
ECONtribute
Discussion Paper No. 117

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Evidence from Ramadan Fasting**

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October 2021

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Religious practice and student performance: Evidence from Ramadan fasting*

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This version: October 2021

Abstract

We investigate how the intensity of Ramadan affects educational outcomes by exploiting spatio-temporal variation in annual fasting hours. Longer fasting hours are related to increases in student performance in a panel of TIMMS test scores (1995–2019) across Muslim countries but not other countries. Results are confirmed in a panel of PISA test scores (2003–2018) allowing within country-wave comparisons of Muslim to non-Muslim students across Europe. We provide evidence consistent with the hypothesis that a demanding Ramadan during adolescence affects educational performance by facilitating formation of social capital and social identity via increased religious participation and shared experiences among students.

Keywords: EDUCATION, RELIGION, RELIGIOUS PARTICIPATION, RAMADAN, SOCIAL IDENTITY, SOCIAL CAPITAL, PISA, TIMMS

JEL Classification: I21, Z12, J24, O15

*We thank Robert Barro, Sascha O. Becker, Razi Farukh, Daniel Hungerman, Murat Iyigun, David Jaeger, Markus Nagler, Jared Rubin, Abhijeet Singh, Felipe Valencia, Yiling Zhao and seminar audiences at the University of Cologne, University of Konstanz, IZA, Ifo Institute, ASREC conference 2018 (Chapman), the CEPR Conference on the Economics of Religion 2019 (Venice), and the CESifo Area Conference on the Economics of Education 2018 for helpful comments and suggestions. Hornung acknowledges that his research was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy - EXC 2126/1 - 390838866. Schwerdt acknowledges that his research was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy - EXC 2035/1 - 390681379.

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1 Introduction

Muslim-majority countries achieved substantially lower average test scores in math (439) and science (449) than Christian-majority countries (495/500) in the 2019 TIMSS assessment of 8th graders. This significant gap in educational performance remains when accounting for income levels and can therefore not be attributed to mere differences in economic development across regions. While this suggests a role of religion for educational performance, conclusive evidence for the existence of such a relationship is missing. Economics has largely focused on the converse effects that education exerts on religiosity, whereas sociology has suggested that religious participation is conducive to educational performance because it facilitates the formation of social capital.¹

Quantifying the effect of religion on education is notoriously difficult due to their endogenous relationship. In this paper, we use a plausibly exogenous source of variation in the intensity of a religious practice and exploit panel variation in prescribed fasting hours during Ramadan to understand its role for educational performance. The holy month of Ramadan is one of the five pillars of Islam and an obligatory element for Muslim believers. During Ramadan, Muslims who reached puberty refrain from eating, drinking, smoking, and sexual activities from sunrise to sunset and engage in various social activities. As explained in more detail below, the month of Ramadan is set in accordance with the Islamic lunar calendar, which is shorter than the Gregorian solar calendar and therefore rotates over the seasons. If Ramadan falls into northern hemisphere summer, Muslim believers on the northern (southern) half of the earth fast more (less) hours than in winter. The change in prescribed fasting hours is further amplified by the distance to the equator. The resulting variation of daily fasting time for Muslim believers during Ramadan can be seen as exogenous in the context of schooling and therefore provides an ideal source to analyze the effect of religious engagement as measured by the intensity of observance of the religious practice.

To analyze the effect of religious practice on education performance, we combine country-specific daily fasting hours with two repeated cross-sectional international student achievement test surveys, TIMSS (Trends in International Mathematics and Science Study) and PISA (Programme for International Student Assessment). Combining the seven waves of TIMSS data for the period 1995 to 2019 into a pseudo-panel, we show that the length of daily fasting hours during the last Ramadan *before* the achievement test was taken, significantly increases the average performance of 8th graders (students around age 15) in Muslim countries, but not in non-Muslim countries.²

¹The recent overview article on the economics of religion by [Iyer \(2016\)](#) and the economics of Islam by [Kuran \(2018\)](#) include sections summarizing the literature on religion and education. For seminal work in economics on the effect of education on religion see, e.g. [Glaeser and Sacerdote \(2008\)](#) and [Hungerman \(2014\)](#) or for the effect of religion on education see, e.g. [Gruber \(2005\)](#) and [Meyersson \(2014\)](#). For seminal work in sociology see, e.g. [Coleman and Hoffer \(1987\)](#), [Muller and Ellison \(2001\)](#) and [Glanville et al. \(2008\)](#).

²Throughout the paper, we will denote Muslim countries as those countries where more than half of the population identifies as Muslims and those countries as non-Muslim where less than half of the population identifies as Muslims.

Because we focus on tests that were conducted *after* the most recent Ramadan, we can abstract from the detrimental direct consequences of fasting during Ramadan and focus on the indirect and persistent consequences for educational performance.³ Furthermore, by focusing on 8th graders, we capture the effect of Ramadan intensity during adolescence, when attitudes toward religious engagement are especially prone to change. Results from our preferred specification suggest that an increase of average Ramadan fasting hours by 10 % increases both math and science test scores by around 11 % of a standard deviation.⁴ These findings are robust to the inclusion of a large set of student and school characteristics, and different categorizations of Muslim countries.

Focusing on eight Western European countries that participated in all six waves of the PISA study between 2003 and 2018, we find test scores to significantly increase in daily fasting hours for students whose parents immigrated from Muslim countries in comparison to students without Muslim-country origins. These specifications use only within-country-wave variation and allow us to address concerns that TIMMS results are driven by spurious trends correlating with the cyclicity of Ramadan intensity. An increase of average Ramadan fasting hours by 10 % significantly reduces the gap in PISA test scores between Muslim and non-Muslim students by 2.5 to 3.0 %, depending on the subject evaluated (mathematics, science, or reading). In sum, based on two independent data sets, our estimates reveal a positive reduced-form effect of religious practice on student performance.

Theoretically, there are several mechanisms that may produce a positive relationship between religious practice and educational performance. Variation in the intensity of religious practice may reflect variation in religiosity which correlates with character skills such as strength of motivation, ability to work on long-term plans, and socio-emotional regulations that improve human capital formation in the long run (see [Heckman, 2013](#)). Religious practices such as Ramadan observance often require patience, self-control and perseverance. If these character skills exert positive externalities on human capital formation, we expect stricter religious practices to be positively related to educational performance.

Alternatively, some religious practices have been associated with the formation of social capital which in turn creates human capital ([Coleman, 1988](#); [Putnam, 2000](#)). Indeed it has been widely confirmed that religious participation shapes social networks and social capital ([Muller and Ellison, 2001](#); [Glanville et al., 2008](#)). Especially during adolescence, more intense religious practices may encourage the choice of peers that share pro-social norms and provide educational resources.⁵ Such ideas are broadly related to the theory of social identity popularized by [Akerlof and Kranton \(2002\)](#). This theory highlights the importance of the social environment of students in the

³Detrimental effects of fasting on educational performance *during* Ramadan have been documented by [Oosterbeek and van der Klaauw \(2013\)](#). Our findings may thus constitute the difference between a direct negative and an indirect positive effect.

⁴An increase of Ramadan fasting hours by 10 % corresponds to an increase of fasting hours by 1.25 hours based on the sample mean of fasting hours in Muslim countries.

⁵[Lavy and Sand \(2019\)](#) show that having a larger number of friends is beneficial for students achievements if friendship is reciprocated and from higher socio-economic background.

context of schooling and predicts that the creation of a more unified school community increases the skill formation of students. Religious practices among students, i.e., the performance of identical rituals, are likely to affirm a common identity and hence increase educational performance if class composition is sufficiently homogeneous with respect to religious preferences. This is in line with findings of [Clingsmith et al. \(2009\)](#), who argue that the communal experience of the pilgrimage to Mekka, the Hajj, fosters a shared identity among pilgrims by performing identical rituals.

We show that longer Ramadan fasting hours are associated with more religious participation using information on the frequency of attending religious services from seven waves of the World Values Survey (WVS) covering the years between 1981 and 2020. This finding holds for adolescents but not for other age cohorts, lending support to our hypothesis that Ramadan is especially influential during this age. Indeed, changes in fasting hours are associated with a higher frequency of attendance at religious services only among Muslims in the age group 15 to 18, when compared to non-Muslim individuals at the same age. Increasing Ramadan fasting hours by 10 % is associated with an increase of the probability to attend religious services more than once per week by 3.3 percentage points. Nevertheless, while more frequent religious participation may lead to higher social capital, it may also reflect higher levels of religiosity and character skills.

To provide more evidence on the relative importance of the two channels, formation of character skills and formation of social capital, we rely on the religious composition of school-cohorts in the PISA data. Information on the origin countries of students allow us to approximate the cohort share of Muslim students for all schools in our sample. If the performance of stricter religious practices among students creates a common identity and provides access to social capital increasing in the number of participating students, we expect to see a stronger increase in educational performance for Muslim students in schools with a higher share of Muslims. Indeed, our estimations based on a triple-interaction specification reveal that the effect of Ramadan intensity is larger in schools with a high share of Muslim students in the cohort. Moreover, our estimates indicate that the positive effect of Ramadan intensity can only be found for students in schools with a high Muslim share but not in schools with a low Muslim share. Although we ultimately cannot exclude other channels such as the presence of spillover effects, we tentatively interpret our estimates as evidence that the religious practice impacts educational performance by facilitating the formation of a common identity among students and providing access to social capital—and not by affecting their individual character skills.

Prior literature has highlighted that certain religious practices are costly and might crowd out other economically relevant activity ([Iannaccone, 1992](#)). In a methodologically similar study, [Campante and Yanagizawa-Drott \(2015\)](#) show that more intensive Ramadan fasting is related to lower GDP growth. Furthermore, Ramadan ob-

servers show lower performance during physically and mentally challenging tasks while fasting. More specifically, grades of university students have been shown to decline in the number of weeks a course *overlaps* with the month of Ramadan (see [Oosterbeek and van der Klaauw, 2013](#)). Consequently, the relationship between the intensity of the religious practice and human capital formation is estimated to be negative in the short-term. Furthermore, in utero exposure to Ramadan fasting has been shown to have detrimental long-term consequences for health, cognitive ability, and labor market performance ([Almond and Mazumder, 2011](#); [Majid, 2015](#)). We add to this literature by documenting the lasting returns to more intensive religious engagement during the impressionable period of adolescence. Note that due to our focus on treatment intensity during a specific period in life, the results do not necessarily contradict the findings of [Oosterbeek and van der Klaauw \(2013\)](#) or [Campante and Yanagizawa-Drott \(2015\)](#). Notwithstanding the potentially negative direct consequences of Ramadan fasting during adulthood on the performance in end-of-course college exams or worker productivity, our results allude to the possibility that the experience of a more intensive Ramadan during adolescence still leads to a level-shift in accumulated human capital.

Furthermore, by providing causal estimates of the effect of the intensity of a religious practice on student performance, this paper adds to a literature that analyzes the effect of religion on educational outcomes that often lacks credible sources of exogenous variation. An exemption is the study by [Gruber \(2005\)](#), who uses the local ancestral density of Christian denominations in the US to instrument individual religious participation, finding positive effects for educational performance. Another exemption is [Meyersson \(2014\)](#), one of the few studies that focuses on the effect of religion on education in a non-Western setting, who provides evidence that Islamic rule increased female secular high school education across Turkish municipalities.⁶ Different from studies that typically focus on the performance of Muslim students in U.S. or U.K. schools, we also provide evidence from countries that predominantly recognize Islam as their official religion and where the majority of the population is of Muslim faith. Thereby, we avoid the issue that values central to the education system contradict those of students and their parents, potentially leading to lower educational participation.

Most studies argue that the direction of causality runs from education to religious participation. Traditionally, social scientists argued that scientific advancements lower societies' attachment to religions. The main idea of this so called "secularization hypothesis" is that an increase in critical thinking reduces believes in supernatural forces.⁷ However, many studies find a positive correlation between the level of education and various religious

⁶On the extensive margin, [Iyer et al. \(2014\)](#) find that religious organizations in India affect the extent to which education is taken up, especially if there is a local lack of public education.

⁷Recent studies which put emphasis on causal inference provide evidence to confirm the secularization hypothesis. Analyzing panel data for German cities between 1890 and 1930, [Becker et al. \(2017\)](#) find that education is negatively correlated with church attendance. Similarly, studies that exploit changes in compulsory schooling laws consistently identify negative effects of education on various measures of religiosity ([Arias-Vazquez, 2012](#); [Cesur and Mocan, 2018](#); [Hungerman, 2014](#); [Mocan and Pogorelova, 2017](#)).

measures across countries and at the individual level (for surveys see [Iannaccone, 1998](#); [Iyer, 2016](#)).⁸ [Glaeser and Sacerdote \(2008\)](#) show that education is positively related to the attendance of religious services, because more educated individuals obtain higher returns from social networks, but negatively related to religious beliefs in samples of individuals from Western countries. An alternative hypothesis advanced by [McCleary and Barro \(2006\)](#) is that educated individuals have a higher level of abstract thinking which is necessary to understand religious ideas.

Our paper further relates to the literature on religious education and economic development in history. According to this literature, Judaism and Christianity (specifically Protestantism) historically promoted education and investments in human capital more than Islam. Many of these studies highlight the importance of major reforms within Protestantism and Judaism that increased human capital formation, which in turn affected occupational choices, and economic prosperity. For seminal work on Judaism and education see, e.g. [Botticini and Eckstein \(2005, 2007\)](#), for Protestantism see, e.g. [Becker and Woessmann \(2009\)](#), for Catholicism see, e.g. [Squicciarini \(2020\)](#), and for Islam see, e.g. [Chaudhary and Rubin \(2011\)](#) and [Saleh \(2016\)](#). In their handbook article on religion in economic history, [Becker et al. \(2021, p. 624\)](#) conclude that “the relationship between Islam and human capital is *vastly* understudied.” We thus contribute to this literature by focusing on a religious practice in Islam instead of religious reforms within the other Abrahamic denominations.

Finally, our paper relates to a growing number of studies that focus on Islam and economic development. Studies in this area investigate the roots of the relative economic underdevelopment of the Islamic world. In general, this literature points at institutional differences with respect to norms that govern economic activity, e.g., inheritance systems, concepts of cooperations, or interest rate restrictions ([Kuran, 2003, 2004](#); [Rubin, 2011](#)). However, some studies have stressed the importance of differences in educational and scientific advancement due to norms and other restrictions imposed by Muslim authorities that impeded educational outcomes of Muslims ([Chaney, 2011, 2016](#); [Cinnirella et al., 2020](#)). While we do not attempt to provide a test of this hypothesis, our results indicate that the Islamic religion did not constitute a barrier to human capital formation in the recent past.

The remaining paper is organized as follow. In Section 2 we provide some background on the religious practices during Ramadan and discuss how they theoretically might affect student performance. Section 3 describes our data set and Section 4 explains our empirical identification strategy. Section 5 presents our main estimation results based on TIMSS and PISA data and Section 6 provides evidence for potential mechanisms that might explain our findings. Finally, Section 7 concludes.

⁸For example, [Brown and Taylor \(2007\)](#) use individual level panel data from the National Child Development Survey and find a positive association between education and church attendance.

2 Background and conceptual framework

2.1 Religious practices during Ramadan and their effects

Ramadan is the ninth month of the Islamic calendar (*Hijri*) and is a sacred month for more than a billion Muslim believers. It is one of the five pillars of Islam and therefore a mandatory element of the religion. Ramadan is a time of devotion, austerity and charitable giving. During this month, Muslims around the world are required to fast (*Sawm*) from sunrise to sunset to commemorate the first revelation of the Quran to Muhammad. Besides abstention from food, Ramadan requires Muslims to refrain from drinking, smoking, and sexual activities during the day. A notable exemption from the practice of Ramadan fasting applies to young children, sick people, elderly, people on journeys, and pregnant, menstruating, or breastfeeding women. Children are required to fast during Ramadan only after they reached puberty, even though younger children are certainly encouraged to practice some fasting.

During Ramadan, social life in Muslim societies undergoes enormous transformations ([Schielke, 2009](#)). At night, mosques are filled with believers who perform the additional voluntary *tarawih* prayers. Daily fast-breaking (*iftar*) at sunset and meals at pre-dawn (*suhur*) have an explicit social character and festive meals are shared at home with family and friends or with the religious community after the evening prayers at the Mosque. Wealthy citizens organize events with free food for the poor and needy and the end of the fasting period is marked by major festivals (*Eid al-Fitr*). Ramadan is thus associated with a range of social, moral, and pious commitments that influence individual decision making and might extend beyond the month of Ramadan itself.

Ramadan fasting is physiologically demanding and direct negative consequences have been well documented in the literature. During the month of Ramadan, individuals reduce their level of activity, loose weight, suffer from headaches, and have more difficulties to concentrate (see, e.g., [Afifi, 1997](#); [Leiper and Molla, 2003](#); [Meckel et al., 2008](#)). While [Toda and Morimoto \(2004\)](#) suggest that these physical conditions do not persist beyond the month of Ramadan, they might translate into future outcomes by affecting different stages of the production process of various socio-economic outcomes. For example, [Campante and Yanagizawa-Drott \(2015\)](#) argue that Ramadan fasting reduces worker productivity and provide evidence that GDP growth in Muslim countries is lower in years with longer average fasting hours. A number of studies find that prenatal exposure to Ramadan fasting reduces birth weight and increases the likelihood of being disabled as an adult ([Almond and Mazumder, 2011](#); [Van Ewijk, 2011](#); [Almond et al., 2015](#); [Majid, 2015](#)). [Oosterbeek and van der Klaauw \(2013\)](#) show that a higher number of weeks that an academic class falls into the month of Ramadan, the lower the final grade of Muslim students.

Next to these direct consequences, changes in individual lifestyles and social behavior during Ramadan may

affect socio-economic outcomes indirectly. For instance, [Campante and Yanagizawa-Drott \(2015\)](#) report that longer fasting hours during Ramadan positively affect subjective well-being, religious participation, beliefs, and attitudes among religiously committed Muslims. Focusing on the Hajj pilgrimage, another pillar of Islam, [Clingingsmith et al. \(2009\)](#) find that eight months after the Hajj, pilgrims are more likely to report that they (a) are regarded as religious persons, (b) increased the observances of global religious practices, (c) reduced participation in localized practices, and (d) changed their attitudes towards equality and harmony.⁹

Due to the fact that fasting will typically be observed more strictly once children become adolescents, a more demanding Ramadan during summer may be more influential for the religious and secular socialization of youths during their impressionable years. In our empirical setting, we assess the educational performance of students at the age of around 15 and therefore interpret the length of daily fasting hours before the test was taken to reflect the experienced intensity of a particularly influential Ramadan fasting. To provide evidence for our hypothesis that the intensity of Ramadan fasting is especially influential for adolescents, we show that their religious participation increases whereas the frequency of participation by other age groups remains unaffected by longer fasting hours in Section 6.

2.2 How religious activities affect educational performance

In this section, we discuss channels through which religious activities could theoretically affect educational performance and human capital formation in a positive way. We can broadly distinguish between theories according to which religious activities promote the formation of character skills via individual investment and theories according to which religious activities promote the formation of social capital and social identity in groups.

The first set of theories suggests that religious activities influence the individual skill set, such as non-cognitive abilities or character skills that are associated with student performance ([Heckman and Rubinstein, 2001](#)). The “strength of motivation, an ability to act on long-term plans, and the socio-emotional regulation needed to work with others” are skills necessary to perform well in school ([Heckman, 2013](#), p. 12). Hence, if character skills exert positive externalities on human capital formation, we should also expect religious activities to be positively related to educational performance. A related hypothesis is that by providing moral directives, role models, and social control, religion incentivizes behavior that is beneficial for learning outcomes ([Bankston and Zhou, 1995; Smith, 2003](#)).¹⁰

⁹Other studies have linked the fact that Ramadan makes religious communities and cultural dissimilarities in Western countries more salient to political polarization in elections ([Colussi et al., 2021](#)).

¹⁰Indeed, a number of empirical studies suggest a link between religious activities of children and their character skills. Several religious measures (e.g., importance of religious faith, church attendance) are inversely related to juvenile drug use, delinquency, absence from school, and high levels of depression ([Cochran and Akers, 1989; Evans et al., 1995; Freeman, 1986; Wright et al., 1993](#)). However, these studies do not consider the competing hypothesis that religious activities lead to social capital formation.

The second set of theories suggests a link between religious activities and educational performance that works through the formation of social capital. Motivated by the debate about why educational achievements of students in Catholic schools exceed those of students in public schools, [Coleman and Hoffer \(1987\)](#) and [Coleman \(1988\)](#) suggest that religious activities promote the formation of social capital which fosters the creation of human capital.¹¹ According to their estimates, attendance of religious services is a stronger determinant of low school dropout than religious affiliation. [Putnam \(2000\)](#) confirms that communities of faith are important repositories of social capital. In fact, while members of religious groups participate in religious activities more frequently, they are also more involved in other forms of civic engagement and report a larger number of friends.¹²

Coleman's and Putnam's work have motivated a number of studies in sociology that link religious participation with academic achievement via the formation of social capital. [Muller and Ellison \(2001\)](#) show that the effect of religious involvement on academic progress can be partly explained by family social capital (the frequency with which parents and students talk about school matters) and community social capital (access to peers with strong achievement values). [Glanville et al. \(2008\)](#) confirm that the relationship can be partly explained by measures of social capital, such as whether parents and friends of students know each other, whether students have access to friends with better grades, or whether students participate in secular social groups. This resonates with findings in the economic peer effects literature which finds that having more friends with higher socio-economic background is beneficial for student achievement ([Lavy and Sand, 2019](#)). [Fan \(2008\)](#) provides a theoretical model in which parent's religious participation is conducive to children's human capital formation. In this model, educational attainment of children is determined by their parental human capital as well as their social capital. As religious participation positively influences the stock of social capital, parents have an incentive to allocate a positive amount of time to religious activities.¹³

Above considerations are further complemented by the theory of social identity popularized by [Akerlof and Kranton \(2002\)](#). This theory highlights the importance of the social environment of students in the context of schooling and predicts that the creation of a more unified school community increases the skill formation of students. Establishing a consensus over ideals mitigates the negative effects of social differences within schools. According to this theory, shared experiences among students, i.e., the performance of identical (religious) rituals, are likely to affirm a common identity and hence increase educational performance. Recent evidence that lends

¹¹See, e.g. [Coleman et al. \(1982\)](#), [Evans and Schwab \(1995\)](#), and [Neal \(1997\)](#) for contributions to Catholic schools debate.

¹²This resonates with [Guiso et al. \(2003\)](#) who show a positive correlation between being actively religious and various measures of trust reported in the WVS. It is also in line with [Smith \(1999\)](#) who links adult political and civic involvement to religious participation during adolescence.

¹³The competing hypothesis that parental concerns about the moral development of their children induces religious participation has been noted many times in the sociological literature. For instance, [Wilson \(1978, p. 263\)](#) states that parents consider the church as a place of character building for their children, which is why "couples with growing children have the highest rate of church attendance."

empirical support to the presumption that shared collective experiences may help building a common identity and, thereby, favorably affecting behavior is provided by [Depetris-Chauvin et al. \(2020\)](#). While their study documents the existence of such identity-building effects triggered by the experience of victories of the national football team in sub-Saharan Africa, a demanding Ramadan arguably constitutes a collective experience of at least similar intensity.

Empirically, it may be hard to fully separate between mechanisms that exclusively work through the formation of character skills or social capital. In fact, the economics of education literature has argued that non-cognitive skills of children are highly correlated with pro-social behavior and social capital ([Heckman and Rubinstein, 2001](#); [Lleras, 2008](#); [Jackson, 2018](#)).¹⁴ However, we address this concern in Section 6, where we show that the intensity of Ramadan affects educational performance only if students are surrounded by a larger number of Muslims but not in their absence, suggesting that social identity and social capital formation are more important than the formation of character skills in our setting.

3 Data

Fasting hours. Following [Campante and Yanagizawa-Drott \(2015\)](#), we use local average daily daylight hours during the month of Ramadan to approximate average fasting hours. Drawing on the data service of the Astronomical Applications Department of the US Naval Observatory, we obtain detailed information on daily sunrise and sunset times, covering an entire year, for all countries included in our study.¹⁵ Combining this data with information on Ramadan dates in the Gregorian calendar, we calculate average daily fasting hours during the month of Ramadan for all countries and years used in our empirical analysis.¹⁶

Because we are interested in the indirect consequences of Ramadan intensity, our analysis relies on country-specific fasting hours of the Ramadan before the test was taken. Specifically, for the analysis of TIMSS data, we assign each student observation the fasting time of the most recent Ramadan, using information on the exact test date.¹⁷ For the analysis of PISA data, we assign each student observation the fasting time of the Ramadan preceding the first day of the year in which a test was officially taken.¹⁸

¹⁴It is also possible that religious communities amplify the effect of individual character skills ([Bankston and Zhou, 1995](#)).

¹⁵Daylight hours can vary within a country. As we do not have information on students' exact location, we use sunrise and sunset times of a country's capital.

¹⁶We converted the dates using the online calendar converter available at <https://muslimphilosophy.com/calconv/index.html>.

¹⁷Exact test dates are available in TIMSS's restricted use files.

¹⁸PISA tests usually take place in the first quarter of the year.

Test scores. We construct two panel data sets from two repeated cross-sectional international student assessment tests: the Trends in International Mathematics and Science Study (TIMSS) and the Program for International Student Assessment Survey (PISA).¹⁹

TIMSS. TIMSS provides data on student assessment test scores in mathematics and science of 8th graders (age 14–15). First conducted in 1995 and repeated on a regular 4-year cycle, TIMSS currently includes 7 waves and covers 24 years (1995–2019) of student assessment test scores. The number of participating countries in a wave varies between 32 and 44, and, to this date, more than 70 countries have participated in the study. We exclude students from countries that (a) participated only once or (b) participated under different names (e.g., countries of the former Yugoslavia) from our data set.

TIMSS employs a two-stage random sample design where, based on a country-specific random sample of schools, one or more classes of 8th graders are randomly selected, and all students of the selected classes participate in the study (LaRoche et al., 2016). Students’ educational performance is assessed by a paper- or computer-based test and results are scaled to the test scores of the students participating in the first wave (Yamamoto and Kulick, 2016).²⁰

TIMSS collects a comprehensive set of background information on students, teacher and schools. When constructing the repeated cross-sectional data set of test scores, we condition on a set of core variables derived from the student and school questionnaires that are consistently provided in all waves.²¹

Our analysis exploits country-level variation in Ramadan fasting hours as TIMSS does not include information on students’ religious denomination or parental background. We categorize a country as Muslim if more than 50% of its population identifies with this religion using information provided by the Pew Research Group (Grim and Karim, 2011).²² Overall, we identify 18 countries with a Muslim majority in our sample: Bahrain, Egypt, Indonesia, Iran, Jordan, Kazakhstan, Kuwait, Lebanon, Malaysia, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Syria, Tunisia, Turkey, and United Arab Emirates.²³

Table 1 presents summary statistics for our main variables.²⁴ The unbalanced repeated cross-sectional data

¹⁹Panel data sets from repeated cross-sectional assessment test scores are also used in, e.g., Hanushek et al. (2013).

²⁰Test scores of the first wave are scaled to have a mean of 500 points and a standard deviation of 100. To link successive waves to the same metric, TIMSS uses a concurrent calibration method, which requires a large proportion of identical test items between two successive tests (Yamamoto and Kulick, 2016).

²¹We include the following background variables in our analysis: Age, gender, immigration status, parental education, books at home, school characteristics (shortage of instructional materials, supplies, school building, heating system). See Table A2 in the Appendix for more information on the background variables.

²²Grim and Karim (2011) estimate the percentage of Muslim inhabitants in a country in 2010 drawing on various sources, e.g., surveys and censuses.

²³A complete list of the countries included is in Table A1 in the Appendix. The 3rd column of Table A1 in the Appendix reports the share of Muslims by country. Figure A1 in the Appendix illustrates the location of Muslim and non-Muslim countries on a map.

²⁴Table A2 in the Appendix presents summary statistics for the comprehensive set of control variables.

set consists of more than 1.4 million student observations from in 58 countries. Average mean fasting hours vary noticeably over the years. For Muslim countries, we find a minimum of average fasting hours of ca. 10.5 hours in 1999 and a maximum of ca. 14.0 hours in 2015. However, average fasting hours across countries mask a great amount of heterogeneity. For example, fasting hours vary between 9.4 to 14.9 hours in Turkey and only between 11.9 and 12.5 in Malaysia. Average test scores in Muslim countries are consistently lower than in non-Muslim countries. The level differences in test scores across countries highlight the importance to adjust our empirical strategy for time invariant country-specific factors.

PISA. PISA provides data on student assessment test scores in mathematics, science, and reading. In contrast to TIMSS' focus on 8th graders, the target population of PISA is the group of 15-year-old students. PISA was first conducted in 2000 and is repeated on a 3-year cycle. We focus on a sample of 8 Western European countries that collected background characteristics on the country or region of origin of students' parents starting in 2003. These countries are: Austria, Belgium, Switzerland, Germany, Denmark, Finland, Great Britain, and the Netherlands. We use this information to identify students whose parents immigrated from a Muslim country to approximate their religious affiliation. The resulting PISA panel includes six waves and covers 15 years (2003–2018) of assessment test scores for approximately 350,000 students.

Table A3 in the Appendix lists all parental countries or regions of origin by wave and participating country. It also indicates (in bold) those origin-countries (or groups of countries) which we categorize as Muslim.²⁵ Note that the survey only provides information on origin countries that are major sources of immigration and combines others into residual categories (other African countries, other EU countries, etc.). Because of this we cannot identify any Muslim students in some years for Denmark, Finland, and Great Britain. In some cases, countries are grouped into larger regions, of which we classify North Africa (Maghreb) and Middle East as Muslim. This implies a potential misclassification of a significant number of Muslim and non-Muslim students, likely resulting in an underestimate of Muslim students. This is further amplified by the fact that we classify only those students as Muslim whose both parents immigrated from a Muslim country. Indeed, the share of Muslim students is smaller than the share of Muslims in the total population of the respective countries.²⁶ However, for our empirical analysis, which relies on the comparison between Muslim and non-Muslim students, such measurement error will likely result in attenuation bias.

Countries participating in PISA employ a sampling process where, based on a random sample of schools drawn using weights proportional to school size, 35 students are randomly selected and included in the study.

²⁵Categorization is based on information provided by PEW Research group to define Muslim countries (Grim and Karim, 2011).

²⁶Table A4 in the Appendix shows the share of Muslim students by country and year for the 8 countries.

PISA uses paper- or computer-based tests to assess students' educational performance in each of the 3 domains (mathematics, science, and reading). Test scores are scaled to have a mean of 500 points and a standard deviation of 100 across the participating countries in each wave. In our analysis we only use background characteristics that are available in all 6 waves between 2003 and 2018 for the 8 countries mentioned above.²⁷

Table 2 gives an overview of the main variables for Muslim and non-Muslim students for the overall sample and separately by wave.²⁸ Similar to TIMSS, Table 2 shows a significant amount of variation in average daily fasting hours and a difference in the level of test scores between students with Muslim-country origins and those without. Additionally, Table 2 indicates a selection of Muslim students into same schools, i.e. Muslim students attend schools with an average share of Muslim students of 0.2, whereas non-Muslims attend schools with an average share of Muslim students of 0.02.

4 Empirical strategy

Our empirical strategy exploits time and cross-sectional variation in Ramadan fasting hours. The month of Ramadan is set in accordance with the Islamic lunar calendar that is 10–12 days shorter than the Gregorian solar calendar. Thus, Ramadan starts earlier each solar year and rotates over the seasons, resulting in variation of daily Ramadan fasting hours over time. A full rotation is completed after 33 years. If Ramadan falls into northern hemisphere summer, Muslim believers on the northern (southern) half of the earth fast more (less) hours than in winter. The strength of the variation depends on the latitude. Countries located closer to the equator experience less variation of average Ramadan fasting hours over time.

Figure 1 illustrates the evolution of fasting hours in 3 Muslim countries for the period studied in our paper (vertical lines indicate TIMSS test years). At the beginning of the period depicted in Figure 1, Ramadan falls into the northern hemisphere winter. In this case, Kazakhstan and Oman fast on average less than 12 hours. The opposite is true for Indonesia, whose capital is located in the southern hemisphere. Average fasting hours increase over time for Muslim believers in Kazakhstan and Oman, but decrease for Muslims in Indonesia. Figure 1 also illustrates that the variance of fasting hours differs between countries. Since Oman is closer to the Equator than Kazakhstan, the variation of average Ramadan fasting hours in Oman is less pronounced.

We use this arguably exogenous variation in fasting hours to estimate the effect of the intensity of a specific religious practice on educational outcomes. As we show in Section 6, religious participation increases in average fasting hours, reflecting the change in individual behavior and social environment due to changes in intensity.

²⁷The following background variables are included: Age, gender, parental occupation, parental education, books at home, and school characteristics (location, type).

²⁸Table A5 in the Appendix summarizes our control variables.

To exploit this sort of variation, we begin by estimating the following model based on TIMSS data:

$$Test_{ict} = \beta_1 Ramadan_{ct} + \delta_c + \gamma_t + \epsilon_{ict}, \quad (1)$$

where $Test_{ict}$ is the standardized assessment test score of student i in country c in year t , $Ramadan_{ct}$ is the log average daily number of fasting hours during the last Ramadan before the test was taken, δ_c and γ_t represent a set of dummy variables to capture country and year fixed effects, respectively.

We include country fixed effects to account for time-invariant differences across countries that capture geographical and cultural factors that may be correlated with $Ramadan_{ct}$. Year fixed effects capture shocks that affect student test scores over time but are constant across countries such as global trends in educational performance or test quality. To further reduce residual variation, we also include a set of control variables (student and school characteristics) in some specifications.

We expect Ramadan intensity to have an effect on student performance only in Muslim countries. Hence, we start by estimating (1) for countries with a Muslim-majority population and expect β_1 be positive. We then extend our estimation sample to include also non-Muslim countries and add interaction terms in (1):

$$Test_{ict} = \beta_1 Ramadan_{ct} + \beta_2 Ramadan_{ct} \times \%Muslim_c + \delta_c + \gamma_t + \eta_t^M + \epsilon_{ict}, \quad (2)$$

where $\%Muslim_c$ is the share of Muslim inhabitants in country c , and η_t^M a set of Muslim country-specific year fixed effects. In this specification, while β_2 is expected to be positive, we expect β_1 to be zero, as fasting hours should not affect test scores in countries with a negligible Muslim population. In further analyses, we allow for non-linear effects by replacing the share of Muslim inhabitants in a country, $\%Muslim_c$, with dummy variables indicating the Muslim share by quartiles of the distribution of countries' Muslim share in our sample.

To provide further evidence for the effect of Ramadan intensity on educational performance, we exploit the fact that we know the country of origin of students' parents in the PISA data. We use this information to approximate students' religious affiliation in the PISA data of 8 Western European countries and estimate the following model:

$$Test_{ict} = \beta_1 Ramadan_{ct} + \beta_2 Ramadan_{ct} \times Muslim_{ict} + \beta_3 Muslim_{ict} + \delta_{ct} + \epsilon_{ict}, \quad (3)$$

where $Muslim_{ict}$ is a dummy variable indicating whether a student is a first or second generation immigrant from an Muslim country. We include country-by-year fixed effects, δ_{ct} , to flexibly allow for country-specific time

trends. In this specification, β_2 measures the difference in marginal effects of Ramadan intensity between Muslims and non-Muslims.

Figure 2 illustrates the variation that we exploit when estimating Equation (3). In this figure, we plot country- and year-specific performance gaps between students whose parents are from Muslim countries and all other students against average daily fasting hours (both variables are adjusted by their country means). The figure shows a positive relationship between performance gaps and fasting hours. In addition, it highlights the nature of our identifying assumption. We identify β_2 as long as year- and country-specific shocks to student performance affect first and second generation migrants from an Muslim country in a similar way as all other students. For example, this assumption would be violated if countries' educational spending is correlated with average fasting hours and if the impact of educational spending on student performance differs between students from Muslim majority countries and other students. We address such concerns in more detail in Section 5.

5 The effect of Ramadan intensity on student performance

In this section, we present our main results on the overall effects of Ramadan intensity on student achievements. Estimates of the effect of Ramadan intensity are presented in Table 3 and Table 4 based on TIMSS and PISA data respectively. To account for the complex data structure, we apply student population weights throughout the entire analysis. These weights are adjusted to sum up to an equal number across country-year clusters to avoid biased estimates towards larger countries.²⁹

5.1 Evidence from TIMSS data

Table 3 reports results from various specifications of Equation (1) and Equation (2) based on TIMSS data. All specifications are estimated separately for math and science test scores and include year fixed effects. To facilitate the interpretation of our estimations, we rescale test scores of each wave to the mean and standard deviation of the test scores of the first wave. Hence, the estimated coefficients can be interpreted in terms of standard deviations of the distribution of test scores of the first TIMSS wave.

In columns (1) to (6) of Table 3, we restrict the sample to Muslim countries and successively add country fixed effects and individual-level control variables. In all three specifications, we find positive effects of Ramadan intensity on test scores. The coefficient is sizable and significant in all specifications for math and science test

²⁹Our results do not change if we apply students weights that do not account for the size of the student population. Additionally, the interpretation of our results are not affected if we use house weights which account for differences in sample size. Results are available upon request.

scores. Estimates of our preferred specification, columns (5) and (6), suggest that an increase of average Ramadan fasting hours by 10 % increases math and science test scores by around 11 % of a standard deviation.

Extending our sample to non-Muslim countries, we confirm our previous results and test whether Ramadan intensity spuriously correlate with the performance of students that presumably do not observe Ramadan. In columns (7) and (8) of Table 3, we find that the effect of Ramadan intensity on student achievements increases with the share of Muslims in the population. Additionally, it is reassuring to see that the effect of Ramadan intensity on test scores for countries without a Muslim population is insignificant and close to zero.

To test for non-linearities in the interaction between Ramadan intensity and the share of Muslims, we classify countries into four bins according to their Muslim share.³⁰ More precisely, we create binary variables indicating whether the share of Muslims is within the 25th and 50th, 50th and 75th, or above the 75th percentile of the distribution in our sample.³¹ We present results when interacting these dummies with average Ramadan fasting hours in columns (9) and (10). Indeed, there is significant effect heterogeneity across quartiles suggesting that the large and significant effect is driven by countries above the 75th percentile, i.e. religiously homogeneous countries with more than 75% Muslim believers.

A potential concern is that countries might deliberately choose test dates depending on average daily fasting hours in a given year. For example, if fasting hours are long, educational authorities in Muslim countries might choose test dates that are sufficiently far away from the last day of Ramadan to avoid potential negative consequences of the physically demanding fasting. If this were the case, we might observe positive effects of fasting hours on test scores if, e.g., negative consequences from fasting on test scores are independent of fasting hours but dependent on the time between the last day of Ramadan and the test date.

We test whether the systematic choice of test dates drives our results by controlling for (a) whether the test was taken during Ramadan and (b) the time difference between the last day of Ramadan and the test date. Results are reported in Table A6 in the Appendix. We find a negative effect on test scores if the test was taken during Ramadan (Panel B of Table A6) and a positive effect for the time between Ramadan and the test date (Panel C of Table A6). In line with the evidence presented in [Oosterbeek and van der Klaauw \(2013\)](#), both results indicate the existence of immediate negative effects of Ramadan intensity on educational performance. Nevertheless, estimates of the indirect effects net of the direct effects remain sizable and significant.

Another concern might be that fasting hours are correlated with other factors which, in turn, affect test scores. Indeed, [Campante and Yanagizawa-Drott \(2015\)](#) show that longer fasting hours are related to lower GDP per

³⁰We found no evidence for non-linearities in Ramadan intensity itself, suggesting the absence of a purely physiological mechanism through which Ramadan intensity affect educational performance.

³¹The last column in Table A1 in the Appendix lists all countries by the quartiles used in this estimation.

capita in Muslim countries. If GDP per capita has a positive effect on test scores through, e.g., higher educational spending, we would obtain downward-biased estimates. Table A7 in the Appendix shows that when controlling for GDP per capita, effects are qualitatively similar, albeit slightly smaller in the sample of Muslim countries and slightly larger in the sample of all countries.

Given the findings of negative long-term consequences of in-utero exposure to Ramadan by [Almond and Mazumder \(2011\)](#) and [Majid \(2015\)](#), a potential concern might be that longer Ramadan fasting hours for 15 years olds today reflect shorter Ramadan fasting hours during their fetal period. Thus, better educational performance may derive from the fact that the in-utero exposure was comparatively light. However, since the children in our dataset are arguably evenly distributed across birth dates such a positive effect should be attenuated.

5.2 Evidence from PISA data

In a next step, we test whether positive effects of Ramadan intensity can also be observed for first and second generation migrants in Western European countries. More specifically, we compare the performance of students with parents from Muslim countries with their counterparts whose parents are from non-Muslim countries. Henceforth, we refer to them as Muslims despite the fact that we don't know their religious affiliation and we only know their parent's country of origin.

Table 4 reports estimation results of Equation (3) based on PISA data. Both specifications—with and without control variables—are estimated separately for math, science, and reading test scores and include country-by-year-fixed effects to capture any wave-specific shocks to students in each country.³² The first row of Table 4 reports the coefficient on the interaction term of average fasting hours and a binary variable indicating whether a student is Muslim. The estimated coefficient measures the difference between the marginal effect of Ramadan intensity for Muslim and non-Muslim students.

Table 4 shows that Ramadan intensity has a positive effect on student achievements for Muslims in comparison to non-Muslim students across all subjects. Our estimates in columns (1), (3), and (5) indicate that an increase of average fasting hours by 10 % increases the difference in test scores between Muslim and non-Muslim students by 4.8 to 5.3 % of a standard deviation. In more demanding specifications—in columns (2), (4), and (6) where we additionally control for a large set of background variables—our estimates become smaller, but remain substantial and significant. An increase of average fasting hours by 10 % increases the difference in test scores between Muslim and non-Muslim students by 2.5 to 3.0 % of a standard deviation. Following the rule-of-thumb calculation

³²In our PISA sample, we rescale test scores of each wave to facilitate interpretation. Due to the specific rescaling method applied in PISA, we use the mean and the standard deviation of the distribution of test scores of all OECD countries in each wave. Therefore, the interpretation of our estimates are in terms of an average standard deviation of the distribution of test scores of OECD countries in all PISA waves.

by [Woessmann \(2016\)](#), this translates to 10 % of student learning in a year.

A potential concern might be that students from Muslim countries are affected by increased government efforts to improve immigrants' educational outcomes. If such efforts are correlated with fasting hours, our identification strategy erroneously assigns positive effects of these government efforts to fasting hours. We address this concern by constructing a placebo group of immigrants from non-Muslim countries and check if we also obtain positive effects for this group.

Figure 3 plots performance gaps between immigrants from Muslim countries and natives on the left and performance gaps between immigrants from non-Muslim countries and natives on the right.³³ While we see a positive relationship between the performance gap and fasting hours for Muslim students, we do not see such a relationship for non-Muslim students.

A similar conclusion can be drawn from the estimation results in Table A9 in the Appendix where we include an interaction term of fasting hours and a binary variable indicating non-Muslim immigrant students to our baseline specification. The interaction term for non-Muslim immigrants is small and insignificant whereas the interaction term for Muslims remains significant and hardly affected.

6 Discussion of mechanisms

We now turn to a discussion of the potential mechanisms through which the estimated reduced-form effect translates Ramadan intensity into better student performance. Based on our theoretical considerations outlined in Section 2, we aim to distinguish between theories arguing that Ramadan intensity affects educational performance through the formation of individual character skills or the formation of social capital and a social identity within groups of students. In this section, we first establish that longer fasting hours during adolescence increase religious participation, which has been associated with higher levels of social capital in the literature. Second, we show that longer fasting hours are associated with higher educational performance only for students in schools with a high share of Muslim students, indicating that our mechanism likely works through forming a social identity and through providing students with access to social capital rather than through the formation of individual character skills.

³³Table A9 in the Appendix lists the selected countries that define the group of non-Muslim immigrant students based on parental country of origin.

6.1 Ramadan intensity and religious participation

Since religious participation has been associated with social capital formation, we argue that a positive relationship with fasting hours may show one of the channels through which student performance is affected. To evaluate the prevalence of this channel, we use data from the World Values Survey (WVS). The WVS has been conducted seven times and covers a time period between 1981 and 2020.³⁴

The WVS includes information on each participants' religious denomination and questions about the frequency of religious participation. As dependent variable, we use information about self-reported attendance in religious services. We generate a binary variable ($Participation_{ict}$) indicating whether an individual attends religious services more than once per week.³⁵ To assess whether longer fasting hours indeed increase the frequency of religious participation, we estimate the following linear probability model (in analogy to our estimation strategy using the PISA data):

$$Participation_{ict} = \beta_2 Ramadan_{ct} \times Muslim_{ict} + \beta_3 Muslim_{ict} + \eta_{ct} + \epsilon_{ict}, \quad (4)$$

where $Ramadan_{ct}$ is the log average daily number of fasting hours during the last Ramadan before the WVS interview, $Muslim_{ict}$ is a binary variable indicating whether subject i stated in the interview to be of a Muslim denomination, and η_{ct} are country times wave fixed effects. The coefficient of interest in Equation (4) is β_2 , which measures the difference in religious participation between Muslims and non-Muslims induced by a change in fasting hours. Since we argue that the effect of Ramadan on religious engagement arises particularly during the impressionable adolescence, when we also measure student performance, we inspect our sample separately for 3 different age groups: 15-18, 19-35, 36-65.

Estimation results are presented in Table 5, where columns (1), (3), and (5) show our baseline estimates and columns (2), (4), and (6) show estimation results when adding a large set of individual-level controls to Equation (4). We find sizable and significant positive effects of Ramadan intensity on religious participation for the age group 15–18 but not for groups of older individuals. Our estimation result in column (2) suggests that an increase of average Ramadan fasting hours by 10 % increases the probability to attend religious services more than once a week by around 3.3 percentage points for Muslim individuals in comparison to non-Muslims. Strikingly, the estimated coefficients are small and relatively precisely estimated for the age groups 19–35 and 36–65. In light

³⁴The first (second, third, fourth, fifth, sixth, seventh) wave was conducted during the years 1981-1984 (1989-1993, 1994-1998, 1999-2004, 2005-2009, 2010-2014, 2017-2020).

³⁵Results are robust to using a binary variable that assumes the value one if the respondents report to attend religious services at least once per week. The survey item asks: "How often do you attend religious services?" Answers include: more than once a week, once a week, once a month, only on special holy days, once a year, less often, practically never.

of the results by [Campante and Yanagizawa-Drott \(2015\)](#), who find a positive effect of the number of fasting hours on religious participation only for committed believers, this result suggest an increase in the share of committed Muslim believers among younger individuals.

While these results may indicate the formation of social capital among adolescents due to more frequent religious participation, they could potentially also reflect higher levels of religiosity and the formation of character skills. Thus, we can ultimately not distinguish between the potential channels with this exercise.

6.2 Common identity and Ramadan intensity

We separate between these channels by comparing the effect of Ramadan intensity for students in schools with a high share of Muslims and a low share of Muslims. To do so, we add information about the share of Muslim students in a school cohort to Equation (3) estimated using PISA data:

$$\begin{aligned}
 Test_{ict} = & \alpha_1 Muslim_{ict} + \alpha_2 Share_{ict} + \alpha_3 Muslim_{ict} \times Share_{ict} + \\
 & \alpha_4 Ramadan_{ct} \times Muslim_{ict} + \alpha_5 Ramadan_{ct} \times Share_{ict} + \\
 & \alpha_6 Ramadan_{ct} \times Share_{ict} \times Muslim_{ict} + \eta_{ct} + \epsilon_{ict},
 \end{aligned} \tag{5}$$

where $Share_{ict}$ measures the fraction of Muslim students in the school of student i in country c and year t . To ease the interpretation of our estimates, we define $Share_{ict}$ to be 1 if the share of Muslim students in the school of student i is above the median of the conditional distribution of the share of Muslim students in schools of country c and year t given a positive share of Muslim students in school and zero otherwise.³⁶

If our reduced-form effect is driven by the formation of social capital and a social identity, we expect α_6 —which measures the marginal effect of fasting for Muslim students in schools with a large share of Muslim students—to be positive. If our reduced-form effect is driven by the formation of individual character skills, we expect both α_6 and α_4 —which measures the marginal effect of fasting for Muslim students in schools with a low share of Muslim students—to be positive.

Table 6 reports our estimation results of Equation (5).³⁷ All specifications are estimated separately for math, science, and reading test scores and include our set of control variables and country times year fixed effects. In columns (1), (3), and (5), we first show the average effect of Ramadan intensity on test scores for students in schools with a higher Muslim share. The coefficient on the interaction term $Ramadan \times Share$ reflects the sum

³⁶ $Ramadan_{ict}$ drops from Equation (5) as it is collinear with country times year fixed effects, η_{ct} .

³⁷ Table A10 in the Appendix shows results if we use a restricted sample of individuals who are in schools with a positive number of Muslims. These results are qualitatively similar.

of α_5 and α_6 in Equation 5 that indicates the effect of longer Ramadan fasting hours for *any* student in schools with a large share of Muslims. Results suggest that all students benefit from having a larger share of Muslim students in school when Ramadan is more demanding. An increase of average fasting hours by 10 % increases the difference in test scores between students in schools with a higher Muslim share and students in schools with a low Muslim share by 3.0 to 3.2 % of a standard deviation.

In columns (2), (4), and (6), we add the Muslim dummy to our estimation equation to assess whether the performance of Muslim students in schools with a high Muslim share is affected more by Ramadan fasting hours than the performance of Muslim students in schools with a low Muslim share. The results support the hypothesis that more intensive Ramadan fasting facilitates the formation of social capital and social identity, as we estimate positive coefficients on the triple interaction term for all subjects, which are significant for science and reading test scores. The coefficient on the interaction term *Ramadan* \times *Muslim* is close to zero and insignificant except for reading which suggests that the overall positive effects of Ramadan intensity are exclusively driven by students in schools with a large share of Muslims. These results indicate that Ramadan intensity does not affect student performance through the formation of individual character skills because such students should also benefit when there are no fellow believers around.³⁸

Interestingly, α_5 the coefficient on the interaction term *Ramadan* \times *Share* is positive, significant and of similar magnitude as α_6 the coefficient on the interaction term *Ramadan* \times *Share* \times *Muslim*. Thus, the educational performance of non-Muslim students also seems to benefit from longer fasting hours in classes with a larger share of Muslims. There are several potential explanations for this result. First, it is likely that we measure Muslim denomination with a some amount of error and many of the students classified as non-Muslims are actually placed in the wrong category. Such measurement error is likely to be more pronounced in schools with a large share of Muslims as we observe a high degree of clustering in Table 2. Second, non-Muslim students may benefit from spill-overs such as a more productive class environment after a more demanding Ramadan. Third, as shown by [Clingsmith et al. \(2009\)](#), the religious practice of the Hajj increased pilgrims' tolerance toward others. Thus, openly practicing religious rituals may increase bridging social capital and could create more tolerance among students with different religious backgrounds. Thus, despite identity formation, in-group and out-group sentiments could be reduced.³⁹

³⁸However, we acknowledge that these findings could be interpreted to imply that the character skills effect only occurs in the presence of fellow believers because they enforce stricter Ramadan fasting rules.

³⁹It is likely, that the intimate school environment provides non-Muslim students with more insights into the daily practices of Muslims during Ramadan leading to reductions in in-group bias than the simple increase in salience of Muslims that leads to increases in in-group bias observed by [Colussi et al. \(2021\)](#).

7 Conclusion

Using plausibly exogenous variation induced by the rotating Islamic calendar and its interaction with country latitude, we provide evidence for a positive effect of longer Ramadan fasting hours on student performance. This evidence is derived from two independent international student achievement tests, one in which we focus on Islamic countries, the other in which we focus on Muslim immigrants in Christian-European countries.

We further establish that longer Ramadan hours are accompanied by increased religious participation among adolescent Muslims but not among Muslims at older ages. This suggests first that social capital formation due to increases religious participation might be the driving force explaining the main result, and second that Ramadans during adolescence are particularly influential. Thus, the experience of a more demanding Ramadan shapes preferences and may even affect behavior during adulthood, resonating with a literature that links current behavior to past experiences (see, e.g. [Malmendier and Nagel, 2011](#); [Giuliano and Spilimbergo, 2014](#); [Madestam and Yanagizawa-Drott, 2011](#)). Finally, by showing that effects of longer Ramadan fasting hours accrue only to students in schools with a high Muslim share, we provide evidence that stricter fasting arguably impacts student performance by creating a common identity among students and by forming social capital in groups, but not by affecting their individual character skills.

Overall, in light of the scarce empirical literature on the effect of religion on educational outcomes—in particular with respect to Islam—our paper provides important insights to recent debates about impeded educational outcomes of Muslims due to norms and other restrictions imposed by Muslim authorities.

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Table 1: Descriptive statistics (TIMSS)

	All	1995	1999	2003	2007	2011	2015	2019
Muslim countries								
<i>Test scores</i>								
Math	419.50 (92.83)	402.70 (53.39)	426.47 (94.50)	405.99 (84.17)	401.18 (90.71)	415.63 (95.25)	429.35 (96.85)	438.98 (92.98)
Science	438.07 (94.97)	440.19 (65.12)	430.22 (89.60)	429.62 (81.95)	434.01 (90.97)	436.72 (95.12)	443.02 (104.87)	448.71 (102.49)
<i>Fasting hours</i>								
Year before test	12.54 (1.51)	11.17 (0.28)	10.51 (1.10)	10.74 (0.69)	11.79 (0.20)	12.98 (0.45)	13.97 (0.83)	13.93 (0.81)
<i>Number of observations</i>								
Students	462,883	9,084	40,072	58,036	48,780	103,919	104,895	98,097
Countries	18	2	7	12	11	16	14	14
Non-Muslim countries								
<i>Test scores</i>								
Math	497.04 (106.14)	506.82 (98.23)	499.12 (106.01)	480.56 (111.81)	475.12 (109.05)	489.74 (109.54)	509.99 (101.79)	517.14 (97.54)
Science	495.86 (103.92)	501.64 (92.98)	498.00 (106.38)	482.49 (112.11)	475.67 (106.57)	490.03 (107.65)	508.81 (97.97)	512.82 (94.37)
<i>Fasting hours</i>								
Year before test	11.94 (2.58)	10.77 (1.10)	9.86 (2.22)	10.38 (2.06)	11.62 (0.43)	13.04 (1.19)	14.13 (2.54)	14.36 (2.42)
<i>Number of observations</i>								
Students	941,869	169,959	132,409	146,815	77,697	146,190	142,916	125,883
Countries	40	22	29	30	18	26	24	24

Note: Mean values of test scores and fasting hours for Muslim and non-Muslim countries. Standard deviations are reported in parentheses. A country is categorized as a Muslim country if more than 50 % of its population is Muslim. See Table A1 in the Appendix for an overview of the countries included and the percentage of Muslims in the population. Survey weights applied are standardized to sum up to 1 for each country-year cluster.

Table 2: Descriptive statistics (PISA)

	All	2003	2006	2009	2012	2015	2018
Muslim students							
<i>Test scores</i>							
Reading	418.78 (92.60)	392.80 (95.60)	402.41 (101.26)	419.68 (84.32)	434.64 (88.96)	430.85 (89.85)	419.37 (92.94)
Science	414.59 (86.88)	388.33 (84.26)	402.77 (86.12)	416.43 (85.20)	426.19 (86.81)	425.81 (86.33)	416.15 (86.83)
Math	432.69 (81.88)	417.16 (80.92)	421.37 (85.05)	434.29 (79.37)	439.63 (83.55)	440.77 (81.82)	434.70 (78.49)
<i>Fasting hours</i>							
Year before test	13.62 (2.75)	8.85 (0.38)	10.63 (0.15)	12.59 (0.05)	14.71 (0.32)	16.30 (0.54)	16.54 (0.72)
<i>School characteristics</i>							
Share of Muslim students	0.20 (0.18)	0.19 (0.14)	0.24 (0.23)	0.23 (0.20)	0.19 (0.15)	0.20 (0.16)	0.19 (0.16)
<i>Number of observations</i>							
Students	10,906	986	1,203	2,117	2,317	2,343	1,940
Countries	8	6	6	7	8	8	6
Non-Muslim students							
<i>Test scores</i>							
Reading	504.43 (92.93)	507.90 (90.15)	505.87 (96.11)	503.59 (90.91)	507.82 (89.69)	503.83 (92.17)	497.52 (97.84)
Science	514.25 (94.31)	512.75 (97.01)	521.04 (94.98)	519.17 (94.03)	518.95 (91.47)	510.60 (94.30)	502.96 (92.71)
Math	515.80 (88.97)	523.34 (92.63)	520.56 (89.96)	517.64 (89.50)	514.70 (89.97)	509.57 (85.31)	508.88 (85.21)
<i>Fasting hours</i>							
Year before test	13.26 (3.08)	8.54 (0.59)	10.52 (0.24)	12.61 (0.09)	14.78 (0.44)	16.46 (0.79)	16.72 (0.85)
<i>School characteristics</i>							
Share of Muslim students	0.02 (0.06)	0.02 (0.05)	0.02 (0.05)	0.03 (0.07)	0.03 (0.06)	0.03 (0.06)	0.02 (0.05)
<i>Number of observations</i>							
Students	340,856	49,028	56,933	58,438	60,694	59,264	56,499
Countries	8	8	8	8	8	8	8

Note: Mean values of test scores, fasting hours, and percentage of Muslim students in school for Muslim and non-Muslim students. Standard deviations are reported in parentheses. A student is defined as being Muslim if his or her mother and father are from a Muslim country. Countries included: Austria, Belgium, Switzerland, Germany, Denmark, Finland, Great Britain, and Netherlands. Survey weights are standardized to sum up to 1 for each country-year cluster.

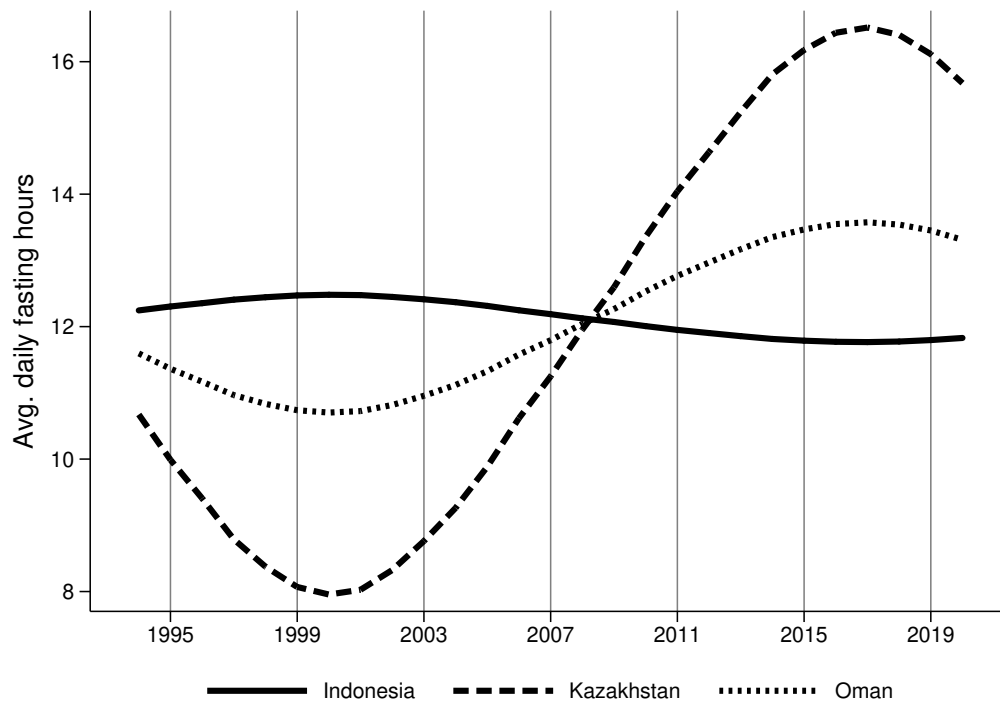


Figure 1: Average daily fasting hours during Ramadan

Note: Average fasting hours during Ramadan of three selected countries. Fasting hours are determined by the time span between sunrise and sunset in each country's capital. Vertical lines illustrate test years of TIMSS.

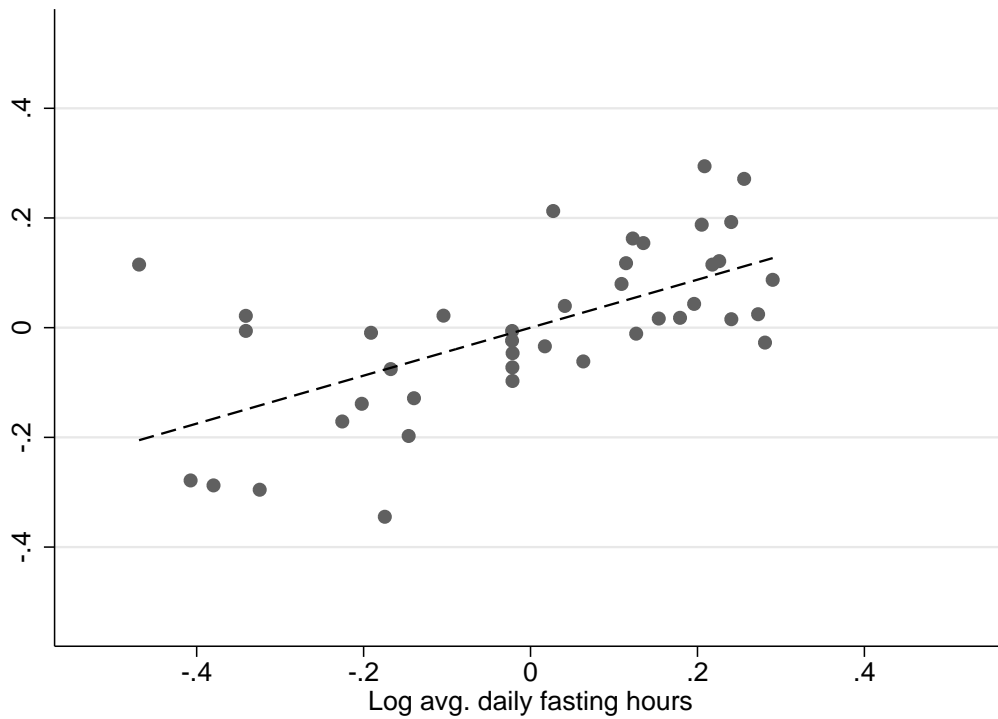


Figure 2: Performance gaps and Ramadan fasting hours (PISA science scores)

Note: Scatter plot of country-year performance gaps in science scores between students whose parents are from Muslim countries and all other students and the logarithm of average daily fasting hours during Ramadan before test was taken. Country-year performance gaps and log average daily fasting hours are adjusted by country means. See Figure A2 in the Appendix for corresponding scatter plots for math and reading test scores.

Table 3: Religious practice and educational performance (TIMSS)

	Only Muslim countries						All countries			
	Math	Science	Math	Science	Math	Science	Math	Science	Math	Science
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Ramadan	2.14*	1.89**	1.43**	1.47***	1.06*	1.07***	-0.19	-0.22	-0.29	-0.33
	(1.02)	(0.78)	(0.65)	(0.40)	(0.57)	(0.37)	(0.18)	(0.19)	(0.20)	(0.24)
Ramadan x % Muslim							1.18*	1.03*		
							(0.59)	(0.55)		
Ramadan x $\mathbb{1}(q_{25} < \% \text{ Muslim} \leq q_{50})$									0.15	0.15
									(0.17)	(0.18)
Ramadan x $\mathbb{1}(q_{50} < \% \text{ Muslim} \leq q_{75})$									0.24	0.30
									(0.23)	(0.25)
Ramadan x $\mathbb{1}(\% \text{ Muslim} > q_{75})$									1.34***	1.25***
									(0.50)	(0.43)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Muslim-by-year FE	No	No	No	No	No	No	Yes	Yes	Yes	Yes
R squared	0.04	0.02	0.16	0.12	0.28	0.24	0.49	0.43	0.49	0.43
Observations	462,883	462,883	462,883	462,883	462,883	462,883	1,406,701	1,405,761	1,406,701	1,405,761

Note: Regressions of standardized achievement test scores on logarithmized average daily fasting hours before test was taken. A country is categorized as a Muslim country if more than 50 % of its population is Muslim. Control variables: Age, gender, immigration status, parental education, number of books at home, school characteristics (shortage of instructional materials, supplies, school building, heating system). See Table A2 in the Appendix for a detailed list of the control variables. Standardized population weights applied. Standard errors in parentheses are cluster-robust at country level.

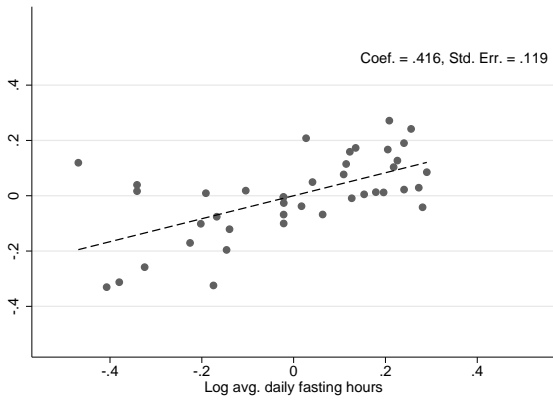
Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: Religious practice and educational performance (PISA)

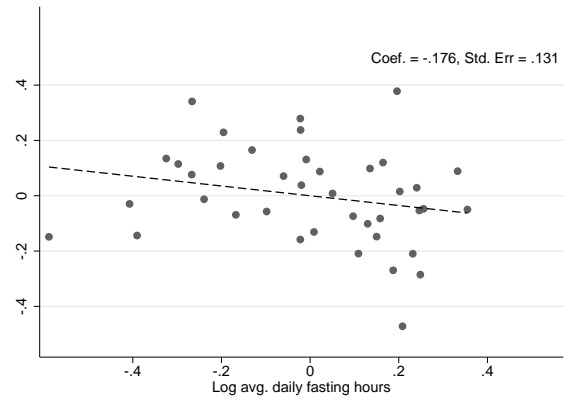
	Science		Reading		Math	
	(1)	(2)	(3)	(4)	(5)	(6)
Muslim x Ramadan	0.53*** (0.08)	0.30*** (0.07)	0.50*** (0.09)	0.25*** (0.09)	0.48*** (0.07)	0.26*** (0.07)
Muslim	-2.33*** (0.20)	-1.07*** (0.20)	-2.12*** (0.24)	-0.91*** (0.24)	-2.05*** (0.19)	-0.92*** (0.18)
Country-by-year FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes
R squared	0.06	0.29	0.05	0.30	0.05	0.28
Observations	351,762	351,762	351,762	351,762	351,762	351,762

Note: Regressions of standardized achievement test scores on logarithmized average daily fasting hours. A student is defined as being Muslim if his or her mother and father are from a Muslim country. Control variables: Age, gender, immigration status, parental occupation, parental education, number of books at home, school location, school type. See Table A5 in the Appendix for a detailed list of the control variables. Standardized population weights applied. Standard errors in parentheses are cluster-robust at the school level.

Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.



(a) Muslim immigrants vs natives



(b) Non-Muslim immigrants vs natives

Figure 3: Placeto performance gaps and Ramadan fasting hours (PISA science scores)

Note: Left (right) scatter plot shows country-year performance gaps in science scores between students whose parents are from Muslim countries (non-Muslim countries) and natives and logarithm of average fasting hours during Ramadan before test was taken. Both variables are adjusted by their country means. See Figure A3 in the Appendix for corresponding scatter plots for math and reading test scores.

Table 5: Religious practice and religious participation (World Values Survey)

	Age 15-18		Age 19-35		Age 36-65	
	(1)	(2)	(3)	(4)	(5)	(6)
Ramadan x Muslim	0.36*	0.33*	0.04	0.04	-0.07	-0.07
	(0.19)	(0.19)	(0.08)	(0.08)	(0.08)	(0.08)
Country x Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes
R squared	0.22	0.23	0.22	0.22	0.19	0.19
Observations	10,133	10,133	140,813	140,813	169,930	169,930

Note: Regressions of religious participation on logarithmized average fasting hours by age groups. Religious participation: Attends more than once per week religious services (binary). Mean values of dependent variable for Muslims: 0.25 (age 15-18), 0.25 (age 19-35), 0.27 (age 36-65). All model specifications include a binary variable indicating Muslim believer. Other control variables: Education level, marital status, gender, social class, income level, and population size of town of residence. Standard errors in parentheses are cluster-robust at country-year level.

Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 6: Mechanisms translating religious practice into educational performance (PISA)

	Science		Reading		Math	
	(1)	(2)	(3)	(4)	(5)	(6)
Ramadan x Share x Muslim		0.26** (0.13)		0.36** (0.14)		0.10 (0.12)
Ramadan x Share	0.31*** (0.06)	0.28*** (0.06)	0.32*** (0.07)	0.29*** (0.07)	0.33*** (0.06)	0.31*** (0.06)
Ramadan x Muslim		-0.09 (0.10)		-0.22** (0.11)		-0.02 (0.10)
Muslim x Share		-0.71** (0.34)		-1.01*** (0.38)		-0.24 (0.32)
Share	-1.10*** (0.16)	-0.99*** (0.16)	-1.10*** (0.18)	-1.01*** (0.17)	-1.13*** (0.16)	-1.08*** (0.16)
Muslim		0.09 (0.26)		0.48* (0.27)		-0.08 (0.25)
Country-by-year FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
R squared	0.30	0.30	0.30	0.30	0.29	0.29
Observations	351,762	351,762	351,762	351,762	351,762	351,762

Note: Regressions of standardized achievement test scores on logarithmized average daily fasting hours. A student is defined as being Muslim if his or her mother and father are from a Muslim country. *Share* is a binary variable indicating above median share of Muslim students in a school cohort. Control variables: Age, gender, immigration status, parental occupation, parental education, number of books at home, school location, school type. See Table A5 in the Appendix for a detailed list of the control variables. Standardized population weights applied. Standard errors in parentheses are cluster-robust at school level.

Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

ONLINE APPENDIX

Table A1: Countries included in study (TIMSS)

	# included	Percentage Muslim	Quartile
Tunisa	3	99.5	4
Iran	7	99.4	4
Morocco	6	99.0	4
Jordan	6	98.2	4
Turkey	4	98.0	4
Palestine	3	98.0	4
Saudi Arabia	4	97.0	4
Kuwait	4	95.0	4
Egypt	4	94.6	4
Syria	2	92.2	4
Indonesia	4	88.2	4
Oman	4	87.7	4
Bahrain	5	81.2	4
Qatar	3	77.5	4
United Arab Emirates	3	76.2	4
Malaysia	6	60.4	3
Lebanon	5	59.3	3
Kazakhstan	3	56.4	3
North Macedonia	3	33.3	3
Cyprus	5	22.7	3
Israel	7	16.7	3
Ghana	3	15.9	3
Singapore	6	14.9	3
Bulgaria	3	12.2	3
Russia	6	11.7	3
Georgia	4	9.9	3
France	2	6.0	3
Thailand	4	5.8	3
Netherlands	3	5.7	3
Philippines	2	5.1	2
Slovenia	4	2.4	2
Sweden	5	2.0	2
Canada	3	2.0	2
Australia	7	1.7	2
South Africa	5	1.5	2
Norway	6	1.0	2
Latvia	3	1.0	2
Italy	6	1.0	2
New Zealand	6	0.9	2
USA	6	0.8	2
Moldavia	2	0.5	2
Ireland	3	0.5	2
Finland	3	0.5	2
Columbia	2	0.5	2
Botswana	4	0.4	1
Romania	5	0.3	1
Malta	2	0.2	1
Hungary	7	0.2	1
South Korea	7	0.1	1
Portugal	2	0.1	1
Lithuania	7	0.1	1
Japan	7	0.1	1
Chile	5	0.1	1
Armenia	3	0.1	1
Taiwan	5	0.0	1
Slovakia	2	0.0	1
Hong Kong	7	0.0	1
Czeck Republic	2	0.0	1

Note: Participating countries in TIMSS from 1995 to 2019 (first column). Number of times participating from 1995 to 2019 (second column). Fraction of countries' population Muslim (third column). Location of country in sample distribution of Muslim population (fourth column). Countries that participated only once in TIMSS are excluded from our analysis.

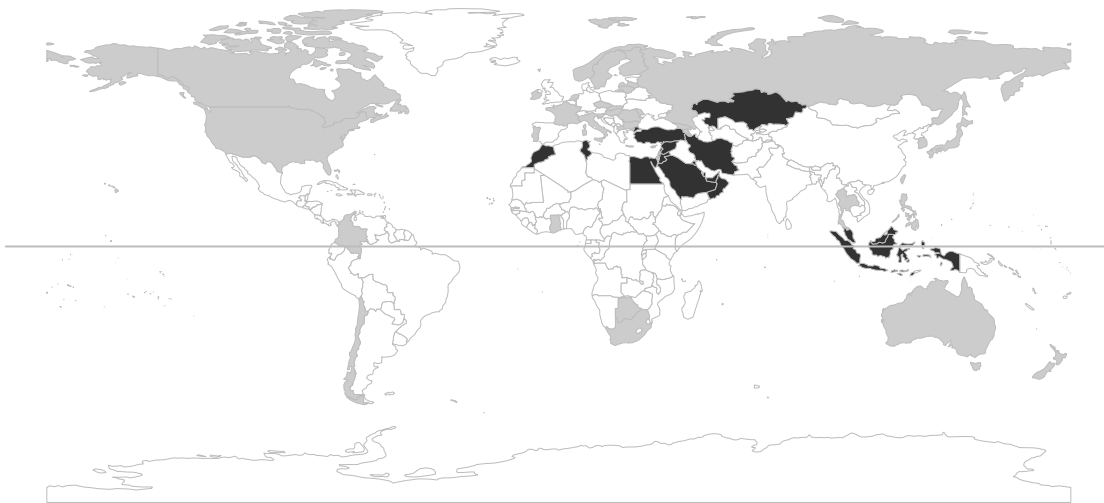


Figure A1: Muslim countries included in TIMSS

Note: Participating countries in TIMSS. Light-colored (dark-colored) areas mark non-Muslim (Muslim) countries. Horizontal line displays the equator.

Table A2: Descriptive statistics of all included variables (TIMSS)

	Non-Muslim countries		Muslim countries	
	Mean	Std. Dev.	Mean	Std. Dev.
<i>Test Scores</i>				
Math	497.04	106.14	419.50	92.83
Science	495.86	103.92	438.07	94.97
<i>Fasting hours</i>				
Year before test	11.94	2.58	12.54	1.51
<i>Student characteristics</i>				
Age	14.34	0.82	14.20	0.85
Female	0.50		0.49	
<i>Immigration status</i>				
Second generation	0.04		0.04	
First generation	0.07		0.13	
<i>Parental education</i>				
University	0.25		0.22	
Post secondary	0.22		0.13	
Upper secondary	0.22		0.22	
Lower secondary	0.08		0.14	
No school	0.05		0.13	
Unknown	0.19		0.15	
<i>Books at home</i>				
0 to 10	0.15		0.26	
11 to 25	0.22		0.34	
26 to 100	0.28		0.23	
101 to 200	0.16		0.08	
More than 200	0.17		0.07	
Unknown	0.02		0.02	
<i>School characteristics</i>				
<i>Shortage: Instructional materials</i>				
Not at all	0.43		0.30	
A little	0.23		0.17	
Some	0.18		0.18	
A lot	0.11		0.32	
Unknown	0.06		0.03	
<i>Shortage: Supplies</i>				
Not at all	0.47		0.34	
A little	0.21		0.17	
Some	0.16		0.21	
A lot	0.11		0.25	
Unknown	0.06		0.03	
<i>Shortage: School building</i>				
Not at all	0.36		0.23	
A little	0.24		0.19	
Some	0.20		0.25	
A lot	0.15		0.29	
Unknown	0.06		0.04	
<i>Shortage: Heating system</i>				
Not at all	0.44		0.27	
A little	0.23		0.22	
Some	0.17		0.22	
A lot	0.10		0.25	
Unknown	0.06		0.04	
<i>Number of observations</i>				
Student	941,869		462,883	
Country	40		18	
Country-year	174		76	

Note: Mean values of variables used in the analysis. A country is categorized as a Muslim country if more than 50 % of its population is Muslim. See Table A1 in the Appendix for an overview of the countries included and the percentage of Muslims in the population. Survey weights applied are standardized to sum up to 1 for each country-year cluster.

Table A3: Parental country of origin by country and year (PISA)

2018	
Austria	Afghanistan , Austria, Former Yugoslavia (Bosnia-Herzegovina, Croatia, Kosovo, Macedonia, Montenegro, Serbia, Slovenia), Germany, Missing, Syria , Turkey , another country inside of Europe (AUT), another country outside of Europe (AUT)
Belgium	A Sub-Saharan country (Africa excl. Maghreb), An Eastern European country, Another country (BEL), Belgium, France, Germany, Missing, Netherlands, North African country (Maghreb) , Other Western European country (BEL), Turkey
Switzerland	Albania , Another country (CHE), Austria, Former Yugoslavia (Bosnia-Herzegovina, Croatia, Kosovo, Macedonia, Montenegro, Serbia, Slovenia), France, Germany, Italy, Liechtenstein, Missing, Portugal, Spain, Switzerland, Turkey
Germany	Another country (DEU), Bosnia and Herzegovina, Croatia, FYR Macedonia, Germany, Greece, Italy, Missing, Montenegro, One of the former USSR republics, Poland, Serbia, Slovenia, Turkey
Denmark	Afghanistan , Denmark, Finland, Greenland, Iceland, Iraq , Lebanon , Missing, Norway, One of the former Yugoslav republics, Other European country (DNK), Other non-European country (DNK), Pakistan , Somalia , Sweden, Syria , The Faroe Islands, Turkey
Finland	Afghanistan , Another country (FIN), China, Estonia, Finland, Former Yugoslavia (Bosnia-Herzegovina, Croatia, Kosovo, Macedonia, Montenegro, Serbia, Slovenia), Iraq , Missing, Russia, Somalia , Sweden, Turkey , Vietnam
Great Britain	Another country (QSC), Another country (QUK), Ireland, Missing, Other European Union country (QSC), United Kingdom (England), United Kingdom (Scotland), United Kingdom (excl.Scotland)
Netherlands	Another country (NLD), Missing, Netherlands
2015	
Austria	Bosnia and Herzegovina, Croatia, Germany, Hungary, Poland, Romania, Russian Federation, Turkey , FYR Macedonia, Serbia, Montenegro and Kosovo, Another country (AUT)
Belgium	Germany, Turkey , France, Netherlands, A Sub-Saharan country (Africa excl. Maghreb), North African country (Maghreb) , Other Western European country (BEL), An Eastern European country, Another country (BEL)
Switzerland	Germany, Turkey , France, Albania , Italy, Liechtenstein, Portugal, Spain, Switzerland, One of the former Yugoslav republics, Another country (CHE)
Germany	Germany, Turkey , Italy, Bosnia and Herzegovina, Croatia, Poland, FYR Macedonia, Montenegro, Serbia, Slovenia, One of the former USSR republics, Another country (DEU),
Denmark	Turkey , One of the former Yugoslav republics, Afghanistan , Denmark, The Faroe Islands, Greenland, Finland, Iceland, Iraq , Lebanon , Norway, Pakistan , Somalia , Sweden, Other European country (DNK), Other non-European country (DNK)
Finland	Turkey , One of the former Yugoslav republics, Finland, Iraq , Somalia , Sweden, Russian Federation, China, Estonia, Thailand, Another country (FIN),
Great Britain	Pakistan , Germany, Poland, India, Ireland, United Kingdom, United Kingdom (excl.Scotland), United Kingdom (Scotland), Other European Union country (QSC), Another country (QUK), Another country (QSC)
Netherlands	Germany, Poland, Turkey , One of the former Yugoslav republics, Iraq , China, One of the former USSR republics, Netherlands, Romania, Belgium, Bulgaria, Iran , Islamic Republic of Morocco , Netherlands Antilles, Suriname, United Kingdom (Great Britain), United States of America, Another country (NLD),
2012	
Austria	Austria, Turkey , Germany, Serbia, Montenegro and Kosovo, Another country (AUT), Missing, Croatia, Poland, Bosnia and Herzegovina, Romania, FYR Macedonia, Russian Federation, Invalid
Belgium	Belgium, Another country (BEL), North African country (Maghreb) , An Eastern European country, Other Western European country (BEL), Turkey , A Sub-Saharan country (Africa excl. Maghreb), Netherlands, Germany, France, Missing, Invalid
Switzerland	Switzerland, Another country (CHE), Italy, Turkey , One of the former Yugoslav republics, Austria, Germany, Spain, Albania , Portugal, France, Missing, Invalid, Liechtenstein
Germany	Germany, Turkey , One of the former USSR republics, Serbia, Another country (DEU), Poland, Italy, Missing, FYR Macedonia, Croatia, Invalid, Greece, Bosnia and Herzegovina, Slovenia, Montenegro
Denmark	Denmark, Missing, Turkey , Afghanistan , Another country (CZE), One of the former Yugoslav republics, Lebanon , Somalia , Pakistan , Iraq , Invalid
Finland	Finland, Somalia , Invalid, Another country (FIN), Russian Federation, Estonia, One of the former Yugoslav republics, Missing, Iraq , Sweden, Turkey , China, Thailand
Great Britain	United Kingdom, Another country (QUK), Missing, United Kingdom (excl.Scotland), United Kingdom (Scotland), Pakistan , Another country (QSC), Africa, India, Invalid, Other European Union country (QSC), China (incl. Hong Kong), Caribbean, Middle Eastern country , Bangladesh
Netherlands	Netherlands, Other European country (NLD), China, Another country (NLD), United States of America, Morocco , Missing, Belgium, Suriname, Turkey , Invalid, Germany, Netherlands Antilles, United Kingdom (Great Britain), Romania, Iran , Islamic Republic of Iraq , One of the former Yugoslav republics, Poland, One of the former USSR republics, Bulgaria

2009	
Austria	Austria, Turkey , Another country (AUT), Germany, Missing, Bosnia and Herzegovina, Serbia and Montenegro, FYR Macedonia, Russian Federation, Croatia, Romania, Invalid, Poland
Belgium	Belgium, France, Netherlands, An Eastern European country, Missing, Other Western European country (BEL), Another country (BEL), A Sub-Saharan country (Africa excl. Maghreb), Germany, North African country (Maghreb) , Turkey , Invalid
Switzerland	Germany, One of the former Yugoslav republics, Switzerland, Another country (CHE), Turkey , Italy, Portugal, Austria, Invalid, Missing, Spain, Albania , France, Liechtenstein
Germany	One of the former USSR republics, Germany, Italy, Turkey , Another country (DEU), Missing, Poland, Bosnia and Herzegovina, Greece, Serbia, Slovenia, Croatia, FYR Macedonia, Montenegro, Invalid
Denmark	Denmark, Somalia , Another country (DNK), Turkey , One of the former Yugoslav republics, Iraq , Lebanon , Afghanistan , Missing, Pakistan , Invalid
Finland	Finland, Another country (FIN), Missing, Sweden, Another country (QVE), Russian Federation, Estonia, Invalid
Great Britain	United Kingdom, Another country (QUK), Missing, Invalid, Another country (QSC), Pakistan , Other European Union country (QSC), China (incl. Hong Kong), Africa, Middle Eastern country , India, Bangladesh , Caribbean,
Netherlands	Morocco , Netherlands, Turkey , Another country (NLD), One of the former Yugoslav republics, Other European country (NLD), Netherlands Antilles, United Kingdom, Missing, Suriname, Italy, Iraq , Spain, Belgium, China, Germany, Iran , Islamic Republic of , One of the former USSR republics
2006	
Austria	Austria, Hungary, Bosnia and Herzegovina, Turkey , Poland, Other countries (AUT), China, Missing, Romania, Serbia-Montenegro, Germany, Albania , Slovenia, Invalid, Slovakia, Croatia, Former Yugoslav Republic of Macedonia, Czech Republic, N/A
Belgium	North African country (Maghreb) , Belgium, Germany, Other countries (BEL), Missing, Netherlands, Turkey , Other Western European country (BEL), A Sub-Saharan country (Africa excl. Maghreb), An Eastern European country, France, Invalid, N/A
Switzerland	Switzerland, Other countries (CHE), Italy, Germany, A former Yugoslav republic, Albania , Missing, Turkey , Spain, Portugal, Austria, Invalid, France, N/A, Liechtenstein,
Germany	Germany, Missing, A former USSR republic, Turkey , Other countries (DEU), Poland, N/A, Montenegro, Invalid, Bosnia and Herzegovina, Italy, Croatia, Greece, Serbia, Former Yugoslav Republic of Macedonia, Slovenia
Denmark	Denmark, Other countries (DNK), Turkey , Missing, Pakistan , A former Yugoslav republic, N/A
Finland	Finland, Other countries (FIN), Invalid, Sweden, Missing, Russian Federation, Estonia, N/A
Great Britain	United Kingdom, Other countries (GBR-QUK), Missing, N/A, United Kingdom (Scotland), China (incl. HongKong), United Kingdom (excl.Scotland), Pakistan , India, Bangladesh , Other European country (QSC), Africa, Middle Eastern country , Other countries (GBR-QSC), Invalid, Caribbean
Netherlands	Netherlands, Other European country (NLD), Missing, Other countries (NLD), N/A, Missing
2003	
Austria	Austria, Turkey , AUT: Other, Czech Republic, Slovakia, Albania , Hungary, AUT: Yugoslavia, Poland, Romania, Slovenia
Belgium	Belgium, BFL: An African country (not Maghreb), BFR: Another country of the EU, BFR: Other, BFR: A Maghreb country , BFR: An African country (not Maghreb), Turkey , BFL: A Maghreb country , BFL: An other country of the EU, BFL: Other, France, Netherlands, An East-European country
Switzerland	CHE: Other, CHE: Switzerland, CHE: Ex-Yugoslavia, CHE: Albania or Kosovo , Turkey , Italy, CHE: Germany or Austria, CHE: France or Belgium, Portugal, Spain
Germany	DEU: Other, Germany, DEU: Russia, Kazakhstan or another former Soviet republic, Italy, Poland, Turkey , Croatia, Bosnia-Herzegovina, DEU: Montenegro, Zambia, DEU: Serbia, Greece, Macedonia, Slovenia
Denmark	Denmark, DNK: Other, Pakistan , Turkey , DNK: The former Yugoslavia
Finland	Sweden, Finland, FIN: Other, Russia, Estonia
Great Britain	United Kingdom, GRB: Other, SCO: Scotland, SCO: England, Wales, N Ireland, India, Pakistan , SCO: Other European country, SCO: Middle East , SCO: Other, Bangladesh , SCO: China (incl Hong Kong), Africa, Caribbean
Netherlands	NLD: Other, NLD: Other European country, Netherlands

Note: List of parental country of origin as provided in the official PISA dataset by participating country and year. Our selected set of Muslim countries are in bold.

Table A4: Percentage of Muslim students per country and year (PISA)

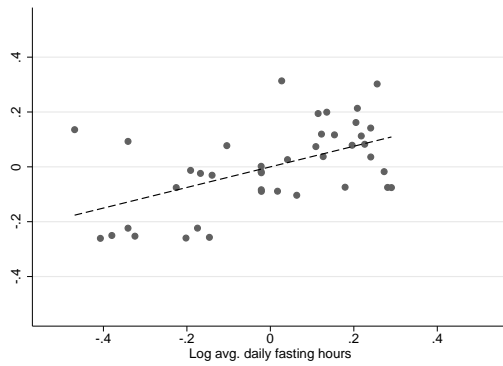
	2003	2006	2009	2012	2015	2018
Austria	3.6	3.9	3.9	3.6	4.2	5.5
Belgium	1.7	4.6	4.5	4.7	5.3	4.8
Switzerland	4.8	3.1	2.2	1.9	2.4	2.3
Germany	4.5	3.9	4.2	2.9	3.2	3.3
Denmark	2.0	2.3	4.1	4.1	4.6	4.4
Finland	0.0	0.0	0.0	0.7	0.7	1.1
Great Britain	0.1	0.1	0.1	0.1	1.4	0.0
Netherlands	0.0	0.0	6.4	5.2	4.9	0.0

Note: The share of Muslim students is equal to 0 for the following country-year pairs: Finland 2003, 2006, 2009, Great Britain 2018, the Netherlands 2003, 2006, 2018.

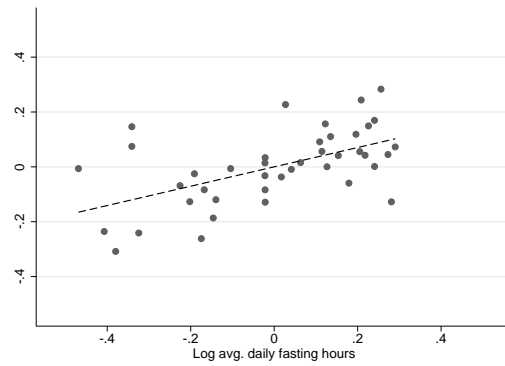
Table A5: Descriptive statistics of all included variables (PISA)

	Non-Muslim countries		Muslim countries	
	Mean	Std. Dev.	Mean	Std. Dev.
<i>Test Scores</i>				
Science	514.25	94.31	414.59	86.88
Reading	504.43	92.93	418.78	92.60
Math	515.80	88.97	432.69	81.88
<i>Fasting hours</i>				
Year before test	13.26	3.08	13.62	2.75
<i>Student characteristics</i>				
Age	15.78	0.29	15.79	0.29
Female	0.49		0.51	
<i>Immigration status</i>				
Native	0.86		0.00	
Secon generation	0.06		0.74	
First-generation	0.05		0.24	
Unknown	0.04		0.02	
Parental occupation (index)	52.18	18.34	39.46	16.91
<i>Parental education</i>				
None	0.01		0.06	
ISCED 1	0.01		0.09	
ISCED 2	0.04		0.17	
ISCED 3B, C	0.10		0.13	
ISCED 3A, 4	0.16		0.13	
ISCED 5B	0.22		0.14	
ISCED 5A, 6	0.26		0.13	
Unknown	0.20		0.15	
<i>Books at home</i>				
0 to 10	0.12		0.31	
11 to 25	0.14		0.27	
26 to 100	0.30		0.27	
101 to 200	0.18		0.08	
201 to 500	0.15		0.03	
More than 500	0.08		0.02	
Unknown	0.03		0.02	
<i>School characteristics</i>				
Avg. of Muslims in cohort	0.02	0.06	0.20	0.18
<i>Location</i>				
Village	0.08		0.02	
Small town	0.27		0.16	
Town	0.36		0.31	
City	0.17		0.25	
Large City	0.06		0.18	
Unknown	0.06		0.07	
<i>Type</i>				
Private	0.02		0.01	
Government dependent	0.19		0.16	
Public	0.69		0.69	
Unknown	0.11		0.14	
<i>Number of observations</i>				
Student	340,856		10,906	
Country	8		8	
Country-year	48		41	

Note: Mean values of all selected variables. A student is defined as being Muslim if his or her mother and father are from a Muslim country. Countries included: Austria, Belgium, Switzerland, Germany, Denmark, Finland, Great Britain, and the Netherlands. Survey weights are standardized to sum up to 1 for each country-year cluster.



(a) Reading score



(b) Math score

Figure A2: Performance gaps and Ramadan fasting hours (PISA reading and math scores)

Note: Scatter plot of country-year performance gaps in reading and math scores, respectively, between students whose parents are from Muslim countries and all other students and logarithm of average daily fasting hours during Ramadan before test was taken. Country-year performance gaps and log average daily fasting hours are adjusted by country means.

Table A6: Robustness checks controlling for test dates (TIMMS)

	Math	Science	Math	Science
	(1)	(2)	(3)	(4)
A: Baseline estimates				
Ramadan	1.06*	1.07***	-0.17	-0.20
	(0.57)	(0.37)	(0.17)	(0.19)
Ramadan x Muslim country			1.19*	1.23***
			(0.62)	(0.41)
B: Test during Ramadan				
Ramadan	1.11*	1.11***	-0.17	-0.20
	(0.57)	(0.37)	(0.17)	(0.19)
Ramadan x Muslim country			1.24**	1.28***
			(0.62)	(0.42)
Test during Ramadan	-0.12	-0.12*	-0.01	-0.01
	(0.07)	(0.07)	(0.04)	(0.04)
Test during Ramadan x Muslim country			-0.12	-0.11
			(0.09)	(0.08)
C: Time between test and Ramadan				
Ramadan	0.96*	0.98**	-0.19	-0.22
	(0.51)	(0.34)	(0.17)	(0.18)
Ramadan x Muslim country			1.10*	1.17***
			(0.56)	(0.38)
Time to test	0.06***	0.05**	0.01	0.01
	(0.02)	(0.02)	(0.01)	(0.01)
Time to test x Muslim country			0.05**	0.04
			(0.02)	(0.03)
Year FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Observations	462,883	462,883	1,404,752	1,403,812

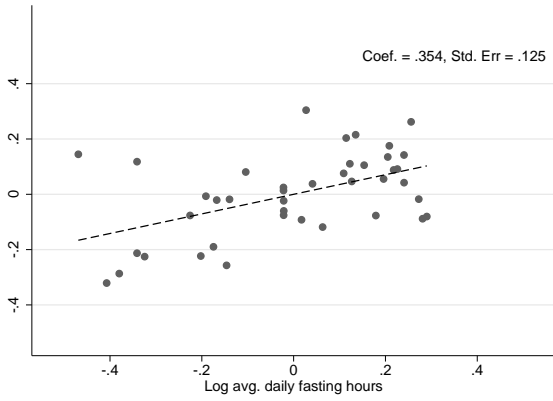
Note: Each panel (A, B, C) shows regressions of standardized achievement test scores on logarithmized average daily fasting hours before test was taken. A country is categorized as a Muslim country if more than 50% of its population is Muslim. Control variables: Age, gender, immigration status, parental education, number of books at home, and school characteristics (shortage of instructional materials, supplies, school building, heating system). See Table A2 in the Appendix for a detailed list of the control variables. *Test during Ramadan* is a binary variable indicating whether a test was taken during Ramadan. *Time to test* measures the days (in logs) between the first day of Ramadan and the test date. Standardized population weights applied. Standard errors in parentheses are cluster-robust at country level. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A7: Robustness checks controlling for GDP per capita (TIMMS)

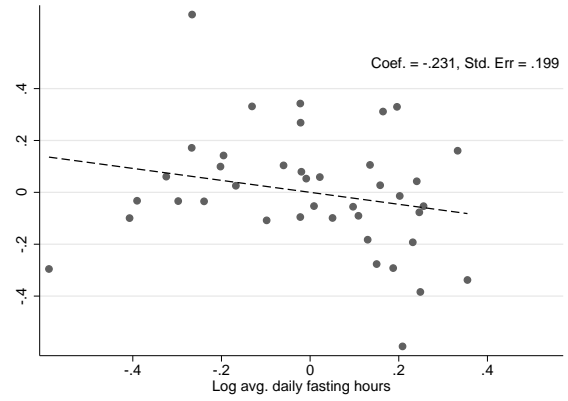
	Only Muslim countries						All countries			
	Math	Science	Math	Science	Math	Science	Math	Science	Math	Science
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Ramadan	2.29**	2.14**	1.13	1.25**	0.82	0.89*	-0.19	-0.22	-0.34*	-0.36*
	(0.98)	(0.77)	(0.74)	(0.56)	(0.65)	(0.50)	(0.18)	(0.19)	(0.18)	(0.20)
Ramadan x % Muslim							1.21**	1.15**		
							(0.60)	(0.56)		
Ramadan x $\mathbb{1}(q_{25} < \% \text{ Muslim} \leq q_{50})$									0.25*	0.22
									(0.14)	(0.13)
Ramadan x $\mathbb{1}(q_{50} < \% \text{ Muslim} \leq q_{75})$									0.23	0.26
									(0.19)	(0.23)
Ramadan x $\mathbb{1}(\% \text{ Muslim} > q_{75})$									1.45***	1.42***
									(0.51)	(0.44)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Muslim-by-year FE	No	No	No	No	No	No	Yes	Yes	Yes	Yes
R squared	0.04	0.03	0.16	0.12	0.28	0.25	0.49	0.43	0.49	0.43
Observations	462,883	462,883	462,883	462,883	462,883	462,883	1,406,701	1,405,761	1,406,701	1,405,761

Note: Regressions of standardized achievement test scores on logarithmized average daily fasting hours before test was taken. A country is categorized as a Muslim country if more than 50 % of its population is Muslim. Control variables: Age, gender, immigration status, parental education, number of books at home, and school characteristics (shortage of instructional materials, supplies, school building, heating system). See Table A2 in the Appendix for a detailed list of the control variables. Additional control variable: log GDP. Standardized population weights applied. Standard errors in parentheses are cluster-robust at country level.

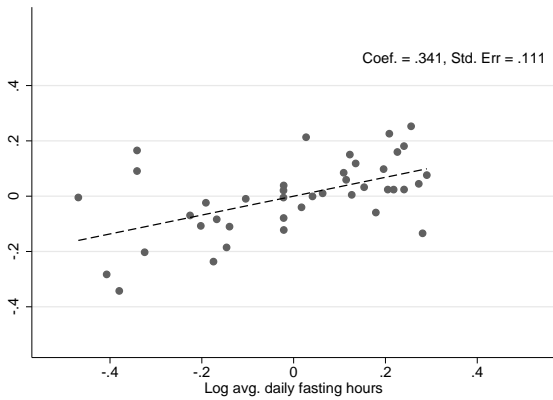
Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.



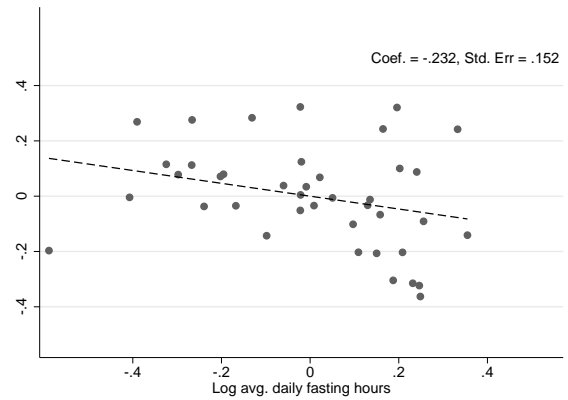
(a) Reading: Muslim immigrants vs natives



(b) Reading: Non-Muslim immigrants vs natives



(c) Math: Muslim immigrants vs natives



(d) Math: Non-Muslim immigrants vs natives

Figure A3: Placedo performance gaps and Ramadan fasting hours (PISA reading and math scores)

Note: Left (right) scatter plots shows country-year performance gaps in science scores between students whose parents are from Muslim countries (non-Muslim countries) and natives and logarithm of average fasting hours during Ramadan before test was taken. Both variables are adjusted by their country means.

Table A8: Non-Muslim countries (PISA)

Country	Non-Muslim majority country of origin
Austria	China, Croatia, Czech Republic, Hungary, Poland, Romania, Russia, Slovakia, Slovenia
Belgium	Germany
Switzerland	Portugal, Spain
Germany	Croatia, Greece, Poland, Slovenia, Serbia, Italy
Denmark	Finland, Greenland, Iceland, Norway, Sweden, other EU
Finland	China, Russia, Thailand, Vietnam
Great Britain	Caribbean, China, Germany, India, Poland, other EU
Netherlands	Belgium, China, Germany, Italy, Poland, Romania, Spain, Suriname, United Kingdom, USA, other EU

Note: List of selected non-Muslim countries for each PISA country included in our analysis. Students are defined as non-Muslim immigrants if both parents are from one of the countries listed in the Table.

Table A9: Robustness check including non-Muslim immigrants (PISA)

	Science (1)	Reading (2)	Math (3)
Muslim x Ramadan	0.30*** (0.07)	0.25*** (0.09)	0.26*** (0.07)
Muslim	-1.06*** (0.20)	-0.91*** (0.24)	-0.91*** (0.18)
Non-Muslim x Ramadan	-0.01 (0.10)	-0.07 (0.10)	-0.04 (0.09)
Non-Muslim	0.10 (0.25)	0.25 (0.27)	0.20 (0.24)
Country x Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
Observations	351,762	351,762	351,762

Note: Regressions of standardized achievement test scores on logarithmized average daily fasting hours. Muslim and non-Muslim students are identified using the country of origin of their parents (see Table A3 and Table A8 in the Appendix). Control variables: Age, gender, immigration status, parental occupation, parental education, number of books at home, school location, school type. See Table A5 in the Appendix for a detailed list of the control variables. Standardized population weights applied. Standard errors in parentheses are cluster-robust at school level.

Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A10: Robustness check using only schools with at least one Muslim student (PISA)

	Science		Reading		Math	
	(1)	(2)	(3)	(4)	(5)	(6)
Ramadan x Share x Muslim		0.26** (0.12)		0.34** (0.13)		0.11 (0.11)
Ramadan x Share	0.30*** (0.08)	0.27*** (0.08)	0.32*** (0.08)	0.29*** (0.08)	0.30*** (0.08)	0.29*** (0.08)
Ramadan x Muslim		-0.09 (0.09)		-0.21** (0.09)		-0.03 (0.09)
Muslim x Share		-0.73** (0.32)		-0.97*** (0.35)		-0.30 (0.30)
Share	-1.06*** (0.20)	-0.96*** (0.21)	-1.12*** (0.22)	-1.02*** (0.22)	-1.06*** (0.21)	-1.01*** (0.21)
Muslim		0.11 (0.24)		0.46* (0.24)		-0.03 (0.23)
Country-by-year FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
R squared	0.33	0.34	0.32	0.32	0.31	0.31
Observations	102,594	102,594	102,594	102,594	102,594	102,594

Note: Regressions of standardized achievement test scores on logarithmized average daily fasting hours. A student is defined as being Muslim if his or her mother and father are from a Muslim country. *Share* is a binary variable indicating a high share of Muslim students in school. Sample restricted to schools with at least one Muslim student. Control variables: Age, gender, immigration status, parental occupation, parental education, number of books at home, school location, school type. See Table A5 in the Appendix for a detailed list of the control variables. Standardized population weights applied. Standard errors in parentheses are cluster-robust at school level.

Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.