtained from the National Institute of Meteorology (Inmet). It should be noted that Inmet does not provide precipitation data for all municipalities in Brazil. Therefore, we use data from meteorological stations to perform a spatial interpolation with univariate deterministic interpolator, based on the inverse of the square of the weighted distance, identified by the following equation:

$$\hat{Z}_m = \frac{\sum_{m=1}^n (\frac{1}{d_m^2} * z_m)}{\sum_{m=1}^n (\frac{1}{d_m^2})} \tag{1}$$

in which \hat{Z}_m is the interpolated value for municipality m ; z_m is the precipitation in millimeters in each season and d_m^2 represents the Euclidean distance between the seasons. In short, data from 919 meteorological stations spread throughout the Brazilian territory were used to obtain rainfall estimates in the 5,570 Brazilian municipalities. The set of variables used is described in table 1.

TABLE 1
Description of the variables used

Label	Description	Source
In(Abs 1 st day)	Natural log of abstentions by municipality on the 1 st day of Enem.	Inep
In(Abs 2 nd day)	Natural log of abstentions by municipality on the 2 nd day of Enem.	Inep
In(Abs income)	Natural log of abstentions for candidates with a monthly family income of (0 -1); (1 -2); (2 -4); (4 -6); (6 -8); (8 -10); (10 -Máx) minimum wages.	Inep
In(Abs Education)	Natural log of candidate abstentions that the mother: (Without Study); (Elementary im-comp); (Elementary comp); (High Comp); (Undergraduate Comp); (Graduate Comp), that is, without study; elementary school incomplete and complete; high school complete; undergraduate complete; graduate complete, respectively.	Inep
% Public school	Percentage of students who attend or attended whole high school in a public school.	Inep
% Women	Percentage of female candidates.	Inep
% Men	Percentage of male candidates.	Inep
% Black	Percentage of black candidates.	Inep
Average income	Average income in minimum wages.	Inep
Average mother's education	Average mother's education. Where: (without study = 0); (Elementary incmp. = 1); (Elementary comp. = 2); (High comp. = 3); (Undergraduate comp. = 4); (Graduate comp. = 5).	Inep
Average father education	Average mother's education. Where: (without study = 0); (Elementary incmp. = 1); (Elementary comp. = 2); (High comp. = 3); (Undergraduate comp. = 4); (Graduate comp. = 5).	Inep
Precipit 1 st day	Precipitation in millimeters on the 1 st day of Enem.	Inmet
Precipit 2 nd day	Precipitation in millimeters on the 2 nd day of Enem.	Inmet

(Continues)

(Continued)

Label	Description	Source
Public transp.	Proxy for public transport (fleet of bus + minibus)/population.	MI and IBGE
Distance (km)	Distance between the centroid of each municipality to the boundary limit for daylight saving time, being negative for the control's municipalities and positive for the treaties.	IBGE
Lat. and long.	Municipality latitude and longitude.	
Border dummies	The border was divided into eight segments: segment 1: it is the border between the states of Mato Grosso and Rondônia; segment 2: Mato Grosso and Amazonas; segment 3: Mato Grosso and Pará; segment 4: Mato Grosso and Tocantins; segment 5: Goiás and Tocantins; segment 6: Goiás and Bahia; segment 7: Minas Gerais and Bahia; and segment 8: Espírito Santo and Bahia.	

Authors' elaboration.

Obs.: Except for $\ln(\text{Abs_1}^{\text{st}} \text{ day})$ and $\ln(\text{Abs_2}^{\text{nd}} \text{ day})$, the other abstention variables are for candidates who were absent during the two days of the exam. All municipal variables refer to the candidate's municipalities of residence.

The choice of variables aimed to capture the characteristics of the candidate and especially about the candidate's family background, since it is already well consolidated in the literature that parent's education is an important determinant in the formation and performance of children (Schultz, 1988; Barros, Foguel and Ulysea, 2006). In addition, were used variables that affect urban mobility, such as rainfall and a proxy for public transport, factors that may make it difficult for candidates to move to the test sites.

Table 2 provides the balance of covariates for the groups of treated municipalities and controls, where the treated group represents those municipalities where the clocks failed, that is, the municipalities covered by the decree of daylight saving time in 2018. The control group represents the municipalities that were not covered by the DST decree. We only use the variables (% public school; % women; % men; % back; average income; average mother's education; average father education; precipit 1st day; precipit 2nd day; public transport) to generate the weights by entropy balancing, since we are interested in evaluating the impact on abstentions. In the next section of empirical strategy, we justify the use of the entropy balancing technique.

TABLE 2
Covariate balancing

	Before balancing			After balancing		
	Treated	Control	P-value	Treated	Control	P-value
ln(Abs_1 st day)	3.857	4.366	0.000***	3.857	2.995	0.000***
ln(Abs_2 nd day)	4.030	4.510	0.000***	4.030	3.078	0.000***
ln(Abs Income 0 –1)	2.438	3.859	0.000***	2.438	2.188	0.000***
ln(Abs Income 1 –2)	3.041	3.097	0.030**	3.041	1.920	0.000***
ln(Abs Income 2 –4)	2.398	1.849	0.000***	2.398	1.242	0.000***
ln(Abs Income 4 –6)	1.273	0.792	0.000***	1.273	0.507	0.000***
ln(Abs Income 6 –8)	0.687	0.369	0.000***	0.687	0.106	0.000***
ln(Abs Income 8 –10)	0.455	0.219	0.000***	0.455	0.137	0.000***
ln(Abs Income 10 –Máx)	0.561	0.290	0.000***	0.561	0.281	0.000***
ln(Abs Without study)	1.127	2.050	0.000***	1.127	0.651	0.000***
ln(Abs Elementary incomp.)	3.045	3.570	0.000***	3.045	2.040	0.000***
ln(Abs Elementary comp.)	2.025	2.224	0.000***	2.025	1.120	0.000***
ln(Abs High comp.)	2.482	2.795	0.000***	2.482	1.895	0.000***
ln(Abs Undergraduate comp.)	1.337	1.506	0.000***	1.337	1.065	0.000***
ln(Abs Graduate comp.)	1.229	1.279	0.015**	1.229	0.558	0.000***
% Public school	0.325	0.289	0.000***	0.325	0.323	0.377
% Women	0.611	0.611	0.507	0.611	0.613	0.379
% Men	0.389	0.389	0.507	0.389	0.387	0.379
% Black	0.410	0.755	0.000***	0.410	0.408	0.617
Average income	2.336	1.101	0.000***	2.336	2.297	0.009***
Average mother's education	2.261	1.943	0.000***	2.261	2.249	0.128
Average father education	1.771	1.343	0.000***	1.771	1.759	0.104
Precipit 1 st day	0.018	0.003	0.000***	0.018	0.017	0.364
Precipit 2 nd day	0.015	0.006	0.000***	0.015	0.015	0.586
Public transp.	0.007	0.003	0.000***	0.007	0.007	0.731

Authors' elaboration.

Obs.: The significance levels are represented by: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$. The null hypothesis of the t -test is that the means are equal. The income concerns the monthly salary ranges. In 2018 the minimum wage was R\$ 954 and in 2019 it was R\$ 998.

As far as the results are concerned, in general, indicate that the sample was balanced satisfactorily in the variables of interest, ensuring that the treated and control groups have on average the same observable characteristics.

5 EMPIRICAL STRATEGY

To achieve the objective of assessing the impact of the watch bug on the abstentions in Enem 2019, we will use the empirical strategy of geographic regression discontinuity design (RDD) Sharp, to explore the discontinuity generated by the municipalities that had daylight saving time, which we will call treated municipalities, and the municipalities that did not have daylight saving time represent the controlling municipalities.

The Discontinuous Regression Design technique has become popular in recent years, being used for causal inference in social and natural sciences when experimentation is not possible (Gelman and Imbens, 2019). However, according to Cattaneo, Idrobo and Titiunik (2019), the way it is interpreted differs significantly between the authors. Thus, in our estimates we will follow the steps suggested in *A practical introduction to regression discontinuity designs: foundations* using the Rdrobust package (Cattaneo, Idrobo and Titiunik, 2019; Calonico et al., 2022).

In RDD, participation in a program is determined in whole or in part by the cutoff, which is a function of a continuous variable, where in our study it is represented by the distances from the centroids of the municipalities to the border that is delimited by the daylight saving time decree. The main assumption of the method is discontinuity, which ensures that individuals above or below the cutoff are comparable, differing only in terms of receiving or not receiving treatment (Imbens and Lemieux, 2008).

For the estimations, we use the non-parametric method with the selection of optimal bandwidth suggested by Cattaneo, Idrobo and Titiunik (2019),¹⁶ which are: *MSEERD*, *MSESUM*, *CERRD* and *CERSUM* together with a triangular kernel, which will assign weights to each observation based on the distance to the cutoff point. These weights decrease linearly and symmetrically as the score value moves away from the cutoff point. The use of the triangular kernel in conjunction with a bandwidth that optimizes the mean square error (MSE) will lead to a point estimator with ideal properties (Cattaneo, Idrobo and Titiunik, 2019).

Furthermore, following a strategy similar to that of Dell (2010), we will include in our specification latitude and longitude, as well as fixed effects of the border segment, which mark the political and administrative divisions between different federative units. Formally, the equation that we will estimate is described by the following expression:

16. In which: *MSEERD* – one common MSE-optimal bandwidth selector for the sum of regression estimates; *MSESUM* – one common MSE-optimal bandwidth selector; *CERRD* – one common Coverage Error Rate optimal bandwidth; and *CERSUM* – one common Coverage Error Rate optimal bandwidth selector.

$$y_m = \alpha + \gamma bug_m + f(Dist_m) + f(Dist_m) * bug_m + f(Geo_m) + \sum_{i=1}^7 seg_m^i + \epsilon_m, \quad (2)$$

in which y_m represents abstention in municipality m ; bug_m is a dummy that takes the value of 1 for the treated municipalities and 0 for the controlled municipalities; $f(Dist_m)$ is the polynomial RD that controls the potential effects according to the Euclidean distance from the centroids of the municipalities to the border; $f(Dist_m) * bug_m$ represents the interaction of the polynomial RD and the treatment dummy; $f(Geo_m)$ contains the functions of geographic location, latitude and longitude, which allow controlling multidimensional discontinuity; seg_m^i represents the division of the border into eight segments, that is, seg takes the value of 1 if municipality m is closer to the border segment s and zero otherwise, and ϵ_m represents the error term of the regression.

In addition, we will use the empirical difference-in-differences (DID) strategy. The DID model is one of the most popular techniques for assessing causal effects and interventions. In our study, we will use the canonical approach with two periods, with data from Enem 2018 and 2019. The DID method will estimate the effect of the clock bug, comparing the average variation of the results experienced by the group of affected municipalities, with the average variation of the results experienced by the group of municipalities that were not affected by the bug (Athey and Imbens, 2006). In formal terms we estimate the following equation:

$$y_{mt} = \alpha + \delta_m bug_m + \delta_t Time_t + \beta (bug_m * Time_t) + \beta' X_{mt} + \epsilon_{mt}, \quad (3)$$

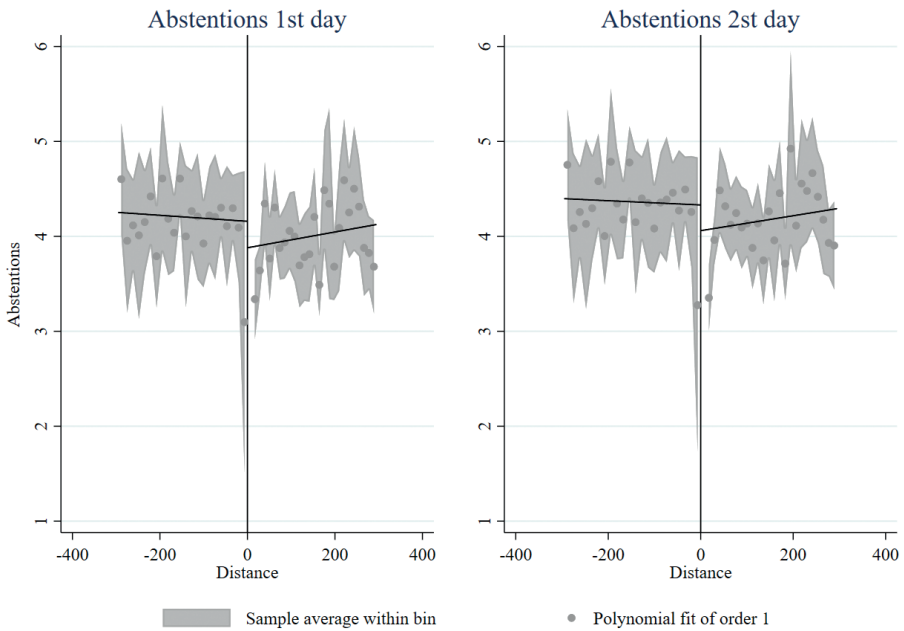
in which y_{mt} represents abstentions in municipality m in year t ; bug_m is a binary variable that takes the value of 1 when the municipality is within the group of municipalities affected by the bug and zero otherwise; $Time_t$ is the binary variable that indicates when the bug occurred, that is, it is 0 for the year 2018 and 1 for the year 2019; $\beta (bug_m * Time_t)$ is the interaction term between binary variables, which will indicate the impact of the bug on abstentions; X_{mt} is the covariate vector of the model and ϵ_{mt} represents the variable term error of the regression.

Finally, to minimize bias in observable characteristics, we will combine the difference-in-difference approach with the Entropy Balancing technique developed by Hainmueller (2012), in order to obtain a more balanced sample. Entropy balancing consists of a non-parametric technique that will generate a vector of weights based on a set of covariates capable of balancing treatment and control groups. In short, weights are generated through an iterative process of entropy maximization so that the weighted control sample meets the specified equilibrium conditions Hainmueller (2012). According to Cefalu et al. (2020), combining difference-in-difference strategy with entropy balance has the potential to reduce bias in the analyses when the assumption of parallel trends is not met directly.

6 RESULTS

In this section, the results found are presented and discussed. First looking at figure 3, it is possible to observe the discontinuity in the natural log of abstentions, for the first and second day of Enem tests 2019. On the left side of each of the graphs we have the municipalities of the control group, which receive a negative distance in kilometers to the border, and on the right side we have the municipalities of the treatment group, which receive a positive distance to the border. The resulting graphs in figure 3 indicate that below the zero cutoff point, the control group observed on average more abstentions than the treatment group for the two days of examination.

FIGURE 3
RD plot with evenly-spaced bins



Authors' elaboration.

Obs.: Figure whose layout and texts could not be formatted due to the technical characteristics of the original files (Publisher's note).

In table 3 we present the results of econometric estimations using the geographic RDD method for the first and second days of the Enem 2019 tests. Specifications (1) to (4) present the results for the first day of exams and specifications (5) to (8) present the results for the second day of exams.

TABLE 3
Results for the 1st and 2nd day of Enem 2019 tests with Geographic RDD

	1 st day of exams				2 nd day of exams			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Conventional	-0.36*** (0.14)	-0.25** (0.11)	-0.28* (0.17)	-0.35** (0.14)	-0.34** (0.14)	-0.23** (0.12)	-0.26 (0.17)	-0.34** (0.14)
Bias-corrected	-0.39*** (0.14)	-0.23** (0.11)	-0.28* (0.17)	-0.34** (0.14)	-0.37*** (0.14)	-0.21* (0.12)	-0.26 (0.17)	-0.32** (0.14)
Robust	-0.39** (0.16)	-0.23* (0.13)	-0.28 (0.18)	-0.34** (0.15)	-0.37** (0.16)	-0.21 (0.13)	-0.26 (0.18)	-0.32** (0.15)
Faults avoided (robust) ¹ (%)	-32.3	-31.6	0	-28.8	-30.9	0	0	-27.4
Total absences avoided ²	-30,260	-28,631	0	-25,888	-34,521	0	0	-29,050
Type bandwidth	Mserd	Msesum	Cerrd	Cersum	Mserd	Msesum	Cerrd	Cersum
Bandwidth estimated (h)	295.64	426.93	192.07	277.37	296.79	426.03	192.82	276.79
Bandwidth bias (b)	509.34	765.29	509.34	765.29	510.31	760.07	510.31	760.07
FE frontier segment	✓	✓	✓	✓	✓	✓	✓	✓
Total absences in treaties	93,700	173,968	55,715	89,817	111,621	204,685	65,733	106,079
N Controls	412	580	281	391	412	578	284	391
N Treaties	561	888	341	516	563	884	343	514

Authors' elaboration.

Notes: ¹ As it is a loglinear model with dummy variable, to obtain the true impact we use the following equation $100 \cdot [\exp^{\beta_i} - 1]$. See more at Giles (2011).

² Estimates based on abstentions in the municipalities covered by Bandwidth (h), and the percentage of absences avoided.

Obs.: The levels of significance are represented by: * significant at 10%; ** significant at 5%; and *** significant at 1%. In which: the bandwidth is in kilometers, with the bandwidth (h) for the estimates (b) and for bias correction (b).

The results found indicate that the failure of the clocks contributed to the reduction in the number of abstentions on the first day of the exam. In percentage terms, we can infer that the bug reduced abstentions between 28.8% and 32.3%. In other words, the watch bug may have prevented up to 30,260 absences, only for the set of municipalities used in the estimates, given that the RDD has a low external validity. Therefore, we concluded that the failure of the watches may have prevented a loss¹⁷ of up to R\$ 3,193,035.20.

The results found for the second day of Enem 2019 tests are noteworthy. Initially, it is expected that there will be no effect on the second exam day, as the event only occurs on the first day of exams. However, it is reasonable to assume that the bug has altered the composition of the groups. In other words, the event may have benefited those candidates most likely to be late, who, once benefited, felt motivated to take the second round of tests, thus reducing abstentions on the

17. The amount of the avoided loss is based on the average cost of the proof multiplied by the avoided abstention $R\$ 105.52 \times 30,260 = R\$ 3,193,035.20$. On November 2019, the exchange rate between the Brazilian Real and the US Dollar was 3.99 R\$/US\$.

second day as well. In general, the results indicate that the bug contributed to a reduction in abstentions by magnitudes like those observed on the first day of the examination, ranging from -27.4% to -30.9%.

In the table 4, we present the estimates for the placebo using a fictitious cutoff of 150 km. In practical terms, two sets of regressions are estimated. First, only the group of control municipalities is regressed, assigning a cutoff 150 km away from the border. Later, the same is done for the group of treated municipalities. We hope that the estimated coefficients are not significant. Otherwise, the causal relationship between the failure of the clocks and the reduction in observed abstentions is compromised.

TABLE 4
Placebo results for the 1st and 2nd day of Enem 2019 with geographic RDD

		1 st day of exam				2 nd day of exams			
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
-150 km	Conventional	-0.28 (0.33)	-0.27 (0.33)	-0.48 (0.39)	-0.45 (0.39)	-0.34 (0.34)	-0.32 (0.33)	-0.54 (0.40)	-0.51 (0.39)
	Bias-corrected	-0.29 (0.33)	-0.28 (0.33)	-0.48 (0.39)	-0.44 (0.39)	-0.38 (0.34)	-0.36 (0.33)	-0.55 (0.40)	-0.51 (0.39)
	Robust	-0.29 (0.41)	-0.28 (0.41)	-0.48 (0.43)	-0.44 (0.43)	-0.38 (0.41)	-0.36 (0.41)	-0.55 (0.43)	-0.51 (0.43)
Type bandwidth		Mserd	Msesum	Cerrd	Cersum	Mserd	Msesum	Cerrd	Cersum
Bandwidth estimated (h)		66.92	69.35	45.50	47.15	65.23	69.06	44.35	46.95
Bandwidth bias (b)		99.93	100.50	99.93	100.50	99.08	100.23	99.08	100.23
FE frontier segment		✓	✓	✓	✓	✓	✓	✓	✓
N Controls		90	92	60	62	86	92	58	62
N Treaties		103	105	63	65	99	105	60	65
150 km	Conventional	0.28 (0.26)	0.29 (0.28)	0.32 (0.34)	0.33 (0.36)	0.31 (0.27)	0.31 (0.28)	0.34 (0.35)	0.34 (0.36)
	Bias-corrected	0.33 (0.26)	0.33 (0.28)	0.35 (0.34)	0.35 (0.36)	0.35 (0.27)	0.35 (0.28)	0.36 (0.35)	0.37 (0.36)
	Robust	0.33 (0.35)	0.33 (0.35)	0.35 (0.38)	0.35 (0.39)	0.35 (0.35)	0.35 (0.35)	0.36 (0.39)	0.37 (0.39)
Type bandwidth		Mserd	Msesum	Cerrd	Cersum	Mserd	Msesum	Cerrd	Cersum
Bandwidth estimated (h)		107.98	99.26	71.99	66.17	107.03	99.34	71.35	66.23
Bandwidth bias (b)		139.28	150.66	139.28	150.66	138.32	149.15	138.32	149.15
FE frontier segment		✓	✓	✓	✓	✓	✓	✓	✓
N Controls		194	180	123	117	193	180	123	118
N Treaties		206	192	135	121	206	192	135	121

Authors' elaboration.

Obs.: The levels of significance are represented by: * significant at 10%; ** significant at 5%; and *** significant at 1%. In which: the bandwidth is in kilometers, with the bandwidth (h) for the estimates (b) and for bias correction (b).

In summary, the results for the placebo of the first and second day of examinations indicate that no coefficient was statistically significant. Thus, we can infer that the results previously found are valid and represent the effect of the failure of clocks on abstentions.

Continuing the estimates, the following tables present the results for the difference-in-differences estimator, with the data from the 2018 and 2019 exams. We estimated 6 specifications, which are 3 for the first day of examination and 3 for the second day. Specifications differ in the use of covariates and weights.

TABLE 5
Results for the 1st and 2nd day of Enem tests using DID

	1 st exam day			2 nd day of exams		
	(1)	(2)	(3)	(4)	(5)	(6)
DID	-0.14*** (0.01)	-0.12*** (0.01)	0.14*** (0.01)	-0.13*** (0.01)	-0.11*** (0.01)	0.14*** (0.01)
Faults avoided (%)	-13.06	-11.31	-13.06	-12.19	-10.42	-13.06
Total absences avoided	85,066	73,631	85,066	79,377	67,826	85,066
Covariates	No	Yes	Yes	No	Yes	Yes
Weights	No	No	Yes	No	No	Yes
N	11,126	11,126	11,126	11,126	11,126	11,126

Authors' elaboration.

Obs.: Significance levels are represented by: * significant at 10%; ** significant at 5%; and *** significant at 1%. The covariates used were: % public school, % women, % men, % black, average income, average mother's education, average father education, precipit 1st day, precipit 2nd day, public transp. The total abstention in the municipalities treated for the first day of Enem 2019 is 651,139.

The results indicate that the watch bug reduced abstentions by up to 13.06% on both days of exam. In other words, the bug reduced by up to 85,066 absences. Therefore, we can infer that the failure of the watches may have prevented a loss¹⁸ of up to R\$ 8,974,463.00.

Table 6 shows the results for the placebo randomly assigned to a set of municipalities respecting the same proportion of municipalities affected by the bug.

18. On November 2019, the exchange rate between the Brazilian Real and the US Dollar was 3.99 R\$/US\$.

TABLE 6
Placebo results for the 1st and 2nd day of Enem tests 2018 and 2019 with DID

	1 st exam day			2 nd day of exams		
	(1)	(2)	(3)	(4)	(5)	(6)
DID	0.02 (0.04)	0.00 (0.01)	0.01 (0.01)	0.02 (0.04)	-0.00 (0.01)	0.00 (0.01)
Covariates	No	Yes	Yes	No	Yes	Yes
Weights	No	No	Yes	No	No	Yes
N	11,128	11,128	11,128	11,128	11,128	11,128

Authors' elaboration.

Obs.: Significance levels are represented by: * significant at 10%; ** significant at 5%; and *** significant at 1%. The covariates used were: % public school, % women, % black, precipit 1st day, precipit 2nd day, public transp., average income and average mother's education.

We observed that for the randomly assigned placebo results, they indicate that no coefficient was statistically significant. Therefore, we have a reason to believe that the results previously found are valid and represent the effect of the clock bug on abstentions.

To confirm the impact of the failure of clocks on abstentions, we have advanced in the estimates, now seeking to identify the socioeconomic profiles of the affected candidates. Therefore, we group absent candidates by family income and mother's education. To summarize the next results of the study, we use the absent candidates in the two days of the exam.

TABLE 7
Abstention results in the two exam days by salary range

	0 -1	1 -2	2 -4	4 -6	6 -8	8 -10	10 -Máx
DID	-0.18*** (0.01)	-0.09*** (0.01)	-0.05*** (0.02)	-0.06*** (0.02)	-0.06*** (0.02)	-0.02 (0.01)	-0.01 (0.01)
Absences avoided (%)	-16.47	-8.61	-4.88	-5.82	-5.82	0	0
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Weights	No	No	No	No	No	No	No
N	11,128	11,128	11,128	11,128	11,128	11,128	11,128

Authors' elaboration.

Obs.: Significance levels are represented by: * significant at 10%; ** significant at 5%; and *** significant at 1%. The covariates used were: % public school, % women, % men, % black, precipit 1st day, precipit 2nd day, public transp.

First, we observe for candidates absent in the two days of examination by family salary range. We found results that support that the failure of the clocks benefited mainly the candidates with family income less than 1 minimum wage. According to Inep (2018a) more than 2/3 of abstentions in Enem 2017, were from exempt candidates for having a monthly family income per capita of up to half

the minimum wage. We can conclude that the bug reduced the abstentions of the group of candidates that most contributes to the high statistics of abstentions in Enem. That is probably because the perception of the education value is related to the income level. In other words, families with higher income have lower chances of missing the exam days.

In terms of magnitudes, we can infer that the bug was responsible for a reduction of abstentions of -16.47% for candidates with a family income of up to 1 minimum wage, and between -4.8% and -8.61% for candidates with a family income between 1 and 8 minimum wages. No significant effects were found for candidates with a family income above 8 minimum wages.

TABLE 8
Abstention results in the two days of examination for the mother's education¹

	Without study	Elementary incomp.	Elementary comp.	High comp.	Undergradu- ate comp.	Graduate comp.
DID	-0.11*** (0.02)	-0.14*** (0.01)	-0.14*** (0.02)	-0.11*** (0.02)	-0.07*** (0.02)	-0.07*** (0.02)
Absences avoided (%)	-10.42	-13.06	-13.06	-10.42	-6.76	-6.76
Covariates	Yes	Yes	Yes	Yes	Yes	Yes
Weights	No	No	No	No	No	No
N	11,128	11,128	11,128	11,128	11,128	11,128

Authors' elaboration.

Note: ¹ Descriptive statistics for these data sets are found in the appendix A.

Obs.: Significance levels are represented by: * significant at 10%; ** significant at 5%; and *** significant at 1%. The covariates used were: % public school, % women, % men, % black, precipit 1st day, precipit 2nd day, public transp.

Looking at the candidate's mother's education, the results corroborate those found previously, given that income is a function of education (Mincer and Polachek, 1974). In terms of magnitudes, we can infer that the failure in the clocks contributed to the reduction of -13.06% abstentions in the groups of candidates, with minor parental education, benefiting mainly the students whose mother has incomplete primary education or only primary education completed.

The results found support that the failure of the clocks caused by the end of daylight saving time contributed significantly to the reduction of abstentions in the 2019 edition of the National High School Exam, conducting to the lowest absenteeism rate since 2001, and also the lowest abstention rate on the second day of tests for the entire exam period. In addition, the candidates who benefited the most, in terms of reducing the number of absences, have a socioeconomic profile with a family income of less than 1 minimum wage, whose mother's education goes up to complete elementary school.

7 CONCLUSION

In two decades of existence, the National High School Examination (Enem), has established itself as the main educational entrance examination to federal universities in Brazil. However, the increasing number of participants was followed by high rates of absenteeism. Our estimates indicate that between 2009-2019 there was an accumulated loss of approximately R\$ 1.84 billion with the abstentions.

Within this context, this work aims to assess the impact of the failure of clocks caused by the end of daylight saving time on absenteeism in the National High School Exam in the 2019 edition. The empirical strategy used was that of geographic regression discontinuity design (RDD) non-parametric and difference-in-differences. The results found support the hypothesis that the failure of clocks contributed significantly to the reduction of abstentions in Enem 2019, benefiting mainly candidates with a socioeconomic profile with a family income below 1 minimum monthly wage, whose mother's education goes up to complete elementary school. In terms of magnitudes, the watch bug may have prevented up to 85 thousand absences in the two days of the exam, preventing the waste of approximately R\$ 9 million.

In view of the results found, we leave as suggestions for policy makers or future studies, the use of Machine Learning and deep Learning classification techniques to build a model based on microdata, able to predict which candidates are most likely to abstain. With the model in hand, it will be possible to think about public policies focusing on these candidates and their guardians.

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APPENDIX A

TABLE A.1
Expenditure with the National High School Exam (Enem)

Year	Subscribers	Abstention	Exempt (%)	Exam entry fee (R\$)	Cost per participant (R\$)	Total loss (R\$)	Loss in July/2020 amounts – IPCA (R\$)
2009	4,148,721	1,564,068	-	35.00	39.24	61,374,028.32	107,373,475.89
2010	4,626,094	1,332,315	-	35.00	38.10	50,761,201.50	86,134,307.20
2011	5,380,857	1,420,546	-	35.00	51.03	72,490,462.38	109,047,844.75
2012	5,814,644	1,622,286	-	35.00	62.74	101,782,223.64	145,491,286.59
2013	7,173,574	2,130,551	73.15	35.00	70.10	149,969,484.89	199,983,558.25
2014	8,760,366	2,520,642	73.19	35.00	77.59	194,996,865.12	238,480,093.56
2015	7,746,442	2,138,016	74.38	63.00	93.23	197,039,554.56	240,978,291.51
2016	8,627,371	2,687,850	76.81	68.00	91.49	243,626,724.00	273,959,615.45
2017	6,731,341	2,017,253	70.29	82.00	87.54	176,590,327.62	193,353,676.58
2018	5,513,662	1,374,430	63.80	82.00	106.13	121,879,722.26	127,633,517.69
2019	5,095,270	1,163,700	67.28	85.00	105.52	122,793,624.00	125,411,338.48
2020	5,687,271	-	83.00	85.00	-	-	-
Total						R\$ 1,493,304,218.29	R\$ 1,847,847,005.95

Sources: Inep (2013; 2017; 2018a; 2018b; 2018c; 2019; 2020a; 2020c) and Último... (2019).
Authors' elaboration.

Obs.: 1. For the period from 2009 to 2013 and 2019 the loss is calculated by multiplying the abstention by the cost per participant, for the remaining years the amount informed by the National Institute of Studies and Educational Research Anísio Teixeira (Inep) was used. On July 2020, the exchange rate between the Brazilian Real and the US Dollar was 5.20 R\$/US\$.
2. IPCA – Broad National Consumer Price Index.

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