Economics of the Time Zone: Let there Be Light

Pavel Jelnov

Abstract

This paper is concerned with the causal effect of clock on economy. I explore the variation in the time zones of Russian administrative regions. During most of the last sixty years, Russia has implemented a policy of shifting time zones downward. Analyzing the 1995-2015 period, I estimate both immediate and lagged effects of clock reforms. My estimates show that Russia could gain at least 4% of GDP within five years if it would, oppositely to what is mostly done, shift the time zones in some regions upward. While exploring channels, I find better human and social capitals with the later clock: a lower consumption of beer and unhealthy food, less desease of the endocrine system, a much lower homicide rate, and much more visits to museums. On the other hand, birth defects would be more frequent and the overall health in the north of the country might worsen. Additionally, agricultural product in the north is significantly lower with the later clock.

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1 Introduction

Managing the clock is an important issue in political economy. Time zones and daylight saving time are differently managed around the globe and discussions around the "best" clock do not seize in many countries. Spain lives in the Central European Time Zone, making travelers surprised by how late the locals go out for dinner. Historically, the reasons for such unnatural time zone in Spain are political. But what are the consequences for the economy and the people? The clock as a factor of economic growth is related to the discussions around the relationship between geography and development (Acemoglu et al. (2001)). By managing the clock, politicians sometimes face the trade-off between nature and politics. Shifting the clock may have political consequences but may also affect the fit between the humans and the nature, altering the socio-economic outcomes.

I take an advantage of an ideal natural experiment to directly measure the effect of clock reforms on the socio-economic outcomes. I explore the variation in the time zones of Russian administrative regions. Not only that Russia, differently from any other country in the world, covers eleven time zones, but its frequent reforms with regards to the time zones allow a unique quasi-experimental setup for a precise investigation. The identification of the causal effect of the clock on the economy relies on the fact that Russia is a large but centralized country. The clock reforms are exogenous in the sense that they are generally initiated by the federal government and not by the treated regions. For example, the reform of 2010 reduced the number of time zones in Russia from eleven to nine. The declared purpose was to improve the governability of the country. As a result, five Russian regions had to move to a different time zone.

The existing literature mostly uses the Daylight Saving Time (DST) transitions to test the effect of the clock on the economy. In DST, the clock is shifted by one hour twice a year, in the spring and in the autumn. The disadvantage in using the DST transitions in empirical design is that by nature the discontinuity event occurs in two specific seasons, similarly every year. Thus, it is impossible to estimate the effect of additional daylight time in other seasons. The current study overcomes this shortcoming because the exogenous variation in Russian time zones is not seasonal. An additional advantage of the current study is that in Russia, time zones may be shifted up to two hours ahead the natural ones. Thus, we can test the monotonicity and linearity of the daylight effect by comparing the effects of the first and the second additional hours of daylight. This is not possible with the DST transitions, which are single hour shifts.

This paper is innovate in two ways. First, it is the first study to use exogenous variation in time zones other than temporal shifts due to daylight saving. Second, I consider a novel explanatory variable, the difference between the actual and the natural time zones when the natural time zone is determined by the region's longitude. I name this explanatory variable time zone bias (TZB). In simple words, having TZB equals zero means that sun's zenith is around 12 am. Having TZB equals one means that sun's zenith is around 1pm and so on. Thus, a higher TZB means later sunrise and sunset. Because of the reforms, the same Russian regions have different TZB in different years. Moreover, because many reforms affected only some of the country's regions, it is possible to control for region-specific trends and year fixed effects. This makes the current paper to be a novel identification exercise of the effect of the clock on the economy.

On the left hand side, I put outcomes starting with GDP. The robust results show that a higher TZB (living ahead the sun) is associated with a higher gross regional product. This effect is observed with a five-year delay and constitutes a 5% larger economy for each additional hour of TZB (in the north of the country, the effect is 7%). I explore the possible channels that could lead to this effect. To this end, I test the relationship between TZB and human and social capitals' determinants. It turns out that TZB of one hour is associated with a 20% reduce in homicide rate, and the second hour gives additional 10 percentage points. Moreover, each hour of TZB is associated with a 3% decrease in consumption of bread in the south of the country (observed with a three-year delay; a 4% decrease is observed with a five-year delay), while in the north we observe a 14% lower consumption of eggs, and a 4% lower consumption of sugar (observed with a five-year delay). The alcohol consumption is aslo affected with a 15% lower consumption of beer in the north when TZB is one hour and additional 5 percentage points when TZB is two hours. However, consumption of wine increases in the north with a five-year delay. No effect on consumption of likeurs is found. The effect on health outcomes includes a 15% decrease in the rate of endocrine system desease (with a five-year delay) for each additional hour of TZB but also a 20% increase in birth defects and a higher rate of skin desease and total desease in the north (the latter two effects are observed with a five-year delay). Labor force participation increases by one percentage point for each hour of TZB. However, agricultural product in the north of Russia is 11% lower for each additional hour of TZB. Last but not least, the leisure habits change when TZB rises, with 30% more visits to museums in the north of the country when TZB is one hour, and additional 20 percentage points when TZB is two hours. Educational outcomes, even though are relevant with regard to clock, are excluded because Russian data on educational achievements is suggestively unreliable. This issue is discussed in more detail in section 3.3.

In 2014, 1% of Russian population lived in regions where TZB was zero. 61% lived in regions where TZB was one hour and 38% lived in regions where TZB was two hours. This paper's results mean that if, hypothetically, the whole country would be shifted to TZB of two hours in 2014, the Russian GDP should grow by 4% within five years. Note that this is not a general equilibrium effect and may be actually a lower bound estimate.

It is important to note the difference between the south and the north. The effect of the time zone on economy is sometimes referred in the literature as "longitude matters" (Stein and Daude (2007)), which is an extension of the well-known discussion of development economists whether "latitude matters" (Acemoglu et al. (2001)). The north-south difference in the time zone effect, documented in the current paper, means that "longitude matters" and "latitude matters" are not necessary two separate discussions. The daylight timing may be related to longitude (for example, when the time zone equalization is supposed to make two places "closer" to each other despite the longitude difference) but the importance of daylight differs across latitudes.

The public discussion over time zones in Russia raises arguments in favor of better governability when the clock in certain regions is equalized versus issues of health and crime raised by opposers of the low sunrise and sunset sometimes caused by these equalizations. The public opinion is generally on the side of longer daylight. The observed in the current paper effects are related not only to the immediate well-being but also to human and social capitals' formation. The outlined above results imply that the clock reforms that moved Russian regions "closer" to Europe or "squeezed" the country into a smaller number of time zones, did not do a good job for many of the socio-economic outcomes. The policy of gradually drifting the country "to the west" started in 1957 but no steady state has been reached. Disputes on clock do not cease in Russia but also in other countries, especially around the daylight saving. Particularly, as currently about 70 countries implement the Daylight Saving Time (DST), while other countries do not (in the U.S. and Canada most regions implement DST but some do not), the issue of daylight remains actual in political economy around the world. Hopefully, this paper sheds some light on the consquences of the time zones policy and can be helpful in further discussions on the optimal clock.

1.1 Related literature

The existing literature on time zones is divided into three groups while two of them are not directly related to the current study.[1] The first group of papers is concerned with the difference between time zones of two locations. On the left hand side, there appear mutual trade (Kikuchi (2006), Kikuchi and Marjit (2010), Kikuchi and Van Long (2010), Christen (2015)), foreign direct investment (Stein and Daude (2007), Hattari and Rajan (2012)), or time use activities affected by watching live television shows (Hamermesh et al. (2008)). The second group of studies considers the Daylight Saving Time (DST) transitions as a discontinuity quazi-experiment where the treatment is sleep deprivation. They establish a short-run effect of sleep deprivation on happiness (Kountouris and Remoundou (2014), Kuehnle and Wunder (2014)), health (Jin and Zebarth (2015), Toro et al. (2015); see footnote 2 in Jin and Zebarth (2015) for a list of references for medical studies linking DST transitions with short-run health changes), and performance of stock markets (Kamstra (2000)). The estimated effects last for no more than few days and, mostly, are observed only in the "bad" DST transition in spring but not in the "good" transition in autumn (Kuehnle and Wunder (2014), Kuehnle and Wunder (2014), Jin and Zebarth (2015)).

The bunch of literature mostly related to the current paper is the small third group of papers which consider the effect of daylight. A few studies in this group use geographical variation in daylight to estimate the effect of daylight on health (Markusen and Røed (2015)) and productivity (Figueiro et al. (2002), Gibson and Shrader (2014)). Using Norwegian data, Markusen and Røed (2015) report that longer daylight is associated with increased entry rate to absenteeism but also a higher recovery rate. The overall effect is positive (less absenteeism) but small (0.3%). Figueiro et al. (2002) collect data from a software development company located in NewYork and find that workers in offices with windows spend more time working on computers than workers in offices without natural light. Because the visual system performs similarly well in both environments, the authors suggest that the reason for the observed difference is a better circadian

[1] In addition, White (2005) provides an intersting discussion on the establishment of time zones in the United States and Canada in 1883. He explains why this is a beautiful example of economic theory in action. The American time standardization was a private initiative, driven by economic interests of a small group of people (railroad managers), which had no legal force until 1918, and nevertheless changed a centuries-old social norm of local time.

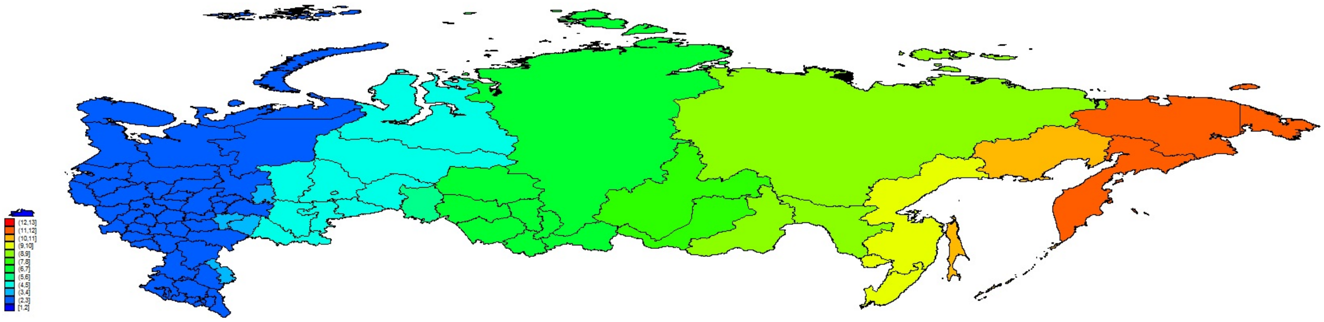
regulation when a human is exposed to daylight. Gibson and Shrader (2014) estimate the wage retutns to sleep, instrumented by sunset time, and find that a one-hour-later sunset decreases the short-run wages by 0.5% and long-run wages by 4.5%. The authors conclude from two-stage regressions that a later sunset leads to a shorter sleep which in turn harms wages. Recently, Doleac and Sanders (2015), Dmonguez and Asahi (2016), and Toro et al. (2016) use regression discontinuity around the day of DST transition to establish the effect of longer daylight on crime. Doleac and Sanders (2015) find a 7% decrease in robberies in the U.S. as a result of the additional hour of daylight, Dmonguez and Asahi (2016) report a large 18% decrease in overall crime in Chile, driven by decrease in robbery, and Toro et al. (2016) find a 14% decrease in homicide in Brasil.

The remainder of this paper proceeds as follows. Section 2 provides background on the reforms in the Russian time zones since 1995. Section 3 presents the empirical strategy and data. Section 4 is dedicated to the main empirical result, considering the Gross Regional Product (GRP). Section 5 presents the analysis of the possible mediating variables which may link time zones with GRP. Section 6 concludes.

2 Clock Reforms in Russia

Russia differs from any other country in the world by the very long distance between its eastern and western ends. The longitude of the capital of the most western of the Russian 85 regions, Kaliningrad Oblast, is 20.5° E. The longitude of the capital of the most eastern region, Chukotka, is 177.5° E. The difference is 157° which corresponds to 11 natural (nautical) time zones (each nautical time zone is 15° width). However, as many other countries do, Russia does not strictly implement its natural time zones. In fact, in the period between 1990 and 2015, out of 2,162 region-year cases, only in 196 (9%) the actual time zone in power during most of the year was equal to the natural one. Between 1995 and 2014, the number is only 20 out of 1,662, which constitutes 1% of the cases. Almost in all of the other cases the actual time zone was higher than the natural one. Between 1990 and 2015, in 52% of the cases the time zone was higher by one hour than the natural one, and in 38% of the cases it was higher by two hours (see Table 1; more details about the table compilation are provided in Section 3). To visually imagine the Russian actual time zones devision, Figure 1 shows the actual time zones as of August 1st, 2016.

Figure 1: Actual times zones in Russia as of August 1st, 2016



Russia differs from other countries also in the relatively frequent reforms with regard to its time zones. The time zones were introduced in 1919 and were expanded to the whole territory of the Soviet Union in 1924. The introduction of the time zones was followed by a long list of reforms which continues until the present. For example, in 1930, the Soviet government introduced "decree time". By this decree, all clocks in the Soviet Union were permanently shifted one hour ahead of standard time for each time zone. The daylight saving time was introduced only in 1981 and existed until 2011. Between 1981 and 1991, the Soviet government gradually eliminated the decree time but de-facto reintroduced it already in the end of 1991. The considerations in these and other reforms have been always a mix of geogrpahical and political ones. One example of political reasons is the 1995 time zone change in Altai Repuplic and Altai Krai, which was reasoned by economic dependence on a strong neighbor, Novosibirsk Oblast. Some reforms, such as the ones of 1919, 1930, 1991, 2011, and 2014 affected the whole country, while other reforms (such as the ones of 1947, 1957, 1981, 1995, 2010, and 2016) affected only a subset of regions.

Starting with 1957, many regions moved “back in time”, adopting a lower time zone. This policy change coincides with destalinization and may be related to a gradual withdraw from the "Stalin’s" decree time. Especially, the wish to have a more "western" clock was strong in 1991 when the Soviet Union collapsed following its democratization. One should remember that despite its definition as a federation, Russia is a very centralized country. Particularly, at any point in time, about 50 regions out of 85 have the same time zone as Moscow. Moreover, as stated in the president’s annual address to the parliament in 2009, the goal of the 2010 reform was to make the Russian distant regions "closer" to Moscow, which should improve the coordination between the local and the central governments. As a result of the reform, the number of regions with the Moscow time zone raised from 50 to 52 (and raised to 54 in 2014). The implementation of the 2010 reform led to some popular protest. Already in the following 2011, the reform was recognized as a failure and a different reform was initiated. This latter reform of 2011 moved the whole country one time zone up and eliminated the daylight saving time. The further reform of 2014 actually cancelled the one of 2011. Later, the reform of 2016 attempted to "correct" the one of 2014.

The current paper focuses on the period between 1995 and 2014. The following is the list of the clock reforms that took place during this period:

1. May 28, 1995 - Altai Krai and Altai Republic move from UTC+7 to UTC+6.

2. March 30, 1997 - Sakhalin Oblast moves from UTC+11 to UTC+10.

3. May 1, 2002 - Tomsk Oblast moves from UTC+7 to UTC+6.

4. March 28, 2010 - Russia reduces the number of its time zones from 11 to 9. Udmurt Republic and Samara Oblast move from UTC+4 to UTC+3. Kemerovo Oblast moves from UTC+7 to UTC+6. Chukotka and Kamchatka Krai move from UTC+12 to UTC+11.

5. August 31, 2011 - Russia eliminates the daylight saving time. The summer time that was in power in the summer of 2011 was declared to be the permanent time which means shifting one time zone up.

6. October 26, 2014 - The whole country except of seven regions moves one time zone down. Magadan Oblast and Zabaykalsky Krai move two time zones down. The five regions affected by the 2010 reform do not move.

7. March 27 to July 24, 2016 - a period which is not covered in the empirical analysis of the current paper - 9 regions move to a higher time zone: Astrakhan Oblast and Ulyanovsk Oblast move from UTC+3 to UTC+4. Altai Krai, Altai Republic, Novosibirsk Oblast, and Tomsk Oblast move from UTC+6 to UTC+7. Zabaykalsky Krai moves from UTC+8 to UTC+9. Magadan Oblast and Sakhalin Oblast move from UTC+10 to UTC+11.

In addition to these changes, on March 30, 2014, few days after annexation of Crimea and Sevastopol to Russia, the time zone in these two regions was changed from UTC+2 to UTC+4.[2]

[2]During the considered period, also minor changes in the administrative division of Russia took place.

Table 1: The distribution of the time zone bias (number of regions), 1990-2015

Year	-1	0	1	2	Total
1990	0	2	40	41	83
1991	2	38	39	4	83
1992	1	37	40	5	83
1993	0	1	41	41	83
1994	1	41	41	0	83
1995	0	1	43	39	83
1996	0	1	43	39	83
1997	0	1	44	38	83
1998	0	1	44	38	83
1999	0	1	44	38	83
2000	0	1	44	38	83
2001	0	1	44	38	83
2002	0	1	45	37	83
2003	0	1	45	37	83
2004	0	1	45	37	83
2005	0	1	45	37	83
2006	0	1	45	37	83
2007	0	1	45	37	83
2008	0	1	45	37	83
2009	0	1	45	37	83
2010	0	3	46	34	83
2011	0	3	46	34	83
2012	0	3	46	34	83
2013	0	3	46	34	83
2014	0	3	46	36	85
2015	1	47	37	0	85
Total	5	196	1,134	827	2,162
	0.2%	9.1%	52.5%	38.3%	100%

The time zones in power most of the year in the 85 Russian federal subjects and the listed above changes are summarized in a table in Appendix. Note that the time zone in power most of the year is not always the official time zone. Particulatly, until 2011 the summer time was in power for most of the year. In the table in Appenix, the columns represent the changes. Bold numbers show the regions affected by the reform (the time zone is different from the column to the left). Note that in some cases, the region shifts by two time zones. This happened in 2014 in Crimea and Sevastopol and later the same year in Magadan Oblast and Zabaykalsky Krai. In all other cases, the region shifts by one time zone.

3 Empirical Model and Data

3.1 Econometric model

The explanatory variable used in the empirical analysis is the bias of the actual zone from the natural (nautical) time zone. It means the deviation of sun's zenith (up to small deviations because of the Earth's uneven speed) from 12 am. That is

$$TZB_{it} = ATZ_{it} - NTZ_i$$

where TZB is the time zone bias of region (federal subject) i during most of the year t, ATZ is the actual time zone and NTZ is the nautical time zone. Because the whole Russia lies in the eastern hemisphere, the nautical time zone (relative to UTC) for Russian regions is defined as

$$NTZ_i = \lceil (longitute_i - 7.5)/15 \rceil$$

where I consider, as the region's longitute, the longitute of the region's capital city (which is almost always the region's by far largest city). Thus, the time zone bias is a descrete variable. Empirically, this variable receives the values of either -1, 0, 1, or 2 (see Table 1).

The empirical specification is

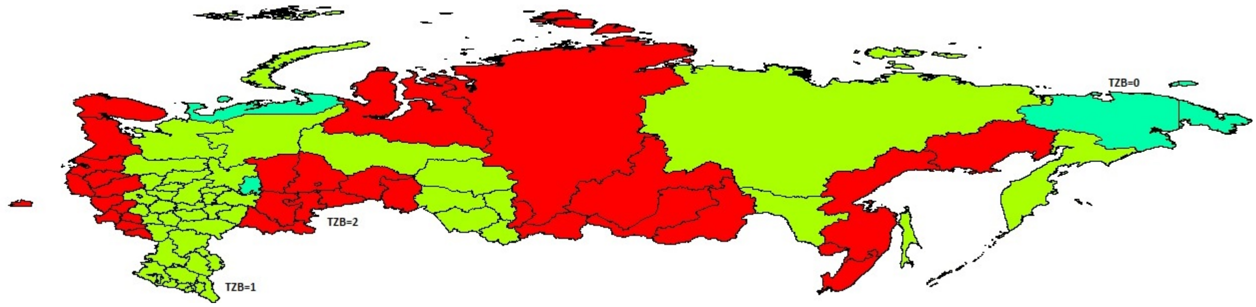
$$Y_{it} = \beta_0 + \beta_1 D^1_{it} + \beta_2 D^2_{it} + \beta_3 D^1_{i,t-j} + \beta_4 D^2_{i,t-j} + \beta_5 long_i + \beta_6 lat_i + \gamma_t + \delta_{it} + \varepsilon_{it} \tag{1}$$

where Y_{it} is the outcome in region i in year t, D^1 is a dummy for TZB=1 and D^2 is a dummy for TZB=2. $long$ and lat are, respectivelly, longitude and latitude of the region's capital. The lagged TZB effect after j years is captured by $D^1_{i,t-j}$ and $D^2_{i,t-j}$. The year fixed effect is γ_t and δ_{it} is the region-specific linear trend, consisting of a set of regional fixed effects and interaction terms between regional dummies and the year.

Note that the case of TZB=-1 is unified with the case of TZB=0 and together these two cathegories constitute the reference group in the regressions. The reason for this unificaiton is that the case of TZB=-1 is extremely rare, as follows from Table 1.

Figure 2 presents the map of TZB in 2014. It is noticable that the southern regions of Russia do not

Figure 2: The Time Zone Bias in Russia, 2014



provide the same level of variation in TZB as the northern regions. Table 2 shows the distribution of time zone bias across regions to the south and to the north of the median region during the 1990-2015 period. The median latitude is 54.5°. The case of zero TZB is similarly rare in both the south and the north. TZB of two hours is less prevalent in the south than in the north, but even in the south it accounts for one third of the cases. The problem is, however, that in southern regions there is not enough variation along time to identify all parameters of equation 1. To observe difference between the regions, the regressions are estimated for the whole country as well as separately for regions northern to the median one. The comparison between the "whole country" coefficients and "north" coefficients provides some evidence of the south-north differences.

It follows from the results section below that the estimated coefficients are stronger in the north than in the south for most outcomes. This is important for the interpretation of the results, because the importance of daylight in the north, where days are shorter for most of the year, should be more acute than in the south. Importantly, a similar segregation into "east" and "west" does not produce different coefficients. This is important for the external validity of the coefficients (keeping in mind that Russia is very "wide") but also for the identification because time zone bias should not be related to the region's longitude to be an exogenous variable. The issue of identification is further referred in section 5.8.

For all outcomes except of the gross regional product, the standard errors are clustered by region. For the gross regional product, however, it is not plausible to assume that year fixed effects absorb all of the correlation between the regions. Thus, error terms for the economic outcomes are clustered in two dimensions,

Table 2: The distribution of the time zone bias (number of regions), south and north of Russia (the threshold latitude is 54.5°)

	South				North				
Year	0	1	2	Total	-1	0	1	2	Total
1990	0	23	18	41	0	2	17	23	42
1991	21	17	3	41	2	17	22	1	42
1992	20	17	4	41	1	17	23	1	42
1993	0	22	19	41	0	1	19	22	42
1994	22	19	0	41	1	19	22	0	42
1995	0	24	17	41	0	1	19	22	42
1996	0	24	17	41	0	1	19	22	42
1997	0	25	16	41	0	1	19	22	42
1998	0	25	16	41	0	1	19	22	42
1999	0	25	16	41	0	1	19	22	42
2000	0	25	16	41	0	1	19	22	42
2001	0	25	16	41	0	1	19	22	42
2002	0	25	16	41	0	1	20	21	42
2003	0	25	16	41	0	1	20	21	42
2004	0	25	16	41	0	1	20	21	42
2005	0	25	16	41	0	1	20	21	42
2006	0	25	16	41	0	1	20	21	42
2007	0	25	16	41	0	1	20	21	42
2008	0	25	16	41	0	1	20	21	42
2009	0	25	16	41	0	1	20	21	42
2010	0	27	14	41	0	3	19	20	42
2011	0	27	14	41	0	3	19	20	42
2012	0	27	14	41	0	3	19	20	42
2013	0	27	14	41	0	3	19	20	42
2014	0	27	16	43	0	3	19	20	42
2015	26	17	0	43	1	21	20	0	42
Total	89	623	358	1,070	5	107	511	469	1,092
	8.3%	58.2%	33.5%	100%	0.5%	9.8%	46.8%	42.9%	100%

on both regional and yearly level.[3] The reason for clustering on the yearly level and not, let us say, use spatial correlation, is that in Russia correlation between regional economies is not neccessarily a decreasing function of the geographic distance. For example, economy of industrial centers (Russia is very strong in arms, and relatively strong in aircraft and cars industries) may depend on the energy prices which also affect the economy of mining-dominated regions. These relationships are not always related to the geographical distance between the regions.

3.2 Concept of credibility

Regression analyses often produce spurious coefficients which do not identify economic effects. To avoid reporting erratic coefficients, I make three robustness requirements and report only results which satisfy all three (with few exceptions). First, the coefficients of TZB should satisfy monotonicity in TZB, in the sense that if both are statistically significant than $\beta_1\beta_2 > 0$ and $|\beta_2| \geqslant |\beta_1|$. Similar properties are expected from the coefficients of lagged TZB. It means that the effect of TZB of two hours is in the same direction and not weaker than the effect of TZB of one hour. Second, the results should be robust to excluding post-2011 period when daylight saving time was eliminated. Thus, the results should be externally valid in the sense that they can be interpreted also in a setup without daylight saving time (currently, about 70 countries implement daylight saving time while others do not). Third, to be reported the coefficients should be of reasonable magnitude.

3.3 Data

The data source in this research is the annual reports "Regions of Russia: socio-economic outcomes" published by the Federal State Statistics Service of Russian Federation (Rosstat). The annual reports cover a wide range of topics and data is aggregated on the regional level. The considered perios is 1995-2014. I select a list of variables of interest: gross regional product (GRP) per capita, agricultural product, number of homicide cases, consumption of different types of food, health outcomes (rate of new cases of different diseases), labor force participation, and leisure (rate of visits to museums).

[3] To this end, I use the STATA command cluster2, developed by Mitchell A.Petersen.

Because the Rosstat data is annual, the considered time zone is the one which was in force during most of the year. In other words, in absence of the dayligh saving time, if a reform took place before June 1st of a year, I consider the post-reform time zone for this year. Similarly, if a reform took place after June 1st, I consider the pre-reform time zone. Furthermore, until 2011, Russia used to have the daylight saving time. The time zone was changed twice a year - on the last Sunday of March (a shift of one time zone up) and October (a shift of one time zone down; the last Sunday of September until 1996). Thus, seven months a year the country lived in a summer time. Therefore, the time zone that I use in my estimation for the 1995-2011 period is the one of the summer time which is one time zone higher than the official time zone. Summary statistics of the Rosstat data are found in Table 3.

It may seem natural to consider also educational outcomes, such as school grades. The relationship between time zones on the one hand and sleep and exposure to daylight on the other suggests a potential effect of the clock on performance in school. However, educational outcomes are excluded by purpose. Russian data on educational achievements is suggestively unreliable. There is plenty of anecdotical evidence that school grades in Russia are manipulated by teachers in order to satisfy the "improvement" requirements, imposed by authorities. Some anecdotical evidence tells that even if a teacher "rebels" and grades the student according to performance, the grade is later "corrected" by the school management. In a recent disturbing story, two girls were expelled from a high school in eastern Russia because of cancer treatments they had to overgo which affected their absenteeism. The school authorities told the parents that the girls "harm the school's achievements". The facts behind the story were later confirmed.[4] Another issue is plagialism. Recently, Rostovtsev and Kostinskiy (2016) discuss the impact of fake degrees and plagialism on the reported statistics of high education in Russia. Importantly, the authors claim that the government backs this practice.

Finally, I analyze homicide, but not robbery and rape. The reason to exclude rape is that the reported by Rosstat numbers are suspiciously low. For example, Rosstat reports that in 2010 the rape rate in Russia was 3.4 per 100,000 inhabitants. This is almost ten times lower than in the United States and almost twenty times lower than in Sweden. Moreover, differently from any other developed country, the reported rape rate is three times lower than the homicide rate. In addition, robbery rate, although it is the issue in some related papers (Doleac and Sanders (2015), Dmonguez and Asahi (2016)), is missing from the results below because

[4]See https://m.lenta.ru/news/2016/10/12/cancer/ and https://lenta.ru/news/2016/10/18/perm/.

Table 3: Summary statistics

variable		N	mean	st. dev.	min	max
year		1785			1995	2015
longitude of the region's capital		1785	60.73842	34.57395	20.5	177.5167
latitude of the region's capital		1785	53.75259	5.856476	42.98491	68.96957
log agricultural product in millions of nominal rubles		1616	9.120652	1.444097	3.465736	12.56556
log GRP per capita in millions of nominal rubles		1519	10.98628	1.286028	7.537803	15.20264
log homicide		1659	5.293975	0.9706451	1.386294	7.466799
log visits to museums per 1000 pop.		1655	5.7644	0.7812318	1.386294	8.410721
log of consumption per capita in kg	bread	1580	4.77769	0.1396036	4.077538	5.141664
	eggs	1585	5.403442	0.2953713	3.135494	5.996452
	meat	1589	4.013108	0.2574669	3.044523	4.736198
	milk	1583	5.412141	0.2587714	4.060443	5.976351
	oil	1584	2.335849	0.2822611	1.458615	3.242592
	potato	1585	4.776481	0.3674355	3.091043	5.746203
	sugar	1586	3.576031	0.2078433	2.995732	4.094345
log of consumption per capita in litres	beer	1435	3.757375	.7162723	-4.60517	5.334167
	likeurs	1434	2.362047	0.5948376	-4.60517	3.703768
	wine	1432	1.790403	.6025977	-4.60517	2.960105
log of new cases per 1000 of population	birth defects	1214	0.5411331	0.5431624	-1.203973	2.397895
	endocrine system deseases	1373	2.256102	0.4157219	0.3364722	4.021774
	eye deseases	1214	3.49949	0.3274428	1.88707	4.561218
	nervous system deseases	1373	2.877043	0.5641608	1.308333	4.530447
	skin deseases	1373	3.859617	0.253835	2.433613	4.689511
	total disease	1601	6.599674	0.2214197	5.004617	7.468513
labor force participation	all	1076	66.92351	4.33581	40.5	89.6
	men	1075	72.18651	4.257268	46.7	85.4
	women	1075	62.15516	4.653978	35.2	82.2
	rural	1049	64.47426	5.062793	39.8	79.6
	urban	1075	67.7214	4.419871	40	86.7

the estimated effect of TZB does no satisfy the credibility conditions defined in 3.2.

4 The results for Gross Regional Product

Table 4 presents the estimation results for the per capita gross regional product (GRP). The gross regional product per capita is dynamically positively related to TZB. While the actual TZB=1 is associated with a 10% larger GRP, this coefficient may be spurious because it is not monotonic in TZB. However, the lagged effect is robust. TZB=1 five years earlier is associated with a 5% larger GRP with effect of 11% for TZB=2 (in the whole country regression). In the north, the coefficients are, respectivelly, 7% and 14%. This is an

Table 4: Regression results - log GRP per capita

	whole country				north			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TZB=1	0.108*	0.106*	0.105*	0.0529	0.0762	0.0752	0.0733	0.0318
	(0.0601)	(0.0570)	(0.0600)	(0.0732)	(0.0692)	(0.0632)	(0.0687)	(0.0879)
TZB=2	0.0442	0.0366	0.0419	-0.00435	-0.0581	-0.0653	-0.0487	-0.0541
	(0.0828)	(0.0802)	(0.0783)	(0.121)	(0.120)	(0.104)	(0.112)	(0.185)
TZB 3 years ago=1		0.0204				0.0276		
		(0.0307)				(0.0599)		
TZB 3 years ago=2		0.0526				0.0721		
		(0.0538)				(0.108)		
TZB 5 years ago=1			0.0536**				0.0704**	
			(0.0264)				(0.0338)	
TZB 5 years ago=2			0.117**				0.141**	
			(0.0478)				(0.0667)	
TZB 10 years ago=1				-0.0103				0.00443
				(0.0259)				(0.0236)
TZB 10 years ago=2				-0.0138				0.00962
				(0.0498)				(0.0407)
Observations	1,519	1,519	1,519	1,203	750	750	750	594

Robust (clustered by region and year) standard errors in parentheses.

All regressions include controls for longitude and latitude, year fixed effects, and regional linear trend.

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

example of a monotonic (almost linear) relationship between lagged TZB and the outcome, which is one of the requirements mentioned in section 3.2. Let us make a back-of-the-envelope calculation to evaluate the total effect on Russian GDP if TZB in all regions would be two hours. In 2014, 1% of Russian population lived in regions where TZB was zero. 61% lived in regions where TZB was one hour and 38% lived in regions where TZB was two hours. The results mean that if, hypothetically, the whole country would be shifted to TZB of two hours in 2014, the Russian GDP should grow by 4% by 2019. Note that this is not a general equilibrium effect and may be actually a lower bound estimate.

5 Channels

5.1 Theoretical considerations

The results in Section 4 imply a larger economy with a later clock. What are the channels that may link clock to the productivity of the economy? Let the production function of the economy be of the form

$$Y = f(\tau \cdot H \cdot L) \tag{2}$$

where τ is a parameter that determines how good the clock fits the human psychology and physiology. For example, have the workers to go to work in darkness? Whereas going to work in darkness matters for productivity, it should be captured in τ. The efficiency of each unit of labor is H which is determined by the workers' skills and health. The amount of labor is L, which is determined by the labor force participation and working hours.

The clock may affect the productivity by changes in τ if, for example, a later sunset or sunrise make the agricultural workers more productive by a better fit of their schedule and the one of nature. The clock may affect H by a better health of workers. In the long term, it may also affect through better educational achievements if they depend on sunrise and sunset timing. Finally, the clock may affect L if it impacts the labor force participation or working hours. Using Rosstat data it is possible to test at least some of these channels. Further, I test the relationship between time zone bias and agricultural product (which may imply effect of the clock on τ). I also estimate the effect of TZB on health by considering the rate of new cases of different types of desease, consumption of different foods, and consumption of alcohol. Additionally, I consider the effect of TZB on homicide rate, labor force participation, and leisure (rate of visits to museums).

5.2 Agriculture

Let us first test the effect of TZB on τ in Equation (2). This parameter measures the goodness of fit between the man and the nature. The major sector of industry where humans and nature are involved is agriculture. Many agricultural workers around the world wake up at unusual for humans hours. Table 5 presents the estimation results of Equation (1) for the agricultural product. The regression for the whole country does not

Table 5: Regression results - log of agricultural product

	whole country				north			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TZB=1	-0.0510	-0.0401	-0.0510	0.213	-0.00912	0.0219	0.00339	0.263
	(0.120)	(0.111)	(0.121)	(0.171)	(0.151)	(0.139)	(0.157)	(0.213)
TZB=2	-0.0846	-0.0549	-0.0838	0.205	-0.00821	0.0430	-0.00628	0.308
	(0.164)	(0.154)	(0.166)	(0.196)	(0.173)	(0.163)	(0.182)	(0.255)
TZB 3 years ago=1		-0.0539				-0.124		
		(0.0563)				(0.0766)		
TZB 3 years ago=2		-0.128				-0.228**		
		(0.0858)				(0.111)		
TZB 5 years ago=1			-0.0325				-0.113**	
			(0.0459)				(0.0539)	
TZB 5 years ago=2			-0.0874				-0.183**	
			(0.0783)				(0.0769)	
TZB 10 years ago=1				-0.0139				0.0106
				(0.0376)				(0.0647)
TZB 10 years ago=2				0.00746				0.0553
				(0.0490)				(0.0735)
Observations	1,616	1,616	1,616	1,296	803	803	803	643

Robust (clustered by region and year) standard errors in parentheses.
All regressions include controls for longitude and latitude, year fixed effects, and regional linear trend.
*** p<0.01, ** p<0.05, * p<0.1

show a statistically significant relationship between TZB and log of the agricultural product. However, in the north of the country, lagged positive TZB is associated with a lower agricultural product. Particularly, TZB of one hour 3 or 5 years earlier is associated with a 11% lower agricultural product in the north of Russia and the effect almost doubles when the lagged TZB is two hours. This is an example of a monotonic (actually, linear) relationship between lagged TZB and the outcome, which is one of the robustness requirements mentioned in section 3.2. Thus, the positive relationship between TZB and GRP, presented in Table 4 is not explained by a better productivity in agriculture when sunrise and sunset occur later.

5.3 Food consumption and health

Tables 6 and 7 present the regression results when the dependent variables are logged per capita consumption (in kg) of different food ingredients. Tables 8 and 9 present the regression results when the dependent variables are logged number of new cases (per 1000 of population) of different diseases. Generally, consumption of unhealthy food decreases with TZB, and the lagged effect is especially notable. First, bread consumption decreases with the lagged TZB and differently from most effects reported in this paper, this coefficient is driven by the south and not by the north of Russia. The curent TZB is not associated with bread consumption. In the whole country, TZB=1 three years earlier is associated with a 3% decrease in bread consumption, while TZB=2 is associated with a 6% decrease. TZB=1 five years earlier leads to a 4% decrease in bread consumption and TZB=2 leads to a 8% decrease. No statistically significant relationship is observed in the north. Second, the consumption of eggs is 15% lower when the current TZB=1 and a similar effect is observed when TZB=2. The lagged TZB does not affect eggs consumption. Eggs consumption is a clear example of monotonicity of the effect in TZB. Third, sugar consumption in the north responds to the clock with a 6% decrease for each hour of TZB five years earlier. Fourth, the consumption of meat is suggestively lower as a function of the current TZB (4% decrease in the north for TZB=1; the coefficient for TZB=2 is not statistically significant). Regarding potato consumption, no statistically significant effects are observed, but all coefficients are negative.

Health outcomes (Tables 8 and 9) plot ambiguous results. First, we observe a very strong positive relationship between TZB and birth defects. The current TZB=1 is associated with a 0.22 log point increase in birth defects while TZB=2 leads to a 0.38 log point increase. The three-year-earlier TZB=1 adds 0.34 log point while TZB=2 adds 0.64 log point. The endocrine system disease is 0.16 log point less prevalent when TZB five years earlier was one and 0.22 log point lower when TZB was two Regarding skin desease in the north, the coefficient for TZB=1 five years earlier is 0.1 and is not statistically significant, but for TZB=2 it is statistically significant and equals 0.235. This almost linear monotonicty draws a suggestive evidence of a positive relationship between lagged TZB and skin desease which makes sense because a higher TZB means a longer daylight. Finally, new cases of desease in general are 5% more frequent in the north when TZB five years earlier was one and 12% when TZB five years earlier was two.

5.4 Alcohol

Table 10 presents the regression results for different types of alcoholic beverages when the dependent variable is log of the per capita consumption in litres. The results show that TZB of one is associated with a 0.16 log points decrease in the consumption of beer in the north, while TZB of two gives additional 5 log points

Table 6: Regression results - food consumption

	log per capita consumption (kg)							
	whole country				north			
	bread	eggs	oil	sugar	bread	eggs	oil	sugar
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TZB=1	-0.0150**	-0.149***	-0.0350	-0.0167	-0.00922	-0.147***	-0.0613	-0.0236
	(0.00719)	(0.0384)	(0.0561)	(0.0142)	(0.00994)	(0.0428)	(0.0528)	(0.0217)
TZB=2	-0.0233	-0.126	-0.0412	0.00594	0.0181	-0.148*	-0.134*	-0.00371
	(0.0229)	(0.0972)	(0.0724)	(0.0232)	(0.0399)	(0.0799)	(0.0730)	(0.0262)
TZB 5 years ago=1	-0.0453**	0.0169	0.0110	-0.00506	-0.0363	-0.0622	-0.000840	-0.0612**
	(0.0201)	(0.0328)	(0.0449)	(0.0257)	(0.0350)	(0.0617)	(0.0209)	(0.0259)
TZB 5 years ago=2	-0.0843**	0.00241	0.0648	-0.0207	-0.0617	-0.139	0.0430	-0.111**
	(0.0391)	(0.0600)	(0.0868)	(0.0468)	(0.0689)	(0.120)	(0.0305)	(0.0457)
Observations	1,580	1,585	1,584	1,586	770	775	774	776

Robust (clustered by region) standard errors in parentheses.
All regressions include controls for longitude and latitude, year fixed effects, and regional linear trend.
*** p<0.01, ** p<0.05, * p<0.1

Table 7: Regression results - food consumption (cont.)

	log per capita consumption (kg)					
	whole country			north		
	meat	milk	potato	meat	milk	potato
	(1)	(2)	(3)	(4)	(5)	(6)
TZB=1	-0.0267**	-0.122	-0.116	-0.0401***	-0.124	-0.0887
	(0.0110)	(0.0997)	(0.0858)	(0.0141)	(0.0984)	(0.0839)
TZB=2	-0.0659	-0.208	-0.0713	-0.121	-0.290	-0.0811
	(0.0677)	(0.129)	(0.116)	(0.0948)	(0.172)	(0.0880)
TZB 5 years ago=1	-0.000873	0.0132	-0.00953	0.0272	0.0147	-0.00349
	(0.0232)	(0.0281)	(0.0245)	(0.0269)	(0.0241)	(0.0520)
TZB 5 years ago=2	0.00477	0.0245	0.0141	0.0542	0.0397	0.0276
	(0.0441)	(0.0563)	(0.0369)	(0.0478)	(0.0466)	(0.0950)
Observations	1,589	1,583	1,585	779	773	775

Robust (clustered by region) standard errors in parentheses.
All regressions include controls for longitude and latitude, year fixed effects, and regional linear trend.
*** p<0.01, ** p<0.05, * p<0.1

Table 8: Regression results - health

	log of new cases per 1000 of population					
	whole country			north		
	birth defects	endocrine sys. disease	eye disease	birth defects	endocrine sys. disease	eye disease
	(1)	(2)	(3)	(4)	(5)	(6)
TZB=1	0.222***	0.126	0.240	0.206***	0.0957	0.264
	(0.0431)	(0.145)	(0.288)	(0.0510)	(0.126)	(0.293)
TZB=2	0.376***	0.224	0.299	0.493***	0.352*	0.285
	(0.103)	(0.175)	(0.298)	(0.0662)	(0.202)	(0.303)
TZB 3 years ago=1	0.344***	-0.0870	0.369	0.356***	0.0786	0.368
	(0.0321)	(0.0977)	(0.364)	(0.0393)	(0.146)	(0.370)
TZB 3 years ago=2	0.637***	-0.0948	0.356	0.658***	0.134	0.302
	(0.147)	(0.145)	(0.366)	(0.235)	(0.277)	(0.373)
TZB 5 years ago=1		-0.158*			-0.0778	
		(0.0880)			(0.109)	
TZB 5 years ago=2	-0.110	-0.223*	0.247	0.143*	0.0436	0.529***
	(0.146)	(0.130)	(0.165)	(0.0726)	(0.229)	(0.0601)
Observations	1,214	1,373	1,214	603	681	603

Robust (clustered by region) standard errors in parentheses.
All regressions include controls for longitude and latitude, year fixed effects, and regional linear trend.
*** p<0.01, ** p<0.05, * p<0.1

Table 9: Regression results - health (cont.)

	log of new cases per 1000 of population					
	whole country			north		
	nervous sys. disease	skin disease	total disease	nervous sys. disease	skin disease	total disease
	(1)	(2)	(3)	(4)	(5)	(6)
TZB=1	0.263	0.0182	0.00903	0.266	-0.00189	0.00345
	(0.270)	(0.0450)	(0.0483)	(0.272)	(0.0567)	(0.0436)
TZB=2	0.310	-0.0157	-0.0287	0.234	0.0380	0.0288
	(0.281)	(0.0732)	(0.0622)	(0.286)	(0.0931)	(0.0436)
TZB 3 years ago=1	-0.000137	-0.00447	-0.0329	-0.0142	0.0606	0.0442
	(0.0703)	(0.0520)	(0.0277)	(0.120)	(0.0709)	(0.0344)
TZB 3 years ago=2	-0.00479	-0.0662	-0.0510	-0.0368	0.0747	0.0918
	(0.114)	(0.0828)	(0.0443)	(0.267)	(0.124)	(0.0655)
TZB 5 years ago=1	-0.0989	0.0529	-0.00609	-0.0947	0.101	0.0548***
	(0.151)	(0.0449)	(0.0215)	(0.163)	(0.0719)	(0.0202)
TZB 5 years ago=2	-0.206	0.103	-0.0148	-0.218	0.235**	0.119***
	(0.159)	(0.0662)	(0.0295)	(0.161)	(0.105)	(0.0400)
Observations	1,373	1,373	1,601	681	681	789

Robust (clustered by region) standard errors in parentheses.
All regressions include controls for longitude and latitude, year fixed effects, and regional linear trend.
*** p<0.01, ** p<0.05, * p<0.1

Table 10: Regression results - alcohol consumption

	log per capita consumption (litres)					
	whole country			north		
	beer	likeurs	wines	beer	likeurs	wines
	(1)	(2)	(3)	(5)	(6)	(7)
TZB=1	-0.0474	0.110	0.0825	-0.155**	0.0908	0.177
	(0.0850)	(0.0874)	(0.0932)	(0.0670)	(0.135)	(0.115)
TZB=2	-0.0433	0.216	0.111	-0.208**	0.228	0.296
	(0.146)	(0.142)	(0.163)	(0.0926)	(0.251)	(0.204)
TZB 5 years ago=1	-0.143	0.113	0.156	-0.148	0.0985	0.384**
	(0.121)	(0.0822)	(0.161)	(0.152)	(0.209)	(0.169)
TZB 5 years ago=2	-0.268	0.132	0.267	-0.247	0.175	0.676**
	(0.217)	(0.143)	(0.296)	(0.288)	(0.410)	(0.299)
Observations	1,435	1,434	1,432	717	717	717

Robust (clustered by region) standard errors in parentheses.
All regressions include controls for longitude and latitude, year fixed effects, and regional linear trend.
*** p<0.01, ** p<0.05, * p<0.1

of decrease. However, no relationship is observed with regard to likeurs. With regard to wines, there is no immediate relationship but a lagged increase of 0.38 log points in the north for TZB=1 and 0.68 log points for TZB=2. The difference between beer, likeurs, and wine may be related to the different social circumstances in which these beverages are consumed.

5.5 Homicide

Table 11 shows the relationship between TZB and the logged number of homicide events in the region. TZB=1 is associated with a 0.2 log point (18%) lower rate of crime in the whole country and in the north. However, for TZB=2 the coefficient is not statistically significant. This is a violation of the monotonicity requirement. Nevertheless, the results are reported because the estimated effect is of the same magnitude as the existing estimates derived with Brasilian data (Toro et al. (2016)).

Table 11: Regression results - homicide

	log homicide	
	whole country	north
	(1)	(2)
TZB=1	-0.196**	-0.209**
	(0.0966)	(0.0992)
TZB=2	-0.112	-0.252
	(0.133)	(0.201)
TZB 3 years ago=1	-0.00101	-0.0346
	(0.0581)	(0.0531)
TZB 3 years ago=2	-0.0286	-0.0993
	(0.108)	(0.100)
TZB 5 years ago=1	-0.0279	-0.126
	(0.0701)	(0.103)
TZB 5 years ago=2	-0.0576	-0.249
	(0.129)	(0.202)
Observations	1,659	840

Robust (clustered by region) standard errors in parentheses.
All regressions include controls for longitude and latitude,
year fixed effects, and regional linear trend.
*** p<0.01, ** p<0.05, * p<0.1

Table 12: Regression results - Labor force participation

	all	men	women	rural	urban
	(1)	(2)	(3)	(4)	(5)
TZB=1	0.0116***	0.0112***	0.00936	0.00335	0.0124***
	(0.00382)	(0.00351)	(0.00830)	(0.00600)	(0.00307)
TZB=2	0.0219*	0.0226**	0.0146	0.0367***	0.0148
	(0.0127)	(0.0112)	(0.0157)	(0.0116)	(0.0129)
Observations	1,076	1,075	1,075	1,049	1,075

Robust (clustered by region) standard errors in parentheses.
All regressions include controls for longitude and latitude, year fixed effects, and regional linear trend.
*** p<0.01, ** p<0.05, * p<0.1

5.6 Labor force participation

The amount of labor directly affects productivity, as captured by L in Equation (2). In Table 12, I estimate the effect of TZB on labor force participation. Overall, the labor force participation increases by one percentage point for each hour of TZB. This effect is driven by increased participation of men. For TZB=1 the increased participation is more prevalent in urban areas, while for TZB=2 it is more prevalent in rural ones.

5.7 Leisure

Table 13 shows the effect of TZB and lagged TZB on logged rate of visits to museums per 1,000 of population. Only the current TZB is associated with a larger rate of visits to museum. However, the effect is strong and monotonic: 0.3 log point increase for TZB=1 and 0.39 log point increase for TZB=2. The difference between the whole country and the north is only for TZB=2 where the north has a coefficient of 0.49, a 0.1 log point stronger relationship than the whole country.

5.8 Identification tests

Balance regression

Are the clock reforms in Russia indeed exogenous to the analyzed above outcomes? In Table 14, I regress the dummy for change in TZB versus previous year on the outcomes (one by one) one and two years earlier.

Table 13: Regression results - Visits to museums

	log number of visits to museums per 1000 population	
	whole country	north
	(1)	(3)
TZB=1	0.295***	0.294***
	(0.0641)	(0.0669)
TZB=2	0.387***	0.493***
	(0.103)	(0.142)
TZB 3 years ago=1	-0.0430	0.00187
	(0.0750)	(0.0945)
TZB 3 years ago=2	-0.0267	0.0222
	(0.130)	(0.173)
TZB 5 years ago=1	0.0449	0.0637
	(0.0723)	(0.121)
TZB 5 years ago=2	0.119	0.179
	(0.131)	(0.239)
Observations	1,655	840

Robust (clustered by region) standard errors in parentheses.
All regressions include controls for longitude and latitude,
year fixed effects, and regional linear trend.
*** p<0.01, ** p<0.05, * p<0.1

Because all shifts in TZB during the 1995-2015 period are downward (see the table in Appendix A) there is no need to separate reforms into "upward" and "downward" ones. All regressions include year and region fixed effects. Out of 2x21=42 coefficients only 3 are statistically significant (on 10% level). Thus, the hypothesis that the reforms are not correlated with the outcomes can not be rejected.

Distance and time difference from Moscow

But perhaps TZB is just a function of longitude? In this case, the results are not driven by the TZB but by the correlated with TZB distance or time difference from some geographical location. To rule out this concern, all regressions in the results section control for longitude and latitude as follows from Equation 1. Furthermore, estimating the regressions separately for "east" and "west" does not show major differences between coefficients (differently from estimating for "north" versus the whole country). But to finally rule out the concern, I consider the distance from a single location as an alternative channel. The natural location to consider is Moscow. Table 15 reports the correlation coefficients of the different time zone bias dummies with

Table 14: Balance test

	Dependent variable: a dummy for time zone change					
	(1)	(2)	(3)	(4)	(5)	
	log agr. product	log GRP per cap.	log homicide	log bread	log eggs	
x (year - 1)	-0.0213	0.0156	0.00301	-0.00468	-0.0249	
	(0.0158)	(0.0242)	(0.0147)	(0.0662)	(0.0355)	
x (year - 2)	0.0222	-0.0520**	-0.00130	-0.0347	0.0225	
	(0.0155)	(0.0233)	(0.0147)	(0.0641)	(0.0327)	
Observations	1,532	1,436	1,573	1,498	1,503	
	(6)	(7)	(8)	(9)	(10)	
	log meat	log milk	log oil	log potato	log sugar	
x (year - 1)	0.0227	-0.0271	0.00265	-0.0152	0.0100	
	(0.0589)	(0.0457)	(0.0396)	(0.0267)	(0.0527)	
x (year - 2)	-0.0381	-0.0392	0.0141	0.0204	-0.0157	
	(0.0589)	(0.0454)	(0.0395)	(0.0256)	(0.0512)	
Observations	1,507	1,500	1,502	1,503	1,504	
	(11)	(12)	(13)	(14)	(15)	(16)
	log birth defects	log endocrine	log eye	log nervous	log skin	log total disease
x (year - 1)	-0.00219	-0.00384	0.00526	-0.0326*	-0.00972	0.0527
	(0.0160)	(0.0219)	(0.0185)	(0.0189)	(0.0337)	(0.0400)
x (year - 2)	0.0232	0.0135	0.0143	0.0479***	0.0129	-0.0449
	(0.0156)	(0.0210)	(0.0183)	(0.0181)	(0.0333)	(0.0402)
Observations	1,126	1,126	1,126	1,126	1,126	1,515
	(17)	(18)	(19)	(20)	(21)	
	log museums	log beer	log likeurs	log wine	lfp	
x (year - 1)	0.00717	-0.0331**	-0.0149	-0.00578	0.0527	
	(0.0114)	(0.0153)	(0.0176)	(0.0139)	(0.0400)	
x (year - 2)	-0.00838	0.0190	0.0172	0.0100	-0.0449	
	(0.0115)	(0.0148)	(0.0179)	(0.0136)	(0.0402)	
Observations	1,571	1,236	1,264	1,263	1,515	

The regressions are linear probability models.

All regressions include year and region fixed effects. *** p<0.01, ** p<0.05, * p<0.1

Table 15: Correlation of the time zone bias with geographical distance from Moscow and time difference from Moscow

	TZB=-1	TZB=0	TZB=1	TZB=2
Distance from Moscow	-0.0058	0.0185	-0.1959	0.1905
Time difference from Moscow	-0.0152	-0.0296	-0.2613	0.2770

geogrpahical distance and time difference from Moscow. The close-to-zero correlation of TZB=-1 dummy can be ignored as it is driven by a single data point. The correlation of TZB=0 dummy is also close to zero. It implies that regions where the actual time zone equals the natural one are randomly located on the map (at least for the 1995-2015 period). The correlation coefficients of TZB=1 and TZB=2 with the distance and time difference from Moscow are not negligible but have an opposite sign. The TZB=1 dummy is negatively correlated with distance and time difference from Moscow. It implies that regions close to Moscow tend to have a one hour time zone bias. However, the TZB=2 dummy has positive correlation with distance and time difference from Moscow, of the same magnitude as the opposite correlation of TZB=1. Would the regression results be driven by distance or time difference from Moscow, the signs of the regression coefficients should be non-monotonic in TZB. But they are monotonic as this is one of the robustness requirements mentioned in Section 3.2 - to be reported, the effect for TZB=2 should be with the same sign and not weaker than the effects for TZB=1. Thus, the concern is turned out.

6 Concluding remarks

This is an empirical study providing evidence of the relationship between the clock and the economy. Let us summarize the main results and figure out possible links suggesting directions for future investigation.

First, clock matters and it matters for a wide spectrum of outcomes. Moreover, I find that shifting the clock two hours beyond the sun (time zone bias of two hours) leads to good effects on most of the outcomes. Because all the shifts in Russian time zones during the considered period were downward, away from TZB of two hours, these results suggest that the clock policy in this country is suggestively not optimal. Second, the effects should be discriminated as immediate and structural ones. Some effects of the daylight are immediate such as in the case of homicide and visits to museums, where only the current time zone makes the difference but the difference is large. For most economic outcomes, the effect is structural. Only with a five-year lag the economy in the northern regions gains 7% of output from an additional hour of daylight. The decreased agricultural output as a function of the time zone five years earlier implies an indeed structural effect of the clock on the economy. On the other hand, the labor force participation immediately increases once the TZB is high. Recall the Russian government's argument that a time zone scheme is related to governability. If this is true, the net effect of a high time zone in a smaller country where distances between regions are short should be actually higher than the one estimated in Russia. In a small country the governability factor does not play a role and should not counterbalance the positive effect of the time zone bias.

The effects on health and nutrition are ambigious. The results imply that the consumption of unhealthy foods (eggs, sugar) decreases with a longer daylight with a few years delay. The endocrine system deseases become less frequent. However, some health problems appear, such as a higher rate of birth deffects. Especially disturbing are the health effects of high TZB in the north of Russia.

Considering the results where intuitive immediate effects coincide with intriguing structural ones guides toward possible research proceedings. The natural next step would be to estimate the general equilibrium effect of TZB.

To recall what the paper starts with, understanding the consequences of the decision to set a specific time zone should ease (but may also complicate) the public discussion of what is the optimal clock for the country.

Appendix

Changes in time zones, in power most of the year, in Russian federal subjects, 1995-2015

Region (Federal Subject)	natural time zone	1995	1997	2002	2010	2014	2015
Altay Kray		7	7	7	7	7	**6**
Amur Oblast		10	10	10	10	10	**9**
Arkhangelsk Oblast		4	4	4	4	4	**3**
Astrakhan Oblast		4	4	4	4	4	**3**
Belgorod Oblast		4	4	4	4	4	**3**
Bryansk Oblast		4	4	4	4	4	**3**
Vladimir Oblast		4	4	4	4	4	**3**
Volgograd Oblast		4	4	4	4	4	**3**
Vologda Oblast		4	4	4	4	4	**3**
Voronezh Oblast		4	4	4	4	4	**3**
Jewish Autonomous Oblast		11	11	11	11	11	**10**
Zabaykalsky Kray		10	10	10	10	10	**8**
Ivanovo Oblast		4	4	4	4	4	**3**
Irkutsk Oblast		9	9	9	9	9	**8**
Kabardin-Balkar Republic		4	4	4	4	4	**3**
Kaliningrad Oblast		3	3	3	3	3	**2**
Kaluga Oblast		4	4	4	4	4	**3**
Kamchatka Kray		13	13	13	**12**	12	12
Karachay-Cherkess Republic		4	4	4	4	4	**3**
Kemerovo Oblast		8	8	8	**7**	7	7
Kirov Oblast		4	4	4	4	4	**3**
Kostroma Oblast		4	4	4	4	4	**3**
Krasnodar Kray		4	4	4	4	4	**3**
Krasnoyarsk Kray		8	8	8	8	8	**7**
Kurgan Oblast		6	6	6	6	6	**5**
Kursk Oblast		4	4	4	4	4	**3**
Leningrad Oblast		4	4	4	4	4	**3**
Lipetsk Oblast		4	4	4	4	4	**3**
Magadan Oblast		12	12	12	12	12	**10**
Moscow City		4	4	4	4	4	**3**
Moskva Oblast		4	4	4	4	4	**3**
Murmansk Oblast		4	4	4	4	4	**3**
Nenets Avtonomnyy Okrug		4	4	4	4	4	**3**
Nizhegorod Oblast		4	4	4	4	4	**3**
Novgorod Oblast		4	4	4	4	4	**3**
Novosibirsk Oblast		7	7	7	7	7	**6**
Omsk Oblast		7	7	7	7	7	**6**
Orenburg Oblast		6	6	6	6	6	**5**
Orel Oblast		4	4	4	4	4	**3**
Penza Oblast		4	4	4	4	4	**3**
Perm Kray		6	6	6	6	6	**5**
Primorye Kray		11	11	11	11	11	**10**
Pskov Oblast		4	4	4	4	4	**3**

Region (Federal Subject)	1995	1997	2002	2010	2014	2015
Adygey Republic	4	4	4	4	4	**3**
Altay Republic	7	7	7	7	7	**6**
Bashkortostan Republiclika	6	6	6	6	6	**5**
Buryat Republic	9	9	9	9	9	**8**
Dagestan Republic	4	4	4	4	4	**3**
Ingush Republiclika	4	4	4	4	4	**3**
Kalmyk Republic	4	4	4	4	4	**3**
Karelia Republic	4	4	4	4	4	**3**
Komi Republic	4	4	4	4	4	**3**
Crimea					**4**	**3**
Mariy-El Republic	4	4	4	4	4	**3**
Mordovia Republic	4	4	4	4	4	**3**
Sakha Republic	10	10	10	10	10	**9**
North Ossetia Republic	4	4	4	4	4	**3**
Tatarstan Republic	4	4	4	4	4	**3**
Tuva Republic	8	8	8	8	8	**7**
Khakass Republic	8	8	8	8	8	**7**
Rostov Oblast	4	4	4	4	4	**3**
Ryazan Oblast	4	4	4	4	4	**3**
Samara Oblast	5	5	5	**4**	4	**4**
St. Petersburg	4	4	4	4	4	**3**
Saratov Oblast	4	4	4	4	4	**3**
Sakhalin Oblast	12	**11**	11	11	11	**10**
Sverdlovsk Oblast	6	6	6	6	6	**5**
Sevastopol					**4**	**3**
Smolensk Oblast	4	4	4	4	4	**3**
Stavropol Kray	4	4	4	4	4	**3**
Tambov Oblast	4	4	4	4	4	**3**
Tver Oblast	4	4	4	4	4	**3**
Tomsk Oblast	8	8	**7**	7	7	**6**
Tula Oblast	4	4	4	4	4	**3**
Tyumen Oblast	6	6	6	6	6	**5**
Udmurt Republic	5	5	5	**4**	4	**4**
Ulyanovsk Oblast	4	4	4	4	4	**3**
Khabarovsk Kray	11	11	11	11	11	**10**
Khanty-Mansiy Avtonomnyy Okrug	6	6	6	6	6	**5**
Chelyabinsk Oblast	6	6	6	6	6	**5**
Chechnya Republic	4	4	4	4	4	**3**
Chuvash Republic	4	4	4	4	4	**3**
Chukot Avtonomnyy Okrug	13	13	13	12	12	12
Yamal-Nenets Avtonomnyy Okrug	6	6	6	6	6	**5**
Yaroslavl Oblast	4	4	4	4	4	**3**

Notes:
1. The table shows the actual time zone in power most of the year relatively to UTC.
2. Bold numbers represent the reforms (time zone different from the column to the left).
3. Crimea and Sevastopol were annexed to Russia in March, 2014. On March 30, 2014, the time zone (winter time) in these two regions was changed from UTC+2, as it used to be since 1996, to UTC+4.

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