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Descriptive Finding

Ambient temperature and sexual activity: Evidence from time use surveys

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Ambient temperature and sexual activity: Evidence from time use surveys

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Abstract

BACKGROUND
Previous research has found that unusually hot temperatures reduce birth rates eight to ten months later.

OBJECTIVE
We examine one of the potential mechanisms behind this relationship: the connection between ambient temperature and sexual activity.

METHODS
We use individual-level data provided by three waves of the Hungarian Time Use Survey between 1986 and 2010 and daily weather data from the European Climate Assessment & Dataset project.

RESULTS
Hot temperatures do not have a significant effect on sexual activity on a given day. Studying the dynamics of the relationship, we found that temperature does not influence sexual activity on subsequent days either.

CONCLUSIONS
Since high temperatures seem to have no negative effect on sexual activity, the relationship between temperature and sexual activity might be a mechanism of minor importance in the relationship between temperature and birth rates.

CONTRIBUTION
Our paper is the first study of the relationship between ambient temperature and sexual activity that uses time use data.

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1. Introduction

Past research has shown that extremely or unusually hot temperatures in a given month reduce birth rates eight to ten months later (Barreca, Deschenes, and Guldi 2018; Becker 1991; Lam and Miron 1991, 1996; Seiver 1989). Since the frequency of hot days will increase in the future due to global climate change, it is important to understand the underlying factors that drive this relationship. In theory three main mechanisms could explain the reduced birth rate after a heat shock (for a formal model, see Lam, Miron, and Riley 1994). First, temperature shocks could decrease sexual activity. Second, extreme temperature could affect the probability of conception, e.g., by reducing semen quality. Third, hot ambient temperatures could influence the development of fertilized embryos or the physical condition of pregnant women, leading to a higher rate of spontaneous fetal loss during the first few weeks of pregnancy. The second mechanism has already been studied (e.g., Durairajanayagam et al. 2014; Gyllenborg et al. 1999; Levine 1991; Levine et al. 1990; Levitas et al. 2013), but there is a gap in the literature regarding the other two mechanisms (some papers study the effect of temperature on the probability of fetal death, but they focus on stillbirths).

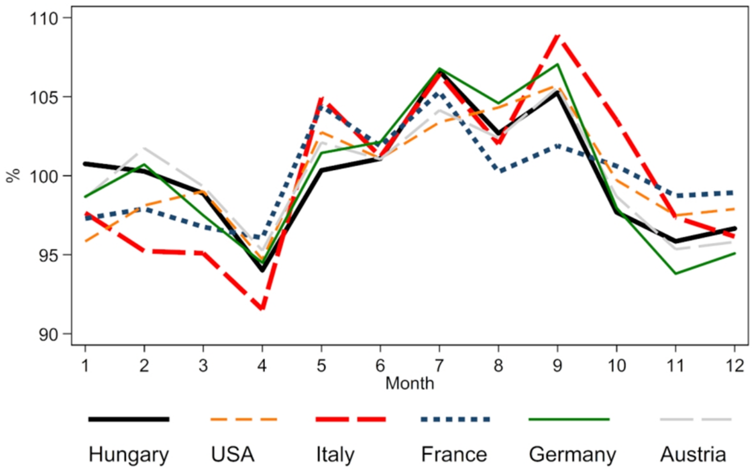
In this paper we examine the first mechanism: the relationship between ambient temperatures and sexual activity. Although previous papers have studied the seasonal variation in sexual activity (Fortenberry et al. 1997; Levin, Xu, and Bartkowski 2002; Markey and Markey 2013; Rodgers, Harris, and Vickers 1992; Udry and Morris 1967; Wood et al. 2017), our paper is among the first to analyze the effect of ambient temperatures explicitly. To our knowledge, only Wilde, Apouey, and Jung (2017) have analyzed temperature-induced changes in sexual behavior. They used monthly-level data and showed that both sexual activity and internet searches of sexually-themed expressions decreased with increasing temperature in sub-Saharan Africa.

Our paper offers several advantages in contributing to this scarce literature. First, we use daily-level time use and weather data. This way we can estimate the immediate and the delayed effects of temperature on sexual activity. Second, unlike Wilde, Apouey, and Jung (2017), who estimate a linear effect, we model the relationship between the temperature and sexual activity in a flexible way.

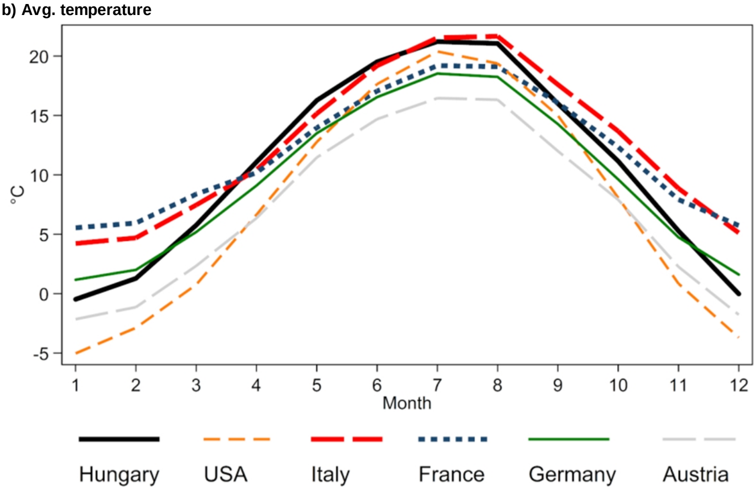
Since we use data from Hungary, whereas the literature on the relationship between birth rate and temperature is mainly based on US data, it is worth looking at the seasonality in birth rates and temperature across some countries (Figure 1). The seasonal pattern of Hungarian birth rates is quite similar to those observed in other European countries or in the United States. There is a peak between July and September (nine months after the coldest months of the year), whereas birth rates are lower than average in April (nine months after July) and in November/December. It suggests that the temperature–birth rate relationship in Hungary might be similar to those reported by previous studies.

Figure 1: Seasonality in average daily births and temperature, 1991–2008

a) Births



b) Avg. temperature



Note: Panel a: The average number of daily births in a given calendar month as a percentage of the average number of daily births between 1991 and 2008. Panel b: Seasonality in average temperature, 1991–2008.
Source: UNSD Demographic Statistics, http://data.un.org/Data.aspx?d=POP&f=tableCode%3A55, downloaded on June 7, 2018; The Climate Change Knowledge Portal (CCKP) of the World Bank http://sdwebx.worldbank.org/climateportal/, downloaded on June 7, 2018.

2. Data and empirical method

We use the individual-level data sets of three waves of the Hungarian Time Use Survey (HTUS) administered by the Hungarian Central Statistical Office. The waves used in this analysis are from 1986/1987, 1999/2000, and 2009/2010. Table 1 shows the most important features of the surveys. The methodology of the time use surveys corresponds to the guidelines of the Harmonized European Time Use Surveys (Eurostat 2009), enables the study of change over time, and ensures international comparability. All waves spread over a yearlong period and follow an open diary design. The sampling units are the households, but only one person per household completes a diary for the previous day (starting at 4 a.m. and covering 24 hours) in the course of a face-to-face interview, providing detailed information on their time allocation.

Table 1: The main characteristics of the three waves of Hungarian Time Use Survey

	1986/1987	1999/2000	2009/2010
Survey time span	01/03/1986–07/03/1987	01/09/1999–06/09/2000	01/10/2009–30/09/2010
Age range	15–79	15–84	10–84
Number of activity codes	480	508	548
Number of diaries	39,600	43,200	8,400
Diaries per person	4 (1 per season)	4 (1 per season)	1
Type of diary	Open diary	Open diary	Open diary

Our dependent variable is a binary indicator denoting whether sexual activity was reported in a diary. In the first two waves of the HTUS, sexual activity was measured with (or included in) a single activity code that was labeled as ‘dating, intimacy.’ In the third wave these two activities were separated, there were different activity codes for ‘dating’ and ‘intimacy.’ To get comparable data we created a new variable in the third wave that measured sexual activity similarly to the first two waves. That is, our sexual activity variable takes the value 1 if the respondent reports any activity coded as ‘dating’ or ‘intimacy.’

The weather data comes from the European Climate Assessment & Dataset project (Tank et al. 2002) that provides daily weather data for five large Hungarian cities from different parts of the country (Budapest, Szeged, Debrecen, Szombathely, and Pécs) between 1901 and 2015. The data set includes information on maximum, minimum, and average temperatures, precipitation, and sunshine hours. Using this data we estimated the daily weather conditions for every Hungarian settlement applying an inverse square distance interpolation method. Then, assuming that weather conditions are quite similar within certain geographic regions, we calculated the average temperature, precipitation, and sunshine values for the 19 Hungarian counties and Budapest (the capital) by taking the mean of the settlement-level values within these larger geographical units. Weather conditions are linked to time use surveys at the day-county level.

To quantify the effect of temperature fluctuations, we estimate the following regression:

$$Y_{ict} = \alpha + \sum_j \beta^j T_{ct}^j + \chi'^{X_i} + \delta h_t + \sum_d \lambda^d dow_t^d + \rho_{cm} + \mu_{ym} + \varepsilon_{ict}, \qquad (1)$$

where *i* denotes the individual, *c* denotes the county (place of residence), and *t* denotes the time (diary day = year-month-day). Y is a dummy variable that indicates the sexual activity of individual i. The ambient temperature is captured by a vector of dummy variables (T), indicating average daily temperatures <0, 0–10, 10–20, and >20°C on the diary day in county *c*. In the regression, $T^{10–20}$ is the omitted category. X is the vector of the additional control variables. It includes age, age squared, and a series of dummy variables for personal characteristics: gender, marital status, education level, labor force status, household size, and type of place of residence. It also includes an indicator variable for whether the survey day was a public holiday in Hungary (h_t) and binary indicators for the days of the week to account for differences throughout the week (dow_t). Although variations in temperature can be considered as exogenous, control variables might improve precision of the estimation. County-by-calendar-month fixed effects (ρ_{cm}) adjust for time-invariant unobserved seasonal differences in sexual activity across counties. Year-by-calendar-month fixed effects (μ_{ym}) control for time-varying common shocks. It means that the effect of the temperature on sexual behavior is identified from daily variations in the temperature after adjustment for differences in county-specific seasonality and time-specific common shocks.

We restrict our analysis to the population aged 18–40 (potential parents). In the period of 1986–2010, 96% of the mothers and 94% of the fathers of newborns were between the ages of 18 and 40. The final sample size is 34,295.

We estimate Equation 1 using a linear probability model. Standard errors are clustered at the county-year-month level. We use an individual weight that adjusts for the unequal inclusion probabilities (provided by the HTUS) combined with another weight that transforms every wave's N equal. Dummies are included for missing control variables.

In the final sample, on average, 2.4% of the respondents reported having sexual activity on the diary day. Most of the survey days fall into the 10–20°C temperature bin (35%), whereas 15% of the survey days have a mean temperature below 0°C, and 19% of the survey days have a mean temperature above 20°C.

3. Results

First, we checked the seasonal pattern of sexual activity in our sample. We calculated average sexual activity by calendar month, and we found that it is the lowest in July and December, and the highest in November. In addition, it is not correlated with the monthly average of daily mean temperature (r = 0.08).

Next, we estimated Equation 1. The effects for the main specification are reported in row 1 of Table 2. Temperature seems to have an insignificant influence on sexual activity. We not only found insignificant coefficients, but there is no clear pattern regarding the signs of the estimated effects. Since a high temperature seems to have no negative effect on sexual activity, the relationship between temperature and sexual activity might be a mechanism of minor importance in the relationship between temperature and birth rates.

We get similar results even if we use 3°C-size temperature bins (Figure 2). Hotter or colder days do not increase or decrease significantly the probability of reporting sexual activity. There is no clear relationship between ambient temperature and sexual activity. However, we note that extremely cold and hot temperatures are rare in Hungary (e.g., only 1.1% of the survey days have a daily mean temperature above 27°C, and 2.8% of them have a daily mean temperature below –6°C), therefore the identification might be weak, and the estimations are less precise.

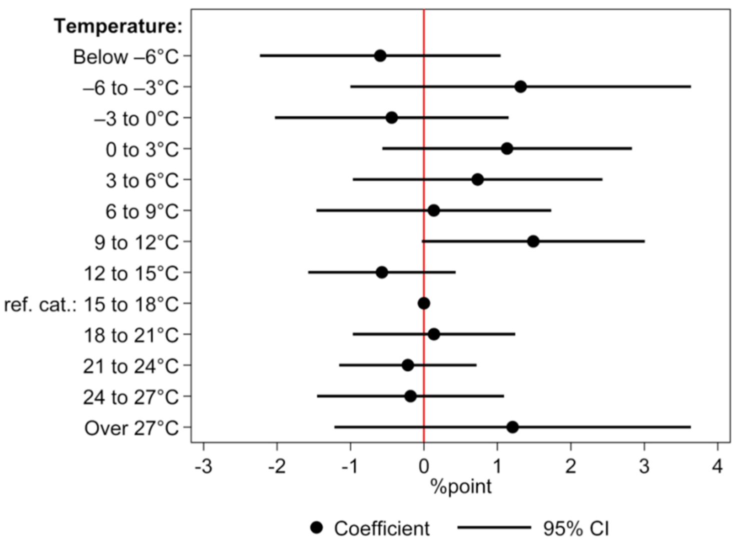
Rows 2 to 12 of Table 2 summarize the results of some robustness tests. First, we changed the control variables. In row 2, we additionally controlled for the daily precipitation and sunshine hours. In row 3, we excluded the individual-level control variables (X_i). Next, we restricted the sample to the population aged 20–34 (row 4) and to counties where the weather stations are located (row 5). In row 6 and 7, we used unclustered standard errors and standard errors clustered at the county level, respectively. We also estimated a Probit model. The average marginal effects from this exercise are reported in row 8. Next, we used temperature values calculated at the microregion level instead of the county level (row 9). In this estimation we included microregion-by-calendar-month and year-by-month fixed effects. Finally, we experimented with the fixed effects. In the baseline regression we used county-by-calendar-month and year-by-month fixed effects. In row 10, we included county, year, and month fixed effects. In row 11, we used county-by-calendar-month and year fixed effects, whereas in row 12, we estimated our regression with county-by-year-by-month fixed effects. None of these changes affected the main conclusion: The relationship between temperature and sexual activity does not seem to be a relevant mechanism for temperature-induced birth seasonality. High temperatures do not decrease sexual activity.

Table 2: The effect of ambient temperature on sexual activity (in percentage points)

		Daily temperature					
		Below 0°C	**0 to 10°C**	**10 to 20°C**	**Over 20°C**	**N**	**R^2**
(1)	Baseline	–0.32 (0.77)	0.67 (0.70)	ref. cat.	0.30 (0.38)	34295	0.040
(2)	With precipitation and sunshine hours	–0.18 (0.75)	0.69 (0.70)	ref. cat.	0.12 (0.41)	34295	0.040
(3)	Without individual controls (Xi)	–0.21 (0.79)	0.71 (0.72)	ref. cat.	0.23 (0.38)	34295	0.027
(4)	Population aged 20–34	–0.93 (1.01)	0.67 (0.92)	ref. cat.	0.38 (0.53)	21786	0.054
(5)	Counties with a weather station	–2.34 (1.41)	–0.61 (1.30)	ref. cat.	–0.09 (0.65)	11422	0.036
(6)	Unclustered robust SE	–0.32 (0.81)	0.67 (0.73)	ref. cat.	0.30 (0.38)	34295	0.040
(7)	SE clustered at the county level	–0.32 (0.78)	0.67 (0.58)	ref. cat.	0.30 (0.26)	34295	0.040
(8)	Probit (avg. marg. effects)	–0.52 (0.57)	0.50 (0.54)	ref. cat.	0.21 (0.35)	34295	0.180[a]
(9)	Microregion-level weather data	–0.96 (0.80)	0.13 (0.74)	ref. cat.	0.20 (0.39)	34295	0.159
(10)	County FE, Year FE, Month FE	–0.21 (0.77)	0.60 (0.68)	ref. cat.	0.21 (0.39)	34295	0.023
(11)	County-by-calendar-month FE, Year FE	–0.10 (0.75)	0.67 (0.68)	ref. cat.	0.20 (0.37)	34295	0.038
(12)	County-by-year-by-month FE	–0.11 (0.79)	0.78 (0.72)	ref. cat.	0.27 (0.37)	34295	0.078

Note: Dependent variable: Binary indicator for whether sexual activity was reported in the diary. (1): Baseline results. (2): Information on daily precipitation (dummies for 0, 0–1, 1–5, and over 5 mm) and sunshine (dummies for 0, 0–2, 2–6, 6–11, and over 11 hours) are added. (3): Individual-level control variables (X_i) are excluded. (4): The sample is restricted to population aged 20–34. (5): Only observations in the 5 counties with a weather station are included. (6): Unclustered robust standard errors. (7): Standard errors are clustered at the county level. (8): Eq. 1 estimated by a Probit regression. Average marginal effects are reported. (9): Microregion-level temperature data with microregion-by-calendar-month fixed effects are used. (10): County, year, and calendar month fixed effects are used. (11): County-by-calendar-month and year fixed effects are used. (12): County-by-year-by-month fixed effects are used. Standard errors are in parentheses. * p<.05, ** p<.01. [a] Pseudo R^2.

Figure 2: The effect of ambient temperature using narrower temperature bins



To test the dynamic nature of the temperature–sexual activity relationship, we ran a model including not only the weather indicators on the diary day (t) but also the weather indicators one day before (t–1). It is possible that extreme temperatures do not influence sexual activity on a given day but they might have a sizeable effect on the subsequent day, which could result in a positive/negative total effect. The total effects are calculated for each temperature category by summing up the estimated coefficients: $\sum_{i=0}^{1} T_{c(t-i)}^{j}$. It can be interpreted as the cumulative effect of the temperature on today's and tomorrow's sexual activity. The main finding of this exercise is that the effects of the current and previous day's temperature are insignificant for all temperature bins (below 0, 0–10, and over 20°C). In addition, the 2-day cumulative effects are highly insignificant (Table 3). We also experimented with longer lag structures; these did not change the main conclusion. We did not find any significant coefficients and the cumulative effects are also insignificant.

Table 3: The dynamic nature of the temperature-sexual activity relationship

Daily temperature	(1) 2-day cumulative effects	(2) 3-day cumulative effects	(3) 4-day cumulative effects
Below 0°C	–0.41 (0.88)	–0.62 (0.91)	–0.78 (1.01)
0 to 10°C	0.16 (0.74)	0.27 (0.74)	0.29 (0.77)
10 to 20°C	ref. cat	ref. cat	ref. cat
Over 20°C	0.31 (0.47)	0.44 (0.53)	0.23 (0.60)

Note: Standard errors are in parentheses. * p<.05, ** p<.01.

4. Conclusions

Using individual-level time use surveys we examined one of the potential mechanisms that could explain the reduced birth rates after a heat shock (Barreca, Deschenes, and Guldi 2018; Lam and Miron 1996; Seiver 1989): the relationship between ambient temperatures and sexual activity. We found no clear pattern in this relationship. The temperature has neither an immediate nor a delayed effect on sexual activity. These findings are in contrast with the results of Wilde, Apouey, and Jung (2017); however, not only does our methodology differ substantially from theirs, but we analyze data from a country where the typical daily mean temperature is much lower than in sub-Saharan Africa. Since high temperatures seem to have no negative effect on sexual activity, our results suggest that the relationship between temperature and sexual activity might be a mechanism of minor importance in the relationship between temperature and birth rates, at least in Central Europe. We note that the effect of temperature on sexual activity might be different in other climate regions and in developing countries or might have been different in the past. Further studies should assess the validity of these results using larger samples covering more years and data from other countries.

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References

Barreca, A., Deschenes, O., and Guldi, M. (2018). Maybe next month? Temperature shocks and dynamic adjustments in birth rates. *Demography* 55(4): 1269–1293. doi:10.1007/s13524-018-0690-7.

Becker, S. (1991). Seasonal patterns of births and conception throughout the world. In: Zorgniotti, A.W. (ed.). *Temperature and environmental effects on the testis*. Boston: Springer: 59–72. doi:10.1007/978-1-4684-5913-5_6.

Durairajanayagam, D., Sharma, R.K., du Plessis, S.S., and Agarwal, A. (2014). Testicular heat stress and sperm quality. In: du Plessis, S.S., Agarwal, A., and Sabanegh, E.S. (eds.). *Male infertility*. New York: Springer: 105–125. doi:10.1007/978-1-4939-1040-3_8.

Eurostat (2009). *Harmonised European time use surveys*. Luxembourg: Eurostat.

Fortenberry, J.D., Orr, D.P., Zimet, G.D., and Blythe, M.J. (1997). Weekly and seasonal variation in sexual behaviors among adolescent women with sexually transmitted diseases. *Journal of Adolescent Health* 20(6): 420–425. doi:10.1016/S1054-139X(96)00275-3.

Gyllenborg, J., Skakkebæk, N.W., Nielsen, N.C., Keiding, N., and Giwercman, A. (1999). Secular and seasonal changes in semen quality among young Danish men: A statistical analysis of semen samples from 1927 donor candidates during 1977–1995. *International Journal of Andrology* 22(1): 28–36. doi:10.1046/j.1365-2605.1999.00137.x.

Lam, D.A. and Miron, J.A. (1991). Temperature and the seasonality of births. In: Zorgniotti, A.W. (ed.). *Temperature and environmental effects on the testis*. Boston: Springer: 73–88. doi:10.1007/978-1-4684-5913-5_7.

Lam, D.A. and Miron, J.A. (1996). The effects of temperature on human fertility. *Demography* 33(3): 291–305. doi:10.2307/2061762.

Lam, D.A., Miron, J.A., and Riley, A. (1994). Modeling seasonality in fecundability, conceptions, and births. *Demography* 31(2): 321–346. doi:10.2307/2061888.

Levin, M.L., Xu, X., and Bartkowski, J.P. (2002). Seasonality of sexual debut. *Journal of Marriage and Family* 64(4): 871–884. doi:10.1111/j.1741-3737.2002.00871.x.

Levine, R.J. (1991). Seasonal variation in human semen quality. In: Zorgniotti, A.W. (ed.). *Temperature and environmental effects on the testis*. Boston: Springer: 89–96. doi:10.1007/978-1-4684-5913-5_8.

Levine, R.J., Mathew, R.M., Chenault, C.B., Brown, M.H., Hurtt, M.E., Bentley, K.S., Mohr, K.L., and Working, P.K. (1990). Differences in the quality of semen in outdoor workers during summer and winter. *New England Journal of Medicine* 323(1): 12–16. doi:10.1056/NEJM199007053230103.

Levitas, E., Lunenfeld, E., Weisz, N., Friger, M., and Har-Vardi, I. (2013). Seasonal variations of human sperm cells among 6455 semen samples: A plausible explanation of a seasonal birth pattern. *American Journal of Obstetrics and Gynecology* 208(5): 406.e1–406.e6. doi:10.1016/j.ajog.2013.02.010.

Markey, P.M. and Markey, C.N. (2013). Seasonal variation in internet keyword searches: A proxy assessment of sex mating behaviors. *Archives of Sexual Behavior* 42(4): 515–521. doi:10.1007/s10508-012-9996-5.

Rodgers, J.L., Harris, D.F., and Vickers, K.B. (1992). Seasonality of first coitus in the United States. *Social Biology* 39(1–2): 1–14. doi:10.1080/19485565.1992.9988800.

Seiver, D.A. (1989). Seasonality of fertility: New evidence. *Population and Environment* 10(4): 245–257. doi:10.1007/BF01255839.

Tank, A.M.G.K., Wijngaard, J.B., Können, G.P., Böhm, R., Demarée, G., Gocheva, A., Mileta, M., Pashiardis, S., Hejkrlik, L., Kern-Hansen, C., Heino, R., Bessemoulin, P., Müller-Westermeier, G., Tzanakou, M., Szalai, S., Pálsdóttir, T., Fitzgerald, D., Rubin, S., Capaldo, M., Maugeri, M., Leitass, A., Bukantis, A., Aberfeld, R., Engelen, A.F.V. van, Forland, E., Mietus, M., Coelho, F., Mares, C., Razuvaev, V., Nieplova, E., Cegnar, T., López, J.A., Dahlström, B., Moberg, A., Kirchhofer, W., Ceylan, A., Pachaliuk, O., Alexander, L.V., and Petrovic, P. (2002). Daily dataset of 20th-century surface air temperature and precipitation series for the European Climate Assessment. *International Journal of Climatology* 22(12):1441–1453. doi:10.1002/joc.773.

Udry, J.R. and Morris, N.M. (1967). Seasonality of coitus and seasonality of birth. *Demography* 4(2): 673–679. doi:10.2307/2060307.

Wilde, J., Apouey, B.H., and Jung, T. (2017). The effect of ambient temperature shocks during conception and early pregnancy on later life outcomes. *European Economic Review* 97: 87–107. doi:10.1016/j.euroecorev.2017.05.003.

Wood, I.B., Varela, P.L., Bollen, J., Rocha, L.M., and Gonçalves-Sá, J. (2017). Human sexual cycles are driven by culture and match collective moods. *Scientific Reports* 7(1): 17973. doi:10.1038/s41598-017-18262-5.