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The Period Effect: The Effect of Menstruation on Absenteeism of School Girls in Limpopo

By Chloé van Biljon and Cobus Burger

Abstract

This paper will aim to answer three questions: (1) Are girls absent from school during their periods? (2) If so, how large is the effect of menstruation on absenteeism? (3) Do the effects differ by socio-economic status (SES)? A large body of research examines the barriers that girls face to schooling, yet little is known about menstruation in particular as an obstacle for school attendance. The few existing studies indicate that menstruation does have repercussions for girl's school attendance. This paper contributes to the literature by using a large provincial dataset to estimate the influence of menstruation on the school attendance of girls in Limpopo.

The data, school administration data of the Department of Basic Education (SA-SAMS data), is collected quarterly from schools as part of the Data Driven Districts (DDD) initiative, which resulted from a partnership between the Department of Basic Education and the Michael and Susan Dell Foundation. The DDD programme aims to provide access to high quality, visualised education performance data across the country. Research on Socio-Economic Policy (ReSEP) has been asked to undertake some analysis of this underlying data to illustrate its potential use for research. The SA-SAMS data includes detailed data on absenteeism for most schools in Limpopo, one of South Africa's poorest provinces. Reasons for absenteeism are not reported, and it is therefore unclear when absenteeism is menstruation-related. In this paper, we develop a structural model to identify whether there are patterns in older girls' absenteeism that could be explained by menstruation. The model is estimated with maximum likelihood methods and is applied to two control groups: girls before they have reached menarche, and boys. The results of the model are compared across these three groups and by school socio-economic status The results indicate that menstruation causes absenteeism for young girls (12-13 year olds in the poorest 60% of schools and 10-11 year olds in the richest 40%), but that older girls do not have a higher probability of being absent during their menses. These results imply that encountering menstruation for the first time presents challenges for girls in relation to school attendance.

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1 Introduction

Equity of educational opportunity gives individuals a means by which to escape poverty and to avoid perpetuating existing inequalities. Worldwide only 66% of countries had achieved gender parity in primary education by 2015. For lower secondary education, this proportion drops to only 45%. For upper secondary, only a quarter of the world's countries have achieved gender parity (Unesco, 2017). While the education of women is important in and of itself, it also carries broader social implications. Increased access to education for women is associated with lower child mortality, lower disease risk, reduced teenage pregnancies and higher household outcomes (Patton et al., 2016; Shariff & Ahn, 1995). A large body of research describes the barriers to schooling faced by girls; however, little is known about menstruation in particular as an obstacle for school attendance (Benshaul-Tolonen et al., 2019; Grant et al., 2013; Jewitt & Ryley, 2014; Miiro et al., 2018). A few studies have examined the relationship between menstruation and girls' school attendance (Grant et al., 2013; McMahon et al., 2011; Miiro et al., 2018). For instance, it has been shown in some cases that provision of free sanitary products has had positive effects on girls' school attendance (Agarwal, 2018; Montgomery et al., 2016). This study contributes to the literature by using a large provincially representative dataset to estimate the influence of menstruation on school attendance of girls in Limpopo. The paper will aim to answer three questions: (1) Are girls absent from school during their periods? (2) If so, how large is the effect of menstruation on absenteeism? (3) Do the effects differ by socio-economic status (SES)?

If menstruation causes significant absenteeism for girls, then this could perpetuate both gender and income inequality. Economic constraints to accessing sanitary products and pain medication could disproportionately affect the poor. A large body of literature discusses the various ways in which girls in rural communities lack preparation and support for their periods (Jewitt & Ryley, 2014; Phillips-Howard et al., 2016; Sumpter & Torondel, 2013). While many inequalities are linked to deep-rooted cultural practices, providing girls with the resources to effectively deal with their menses may be a relatively simple and inexpensive intervention in improving girls' educational attainment. This notion has recently gained traction in the media, NGO's and governments. Many governments and NGO around the world have established programs to ameliorate access to sanitary products for school girls (Jewitt & Ryley, 2014).

Within South Africa, some provincial-level policies have attempted to address this matter, with different interventions at various points in time. Some provinces distribute disposable sanitary pads while others distribute reusable menstrual cups. In some cases, the distribution of sanitary products is combined with an educational program about health and hygiene, menstrual cycles and sex (Department of Women, 2017). Limited information is available on the scope of these projects, but anecdotal evidence suggests that these interventions affect very few schools and in an inconsistent manner (Parliamentary Monitoring Group, 2018a, 2018b). In 2017, the Department of Women developed a sanitary dignity policy framework to consolidate the existing uncoordinated response. This framework outlines the government's plans to improve access to sanitary products for South African women and girls, with the overarching aim to "preserve a woman's dignity during menstruation" (Department of Women, 2017). The program further aims to "reduce drop-out rate of girl learners caused by missing out on school, due to not being able to afford sanitary pads" (Department of Basic Education, 2017). To help inform the national roll-out, a pilot program was launched on 1 April 2019 in Mpumalanga (Dlamini, 2019). NGO's have also intervened, for example, between 2010 and 2018 Project Dignity has distributed over 100 000 reusable pads to school girls across the country (Geismar, 2018).

This paper provides new information on the extent to which the South African government may expect improvements in attendance from their new, consolidated sanitary dignity intervention. Existing provincial interventions may cause the estimated effect to be downwardly biased; however, the small scale and poor execution of these interventions makes it unlikely that their effect on the aggregate is significant (Parliamentary Monitoring Group, 2018a, 2018b). The paper examines detailed data on absenteeism for schools in Limpopo province of South Africa. It is drawn from the South African Department of Basic Education's SA-SAMS data that records daily attendance at the individual level.[1] Reasons for absenteeism are not reported; therefore it is unclear when absenteeism is mentruation-related. Identification therefore relies on finding patterns in older girls' abseeteism that could be explained by menstuation. Studies across a range of countries show that length of menstrual cycle is distributed around a median of 27-30 days with a mode of 28 days (Beach, 1968; Chiazze, Brayer, Macisco, Parker, & Duffy, 1968; Flug, Largo, & Prader, 1984; Guo, Manatunga, Chen, & Marcus, 2005; Jeyaseelan, Antonisamy, & Rao, 1992). Following the literature, a Cox proportional hazard model is used to estimate the absence hazard for 28 day distances. The results do not support the hypothesis that girls miss school excessively during their menses.

[1] The data is collected quarterly from schools as part of an initiative of the New Leaders Foundation and the Michael and Susan Dell Foundation, to use in dashboards to assist management decision making in the school system. Altogether 85% of South African schools provide these data. However, the decision was taken to work only with Limpopo data so as to contain the analysis, but also because quintile categories (used later in the analysis) were more readily available for this province.

However, estimating a "period effect" with the hazard model is difficult; to address this, we set up a structural model. This model identifies whether there are patterns in older girls' abseeteism that could be explained by menstuation. The model is then estimated with the use of maximum likelihood. The model is applied to two control groups: girls before they have reached menarche, and boys. The results of the model are compared across these three groups. Finally the probability of being absent due to menstruation is compared across school socio-economic status (SES). Evidence of menstruation-related absenteeism is found for young girls. The results indicate that newly menstruating girls struggle to attend school while menstruating, but menstruation may not pose a significant barrier to attending school for older girls in low SES settings.

The following section discusses the circumstances and contexts in which we may expect girls to miss school when menstruating. This is followed by a description of the data. Thereafter, the econometric and structual models are introduced and their results discussed. The essay closes with some concluding remarks.

2 Background

Negative attitudes to menstruation are held in developed and developing countries alike (Rosewarne, 2012; Stubbs, Rierdan, & Koff, 1989). "Menstruation creates a set of physical, socio-cultural and economic challenges that may interfere with a young woman's ability to attend school or to participate fully in classroom activity" (Grant et al., 2013). The barriers girls face in attending school during their menses can be classified into four main categories: (1) social norms around restricting women's movement, (2) ability to hide menstruating status, (3) parental fears and expectations and (4) physical discomforts. Each of these factors will be considered in turn.

Many cultures in Sub-Saharan Africa (SSA) harbour beliefs that menstruating women carry illness and disease, thereby developing a sense of stigma around menstruation that has limited the mobility of African women for centuries (Beinart & Brown, 2013; Moloantoa, 1981). For example, across many Setswana, isiXhosa and Zulu-speaking areas menstruating women are not permitted near new-born babies, weapons or cattle (Beinart & Brown, 2013; Moloantoa, 1981). The stigma around menstruation results in women feeling obliged to hide the fact that they are menstruating. This shame attached to menstruation, coupled with the practice of restricting women's movement during menstruation, creates an environment in which girls' absence from school during this time might be expected. Girls may stay home from school out of fear that they will be found out and subsequently accused of causing harm to others through their menstruating state (UNICEF, 2011). In addition, observing their elders modify their daily lives to avoid forbidden places when menstruating sets an example for girls that habits must be changed during menses and that freedom of movement is curtailed.

The second important barrier to school attendance during menstruation is girls' ability to hide their menstruating status (Grant et al., 2013; Jewitt & Ryley, 2014; McMahon et al., 2011; Sommer & Sahin, 2013; Tegegne & Sisay, 2014). If girls are successfully able to hide their menses, they may be able to circumvent the stigma and traditional beliefs that prevent them from attending school. But poor toilet facilities in schools make it difficult for girls to manage their menses in private. Lack of disposal facilities creates difficulties for the discreet disposal of sanitary products (Jewitt & Ryley, 2014; Tegegne & Sisay, 2014). Many girls cannot afford manufactured sanitary products and consequently use homemade alternatives. Homemade products often leak and are less secure than manufactured products. When using homemade products, girls face an increased risk of staining of clothes, thereby revealing their menstruating status (Grant et al., 2013; Jewitt & Ryley, 2014; Tegegne & Sisay, 2014). Rather than facing this risk, girls may choose to stay home from school.

The onset of menstruation – referred to as menarche -- signals the fertility of a girl, which may cause parental fears of unwanted pregnancy. This fear may cause parents to increase supervision of their daughter and discourage school attendance. Alternatively, the onset of fertility may lead to parental expectations that their daughter should marry (Jewitt & Ryley, 2014). Once married girls often attend school sporadically or drop out completely.

Finally, menstruation can cause menstrual cramps, headache, backache, nausea, and diarrhea. Most girls in low-income settings do not have the economic means to afford medication to manage these symptoms. The physical discomforts -- and a lack of means by which to deal with them -- may cause girls to stay home when menstruating (Grant et al., 2013). Long walking distances to school make it even more challenging to attend school when experiencing pain (Jewitt & Ryley, 2014).

The status of menstruation as a taboo topic has caused poor development of institutional support for menstruating women. A persistent social reluctance to talk about menstruation has made it difficult for women to raise issues and incite change. The issue has recently gained traction in the media as well as with policy makers, but real change has been slow. As a result, girls and women lack adequate institutional support such as education on menstrual hygiene management (MHM) and water, sanitation and hygiene (WASH); this holds true in many contexts both within and outside Africa.

2.1 South African Context

A study in Limpopo found that prior to menarche, 94% of women were aware of the social and religious restrictions related to menstruation, while only 27% reported knowledge of the physical changes that relate to menarche, and only 48% were aware of hygienic practices (Ramathuba, 2015). These statistics illustrate that the focus of sex education is on the stigma attached to menstruating. While young women are well informed about the mobility restrictions that menstruation involves, they lack important information for managing their own health.

Education on MHM is not the only barrier young South African women face to achieving proper management of their periods. In March 2018, 8 679 out of a total of 23 437 schools provided no toilets other than pit latrines (Department of Basic Education, 2018b). Even in schools with good ablution infrastructure, studies have found privacy and hygiene of toilets to be insufficient. A study conducted by Equal Education found that 84% of schools visited had no toilet paper, 69% of toilets did not have locking doors, 50% of the schools had no sanitation bins in girls' bathrooms and 89% of schools did not provide any soap in bathrooms (Equal Education, 2018). The condition of WASH in South African schools poses a health concern for all students. Lack of privacy, soap and toilet paper make it difficult for girls to manage their menses discretely and could therefore discourage them from attending school during menstruation.

2.2 The Effects of Absenteeism

Studies have found that the major risk factors contributing to learner absenteeism in South Africa include the following: transport, child labour, domestic and agricultural chores, food insecurity, dysfunctional family structures, lack of parental involvement , difficulty coping academically, violence in schools, teenage pregnancy, and health of students and family members (including the effect of HIV/AIDS) (Weideman et al., 2007). Being absent from school is thought to affect students in various capacities. The decrease in instruction time has been found to negatively effect students test scores (Chen & Stevenson, 1995; Connell, Spencer, & Aber, 1994; Finn, 1993). In a study on South Africa, Van der Berg and Louw (2007) find that for each day absent per month students have a one-point (1% of a standard deviation) lower test score on the SACMEQII (Southern African Consortium for Monitoring Education Quality) mathematics test score.[2] Absent students are at risk of falling behind the curriculum due to lost instruction time. This may cause disengagement from school, which in turn could lead to further deterioration in their performance as well as behavioural problems as students begin to feel alienated from their classmates, teachers, and schools (Ekstrom, Goertz, Pollack, & Rock, 1986; Finn, 1989; Johnson, 2005; Newmann, 1981). These factors all contribute to putting chronically absent students at higher risk of dropping out of school and thus a higher chance of unemployment (Alexander, Entwisle, & Horsey 1997; Broadhurst, Patron, & May-Chahal, 2005; Kane, 2006) (Kearney, 2008).

Empirical studies that have analysed the effects of absenteeism on other outcomes have found it to be correlated with mental health problems, teenage pregnancy, violent behaviour and substance use (Almeida et al., 2006, Chou et al., 2006, Denny et al., 2003, Grunbaum et al., 2004, Guttmacher et al., 2002, Hallfors et al., 2002, Henry and Huizinga, 2007). Further research has found that school dropout is associated with economic deprivation, and social, marital, and psychiatric problems in adulthood (Kogan et al., 2005, Tramontina et al., 2001, US Census Bureau, 2005). The next section considers the literature on menstruation as a cause of absenteeism.

2.3 The Effects of Menstruation on Absenteeism

There are two types of studies that provide evidence of how menstruation affects absenteeism of school girls: studies that measure the effect of menstruation on absenteeism directly (Benshaul-Tolonen et al., 2019; Grant et al., 2013; Miiro et al., 2018; Oster & Thornton, 2011; Tegegne & Sisay, 2014), and studies that measure the impacts of MHM interventions on absenteeism (Agarwal, 2018; Benshaul-Tolonen et al., 2019; Mason et al., 2015; Montgomery et al., 2016; Oster & Thornton, 2011; Phillips-Howard et al., 2016). Additionally, in cases where reasons for absenteeism are not reported, there is a literature that looks for patterns in absenteeism that resemble the menstrual cycle. However, such studies have only considered adult women's absenteeism from work (Herrmann & Rockoff, 2012; Ichino & Moretti, 2009; Rockoff & Herrmann, 2009).

[2] South Africa has a mean score of 486.1 for the SACMEQII mathematics test scores.

The proportion of school girls who reported missing at least one day of school in their last menstrual period varies between 20% in Uganda (Miiro et al., 2018), 32% in Malawi (Grant et al., 2013), 55% in Ethiopia (Tegegne & Sisay, 2014) and 60% in India (Government of India, 2015). However, studies that quantified the proportion of total absences due to menstruation found the share to be minor (Benshaul-Tolonen et al., 2019; Grant et al., 2013; Oster & Thornton, 2011).[3] Oster and Thornton (2011) found that in Nepal menstruation accounts for 0.4 school days missed for each girl per year or a 2.4 percentage point decrease in the probability of attending school when menstruating. Benshaul-Tolonen et al. (2019) find a similar result for Kenya, with 0.5 school days being missed annually due to sickness, including menstruation. This places an upper bound of 0.5 school days per year missed due to menstuation for their sample of Kenyian girls. Meanwhile, for Malawi, Grant et al. (2013) report that only 2.4 percent of girls' absences are accounted for by menstruation. The exception is Uganda where the effect of menstruation on absenteeism is reportedly large. Miiro et al. (2018) found that school absence was reported on 28% of period-days, compared with 7% of non-period days.

The need for HMH interventions in schools is widely acknowledged; however, the impact of MHM interventions on absenteeism specifically is mixed.[4] Distribution of sanitary pads has proven successful in reducing absenteeism in India (Agarwal, 2018), Kenya (Benshaul-Tolonen et al., 2019) and Uganda (Montgomery et al., 2016). A sanitary pad distribution program in Ghana appeared successful initially, but control villages caught up within five months (Montgomery, Ryus, Dolan, Dopson, & Scott, 2012). Distribution of menstrual cups to school girls has proven less effective in reducing absenteeism in Nepal and Kenya (Benshaul-Tolonen et al., 2019; Oster & Thornton, 2011). However this result could be due to the short time-frame of these studies; in a different study in Kenya, the distribution of menstrual cups had no initial effect on drop-out from school but proceeded to have significant positive effects in the long-run (after 12 months) (Phillips-Howard et al., 2016).[5] The results of this study raise concerns that papers that only look at short-term effects of menstrual cups may be missing positive long-term results.

Using MHM intervention studies to understand whether menstruation causes absenteeism is not straightforward. Impact evaluations on MHM interventions do not give

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[3] All these studies use self-reported reasons for absence. Given the stigma attached to menstruation, this raises concerns that girls may under-report menstruation as a reason for absence and its importance as a cause of absenteeism may under estimated.

[4] WASH interventions have not been included because the evidence they provide on menstruation as a source of absenteeism is weaker. Girls may miss school due to poor WASH at their school all month round (not just during their menses). Therefore, if a WASH intervention has a positive effect on girls attendance this does not directly point to menstruation as a challenge to absenteeism.

[5] This is consistent with the findings of Oster and Thornton (2012) that menstrual cup take up is slow.

direct evidence of how menstruation may affect absenteeism. Studies that find positive effects illustrate that lack of MHM was a constraint to attending school and therefore menstruation causes absenteeism. Those that find no effect do not, however, prove that menstruation has no effect on absenteeism. There could be many reasons why studies fail to find MHM interventions to be effective. Menstruation may not be a significant cause of absenteeism, or alternatively the intervention may not be effective in helping girls overcome the challenges to attending school while menstruating. This literature finds evidence that menstruation is a cause of absenteeism in India (Agarwal, 2018), Kenya (Benshaul-Tolonen et al., 2019) and Uganda (Montgomery et al., 2016) while conclusions cannot be drawn for Nepal (Oster & Thornton, 2011) and Ghana (Montgomery et al., 2012).

The literature that is closest in methodological approach to this essay are studies that look for patterns in absenteeism that resemble the menstrual cycle. Ichino and Moretti (2009) conducted the first study of this type. The authors looked for 28 day cycles in absenteeism for women working in an Italian bank. Using a Cox proportional hazard model, the authors found a 28-day distance between two absence spells to significantly increase the hazard of being absent for pre-menopausal women. Based on this, the authors concluded that menstruation does indeed cause absenteeism. Their work was later reviewed by Rockoff and Herrmann (2009) who, using the same data and code, found errors in their approach. After correction of coding errors and allowing for serial correlation, they find that there is a significantly higher absence hazard for a 28-day interval for menstruating women when compared to same-aged men. However, when comparing younger and older men they find that the effect of a 28 day-interval is even larger. Rockoff and Herrmann (2009) conclude that the results do not support the hypothesis that menstruation causes absenteeism for Itailain bank employees.

Herrmann and Rockoff (2012) conducted another study where they replicated the methodology used to look at Italian bank employees and applied it to the case of New York City public school teachers. They find no evidence that young female teachers experience higher rates of absence at 28-day intervals than their same-aged male co-workers. The authors conclude that while missing work due to menstruation is commonly reported, the fraction of days missed due to menstruation appears to be small (Herrmann and Rockoff, 2012). This is consistent with the findings in the literature on school girl absenteeism (Benshaul-Tolonen et al., 2019; Grant et al., 2013; Oster & Thornton, 2011).

My paper brings together these different literatures; we look at school girls rather than adult women but use a methodological approach closer to the studies that look for patterns in absenteeism. While most of the studies that consider school girls are set in developing countries, the studies that look for menstrual-like patterns in absenteeism have only been conducted in developed countries. This study is therefore the first of its kind to implement this methodology to look at school girls and the first to embed this approach in a developing country context.

3 The Data

As noted above, the data, derived from SA-SAMS data collected by the South African Department of Basic Education, includes detailed information on absenteeism. Daily attendance data at the individual level is captured as well as other variables such as gender, age, grade, school SES and school district. Of the 25 992 schools in South Africa, the data from which the provincial sample was drawn includes learner level data for 23 817 schools of which 22 106 schools collected attendance data for 2018.[6] This consists of a total of 12.8 million learners across grades one to twelve. Due to limited computing power and the availability of better quintile information for this province, this study focused on Limpopo and only a subsample of learners was included in the analysis. A random sample of 1.85 million students attending school in Limpopo was selected from the total of 12.8 million.[7] Further, we use only the 2018 data for each student, as this year has the most complete coverage of different schools, and as it is also the most relevant for understanding current circumstances.

[6] The poorest 60% of schools (quintile 1-3) schools are over represented in the sample that collected attendance data. This does not cause concern for bias as the results will be compared across school SES. In other respects the data seems quite representative of Limpopo province.

[7] As a robustness check different samples of size 1.85 million were selected and the analysis repeated. The results remain consistent.

4 Descriptive Statistics

Table 1 shows summary statistics for the sample of students used for the analysis. The average student is absent 4.6 days a year or 0.48 days per month.[8] This is lower than what other studies on South Africa have found. A SACMEQ report estimated the average number of days absent per month for Grade 6 South African students to be 1.6 in 2000 and 1.0 in 2007 (Hungi, 2011). Similar levels are found by Spaull (2011). The discrepancy could be due to problems with the quality of the reporting in the SACMEQ data but perhaps also because of data quality issues in the SA-SAMS data. In order to limit potential bias caused by poor quality data, outlier schools were excluded from the analysis.[9] Alternatively, the low numbers for the SA-SAMS data in 2018 could simply reflect a continuation of the positive trend observed between 2000 and 2007. In 2007 South Africa had the third best attendance of all SSA countries. Absentee rates of 0.36-0.67 days per month would leave South Africa's ranking unchanged. Botswana (0.4 in 2007) and Swaziland (0.4 in 2007) are the only countries with better attendance. For reference, Zambia has the worst attendance in SSA, with students missing an average 2.5 days per month (Hungi, 2011).

In Table 1 older students (age 11 or more) are compared to younger students; within each group, girls are compared to boys. Consecutive days of absence are grouped into spells. For both age groups, boys have more individual days of absence as well as more absence spells per year compared to girls. Boys also have more long absence spells. Boys are more likely to be absent at least once over the course of the academic year. Fewer than 2% of students are chronically absent, with boys more likely to be chronically absent compared to girls. Overall, boys are absent more regularly and for longer periods than girls. This pattern is seen for younger students, where few girls have reached menarche, as well as for older students, of which many girls will be menstruating.

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[8] Taken as the average of 0.36 in February, 0.41 in March, 0.42 in April, 0.62 in May, 0.43 in July, 0.67 in August, 0.54 in September and 0.4 in October (January, June, November and December omitted due to long holidays during these months).

[9] Schools with very high proportions of students never recorded absence and schools with very high variance in the proportion of students absent each day were excluded from the sample.

Table 1: Summary Statistics on Students by Gender and Age Group

	Younger than Age 11		Age 11 and Older		All
	Girls	Boys	Girls	Boys	
Number of students	438 817	441 860	467 111	502 147	1 849 935
Age	7.78	7.79	14.34	14.51	11.27
Black	92%	92%	91%	91%	92%
White	4%	4%	6%	5%	5%
Coloured	3%	3%	3%	3%	3%
Nr of days absent	4.50	4.91	4.04	4.74	4.55
Nr of absence spells	3.36	3.64	2.92	3.43	3.33
Nr of 1-day absence spells	2.81	3.03	2.44	2.84	2.78
Nr of 2-3-day absence spells	0.50	0.55	0.41	0.49	0.49
Nr of 4+day absence spells	0.13	0.15	0.14	0.17	0.15
Percent with no absence spell	20%	18%	26%	23%	22%
Percent with 2-4 absence spells	36%	36%	32%	33%	34%
Percent with 5-7 absence spells	15%	16%	12%	14%	14%
Percent with 8+ absence spells	11%	13%	10%	13%	12%
Percent chronically absent[10]	1.1%	1.3%	1.1%	1.7%	1.3%

Figure 1 takes a closer look at patterns of attendance by age. The figure illustrates the average number of days absent in 2018 by gender. The grey lines indicate the 95% confidence interval. In the first panel only students attending one of the poorest 20% of schools in South Africa (quintile 1 schools) are included.[11] On average, boys miss more days of school than girls at all ages except for the oldest students, where girls overtake boys. For both girls and boys, a U-shaped pattern emerges with respect to age. However, girls are seen to experience a larger improvement in their attendance between the ages of 7 and 12 followed by a more rapid deterioration from the age of 12 onwards. The pattern seen for quintile 1 schools is consistent with the hypothesis of menstruation being a challenge to school attendance for girls.

The second panel of Figure 1 shows the average number of days absent by age but for students attending the richest schools (quintile 5 schools). Compared to students in quintile 1 schools, the patterns for girls and boys are more similar over age.[12] This is consistent with the

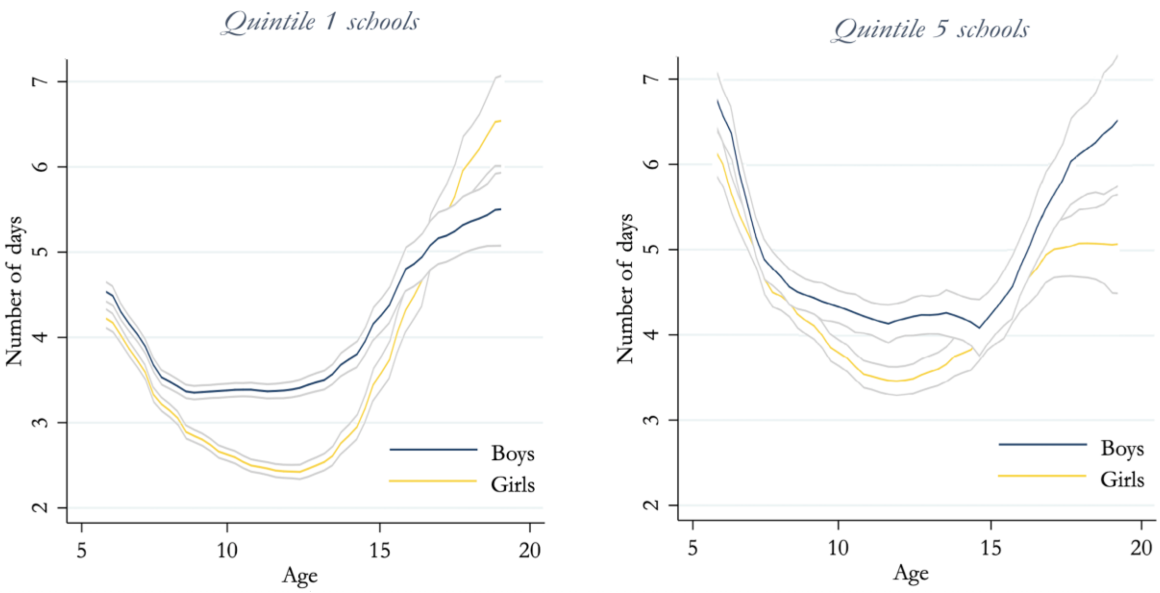
[10] Chronically absent is defined as missing 10% or more of school or absent 18 days or more over a 180-day school year (Chang & Romero, 2008).

[11] Classification of schools into 5 quintiles based on the SES of the children who attend the school is common in South Africa. There is a commonly agreed to classification of all schools used by government and researchers. The schools were already classified in the data received.

[12] Compared to quintile 1 schools the 95% confidence intervals are bigger for quintile 5 schools because more quintile 1 schools collected attendance data.

fact that students in these schools have better access to sanitary products than their poorer counter parts in quintile 1 schools.

Figure 1: Average number of days absent per year



Finding cyclical patterns in absenteeism that resemble the menstrual cycle relies on analysing patterns in the distance between absence spells. Figure 2 shows the distribution of the distances between all days absent for the sample of students. The density consistently spikes on multiples of seven. This is due to the fact that, for any given weekday, seven days away will always fall on a weekday while days one to six days away may fall on a weekend. It is therefore more likely to be a school day seven days from a current absence.

Rockoff and Herrmann (2009) find the same pattern. They further illustrate that if men have a higher probability of being absent on any given day then this difference would be exaggerated at distances with the highest densities. This would cause larger differences in the densities of men and women on multiples of seven. As illustrated in Figure 1, boys in Limpopo do have a higher probability of being absent from school. This will cause any measured "period effect" (i.e., a comparison of girls' 28-day patterns of absenteeism with the corresponding pattern for boys) to be biased downwards.

Figure 2: Distances between all pairs of absences

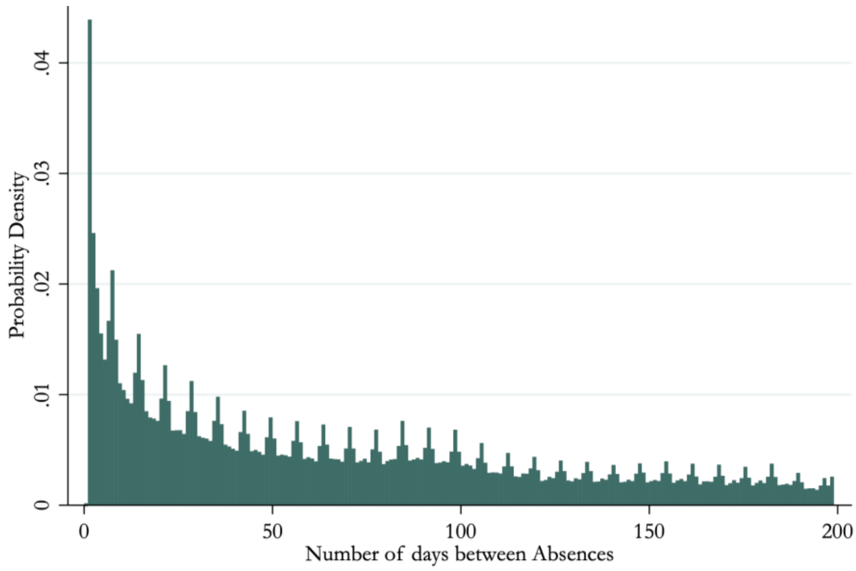
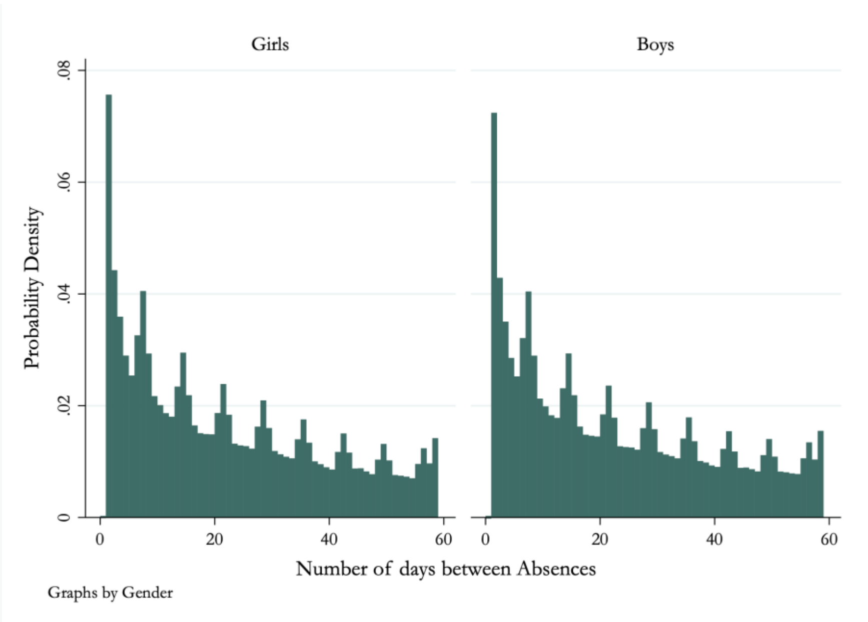


Figure 3 shows a histogram of the distances between all absences for girls and boys. While girls have a higher density for absences the next day (one day distance) the densities are similar across the range of distances. Notably, when compared to boys, girls seem not to have a higher probability of being absent with a 26-31 day distance from a previous absence.[13] However, this could be biased downward for the reasons discussed.

Figure 3: Distances between all absences for girls and boys



[13] A larger range is allowed for to account for the variability of younger women's menstrual cycles as discussed in section 6.2.1.

5 Hazard Model

Following the approach used by Herrmann and Rockoff (2012) a Cox proportional hazard model is used to test for gender differences in absence patterns. The following is estimated:

$$h(t, X_{it}, \Psi) = \lambda(t) e^{\alpha + \gamma F_i + \beta M_{it} F_i + \delta S_{it} F_i + \theta Z_{it}}$$

In this specification, t indexes days from the start of the previous absence spell, X_{it} are covariates, and Ψ is a vector of coefficients. Two specifications are used; one in which the sample is restricted by age, and girls are compared to same aged boys, and another where the sample is restricted by gender, and younger students are compared to older students of the same gender. The coefficient of interest in the first (second) specification is β, which measures the difference in the absence hazard rates of boys and girls (older and younger students) 28 days after the start of a previous spell. Two important control variables are (1) an indicator for being female (older) (F_i), and (2) an interaction of the female (older) indicator with an indicator for distances that are multiples of seven (S_{it}). These controls allow us to measure the effect of a 28-day distance after allowing for both a different baseline hazard (γ) and seven-day periodicity (δ) for girls (older students). Z_{it} is a vector of controls for age, day of the week and race.

The advantage of using a hazard model over a linear probability model or a probit is that the hazard model inherently controls for persistence in absences. Students are not at risk for a new absence spell until they return to school (absence spells are treated as left-truncated). Distances between menstrual cycles are measured as the number of days between their onsets. Conceptually, the model corresponds to this by using the distance between the starts of absence spells (Herrmann & Rockoff, 2012).

5.1 Results of the Hazard Model

The results are given in Table 2. A difference from the specification used by Herrmann and Rockoff (2012) is that, given the typically longer cycle lengths of younger women, interactions for 29 and 30 day distances are also included.[14] The first two columns report the within-age-group comparisons of girls and boys, while the last two columns report the within-

[14] See section 6.2.1 for a discussion of cycles lengths of younger women.

gender comparisons of students younger than 11 and those 11 and older.[15] Comparing same aged girls and boys we see that neither younger nor older girls are more likely than boys to initiate absence spells in 28, 29 or 30-day cycles. Consistent with Herrmann and Rockoff (2012), we find that most of the interactions between the older indicator and multiples of seven are statistically significant. There is no evidence of older girls being more likely to have absence spells in 28-, 29- or 30-day cycles. If anything, younger girls are more likely than older girls to initiate absence spells in 29- and 30-day cycles. Similar trends are observed when comparing younger and older boys.

Table 2: Hazard Rates of Absence Spells

Panel A	Age < 11	Age≥11	**Panel B**	Girls	Boys
	(1)	(2)		(3)	(4)
Female	1.012	1.009	Older	1.040	1.051
	(0.002)***	(0.002)***		(0.005)***	(0.005)***
Female×28	0.987	0.991	**Older×28**	0.976	0.975
	(0.019)	(0.018)		(0.026)	(0.027)
Female×29	0.985	0.991	**Older×29**	0.915	0.918
	(0.024)	(0.023)		(0.004)***	(0.004)***
Female×30	0.985	0.992	**Older×30**	0.900	0.978
	(0.028)	(0.027)		(0.008)***	(0.008)***
Controls	yes	yes		yes	yes
N	1 018 635	1 111 124		940 393	1 189 366

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

5.2 Limitations of the Hazard Model

The potential sources of bias in trying to estimate a "period effect" can be understood by looking at the underlying theoretical model. Following the approach used by Herrmann and Rockoff (2012), let us assume the health of a student i of gender g on day t follows an AR-1 process:

$$H_{igt} = \rho_g H_{ig,t-1} + \varepsilon_{igt}$$

Where the errors, ε_{igt}, are independent and normally distributed with mean zero and variance one.

[15] The results are robust to different age cut offs.

Students are ill if their health is below a sickness threshold (t_g). This threshold, as well as the rate of health shock persistence (ρ_g) may differ by gender. Under this model the periodicity of absence spells at multiples of seven are the same for girls and boys if health is not persistent ($\rho_f = \rho_m = 0$). However, if health is persistent and recovery rates differ by gender then periodicity of absence rates differs by gender. This implies that factors other than menstruation could cause differences in the absence hazard at 28 (a multiple of seven) (Herrmann & Rockoff, 2012). The approach above, as used by Herrmann and Rockoff (2012), attempts to account for this with placebo tests. The absence hazard at 28 of older girls (column 2), where we may expect to find an effect, is compared to that of younger girls (column 1). Similarly, a comparison is made between the absence hazard at 28 days of girls (column 3) to that of boys (column 4). No statistically significant differences were found in the coefficients between either pair of groups. This points to factors other than menstruation causing the absence hazard at 28 to be significant. In the next section, we pursue a different approach to overcoming this problem. This more structural approach allows girls and boys to have different tendencies probabilities of absence, and therefore does not rely on comparisons between groups to draw conclusions.

The hazard model suffers from some methodological challenges. Due to school holidays and weekends, girls are rarely observed as present or absent every 28 days. This poses a problem to estimating the hazard for 28-day distances. In addition, if girls were to be absent during menstruation every other period, this would not be captured by the hazard model. The structural model set out in the next section accounts for these possibilities and makes it possible to link two period-related absence spells that are up to 3 months away from each other. This makes it possible to find period-related absence spells even when girls' periods sometimes fall on weekends, or when girls miss periods, or attend school during some periods. The structural model is therefore able to make better use of the longitudinal element of the data.

Variability in menstrual cycles across and within women is common, particularly for young girls. By allowing only for periods at specified lengths, the hazard model limits our ability to capture longer or shorter cycles. The hazard estimated in the previous section included dummy variables to capture cycles of 28, 29 and 30 days, using the specification of Herrmann and Rockoff (2012). However, this still only allows for a small range of days on which menstruation can occur. The structural model that follows is more flexible and allows menstrual cycle length to take on a distribution centred around 28 days. This allows a better chance at being able to capture absences that are related to menstruation.

6 Structural approach

The difficulties encountered in sections 4 and 5 in identifying period-related absence illustrate the need for a more structured approach to modelling school absence. This section sets out a theoretical model of the likelihood of being absent. Theoretical models rarely simplify to linear relationships that can be recovered through conventional ordinary least squares regression and other pre-packaged estimators. Therefore, maximum likelihood is used to recover the set of parameters that are most likely to have produced the attendance data that we observe.

6.1 Modelling Absenteeism

Reasons for absenteeism are not reported, so it is not known when absenteeism is mentruation-related. In our model we want to allow for both channels; we therefore allows for two different types of absenteeism: sick absenteeism (s_absent) and period absenteeism (p_absent).

The probability of being absent on any given school day due to sickness or to any other non-menstrual reason is given by:

$$a = P(s\_absent_t = 1)$$

And the probability of being absent on any given school day due to menstruating is given by:

$$p = P(p\_absent_t = 1 \mid period_t = 1)$$

Where $period_t = 1$ if a student is on her period on day t.

Students can therefore be absent for either non-menstruation related or menstruation related reasons. If I(.) is an indicator function for absence due to either cause, then:

$$I(absent_t = 1) = max\,[I(p\_absent_t = 1), I(s\_absent_t = 1)]$$

Table 3 summarises how the probability of being absent differs based on whether a student is menstruating.

Table 3: Probability of being absent on any given day

State (Ω)	$period_t = 0$	$period_t = 1$
$P(absent_t = 1 \mid \Omega)$	a	$1-(1-a)(1-p)$
$P(absent_t = 0 \mid \Omega)$	$1-a$	$(1-a)(1-p)$

6.2 Modelling Menstruation

We do not observe whether a girl is menstruating on any given day. To allow for the probability of absenteeism to differ for menstruating girls, we model menstruation. To allow for variation in girls' menstrual cycles a distribution of possible menstruating days is allowed.

We start with a very simple model where the probability of menstruating on a given day if you began your menstrual cycle 28 days ago (expected cycle length) is given by:

$$e = P(period_t = 1 \mid period_{t-28} = 1)$$

While menstruating on a given day if you began your menstrual cycle 27 or 29 days ago (one day off the expected cycle length) is given by:

$$u = P(period_t = 1 \mid period_{t-27} = 1) = P(period_t = 1 \mid period_{t-29} = 1)$$

This can be extended into the future to allow for the possibility that girls may skip periods or attend school during some periods. Figure 4 illustrates:

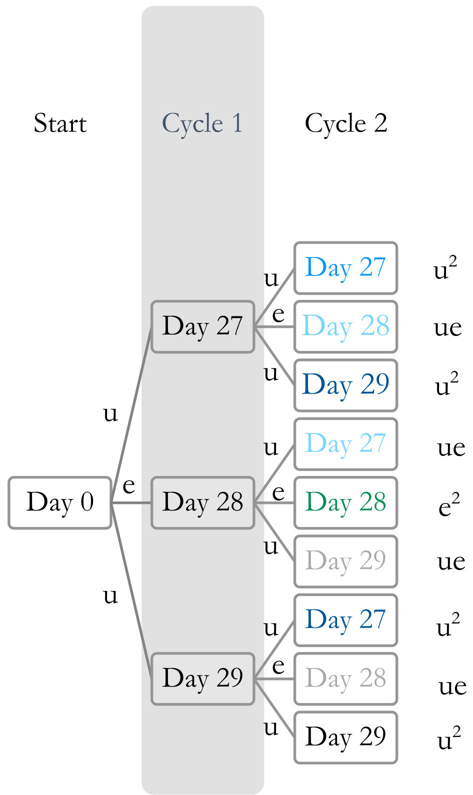


Figure 4: Menstrual Cycle Length

As defined earlier, there is a constant probability of being absent when you are on your period, p. Thus, we can use Figure 4 to calculate the probability of being absent on a given day, conditional on our knowing when, in the past, menstruation occurred.

Given: $p = P(p\_absent_t = 1 \mid period_t = 1)$

Then: $P(p\_absent_t = 1 \mid \Omega) = P(p\_absent_t = 1 \mid period_t = 1) \times P(period_t = 1 \mid \Omega)$

$= p \times P(period_t = 1 \mid \Omega)$

Table 4 summarises how the probability of being absent differs based on different assumptions about when the last two menstrual cycles started.

Table 4: Probability of being absent due to menstruation on any given day

State (Ω)	$P(period_t = 1 \mid \Omega)$	$P(p\_absent_t = 1 \mid \Omega)$
Cycle 1		
$period_{t-27} = 1$	u	pu
$period_{t-28} = 1$	e	pe
$period_{t-29} = 1$	u	pu
Cycle 2		
$period_{t-54} = 1$	u^2	pu^2
$period_{t-55} = 1$	2eu	2peu
$period_{t-56} = 1$	$2u^2 + e^2$	$p(2u^2 + e^2)$
$period_{t-57} = 1$	2eu	2peu
$period_{t-58} = 1$	u^2	pu^2

This method can be repeated to find the probability of being absent multiple cycles from the assumed menstruating day. This simplifies the problem dramatically, as no knowledge is required about whether an individual is currently menstruating or not, but only when her first menstruation of the year occurred.

This model is then expanded to allow for a wider distribution of possible menstrual cycle lengths. Studies across a range of countries show that length of menstrual cycle is distributed around a median of 27-30 days with a mode of 28 days (Beach, 1968; Chiazze et al., 1968; Flug et al., 1984; Guo et al., 2005; Jeyaseelan et al., 1992). Median length of menstrual cycle has been found to decrease with age (Flug et al., 1984; Guo et al., 2005; Münster, Schmidt, & Helm, 1992; Umeora & Egwuatu, 2008). Chiazze et al. (1968) provide detailed distributions of menstrual cycle length for 30 655 recorded menstrual cycles from 2 316 women in their study. Appendix Table A shows the distribution found by Chiazze et al. (1968) for girls aged 15-19. The distribution centres at a median of 29 days and is skewed to the right.[16] When estimating the model, instead of estimating the probabilities e and u, girls' cycles will be assumed to follow the distribution found by Chiazze et al. (1968) and reported in Appendix Table A.[17]

[16] Many studies focus on the mean menstrual cycle length which will be upwardly biased by the long right tail in the distribution (Harlow, Campbell, Lin, & Raz, 1997; Umeora & Egwuatu, 2008).

[17] The distribution found by Chiazze et al. (1968) was chosen because they conduct the largest study which reports a detailed frequency distribution for teenagers.

6.3 Likelihood Model

Based on the above, the likelihood function for individual, i, for day t, given state Ω, is given by:

$$L_{it|\Omega} = absent_t \times P(absent_t = 1 \mid \Omega) + (1 - absent_t) \times P(absent_t = 0 \mid \Omega)$$

The model allows us to calculate the absence probability for each day having knowledge on when your first period of the year occurred. The likelihood function for individual i for day t, assuming the first period of the year occurs on the k^{th} day of the term is therefore given by:

$$L_{itk} = absent_{it} \times P(absent_{it} = 1 \mid \Omega_k) \times I(\Omega_k) + (1 - absent_{it}) \times P(absent_{it} = 0 \mid \Omega_k) \times I(\Omega_k)$$

where Ω_k is the state that $period_k = 1$, where $k \in (1,28)$

The overall likelihood for individual i for starting day k is found by summing equation above over all possible days, t.

$$L_{ik} = \sum_{\forall t} L_{itk}$$

6.3.1 <u>Finite Mixture Model</u>

To estimate the model, no knowledge is required about whether an individual is currently menstruating but only when her first menstruation of the year occurred. A likelihood is calculated assuming first menstruation is on 22 January to 19 February (first 28 days of term), each in turn:

$$L_{ik} = \sum_{\forall t} L_{itk}$$

where $k \in (1,28)$.

The assumed probability of menstruating, given k, is shown in Figure 5.

The likelihood for individual i can now be found by taking the weighted sum over all possible values of k:

$$L_i = \frac{1}{28} \sum_{k \in (1,28)} L_{ik}$$

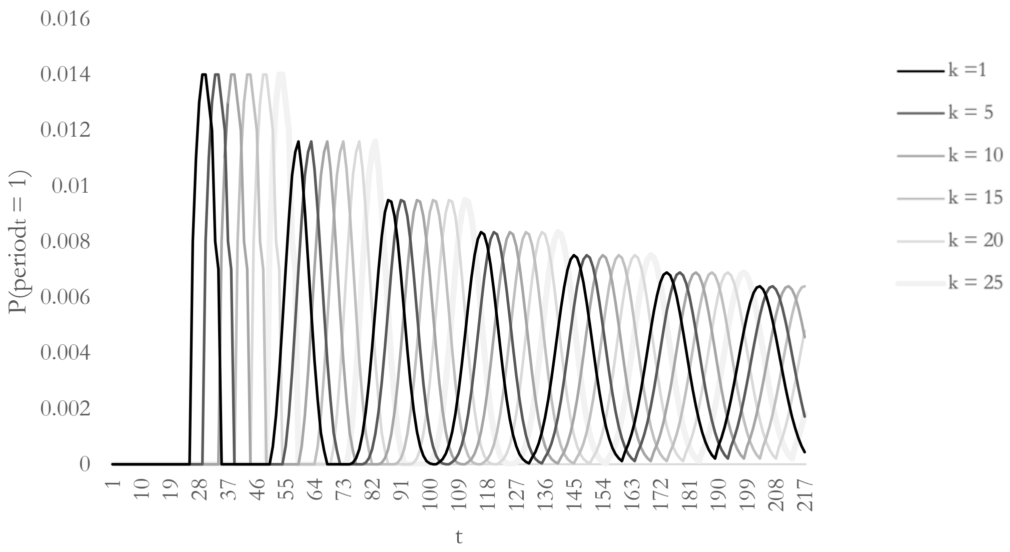
Finally, the overall likelihood to be maximized is found by summing over all individuals:

$$L = \sum_{\forall i} L_i$$

The estimates for a and p are then found by maximizing the log of the overall likelihood:

$$\hat{a}, \hat{p} = arg\,\max_{a,p}(ln\,(L))$$

Figure 5: Finding starting value: FMM model



6.3.2 <u>Testing the model</u>

The model was used to estimate p for simulated data where the true p was 10%. This was repeated 10 times with 3 different samples size (N= 500, N=1000, N=5000). Appendix Figure A shows the distribution corresponding to each sample size. None of the models appear to be biased, and models with larger sample have less variance. For a sample size of 1000, more than 90% of the predictions are within 2 percentage points of the actual estimate.

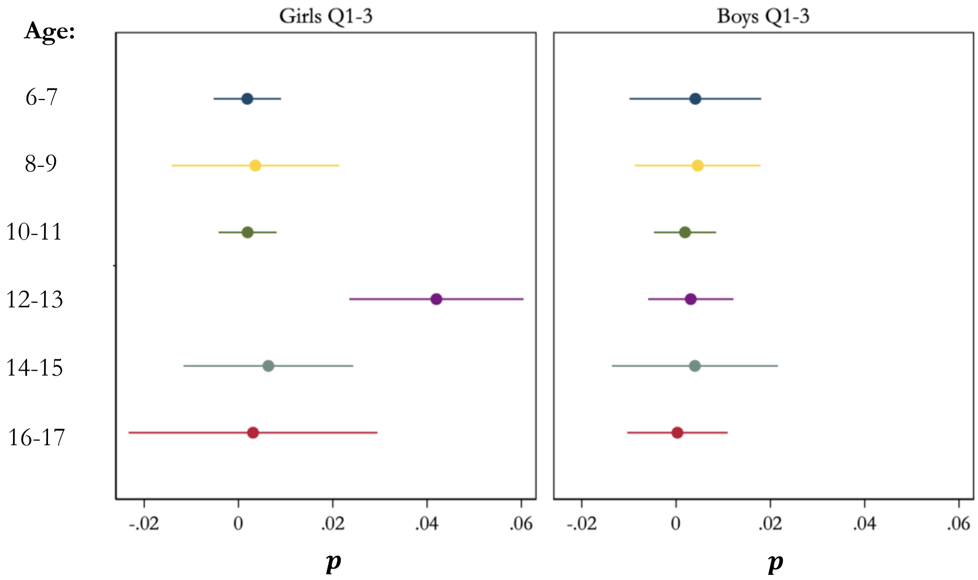
7 Results

Figure 6 and 7 report the estimates for p, the probability of being absent from school when menstruating. Figure 6 reports the estimates for students in quintiles 1-3, Figure 7 compares the estimates for students in quintiles 4 and 5.[18] The results are further disaggregated by gender and age. This disaggregation decreases the sample size for each individually estimated model; however, Monte Carlo simulations show that most of the identification comes from observing the same individuals over multiple days, rather than from having a large sample of individuals. We therefore do not think this decrease in sample size poses a threat to reliable estimates. Indeed, we find that we have enough power to estimate an exact zero for the coefficients.

When comparing girls and boys in quintile 1-3 schools (Figure 6), we find that only 12-13 year old girls have a higher probability of being absent in cyclical trends that resemble menstrual cycles. While p is zero for all other groups, p is estimated to be 3.5% for this group. This corresponds to a 4.2 percentage point increase in the probability of being absent when menstruating. The magnitude of this coefficient is in line with what other authors have found (Oster & Thornton, 2011). While only finding an effect for 12-13 year old girls and not for their older counter parts may seem surprising initially, 98% of South African girls reach menarche between the ages of 11 and 14 (Ramathuba, 2015) and some have argued that this is the most difficult time in managing menses for girls (Benshaul-Tolonen et al., 2019).

[18] Studies find quintiles 1-3 to have similar educational outcomes, but to differ significantly from those of quintile 4 and 5 (Van der Berg, 2008).

Figure 6: Estimates for p – girls vs boys



When comparing girls in quintile 1-3 schools to girls in quintile 4-5 schools (Figure 7) we find evidence that menstruation also affects attendance of girls in quintile 4-5 schools. However, while menstruation affects 12-13 year olds in quintile 1-3 schools, younger girls, aged 10-11, are affected in quintile 4-5 schools. This is consistent with the fact that menarche occurs at a younger age when girls are better nourished (Satyanarayana & Naidu, 1979). This result raises questions regarding the channel though which menstruation affects the attendance of girls. We would expect girls in quintile 4-5 schools to have better access to manufactured sanitary products, but this assumption may be inaccurate. Alternatively, this result may indicate that stigma plays an important role and that therefore no socio-economic class is immune to the challenges associated with menstruation. Both sets of results emphasize that menarche is a trying time and that encountering menstruation for the first time presents challenges for girls in relation to school attendance.

Figure 7: Estimates for p – Q1-3 vs Q4-5 schools

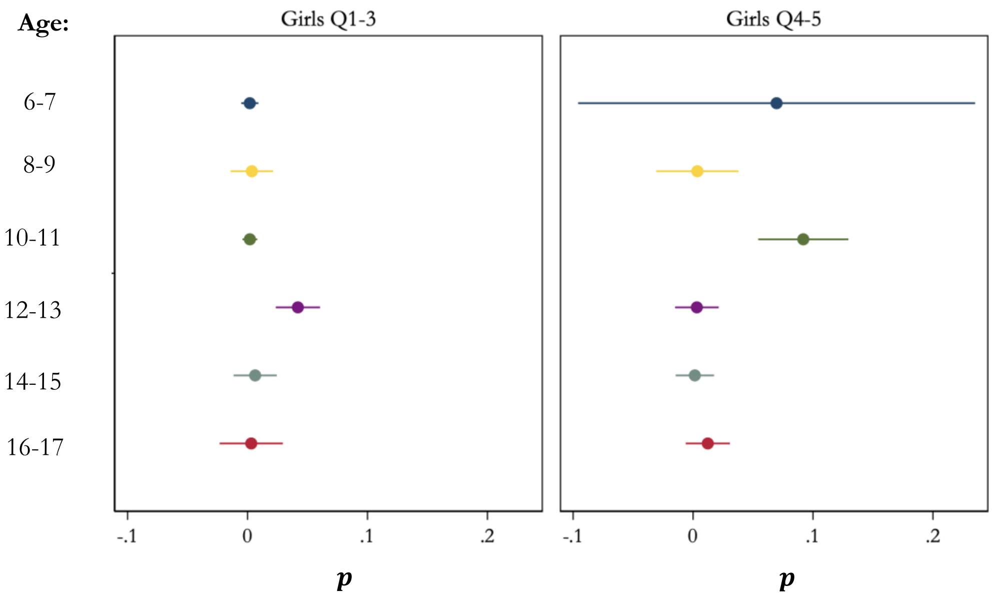


Table 5, and appendix Tables B and C report the full estimation results. To allow for weekly trends common to all students, the probability of being absent on any given school day, a, is estimated as:

$$P(absent_t = 1) = a\left(\frac{\#\,students\ absent_w}{mean(\#students\ absent)}\right)^m$$

Where: $w \in (1, W)$ denotes the week and day t falls within week w,

$\#\,students\ absent_w = \sum_{i=1}^{N} I(absent_{iw} = 1)$,

$mean(\#\,students\ absent) = \frac{1}{W}\sum_{w=1}^{W}\sum_{i=1}^{N} I(absent_{iw} = 1)$ and

m measures the elasticity to weekly trends.

The baseline probability of being absent varies between 1.0-2.3% with higher probabilies for boys in general. The elasticity also differs between groups, with younger students showing more sensitivity to weekly trends.

Table 5: Model estimates for girls in quintile 1-3

Age	6-7	8-9	10-11	12-13	14-15	16-17
Baseline (a)	0.021	0.014	0.011	0.010	0.017	0.020
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.001)***
Period (p)	0.002	0.004	0.002	0.042	0.006	0.003
	(0.004)	(0.009)	(0.003)	(0.009)***	(0.009)	(0.013)
Elasticity (m)	1.001	1.013	1.003	1.151	1.014	1.009
	(0.021)***	(0.040)***	(0.029)***	(0.047)***	(0.040)***	(0.044)***
N observations	1 340 160	1 327 200	1 290 880	1 046 560	460 480	308 480
N students	8376	8295	8068	6541	2878	1928

8 Conclusion

The results of this study indicate that menstruation causes absenteeism for young girls (12-13 year olds in quintile 1-3 and 10-11 year olds in quintile 4-5), but that older girls do not have a higher probability of being absent during their menses. This pattern could be explained by selection bias in older girls, those that remain in school may have better support for their periods. However, girls are overrepresented in secondary school in South Africa (Department of Basic Education, 2018a), there would therefore need to be other factors that affect school dropout of boys disproportionatly. More plausible perhaps, is that older girls learn coping mechanisms that enable them to attend school. The results point to menstruation having a temporary effect around the time of menarche, implying that menstruation may not pose a significant barrier to attending school for older girls in low SES settings. However, even a temporary period of repeated absence may have long term consequences for the educational outcomes of girls.

Given the large sample size, one can reasonably claim that these results are valid for Limpopo in general. However, there is no reason to believe that they would hold true for any other country. Large differences in cultural beliefs, gendered power dynamics and access to manufactured sanitary products exist between countries and perhaps even between South African provinces. It is therefore possible that menstruation affects absenteeism differently across countries (Jewitt & Ryley, 2014). However, this finding is in line with the literature; in most contexts where this question has been considered rigorously, menstruation has been found to have a limited affect on school attendance (Benshaul-Tolonen et al., 2019; Grant et al., 2013; Oster & Thornton, 2011).

While the results do not point to menstruation as a major source of absenteeism for South African school girls, this does not mean that girls are sufficiently prepared for and supported during their menses. Other evidence indicates that girls seem to be utilizing homemade sanitary products or accessing manufactured products that enable them to attend school, but nevertheless there are many ways that menstruation could negatively affect those without sufficient access to MHM and WASH. For example, studies have found that fear of soiling uniforms is stressful and distracting, making it more difficult for girls to concentrate while at school (Jewitt & Ryley, 2014; Mason et al., 2015; Tegegne & Sisay, 2014). Moreover, to minimize risk of leakage from sanitary products, girls may decrease their movement and therefore participate less in classroom and leisure activities. Due to data limitations, this study did not explore the effects of menstruation on learning outcomes or mental health; further research on the relationship between menstruation and these factors is urgently needed. The results suggest that the envisaged South African government's sanitary product distribution project could have important impacts on the attendance of younger girls and should therefore focus on supporting girls at the time of menarche. The intervention is unlikely to affect the attendance of older girls. However, the project may affect learning outcomes and the well-being of all girls; absenteeism is not the only reason to pursue "sanitary dignity" as a goal.

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10 Appendix

10.1 Tables and Figures

Table A: Frequency Distribution of Menstrual Cycles of Teenagers by Cycle Length

Cycle Length	Nr of women	% of women	Cum %
<25	776	13,6%	13,6%
25	296	5,2%	18,8%
26	396	7,0%	25,8%
27	502	8,9%	34,7%
28	533	9,4%	44,1%
29	528	9,3%	53,4%
30	505	8,9%	62,4%
31	439	7,8%	70,1%
32	313	5,5%	75,7%
33	253	4,5%	80,2%
34	190	3,4%	83,5%
35	166	2,9%	86,4%
>35	766	11,6%	88,4%
Total	5653	100%	

Source: Chiazze et al. (1968), Table 4, pg 91

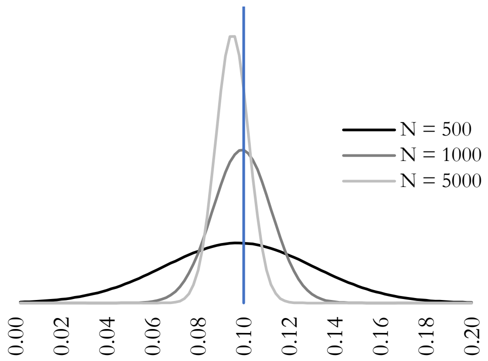
Table B: Model estimates for boys in quintile 1-3

Age	6-7	8-9	10-11	12-13	14-15	16-17
Baseline (a)	0.023	0.016	0.015	0.016	0.018	0.023
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
Period (p)	0.004	0.005	0.002	0.003	0.004	0.000
	(0.007)	(0.007)	(0.003)	(0.005)	(0.009)	(0.005)
Elasticity (m)	1.010	1.016	1.004	1.009	1.007	0.999
	(0.025)***	(0.031)***	(0.024)***	(0.027)***	(0.035)***	(0.031)***
N observations	1 365 920	1 330 080	1 279 200	1 085 280	595 680	358 880
N students	8537	8313	7995	6783	3723	2243

Table C: Model estimates for girls in quintile 4-5

Age	6-7	8-9	10-11	12-13	14-15	16-17
Baseline (a)	0.025	0.020	0.015	0.019	0.022	0.023
	(0.003)***	(0.001)***	(0.001)***	(0.000)***	(0.001)***	(0.001)***
Period (p)	0.07	0.004	0.092	0.003	0.001	0.012
	-0.084	-0.018	(0.019)***	-0.009	-0.008	-0.009
Elasticity (m)	1.112	1.008	1.227	1.004	1.004	1.008
	(0.133)***	(0.065)***	(0.089)***	(0.061)***	(0.066)***	(0.062)***
N observations	245 440	292 480	260 480	238 880	120 160	89 440
N students	1534	1828	1628	1493	751	559

Figure A: Monte Carlo Simulation - parameter p



10.2 Code for Finite Mixture Model

```
*-----------------------------------------------------------------------------
*--- Finite Mixture Model that allows for distribution around 28 day cycle ---
*-----------------------------------------------------------------------------

capture program drop FMM_periods_with_weeklytrend
program define FMM_periods_with_weeklytrend

  args todo b lnf
  local a =  1/(1+exp(-`b'[1,1]))            // set a to be between 0 and 1
  local p =  1/(1+exp(-`b'[1,2]))            // set p to be between 0 and 1
  local m = 10/(1+exp(-`b'[1,3]))            // set p to be between 0 and 10

matrix P = J(29, 29, 0)
  forvalues n = 1(1)29 {
    cap matrix P[`n',`n'-4] = $prop25
    cap matrix P[`n',`n'-3] = $prop26
    cap matrix P[`n',`n'-2] = $prop27
    cap matrix P[`n',`n'-1] = $prop28
    cap matrix P[`n',`n'  ] = $prop29
    cap matrix P[`n',`n'+1] = $prop30
    cap matrix P[`n',`n'+2] = $prop31
    cap matrix P[`n',`n'+3] = $prop32
    cap matrix P[`n',`n'+4] = $prop33
  matrix S = J(1, 29, 0)
  matrix S[1,15] = `p'

  tempvar FMM_L l L
  qui gen double `FMM_L' = 0

  forvalues day0 = 1(1)28 {
    local buffer = (29-15) + `day0'
    matrix Z0 = J(1, `buffer', 0)
          matrix Z0[1,`day0'] = S[1,15]
          matrix P_p = (Z0, S*P, S*P*P, S*P*P*P, S*P*P*P*P, S*P*P*P*P*P, S*P*P*P*P*P*P)
          qui cap drop `l'
          qui gen double `l' = 0
          qui cap drop `L'
          qui gen double `L' = 1
          forvalues i = 1(1)$days {
            qui replace `L' = P_p[1,`i'] + (`a')*((W[1,`i'])^`m') - P_p[1,`i']*(`a')*((W[1,`i'])^`m')
            qui replace `L' = 1 - `L'                      if day`i' == 0
            qui replace `L' = 1                            if day`i' == .
            qui replace `L' = 0.0000001                    if    `L' == .
            qui replace `l' = `l' + log(`L')
          }

      qui replace `L' = `L' + exp(`l')
  }
  qui replace `FMM_L' = 0.0000001 if `FMM_L'== .
  mlsum `lnf' = ln(`FMM_L')

end

*-----------------------------------------------------------------------------

ml model d0 FMM_periods_with_weeklytrend /a /p /m
ml init /a = -1
ml init /p = -2
ml init /m = -4
ml max, difficult tolerance(0.00000001) nonrtolerance
eststo b_`age'_q`q': nlcom (a: 1/(1+exp(-_b[a]))) (p: 1/(1+exp(-_b[p]))) (m: 10/(1+exp(-_b[m]))-1), post

*-----------------------------------------------------------------------------
```