Religious practice and student performance: Evidence from Ramadan fasting*

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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 TIMSS 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 that a demanding Ramadan affects PISA test scores of Muslim students only in cohorts with a large share of co-religionists. This finding is consistent with the hypothesis that shared experiences during more intensive Ramadans facilitate the formation of social capital and a social identity conducive to learning outcomes.

Keywords: Education, Religion, Religious Participation, Ramadan, Social Identity, Social Capital, PISA, TIMSS
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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]

[1] The 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).

[2] Throughout 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 TIMSS 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 Ramadan intensity and educational performance. Many of these channels are expected to increase the educational performance of individual students, independent of whether their peers participate in the religious practice. For example, intensive religious practices might shape non-cognitive abilities which are important determinants of educational outcomes (Heckman and Rubinstein, 2001). Ramadan observance arguably requires self-discipline, impulse control, patience, and perseverance or grit. These skills are solidified around the time of puberty and increase the benefits of education (Kautz et al., 2014). Hence, an intensive Ramadan during adolescence could shape non-cognitive abilities and thereby boost educational performance. Next to shaping abilities, Ramadan observance could be associated with changes in time use. Due to a lack of alternative activities, the opportunity cost of studying may decline during Ramadan, leading to an improvement in educational outcomes. For the same reason, parents might be able to spend more time with their offspring and facilitate learning outcomes during more intensive Ramadan. Furthermore, changes in eating habits during Ramadan may create health benefits that lead to higher student achievement (Hoddy et al., 2020; Patterson and Sears, 2017).

Alternatively, the educational performance of students might improve because they participate in the reli-

[3] Detrimental 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 a indirect positive effect.

[4] An 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.

gious practice with their peers. For instance, all of the aforementioned mechanisms could become effective when Ramadan norms are enforced by peers. In addition, the shared experience of an intensive Ramadan could facilitate the formation of social capital or a social identity conducive to educational performance. It has been widely confirmed that religious participation shapes social networks and social capital (Muller and Ellison, 2001; Glanville et al., 2008). In the spirit of Coleman (1988) and Putnam (2000), joint Ramadan rituals could allow students to form new friendship ties with peers that provide educational resources beneficial for educational achievement.[5] Next to social capital formation, the shared experience of an intensive Ramadan may shape the social identity of student cohorts across schools. Akerlof and Kranton (2002) highlight the importance of the social environment of students and predict that the creation of a more unified school community increases the skill formation of students. The performance of joint Ramadan rituals likely enhances a sense of community and hence increases educational performance. This is in line with findings of Clingingsmith 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.

To provide evidence with respect to the mechanisms, we take a first step and 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. These results allow us to argue that Ramadan intensity is indeed positively related to religious participation which may lead to higher social capital. However, this finding is also in line with the hypothesis that religious participation crowds out activities that are detrimental for educational outcomes or with the idea that religiosity shapes non-cognitive abilities.

For a second step, we rely on the religious composition of school-cohorts in the PISA data. Using these data, we study whether the educational benefits occur for Muslim students in cohorts with and without fellow Muslim believers. 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 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

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

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, whereas the positive effect of Ramadan intensity cannot be found for students in schools with a low Muslim share. Although we ultimately cannot exclude other channels, we tentatively interpret our findings 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.

Prior literature has highlighted that certain religious practices are costly and might crowd out other activities (Iannaccone, 1992; Gruber and Hungerman, 2008). In a methodologically similar study, Campante and Yanagizawa-Drott (2015) show that more intensive Ramadan fasting is related to lower GDP growth. Furthermore, Ramadan observers 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

[6]On 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.

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.

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.

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 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 prewdawn (*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 consequences have been well documented in the literature. During the month of Ramadan, individuals reduce their level of activity, suffer from headaches, and have more difficulties to concentrate (see, e.g., Afifi, 1997; Leiper and Molla, 2003; Meckel et al., 2008). While nutritional quality may improve because Ramadan observers spend larger sums on food, consume more home-cooked meals, or benefit from charitable giving, time restricted meals might focus on rapid calorie intake. During more intensive Ramadans, observers may tend to overeat on dishes that provide carbohydrates and fat (Shatila et al., 2021). Nevertheless, Ramadan fasting is found to result in weight loss, which is regained within 2–5 weeks after Ramadan (Hoddy et al., 2020; Kul et al., 2014; Fernando et al., 2019). While evidence points toward small improvements in cholesterol levels, there is mixed evidence for improvements in all other metabolic markers (Patterson and Sears, 2017; Kul et al., 2014; Faris et al., 2020).

Although Toda and Morimoto (2004) suggest that 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 direct consequences, changes in individual lifestyles, time use, 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.[7]

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 asses 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 in a positive way. We broadly distinguish between channels according to which student achievement could improve due to observing Ramadan *individually* or in *groups* of fellow believers. While we cannot exclude that all of these channels are important to produce our results, we provide some evidence in line with the latter mechanisms in Section 6.

[7] Other 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).

Observing Ramadan as an individual In the first set of channels, the educational performance of Muslim students increases by more after an intensive Ramadan independent of whether they share this experience with other Muslim students. The resulting performance boost may arise for various reasons including the shaping of non-cognitive abilities, changes in the opportunity costs of studying, changes in the opportunity costs of parenting, or changes in nutritional quality during more intensive Ramadan.

Religious activities might shape non-cognitive abilities that are associated with student performance (Heckman and Rubinstein, 2001). Ramadan observance arguably requires self-discipline, impulse control, patience, and perseverance or grit. These skills are solidified around the time of puberty and increase learning outcomes (Kautz et al., 2014). According to Heckman (2013, p. 12) strength of motivation and the ability to act on long-term plans are skills necessary to perform well in school.[8] Hence, an intensive Ramadan may shape non-cognitive skills and by doing so improve educational performance.[9]

Gruber and Hungerman (2008) argue that benefits of religious participation may result from the fact that religious activities crowd out secular alternatives, including risky behavior such as alcohol and drug consumption. Due to the absence of alternative activities during Ramadan, students may spend less time on activities detrimental for schooling outcomes and spend more time to study. For the same reason, Ramadan might change how much time parents spend with their children, leading to higher quality parenting with beneficial consequences for student performance. Hence, a more intensive Ramadan may lower the opportunity costs of studying for students and of spending quality time with their children for parents.

Ramadan might also improve individual student performance by changing eating habits. While the literature discussed in Section 2.1 is somewhat inconclusive with respect to the nutritional benefits of Ramadan fasting and only finds evidence for short-term weight losses, there might still be persistent changes in nutritional intake for adolescents. In line with the literature on childhood health and education (Chong et al., 2016; Krämer et al., 2021; Miguel and Kremer, 2004), an improvement of nutritional quality during a more intensive Ramadan could increase students performance.

Observing Ramadan in a group In the second set of channels, the educational performance of Muslim students increases by more after an intensive Ramadan only if this experience is shared with other Muslim students.

[8] 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). It could also be that parental concerns about the moral development of their children induce religious participation. 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."

[9] Indeed, a number of empirical studies suggest a link between religious activities of children and their non-cognitive abilities. 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).

The resulting performance boost may arise from the formation of social capital and a group identity conducive to learning outcomes during more intensive Ramadan.

The sociology literature suggests that religious participation is associated with higher academic achievement because it facilitates the formation of social capital (Coleman, 1988; Putnam, 2000). For example, the attendance of religious services could result in the formation of friendship ties among students from different backgrounds, providing low-achieving students with access to better educational resources. Hence, a more intensive Ramadan may lead to higher religious participation, increasing social capital, thereby boosting educational performance.

Evidence for the relationship between religious participation and social capital formation is provided by Putnam (2000) who shows that members of religious groups participate in religious activities more frequently, they are more involved in other forms of civic engagement, and they report a larger number of friends.[10] Coleman and Hoffer (1987) and Coleman (1988) further suggest that religious activities promote the formation of social capital, which in turn fosters the creation of human capital.[11] Building on Coleman and Putnam, Muller and Ellison (2001) show that the effect of religious involvement on academic progress can be partly explained by community social capital, i.e. access to peers with strong achievement values. Glanville et al. (2008) confirm that measures of social capital, such as whether students have access to friends with better grades, or whether students participate in secular social groups partly explain higher educational achievement of religious students. This also 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).[12]

The communal experience of Ramadan has an aspect of shared worship that creates a common social identity among students. In this way it may be similar to the Hajj pilgrimage described by Clingingsmith et al. (2009). According to Akerlof and Kranton (2002), social identity is of importance in the context of schooling because a 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 enhance a sense of community and thereby increase educational performance. Recent evidence that lends empirical support to the presumption that shared collective experiences may help building a common identity and, thereby, favorably affect behavior is

[10] This 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.

[11] This research is motivated by the debate about why student achievement of students in Catholic schools exceed those of students in public schools. See, e.g. Coleman et al. (1982), Evans and Schwab (1995), and Neal (1997) for contributions to the Catholic schools debate.

[12] A related idea is formalized by Fan (2008) who 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.

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.

It may be hard to empirically separate between the mechanisms described above. For example, the economics of education literature argues that non-cognitive skills of children such as cooperation and perspective taking are highly correlated with pro-social behavior and social capital (Heckman and Rubinstein, 2001; Lleras, 2008; Jackson, 2018).[13] Hence, we abstain for making strong claims about their relative importance. In Section 6, we show that the intensity of Ramadan affects educational performance only if students are surrounded by a larger number of other Muslims, in line with the hypothesis that the formation of social capital and a social identity could at least be relevant mechanisms.

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.

Because our data does not provide any information on students' exact location, we follow Campante and Yanagizawa-Drott (2015) in using sunrise and sunset times of a country's capital to proxy for each students' prescribed fasting hours. This might introduce some measurement error in our analysis, which would cause attenuation bias in case of classical measurement error. We probe the robustness of our results using alternative coordinates to measure prescribed fasting hours. In particular, we use daylight hours for country-specific population-weighted centroids, i.e. the center of population, based on a method proposed by Hall et al. (2019). Overall, these robustness checks reveal that our estimation results are hardly affected by using alternative coordinates.[14]

Combining the data on daylight hours 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.[15]

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

[13] It is also possible that religious communities amplify the effect of non-cognitive skills (Bankston and Zhou, 1995).
[14] Results of these robustness checks are reported in Tables A1-A4 in the Appendix.
[15] We converted the dates using the online calendar converter available at https://muslimphilosophy.com/calconv/index.html.

assign each student observation the fasting time of the most recent Ramadan, using information on the exact test date.[16] 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.[17]

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).[18]

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).[19]

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.[20]

Our analysis exploits country-level variation in Ramadan fasting hours as TIMSS does not include information on students' location, 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

[16] Exact test dates are available in TIMSS's restricted use files.

[17] PISA tests usually take place in the first quarter of the year.

[18] Panel data sets based on repeated cross-sectional assessment test scores are also used in, e.g., Hanushek et al. (2013). International student assessment surveys, such as TIMSS and PISA, are widely used in the economics of education literature. Cordero et al. (2018) provide a list of studies that use international student assessment surveys (TIMSS, PISA, or PIRLS) to estimate causal effects of various factors on student performance.

[19] Test 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).

[20] We 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 A5 in the Appendix for more information on the background variables.

(Grim and Karim, 2011).[21] 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.[22]

Table 1 presents summary statistics for our main variables.[23] The unbalanced repeated cross-sectional data set consists of more than 1.4 million student observations from 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 A7 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.[24] 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

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

[22] A complete list of the countries included is in Table A6 in the Appendix. The 3rd column of Table A6 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.

[23] Table A5 in the Appendix presents summary statistics for the comprehensive set of control variables.

[24] Again, we categorize a country as Muslim if more than 50 % of the population identifies as Muslim using information from the PEW Research group (Grim and Karim, 2011).

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.[25] 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.

By using parental country of origin to identify Muslim students, we build on studies that find high persistence in the intergenerational transmission of religious traits—in particular among minority groups that have a higher incentive to spend resources on the transmission of ethnic and religious traits through family socialization (Bisin and Verdier, 2000). The key assumptions of our approach is that a higher share of Muslims in the country of origin increases the likelihood that immigrant parents are Muslim believers and transmit their religious beliefs to their children. To assess the error rate of this approach, we use data from the European Social Survey (ESS), a data set that includes all 8 European countries studied in our paper and provides information on religious affiliation and parental country of origin of each survey participant. We calculate the share of participants who report to be Muslim for survey participants with and without parents from Muslim-majority countries (see Appendix Table A9 and Table A10 for a restricted sample of survey participants below 25).[26] We find that, for each country included in our study, around two-thirds or more of the survey participants with parents from Muslim-majority countries report being Muslim in the survey. Overall, we interpret this finding as supportive evidence for our approach.

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. PISA uses paper- or computer-based tests to assess students' educational performance in 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

[25] Table A8 in the Appendix shows the share of Muslim students by country and year for the 8 countries.

[26] We use the same set of countries as in the PISA data to classify parents as immigrants from Muslim-majority countries, i.e., we deliberately categorize parents from Muslim-majority countries as from non-Muslim majority countries if their country of origin is not listed in Table A7 in the Appendix of our paper.

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

[28] Table A11 in the Appendix summarizes our control variables.

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

$$Test_{ict} = \beta \; Ramadan_{ct} + \lambda_c + \theta_t + \epsilon_{ict}, \tag{1}$$

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, λ_c and θ_t represent a set of dummy variables to capture country and year fixed effects, respectively.[29] We estimate equation (1) using robust standard errors adjusted for clustering at the country level.[30]

[29] We follow Campante and Yanagizawa-Drott (2015) and use the natural logarithm of fasting hours. Results are qualitatively similar without the logarithmic transformation (see Appendix Table A12).

[30] Results are robust to alternatively using two-way clustered standard errors by survey year and country.

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 the educational performance of Muslim students rather than that of non-Muslim students. Hence, we expect to see meaningful and positive estimates of β in equation (1) only for regressions based on a sub-set of countries with a substantial share of Muslim population and start our empirical analysis by estimating (1) for countries with a Muslim-majority population.[31]

We then extend our estimation sample to include also non-Muslim countries and add interaction terms in (1):

$$Test_{ict} = \beta_1 \, Ramadan_{ct} + \beta_2 \, Ramadan_{ct} \times \%Muslim_c + \lambda_c + \theta_t + \eta_t^M + \epsilon_{ict}, \tag{2}$$

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:

$$Test_{ict} = \gamma_1 \, Ramadan_{ct} \times Muslim_{ict} + \gamma_2 Muslim_{ict} + \kappa_{ct} + \epsilon_{ict}, \tag{3}$$

where $Muslim_{ict}$ is a dummy variable indicating whether a student is a first or second generation immigrant from an Muslim country. $Ramadan_{ct}$ is the log average daily number of fasting hours during the last Ramadan before the test was taken in the country of residence.[32] We include country-by-year fixed effects, κ_{ct}, to flexibly

[31] A potential concern of this approach is that a substantial share of Muslims in Muslim-majority countries does not observe Ramadan. However, surveys find that observance of Ramadan fasting is widespread among Muslims in Muslim-majority countries (Lugo et al., 2012). Lugo et al. (2012) interviewed more than 38 000 Muslims from 39 countries and asked participants whether they fast during the month of Ramadan. In almost all of the nine Muslim-majority countries included in our TIMSS sample as well as in Lugo et al. (2012) the percentage of Muslims that practice Ramadan fasting is very high (percent in parenthesis): Tunisia (96), Morocco (98), Jordan (86), Turkey (84), Palestine (94), Indonesia (99), Malaysia (99), Lebanon (88), Kazakhstan (30).

[32] Burhani (2013) provides some qualitative evidence showing that Muslim believers fast in accordance with the daylight hours in the location they are residing.

allow for country-specific time trends. In this specification, γ_1 measures the difference in marginal effects of Ramadan intensity between Muslims and non-Muslims. In our analysis using PISA data, we cluster standard errors at the level of schools, which are the primary sampling units of the PISA surveys.[33]

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 γ_1 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.[34]

Note that, in line with other studies using variation of prescribed fasting hours (e.g., Campante and Yanagizawa-Drott, 2015; Aksoy and Gambetta, 2022), both our empirical approaches only allow us to identify the overall reduced form effect of a stricter Ramadan. That is, we do not identify the isolated effect of complying with the variation in prescribed fasting hours by actually fasting more or less hours. The reduced form effect of a stricter Ramadan is itself of considerable policy and research interest, because a stricter Ramadan may induce other changes in students' behavior or their environment that may affect skill production over and beyond any effect arising through changes in actual individual fasting hours.

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 achievement. 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.[35]

[33] Our results are also robust to using two-way clustered standard errors by survey year and country.

[34] Please note that issues due to reverse causality caused by international relocation decisions only arise if international relocation decisions differ between Muslim and non-Muslim students and are correlated with fasting hours. For example, when fasting hours are high, low-performing Muslim students are more likely to migrate internationally than non-Muslim students, in comparison to years when fasting hours are low.

[35] Our 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.

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 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 achievement 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.[36] 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.[37] 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.

[36] We 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.

[37] The last column in Table A6 in the Appendix lists all countries by the quartiles used in this estimation.

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 A13 in the Appendix. We find a negative effect on test scores if the test was taken during Ramadan (Panel B of Table A13) and a positive effect for the time between Ramadan and the test date (Panel C of Table A13). 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 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 A14 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.[38] The first row of Table 4 reports the coefficient on the interaction term of average fasting hours and a binary variable indicating whether

[38] In 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.

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 achievement 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 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.[39] 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.

In Appendix Table A16, we empirically assess this differential effect of fasting hours on performance gaps between Muslim students and natives and non-Muslim immigrants and natives by including an interaction term of fasting hours and a binary variable indicating non-Muslim immigrant students to our baseline estimation equation. Reassuringly, the interaction term for non-Muslim immigrants is small and insignificant whereas the interaction term for Muslims remains significant and is 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 broadly distinguish between channels ac-

[39] Table A16 in the Appendix lists the selected countries that define the group of non-Muslim immigrant students based on parental country of origin.

cording to which Ramadan intensity affects educational performance if students observe Ramadan *individually* or in *groups* of co-religionists. In this section, we first establish that longer fasting hours during adolescence increase religious participation. While this does not allow us to separate between many of the channels described in Section 2, it confirms that adolescents indeed respond to more intensive Ramadan by becoming more involved in religious activities. 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 mechanisms that potentially work through social identity and social capital formation are relevant.

6.1 Ramadan intensity and religious participation

While most channels discussed in Section 2 require that students participate in religious rituals, the social capital channel additionally requires that students participate in public religious activities more frequently following a more intensive Ramadan. To evaluate this necessary condition of the social capital 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.[40]

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.[41] 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):

$$Participation_{ict} = \delta_1 \, Ramadan_{ct} \times Muslim_{ict} + \delta_2 \, Muslim_{ict} + \kappa_{ct} + \epsilon_{ict}, \tag{4}$$

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 κ_{ct} are country $\times$ wave fixed effects. The coefficient of interest in Equation (4) is δ_1, 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

[40] The 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).

[41] Results 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.

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, suggesting that adult Muslims do not change their religious participation in response to Ramadan intensity.[42]

While these results confirm that Ramadan length is positively associated with participation in religious services which arguably affects social capital formation among adolescents, they do not allow us to distinguish between the potential other channels. In fact, a more frequent attendance of religious services could also crowd out activities that are detrimental for schooling outcomes or reflect higher levels of religiosity associated with the formation of beneficial non-cognitive abilities.

6.2 Social capital, common identity, and Ramadan intensity

We further aim to provide evidence that social capital and social identity formation are relevant channels to associate Ramadan intensity with educational performance by comparing 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:

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

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

[42] Different from Campante and Yanagizawa-Drott (2015), we do not distinguish between screening and commitment mechanisms in this paper and abstain from exploring heterogeneity with respect to level of religious commitment within age groups here. It may well be that religious participation increases for sub-groups of older subjects.

country c and year t given a positive share of Muslim students in school and zero otherwise.[43]

A positive coefficient on α_6, which measures the marginal effect of fasting for Muslim students in schools with a large share of Muslim students, may be interpreted to show that the beneficial effects of observing Ramadan only arise if the experience is shared with fellow believers. Thus, the reduced-form effect may be partly explained by the formation of social capital and a social identity. Positive coefficients on α_6 *and* α_4, which measures the marginal effect of fasting for Muslim students in schools with a low share of Muslim students, could be interpreted to show that the beneficial effects of observing Ramadan arise for each student individually, independent of whether their peers participate in the religious practice. Such a finding would not allow us to distinguish between the channels discussed in Section 2.[44]

Table 6 reports our estimation results of Equation (5).[45] 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 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 estimating 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. While the coefficient on the interaction term *Ramadan* $\times$ *Share* $\times$ *Muslim* is positive for all outcomes and significant for science and reading, the coefficient on *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 support the idea that a more intensive Ramadan is only beneficial when experienced among fellow Muslim students, lending some credence to channels associated with social capital and social capital formation. However, these findings could also be interpreted to imply that the effect only occurs in the presence of fellow believers because they enforce Ramadan norms whose beneficial effects work through other channels.

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

[44] As the allocation of students to schools is not random, we cannot fully rule out the possibility that unobserved factors that are correlated with $Share_{ict}$ also influence our estimation of the interaction effect.

[45] Table A17 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.

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 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 Clingingsmith et al. (2009), the religious practice of the Hajj increased pilgrims' tolerance toward others. Thus, openly practicing Ramadan 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.[46]

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 that the intensity of Ramadan experienced during adolescence is particularly influential. Thus, a more demanding Ramadan might shape preferences and may continue to 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). In combination with the finding that effects of longer Ramadan fasting hours accrue only to students in schools with a high Muslim share, we argue that the formation of social capital and a common identity may be among the relevant channels to explain the reduced form effect.

We envision that a more intensive Ramadan could affect student performance in the following way but abstain from too strong claims due to the reduced-form nature of our analyses. During a more intensive Ramadan, Muslim students attend services at the Mosque more frequently. Here they share experiences with students in their school

[46] It 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).

cohort from various backgrounds with whom they would not interact otherwise. This form of social capital allows them to access better educational resources. In addition, the shared experiences create a common identity within a cohort, enhancing a sense of community which helps to overcome the negative effects of social differences that impede better learning at school.

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								
Test scores								
Math	419.50	402.70	426.47	405.99	401.18	415.63	429.35	438.98
	(92.83)	(53.39)	(94.50)	(84.17)	(90.71)	(95.25)	(96.85)	(92.98)
Science	438.07	440.19	430.22	429.62	434.01	436.72	443.02	448.71
	(94.97)	(65.12)	(89.60)	(81.95)	(90.97)	(95.12)	(104.87)	(102.49)
Fasting hours								
Year before test	12.54	11.17	10.51	10.74	11.79	12.98	13.97	13.93
	(1.51)	(0.28)	(1.10)	(0.69)	(0.20)	(0.45)	(0.83)	(0.81)
Number of observations								
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								
Test scores								
Math	497.04	506.82	499.12	480.56	475.12	489.74	509.99	517.14
	(106.14)	(98.23)	(106.01)	(111.81)	(109.05)	(109.54)	(101.79)	(97.54)
Science	495.86	501.64	498.00	482.49	475.67	490.03	508.81	512.82
	(103.92)	(92.98)	(106.38)	(112.11)	(106.57)	(107.65)	(97.97)	(94.37)
Fasting hours								
Year before test	11.94	10.77	9.86	10.38	11.62	13.04	14.13	14.36
	(2.58)	(1.10)	(2.22)	(2.06)	(0.43)	(1.19)	(2.54)	(2.42)
Number of observations								
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 A6 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							
Test scores							
Reading	418.78	392.80	402.41	419.68	434.64	430.85	419.37
	(92.60)	(95.60)	(101.26)	(84.32)	(88.96)	(89.85)	(92.94)
Science	414.59	388.33	402.77	416.43	426.19	425.81	416.15
	(86.88)	(84.26)	(86.12)	(85.20)	(86.81)	(86.33)	(86.83)
Math	432.69	417.16	421.37	434.29	439.63	440.77	434.70
	(81.88)	(80.92)	(85.05)	(79.37)	(83.55)	(81.82)	(78.49)
Fasting hours							
Year before test	13.62	8.85	10.63	12.59	14.71	16.30	16.54
	(2.75)	(0.38)	(0.15)	(0.05)	(0.32)	(0.54)	(0.72)
School characteristics							
Share of Muslim students	0.20	0.19	0.24	0.23	0.19	0.20	0.19
	(0.18)	(0.14)	(0.23)	(0.20)	(0.15)	(0.16)	(0.16)
Number of observations							
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							
Test scores							
Reading	504.43	507.90	505.87	503.59	507.82	503.83	497.52
	(92.93)	(90.15)	(96.11)	(90.91)	(89.69)	(92.17)	(97.84)
Science	514.25	512.75	521.04	519.17	518.95	510.60	502.96
	(94.31)	(97.01)	(94.98)	(94.03)	(91.47)	(94.30)	(92.71)
Math	515.80	523.34	520.56	517.64	514.70	509.57	508.88
	(88.97)	(92.63)	(89.96)	(89.50)	(89.97)	(85.31)	(85.21)
Fasting hours							
Year before test	13.26	8.54	10.52	12.61	14.78	16.46	16.72
	(3.08)	(0.59)	(0.24)	(0.09)	(0.44)	(0.79)	(0.85)
School characteristics							
Share of Muslim students	0.02	0.02	0.02	0.03	0.03	0.03	0.02
	(0.06)	(0.05)	(0.05)	(0.07)	(0.06)	(0.06)	(0.05)
Number of observations							
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.

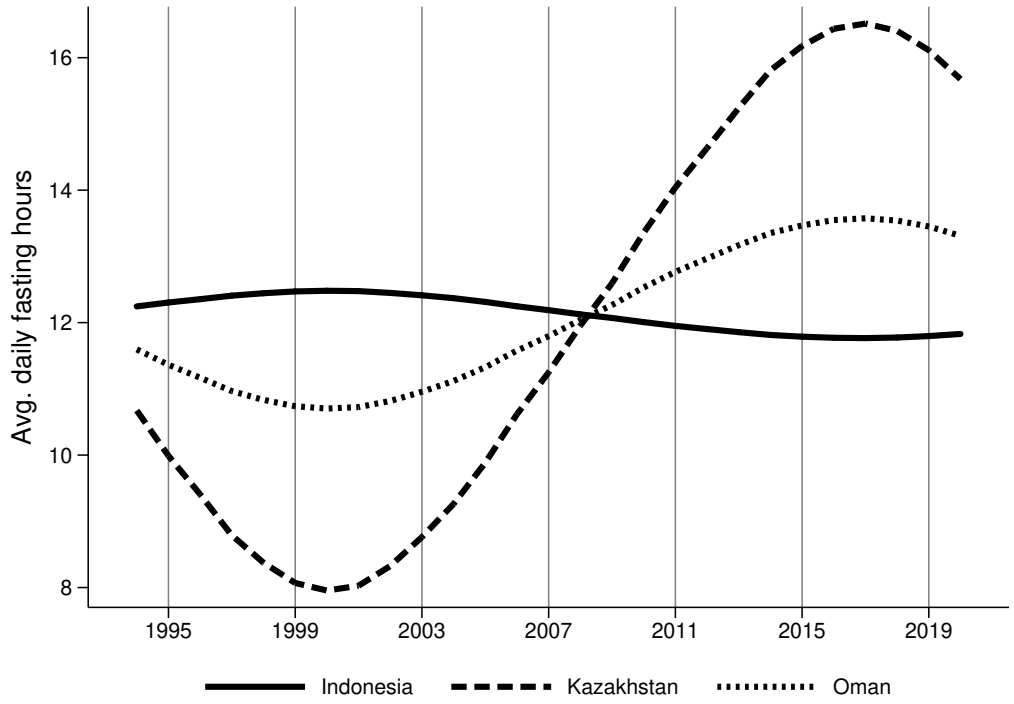


Figure 1: Average daily fasting hours during Ramadan

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.

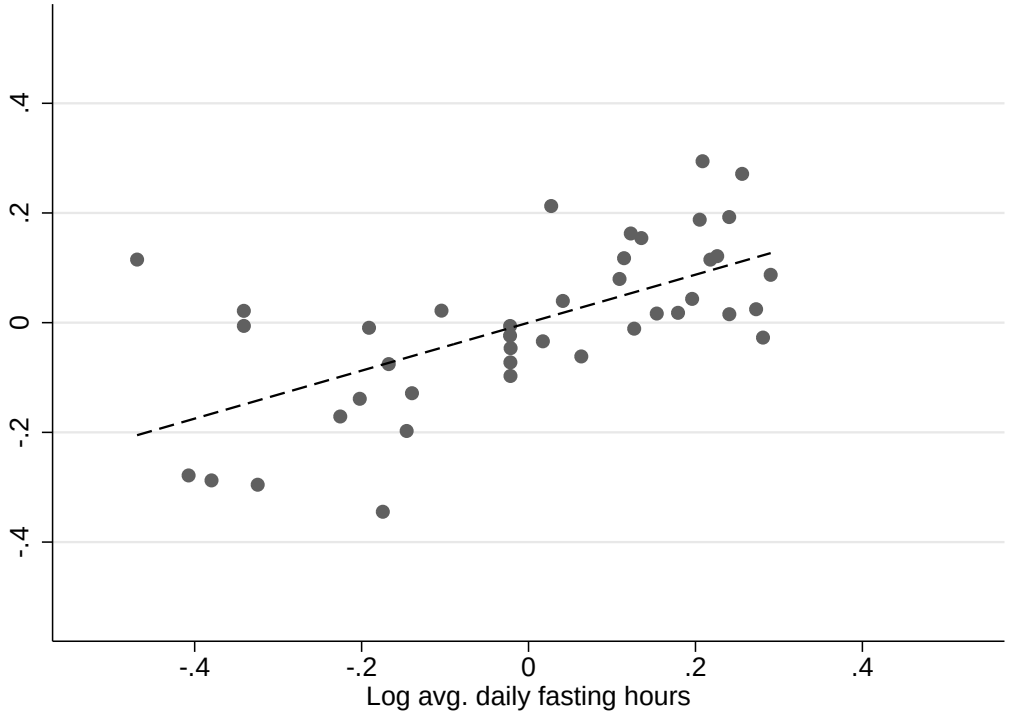


Figure 2: Performance gaps and Ramadan fasting hours (PISA science scores)

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)

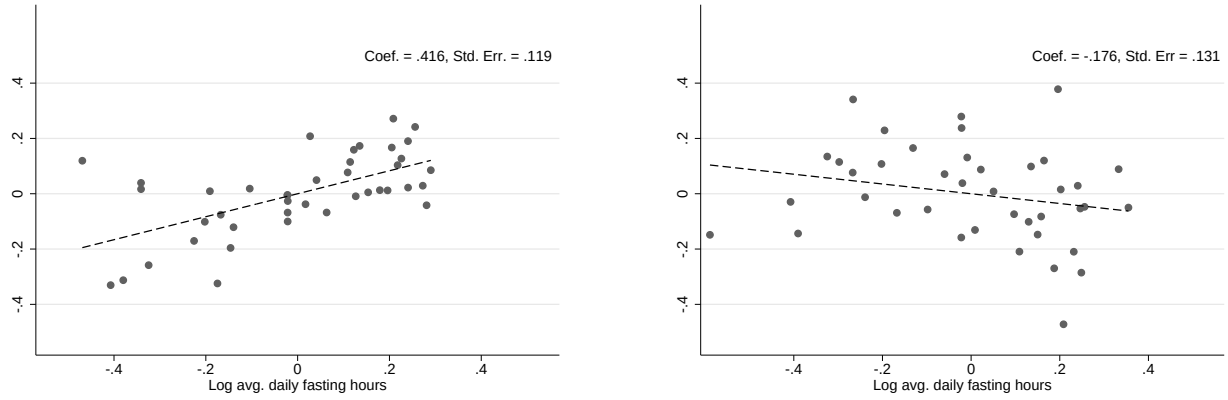
	Only Muslim countries						All countries			
	Math	Science	Math	Science	Math	Science	Math	Science	Math	Science
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Ramadan	2.14*	1.89**	1.43**	1.47***	1.06*	1.07***	-0.19	-0.22	-0.29	-0.33
	(1.02)	(0.78)	(0.65)	(0.40)	(0.57)	(0.37)	(0.18)	(0.19)	(0.20)	(0.24)
Ramadan 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 A5 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***	0.30***	0.50***	0.25***	0.48***	0.26***
	(0.08)	(0.07)	(0.09)	(0.09)	(0.07)	(0.07)
Muslim	-2.33***	-1.07***	-2.12***	-0.91***	-2.05***	-0.92***
	(0.20)	(0.20)	(0.24)	(0.24)	(0.19)	(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 A11 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: Placedo 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**		0.36**		0.10
		(0.13)		(0.14)		(0.12)
Ramadan x Share	0.31***	0.28***	0.32***	0.29***	0.33***	0.31***
	(0.06)	(0.06)	(0.07)	(0.07)	(0.06)	(0.06)
Ramadan x Muslim		-0.09		-0.22**		-0.02
		(0.10)		(0.11)		(0.10)
Muslim x Share		-0.71**		-1.01***		-0.24
		(0.34)		(0.38)		(0.32)
Share	-1.10***	-0.99***	-1.10***	-1.01***	-1.13***	-1.08***
	(0.16)	(0.16)	(0.18)	(0.17)	(0.16)	(0.16)
Muslim		0.09		0.48*		-0.08
		(0.26)		(0.27)		(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 A11 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:
Religious practice and educational performance (TIMSS), fasting hours at population center

	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**	1.99**	1.49**	1.53***	1.12*	1.12**	-0.16	-0.18	-0.27	-0.32
	(1.08)	(0.83)	(0.69)	(0.43)	(0.60)	(0.39)	(0.16)	(0.16)	(0.21)	(0.24)
Ramadan x % Muslim							1.25**	1.13**		
							(0.61)	(0.54)		
Ramadan x $\mathbb{1}(q_{25} < \%\text{ Muslim} \leq q_{50})$									0.17	0.18
									(0.17)	(0.18)
Ramadan x $\mathbb{1}(q_{50} < \%\text{ Muslim} \leq q_{75})$									0.27	0.34
									(0.21)	(0.23)
Ramadan x $\mathbb{1}(\%\text{ Muslim} > q_{75})$									1.41***	1.31***
									(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	0.02	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. Country-specific fasting hours are calculated based on population centroids using the approach outlined in Hall et al. (2019) for the year 2003 and applying the location algorithm by Aboufadel and Austin. 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 A5 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 A2:
Religious practice and educational performance (PISA), fasting hours at population center

	Science		Reading		Math	
	(1)	(2)	(3)	(4)	(5)	(6)
Muslim x Ramadan	0.52***	0.29***	0.48***	0.23***	0.46***	0.25***
	(0.08)	(0.07)	(0.09)	(0.09)	(0.07)	(0.07)
Muslim	-2.29***	-1.04***	-2.07***	-0.87***	-2.02***	-0.90***
	(0.20)	(0.20)	(0.24)	(0.24)	(0.18)	(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. Country-specific fasting hours are calculated based on population centroids using the approach outlined in Hall et al. (2019) for the year 2003 and applying the location algorithm by Aboufadel and Austin. 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 A11 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: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A3:
Religious practice and religious participation (WVS), fasting hours at population center

	Age 15-18		Age 19-35		Age 36-65	
	(1)	(2)	(3)	(4)	(5)	(6)
Ramadan x Muslim	0.36*	0.33*	0.04	0.03	-0.07	-0.07
	(0.18)	(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. Country-specific fasting hours are calculated based on population centroids using the approach outlined in Hall et al. (2019) for the year 2003 and applying the location algorithm by Aboufadel and Austin. 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 A4:
Mechanisms translating religious practice into educational performance (PISA), fasting hours at population center

	Science		Reading		Math	
	(1)	(2)	(3)	(4)	(5)	(6)
Ramadan x Share x Muslim		0.27**		0.37**		0.10
		(0.13)		(0.14)		(0.12)
Ramadan x Share	0.31***	0.28***	0.31***	0.29***	0.32***	0.31***
	(0.06)	(0.06)	(0.07)	(0.07)	(0.06)	(0.06)
Ramadan x Muslim		-0.10		-0.24**		-0.03
		(0.10)		(0.10)		(0.10)
Muslim x Share		-0.72**		-1.02***		-0.25
		(0.34)		(0.37)		(0.32)
Share	-1.10***	-1.00***	-1.10***	-1.01***	-1.13***	-1.08***
	(0.16)	(0.16)	(0.17)	(0.17)	(0.16)	(0.16)
Muslim		0.12		0.53*		-0.05
		(0.26)		(0.27)		(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. Country-specific fasting hours are calculated based on population centroids using the approach outlined in Hall et al. (2019) for the year 2003 and applying the location algorithm by Aboufadel and Austin. 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 A11 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 A5: Descriptive statistics of all included variables (TIMSS)

	Non-Muslim countries		Muslim countries	
	Mean	Std. Dev.	Mean	Std. Dev.
Test Scores				
Math	497.04	106.14	419.50	92.83
Science	495.86	103.92	438.07	94.97
Fasting hours				
Year before test	11.94	2.58	12.54	1.51
Student characteristics				
Age	14.34	0.82	14.20	0.85
Female	0.50		0.49	
Immigration status				
Second generation	0.04		0.04	
First generation	0.07		0.13	
Parental education				
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	
Books at home				
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	
School characteristics				
Schortage: Instructional materials				
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	
Shortage: Supplies				
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	
Shortage: School building				
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	
Shortage: Heating system				
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	
Number of observations				
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 A6 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 A6: 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.

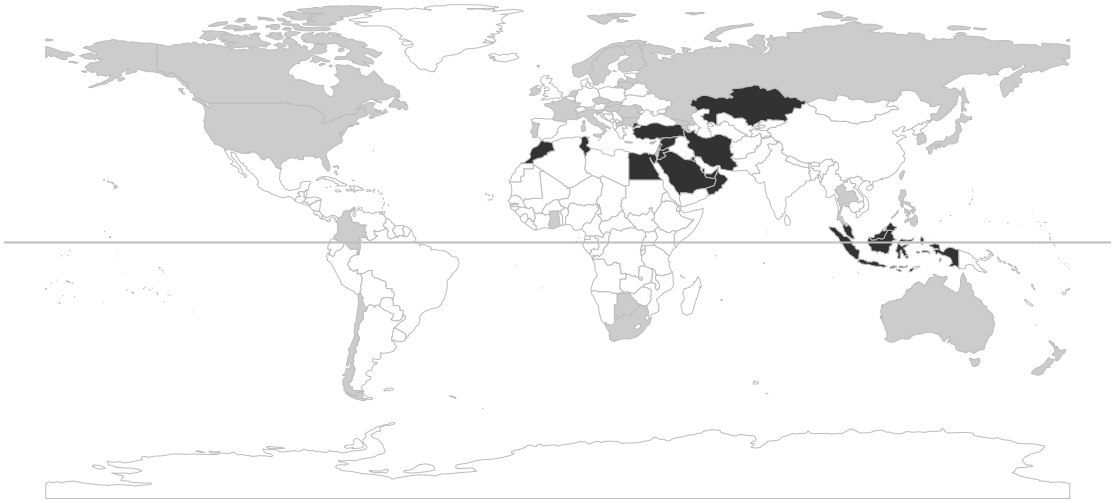


Figure A1: Muslim countries included in TIMSS

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

Table A7: 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, Slowenia
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, Slowenia
Denmark	Denmark, DNK: Other, **Pakistan**, **Turkey**, DNK: The former Yuguslavia
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 A8: 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 A9:
ESS: Muslim believers by parental country of origin

	Parents from non-Muslim majority country			Parents from Muslim majority country		
	No religon	Other religion	Islamic	No religon	Other religion	Islamic
AT	2,928	7,627	112	36	9	156
	(27.45)	(71.50)	(1.05)	(17.91)	(4.48)	(77.61)
BE	7,991	5,444	214	55	17	463
	(58.55)	(39.89)	(1.57)	(10.28)	(3.18)	(86.54)
CH	4,515	8,278	378	40	10	99
	(34.28)	(62.85)	(2.87)	(26.85)	(6.71)	(66.44)
DE	10,036	12,036	266	67	18	285
	(44.93)	(53.88)	(1.19)	(18.11)	(4.86)	(77.03)
DK	4,397	6,243	76	19	2	115
	(41.03)	(58.26)	(0.71)	(13.97)	(1.47)	(84.56)
FI	6,097	7,752	37	4	2	24
	(43.91)	(55.83)	(0.27)	(13.33)	(6.67)	(80.00)
GB	9,212	8,101	182	19	66	165
	(52.66)	(46.30)	(1.04)	(7.60)	(26.40)	(66.00)
NL	8,797	5,223	122	82	19	230
	(62.20)	(36.93)	(0.86)	(24.77)	(5.74)	(69.49)

Note: European Social Survey, waves 2-9 (2004-2018), pooled sample (wave 1 does not include information on religious denomination). Absolute number of survey participants by parental country of origin and religious denomination (percent in parentheses). Only those countries are categorized as Muslim-majority countries that are listed in Table A15.

Table A10:
ESS: Muslim believers by parental country of origin, survey participants below 25

	Parents from non-Muslim majority country			Parents from Muslim majority country		
	No religon	Other religion	Islamic	No religon	Other religion	Islamic
AT	577	872	25	9	2	48
	(39.15)	(59.16)	(1.70)	(15.25)	(3.39)	(81.36)
BE	1,623	582	88	10	3	124
	(70.78)	(25.38)	(3.84)	(7.30)	(2.19)	(90.51)
CH	751	885	98	5	3	14
	(43.31)	(51.04)	(5.65)	(22.73)	(13.64)	(63.64)
DE	1,579	1,386	100	16	7	93
	(51.52)	(45.22)	(3.26)	(13.79)	(6.03)	(80.17)
DK	849	579	22	2	0	45
	(58.55)	(39.93)	(1.52)	(4.26)	(0.00)	(95.74)
FI	960	871	15	0	1	18
	(52.00)	(47.18)	(0.81)	(0.00)	(5.26)	(94.74)
GB	1,274	452	34	4	21	31
	(72.39)	(25.68)	(1.93)	(7.14)	(37.50)	(55.36)
NL	1,027	309	30	14	5	56
	(75.18)	(22.62)	(2.20)	(18.67)	(6.67)	(74.67)

Note: European Social Survey, waves 2-9 (2004-2018), pooled sample (wave 1 does not include information on religious denomination). Absolute number of survey participants by parental country of origin and religious denomination (percent in parentheses). Only those countries are categorized as Muslim-majority countries that are listed in Table A15.

Table A11: Descriptive statistics of all included variables (PISA)

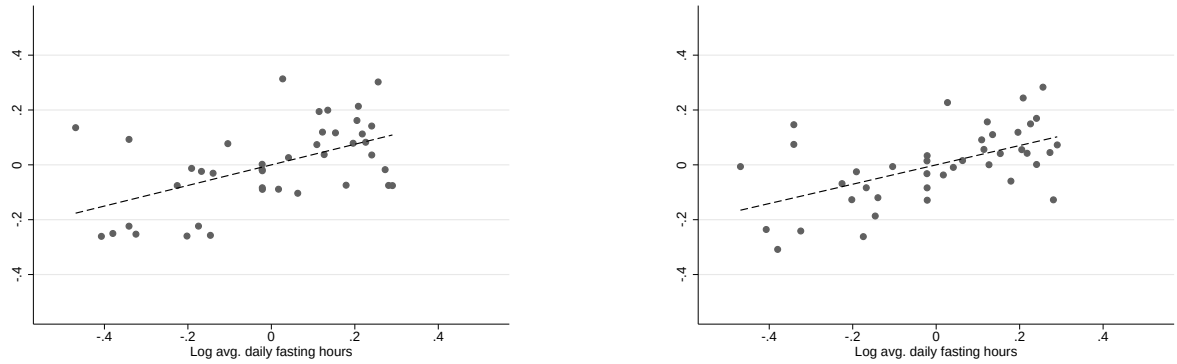
	Non-Muslim countries		Muslim countries	
	Mean	Std. Dev.	Mean	Std. Dev.
Test Scores				
Science	514.25	94.31	414.59	86.88
Reading	504.43	92.93	418.78	92.60
Math	515.80	88.97	432.69	81.88
Fasting hours				
Year before test	13.26	3.08	13.62	2.75
Student characteristics				
Age	15.78	0.29	15.79	0.29
Female	0.49		0.51	
Immigration status				
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
Parental education				
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	
Books at home				
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	
School characteristics				
Avg. of Muslims in cohort	0.02	0.06	0.20	0.18
Location				
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	
Type				
Private	0.02		0.01	
Government dependent	0.19		0.16	
Public	0.69		0.69	
Unknown	0.11		0.14	
Number of observations				
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.

Table A12: Religious practice and educational performance (TIMSS), no logarithmic transformation

	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	0.18**	0.15**	0.12**	0.12***	0.09*	0.08**	-0.02	-0.02	-0.02	-0.03
	(0.08)	(0.06)	(0.05)	(0.03)	(0.05)	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)
Ramadan x % Muslim							0.10*	0.09*		
							(0.05)	(0.05)		
Ramadan x $\mathbb{1}(q_{25} < \%\text{ Muslim} \leq q_{50})$									0.01	0.01
									(0.01)	(0.02)
Ramadan x $\mathbb{1}(q_{50} < \%\text{ Muslim} \leq q_{75})$									0.02	0.03
									(0.02)	(0.02)
Ramadan x $\mathbb{1}(\%\text{ Muslim} > q_{75})$									0.11***	0.10***
									(0.04)	(0.04)
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 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 A5 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: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.



(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 A13: Robustness checks controlling for test dates (TIMSS)

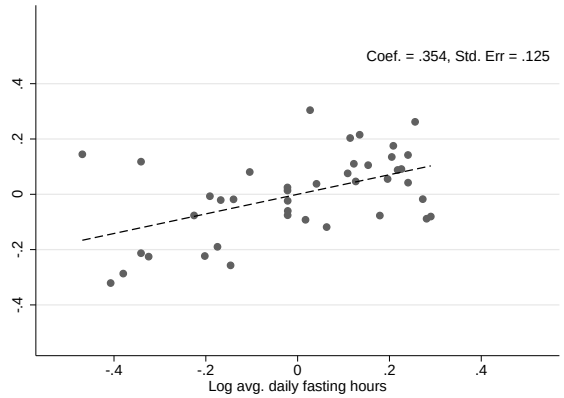
	Math	Science	Math	Science
	(1)	(2)	(3)	(4)
A: Baseline estimates				
Ramadan	1.06*	1.07***	-0.17	-0.20
	(0.57)	(0.37)	(0.17)	(0.19)
Ramadan x Muslim country			1.19*	1.23***
			(0.62)	(0.41)
B: Test during Ramadan				
Ramadan	1.11*	1.11***	-0.17	-0.20
	(0.57)	(0.37)	(0.17)	(0.19)
Ramadan x Muslim country			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 A5 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: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

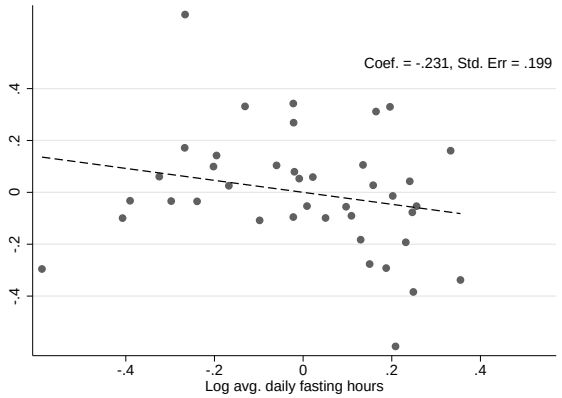
Table A14: Robustness checks controlling for GDP per capita (TIMSS)

	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	2.29**	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

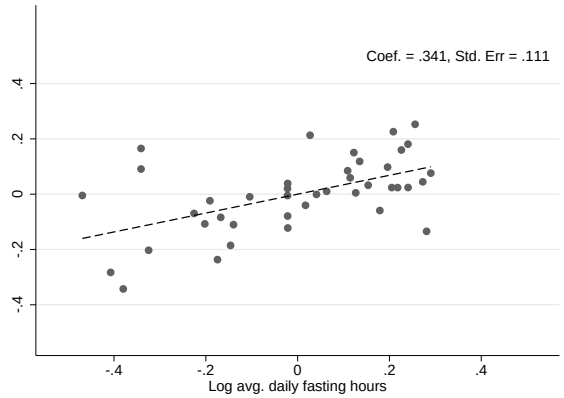
Note: Regressions of standardized achievement test scores on logarithmized average daily fasting hours before test was taken. A country is categorized as a Muslim country if more than 50 % of its population is Muslim. Control variables: Age, gender, immigration status, parental education, number of books at home, and school characteristics (shortage of instructional materials, supplies, school building, heating system). See Table A5 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: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.



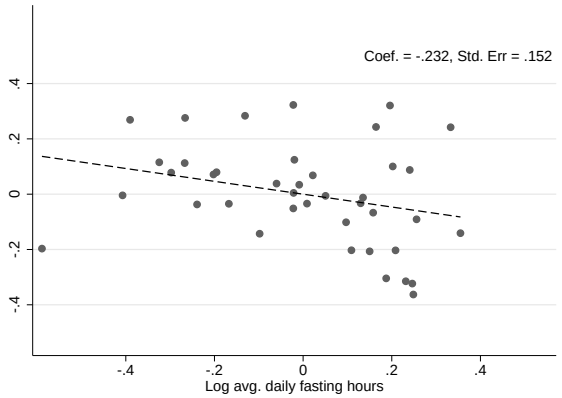
(a) Reading: Muslim immigrants vs natives



(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 A15: 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 A16: Robustness check including non-Muslim immigrants (PISA)

	Science (1)	Reading (2)	Math (3)
Muslim x Ramadan	0.30***	0.25***	0.26***
	(0.07)	(0.09)	(0.07)
Muslim	-1.06***	-0.91***	-0.91***
	(0.20)	(0.24)	(0.18)
Non-Muslim x Ramadan	-0.01	-0.07	-0.04
	(0.10)	(0.10)	(0.09)
Non-Muslim	0.10	0.25	0.20
	(0.25)	(0.27)	(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 A7 and Table A15 in the Appendix). Control variables: Age, gender, immigration status, parental occupation, parental education, number of books at home, school location, school type. See Table A11 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 A17: 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**		0.34**		0.11
		(0.12)		(0.13)		(0.11)
Ramadan x Share	0.30***	0.27***	0.32***	0.29***	0.30***	0.29***
	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)
Ramadan x Muslim		-0.09		-0.21**		-0.03
		(0.09)		(0.09)		(0.09)
Muslim x Share		-0.73**		-0.97***		-0.30
		(0.32)		(0.35)		(0.30)
Share	-1.06***	-0.96***	-1.12***	-1.02***	-1.06***	-1.01***
	(0.20)	(0.21)	(0.22)	(0.22)	(0.21)	(0.21)
Muslim		0.11		0.46*		-0.03
		(0.24)		(0.24)		(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 A11 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: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.