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Research paper

Religion as an informal institution: A case of true pure land Buddhism and missing women in early modern Japan☆

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A B S T R A C T

In early modern Japan, infanticide was used for birth control and sex selection. However, some historians hypothesized that people who believed in the True Pure Land (TPL) sect of Japanese Buddhism were less likely to commit infanticide. I statistically examine this hypothesis using a quasi-natural experiment of *hinoeuma* (fire-horse) year with a two-way fixed-effects estimation. Girls born in a *hinoeuma* year were reckoned to be inauspicious and subjected to sex-selective infanticide. In 1846 and 1906 *hinoeuma*, TPL-dominant areas experienced a smaller increase in the male-to-female ratio in the cohort than the areas with less TPL dominance. Additional regressions support the hypothesis that the TPL's prohibition of infanticide led to this smaller effect.

1. Introduction

Recent years have seen a revival of the economic analysis of religion. This growing interest aligns with a broader research agenda exploring how socioeconomic outcomes depend on informal institutions, such as social norms, ethics, and religion, to be complemented or supplemented by formal institutions, such as legal systems and the rule of law (Iyer, 2016; Becker et al., 2021). Iyer (2016) highlights several underinvestigated research agendas in the economic analysis of religion. Specifically, she calls for a rigorous econometric analysis of the impact of religion on marketing, political processes, and demography. Furthermore, the scarcity of research on religions beyond Judaism, Christianity, Islam, and Hinduism highlights a notable gap that must be addressed to foster a more comprehensive understanding of the economic impact of religion and informal institutions in general.

This study provides an econometric analysis of the impact of religion on demographic aspects, with a specific focus on Buddhism in nineteenth- and early twentieth-century Japan. I examine the influence of differences in religious teachings among Buddhist sects on children's selections. Early modern Japan provides an intriguing case study to examine the impact of religious teachings on demographic behavior for both institutional and econometric reasons.

First, during this period of weak law enforcement, infanticide for birth control and sex selection was common, while Buddhism, characterized by various sects with distinct teachings, significantly influenced people's lives.[1] Only one of the sects imposed stringent restrictions on infanticide. Thus, examining the impact of this Buddhist sect on the prevalence of child selection offers a unique

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[1] Japanese Buddhism is divided into 13 main and several minor sects. The differences in the teachings of the sects I analyze roughly correspond to the differences in the teachings among, for example, Baptist, Methodist and Lutheran denominations in American Protestantism.

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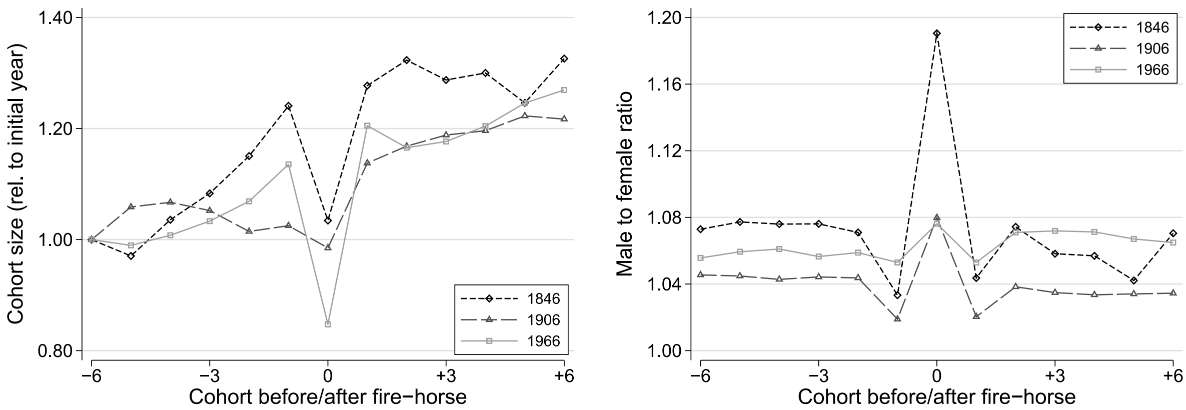

Fig. 1. Cohort size (left) and male-to-female ratio (right) during fire-horse episodes (13-year periods). The left panel shows the cohort size relative to the six years before the fire-horse. The right panel shows the male to female ratio. The data for the 1846 episode is based on the 1886 population count and then adjusted for the difference in the number of days in each year during lunisolar calendar system (see Appendix B.1). The data for the 1906 and the 1966 episodes are based on the birth count. See Section 4.2 for the data source.

evaluation of the supplementary role played by religious teaching in weak law enforcement. Second, the distribution of Buddhist sects exhibits geographical variation, which results in cross-sectional identification variation. Third, I exploit quasi-natural experimental events as additional sources of variation in the identification. These events altered parents' incentives to have baby girls, but not boys, in particular years compared to other years. This temporal variation allows me to include an area fixed effect to account for various unobservable characteristics, distinguishing my approach from many econometric studies of religion on demographic behavior that rely on cross-sectional variations for identification.

The geographical distribution of Buddhist sects corresponds to a geographical variation in people's behavior driven by variations in religious teachings. During the early modern era, the *Shin-shū*, or True Pure Land sect (henceforth referred to as only TPL),[2] stood out for its stringent restrictions on infanticide and abortion compared with other sects. Given that infanticide and abortion were common practices, the strictness of TPL's teachings was widely acknowledged by educated individuals at that time as well as by current scholars (see Section 3). Nevertheless, the absence of statistical evidence leaves room for skepticism among scholars. I employ econometric methodology for a reexamination of this debate.

I utilize quasi-natural experimental events known as *hinoeuma* (fire-horse or FH) in 1846 and 1906, which trigger distinct behaviors in individuals strongly influenced by TPL and in those who are not. The term "fire-horse" refers to specific years in Japan's sexagenary year-naming system. Girls born in the fire-horse year, one of the sixty-year cycles, were believed to bring calamities to their families and potential future in-laws (in case of marriage). Consequently, parents sought to avoid having daughters born during the fire-horse years. At the national aggregate level, the number of births decreased drastically in 1846, 1906, and 1966. The male-to-female (MF) ratio increased in 1846 and 1906 as well (see Fig. 1).[3] Many researchers have analyzed fire-horse effects by using aggregate time-series data (see Section 2).

Distortions in the MF ratio can result from sex-selective abortions, infanticide use, or false reporting of birth years. In 1966, both sex-selective abortion and infanticide were illegal, and the laws were strictly enforced, resulting in negligible MF-ratio distortions (see Appendix A). Some researchers who analyzed aggregate data suggest that the MF ratio distortion in 1906 was due to false reporting (Ministry of Health Welfare Japan, 1969; Rohlfs et al., 2010), but Kurosu (1992), analyzing area (prefecture)-level data, finds that false reporting can explain only part of the MF-ratio distortion. In 1846 and 1906, sex-selective abortion was technologically infeasible, and while infanticide was illegal, it might have contributed to MF-ratio distortion under weak law enforcement. However, religious teachings against infanticide may have supplemented formal institutions; the TPL discouraged infanticide, even for those with incentives to avoid having female children.

This study primarily examines the TPL's role in mitigating MF-ratio distortion while addressing false reporting and other empirical issues. Because my empirical approach relies on MF-ratio distortions, I relegate the analysis of the 1966 episode to Appendix A and concentrate on the 1846 and 1906 episodes in the main text.

The prefecture-level maps illustrate the relationship between MF-ratio distortion (Fig. 2) and the presence of TPL (Fig. 3). Fig. 2 shows the deviation in the MF ratio relative to the usual years (excluding the three years around the fire-horse years) for each prefecture.[4] Shading indicates a large increase in the MF ratio, which implies a large fire-horse effect. The considerable geographical variation shown in Fig. 2 has not yet been fully explained (Kurosu, 1992, 1994). Fig. 3 illustrates the ratio of TPL temples to the

2 The sect is sometimes referred to as *Jōdo Shin-Shū*, which translates to the true (*shin*) pure land (*Jōdo*) sect (*Shū*).

3 The cohort size for the 1846 episode represents the population count of each year relative to the 1840 cohort, based on the 1886 population count data, and adjusted for the difference in days in years due to the lunisolar calendar system (see Appendix B.1). The MF ratio for the 1846 episode is based on 1886 population count data. Birth data is unavailable for the 1846 episode. The figures for the 1906 and 1966 episodes show the number of births relative to 1900 and 1960, respectively, and the MF ratio of registered births for each year. See Section 4.2 for a detailed explanation.

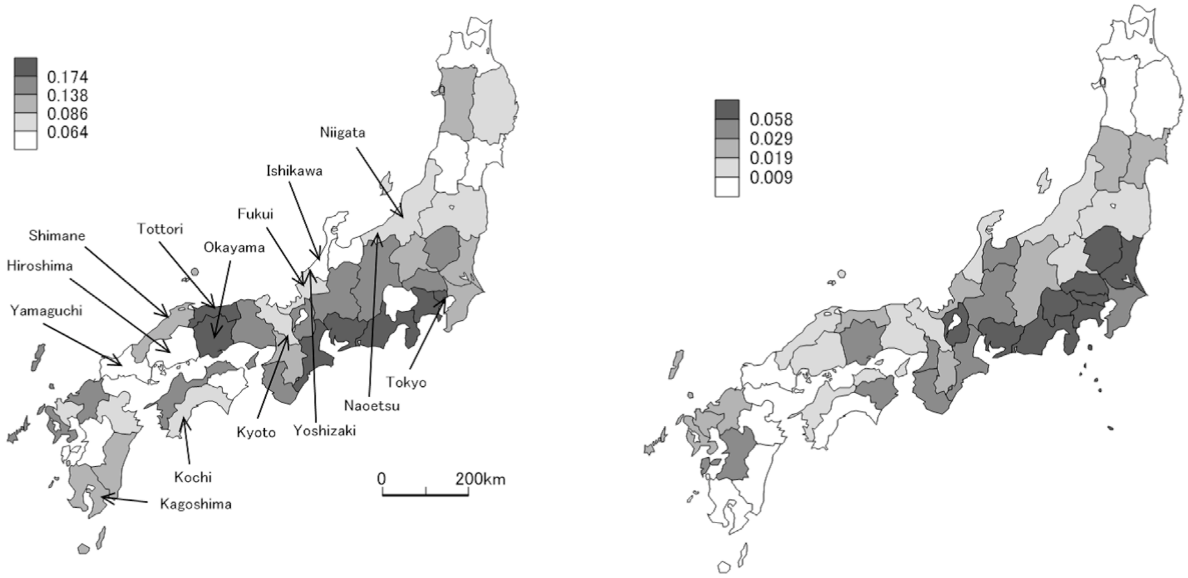

Fig. 2. Deviations of the male-to-female ratio in the fire-horse years from the normal years (Left panel: 1846 episode, right panel: 1906 episode). The left panel is based on the 1886 population count. The right panel is based on the birth count. The difference between the average and the value in the year. The average is based on two to six years before and after the fire-horse year. See Section 4.2 for the data source.

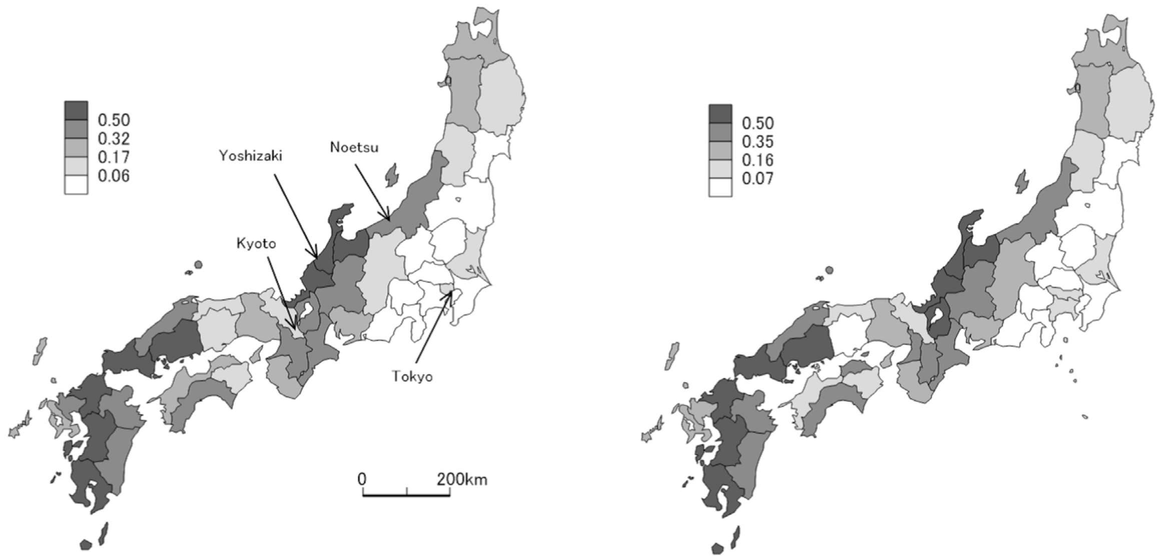

Fig. 3. The ratio of TPL temples to total temples (Left panel: data from the 1880s, right panel: data from 1899.) See Section 4.2 for the data source.

total number of temples in each prefecture.[5] Darker areas correspond to a greater presence of TPL. The hypothesis posits that areas with a stronger TPL (darker in Fig. 3) correspond to areas with a weaker fire-horse effect (brighter in Fig. 2). An illustrative contrast is evident at the western tip of the main island. Fig. 2 (Fig. 3) shows that the three western prefectures (Hiroshima, Yamaguchi, and Shimane) appear brighter (darker), whereas the two neighboring prefectures (Okayama and Tottori) appear darker (brighter). Similar correspondence is also observed in other areas. Nonetheless, the effects may depend on various other factors. Therefore, conducting a formal econometric analysis is crucial.

[4] Section 4 provides details about the data source. The prefecture borderline in the 1846 figure differs slightly from the current figure. See footnote 12 in the subsection on Data for clarification. For both the 1846 and 1906 episodes, the analysis excluded the Hokkaido and Okinawa prefectures. These two prefectures were politically and culturally independent until the late nineteenth century.

[5] See Section 4 for the details.

A two-way fixed-effects regression suggests that the MF ratio of 1846 fire-horse year is 16 percentage points higher than that in average years, but TPL substantially mitigates this fire-horse effect. An increase in the TPL ratio from 9% (1st quartile) to 44% (3rd quartile) eliminates one-third of the total fire-horse effect. In the 1906 episode, the MF ratio increases by 6.5 percentage points, with the difference between the 1st and 3rd quartile of TPL again offsetting approximately one-third of the total effect. The mitigation effect of TPL remains robust even after controlling for other observable characteristics, including the total number of temples per capita. The presence of temples also contributes to mitigating the fire-horse effect in the 1846 episode but not in the 1906 episode. Moreover, similar regressions using other sects of Buddhism as the key explanatory variables indicate no coherent patterns. The specificity of TPL highlights that its observed impact is unique to TPL and is not a general feature of overall religiosity or other sects.

Overall, the results for the 1846 episode remains reasonably robust after controlling for socioeconomic variables, measurement issues, and potential false reporting. The result for the 1906 episode is smaller and less robust, which is expected because of the gradual intensification of the legal prohibition on infanticide, leaving less room for religious influence. In fact, an additional analysis of the 1906 episode reveals that TPL has a substantial impact where the enforcement of formal institutions is weak. Moreover, there are no complementary effects of formal and informal institutions. Thus, religion substitutes for weak formal institutions, but if the formal institution is enough strong, the role of religion is minimal.

This sizable TPL effect can be attributed to two possible mechanisms. First, TPL followers might not have believed in the fire-horse superstition. Second, TPL adherents believed in superstitions but did not resort to child selection. Although data limitations prevent the separate identification of these mechanisms, three sets of supplementary statistical analyses support the second mechanism.

The first analysis focuses on the marital status. In areas where people did not believe in superstitions, women born in the fire-horse years should not experience discrimination in marriage. The data revealed no positive correlation between the unmarried rate of fire-horse women and the TPL ratio, suggesting that TPL followers believed in superstitions as much as others did. The second analysis examines the results of a 1946 prefecture-level survey that directly asked people about their avoidance of fire-horse women and other superstitious behaviors. The regression results show no correlation between the degree of avoidance of fire-horse women and the TPL ratio, indicating the existence of similar beliefs of fire-horse superstition in TPL and non-TPL areas. The third analysis explores homicide and suicide rates between 1884 and 1885. Given TPL prohibited killings, the TPL-dominant area had lower homicide and suicide rates, supporting the idea that TPL mitigated these behaviors. Based on these supportive results, I conclude that people in TPL areas believed in fire-horse superstition as much as people in other areas. However, TPL, as an informal institution, effectively mitigated the distortion of the MF ratio.

The remainder of this paper is organized as follows. Section 2 explains the contribution to the literature, and Section 3 gives the historical and institutional background. Section 4 describes our empirical strategy and data. Section 5 presents the results, and Section 6 concludes the paper.

2. The literature

This study contributes to two strands of literature: the economics of religion and missing women. Although many studies have explored the influence of religion on demographic behavior (for example, Lehrer and Chiswick, 1993; Adsera, 2006; Iyer and Joshi, 2013; Becker and Woessmann, 2018; Berman et al., 2018; De la Croix and Delavallade, 2018), a significant gap remains in the analyses of religions other than Judaism, Christianity, Islam, and Hinduism. Vu and Yamada (2024) examine the impact of Confucianism on the MF ratio, and gender gaps in economic participation and education. Vu and Yamada (2020) explore the impact of overall religiousness in Buddhism on the MF ratio in Vietnam. I focus on the specific influence of variations in religious teachings among Buddhist sects.

The examination of differences in teachings among Buddhist sects supplements the emerging literature focusing on the differential impacts of subdivisions within a religion. Recent works acknowledge substantive differences in mission stances among Catholic and Protestant subdivisions. Waldinger (2017) discovers that, among Catholics, areas where Mendicant orders were more intense during Catholic missions in colonial Mexico led to higher current educational outcomes than areas where Jesuits were more intense. Valencia Caicedo (2019) shows the positive impact of Jesuit missions compared with Franciscan missions in colonial South America on current education and income.[6] Regarding Protestants, Jedwab et al. (2021) compare the differential impacts of historical missions of Methodists and Presbyterians (and Catholics) on current socioeconomic outcomes in Ghana. These works consider the differences in the targets of the missionaries and their approaches, while my work considers differences in teachings among subdivisions. The difference in teachings in subdivisions (denominations, branches, and sects) of a religion is not limited to Japanese Buddhism; different subdivisions exist because they have differences in some aspects of their teachings. The insight drawn is that the statistical examinations based on a deep understanding of differences in religious teachings among subdivisions of a religion is applicable beyond the specific context of Japan.

In the Japanese context, this study provides the first econometric result determining the role of religion and informal institutions broadly. Hayashi and Prescott (2008) posit the impact of family ethics in explaining Japan's pre-World War II slow growth, but they do not statistically test the role of ethics. Furthermore, the literature across various fields has frequently referenced the idea that TPL strictly prohibits abortion and infanticide use (Takahashi, 1941; Sekiyama, 1957; Umemura, 1965; Arimoto, 1995; Drixler, 2013). However, this hypothesis has yet to be rigorously validated through statistical analysis. Studies using regional or household data

[6] See their discussions for seemingly contradicting results (p.356 of Waldinger (2017) and p.536 of Valencia Caicedo (2019)).

do not find statistically significant effects of TPL on population growth or the number of children (Umemura, 1965; Arimoto, 1995; Hiroshima, 2006, 2008; Ogawa, 2016). The statistical insignificance of these studies is natural, as population growth and the number of children are influenced by a myriad of factors, including income, parental preferences, and various unobservable characteristics. This study aims to address this gap in the literature by providing a statistical examination of the role of TPL in shaping demographic behavior in early modern Japan.

The second strand of the literature is missing women. Missing women, an apparent sex imbalance observed in the population and/or birth statistics of some Asian and African countries, is an important issue (c.f., Anderson and Ray, 2010). Religion is sometimes considered a potential determinant, but the evidence is mixed. Vu and Yamada (2020) show the effect of religiousness in Buddhism on the MF ratio in Vietnam. By contrast, Sen (2003) and Jha et al. (2006) do not find a similar explanatory power for the Hindu/Muslim distribution in India. One reason for the limitations of the Hindu-Muslim dichotomy in explaining the issue of missing women could be its oversimplified nature. Borooah et al. (2009) and Iyer and Joshi (2013) compare three groups of households, upper-caste Hindus, Muslims, and lower-caste Hindus. After controlling for various socioeconomic and regional characteristics, Muslim girls were found to have had a lower infant mortality rate than lower-caster Hindus. In this context, my study emphasizes the significance of the differences in teaching among subdivisions of a religion.

In contrast to many studies that rely primarily on cross-sectional variations in the distribution of religion when examining its impact on missing women, I leverage a unique quasi-natural experimental setting. This setting introduces time-series variation, allowing control for a wide range of unobservable characteristics by incorporating both cross-sectional and time-fixed effects. Exploiting time-series variation is methodologically similar to examining the impact of other aspects of culture or informal institutions on socioeconomic outcomes, such as in Ashraf et al. (2020) and Cao et al. (2022). This approach enhances the depth and robustness of the analysis.

The Japanese version of the missing women's problem, the fire-horse year, has also been the subject of many studies (for example, Azumi, 1968; Kaku, 1972, 1975; Rohlfs et al., 2010) using aggregate time-series data, but the literature cannot explain the cross-sectional variations (Kurosu, 1992, 1994). I argue that TPL's religious teachings help explain this variation.

3. Background

In this section, I explain three elements of the background: fire-horse superstition, Buddhism in Japan, and abortion and infanticide. The purpose is twofold. First, I reinforce the main tested hypotheses based on the historical context and literature. Second, I explain the background of the identification variations.

3.1. Fire-horse

The fire-horse superstition in Japan is based on the sexagenary cycle used to label calendar years. This sixty-year cycle combines five elements and twelve animals, designating one of those years as a fire-horse year, such as 2026, 1966, 1906, 1846, 1786, and so on.

The origins of this myth can be traced to the belief in China during the Song dynasty, that the years of the fire-horse and fire-sheep brought trouble (Kobayashi, 1941). This superstition came to Japan in the 1660s. The story of Oshichi, a girl believed to have been born in the fire-horse year of 1666 and caused a major fire in Edo (present-day Tokyo) in 1683, contributed to this superstition. Oshichi's story was adapted into a novel and various performing arts, leading to fire-horse girls being associated with calamity. By the fire-horse year 1786, this superstition was well known across Japan (Kobayashi, 1941; van Steenpaal, 2015). In the fire-horse year 1966, over 90% of married women under 40 were aware of this superstition, with 30% expressing a desire to avoid having a baby in that year (Ministry of Health Welfare Japan, 1969).

This cultural phenomenon created a significant bias against women born in the fire-horse years, leading to unique demographic changes that are utilized in this study.

3.2. History of Buddhism in Japan and the expansion of TPL

This section explores the origins and regional distribution of TPL, offering a context for understanding the sources of identification variation.[7]

Japanese Buddhism belongs to the Mahayana school and emphasizes the enlightenment of all individuals. Introduced in the sixth century, Buddhism gradually gained recognition despite initial opposition from the indigenous polytheistic religion *Shintō*. Temples initially received support from aristocrats and focused on scholarly activities, such as Zen meditation (*Shingon* sect). Notably, Mount *Hiei* of the *Tendai* sect, located near Kyoto, emerged as a central hub for Buddhist learning.

During the civil war periods (the twelfth and sixteenth centuries), major temples, such as Mount *Hiei*, acquired vast lands, armed themselves to protect against samurai warriors, and became connected to political power. Meanwhile, other traditional temples were devastated because of the loss of financial support from aristocrats who lost their assets. Several new sects emerged, including *Jōdo*, *Rinzai*, *Sōtō*, *Nichiren*, and TPL, who simplified teaching to target commoner support and donations.

[7] This section draws primarily from Tamura (2000).

The founder of TPL, Shinran (1173–1263), initially studied Buddhism at Mount *Hiei* and later under Hōnen (1133–1212), the founder of the *Jōdo* sect. Hōnen's teachings centered on the repetition of the name Amida in the hope of rebirth in Pure Land. His growing popularity aroused envy and anger from Mount *Hiei* and led to his exile in the current Kochi prefecture in 1207. Concurrently, one of Hōnen's disciples, Shinran, was exiled to Naoetsu in the Niigata Prefecture. This geographical separation led to a differentiation in their teachings, with Shinran emphasizing that one moment of faith guaranteed rebirth in Pure Land. After Shinran died, his successors established TPL, but this was minor until Rennyo (1415–1499), a descendant of Shinran, led the sect.

Rennyo distributed letters summarizing his core teachings, gaining popularity and opposition from other sects. In 1465, Mount *Hiei* declared Rennyo's teaching heretical and destroyed his temple. Rennyo took refuge in Yoshizaki village on the border between Fukui and Ishikawa prefectures. The choice of destination was coincidental; his childhood academic (not TPL) teacher owned land there and willingly provided it. Rennyo continued to develop his teachings and gain popularity. With growing support, he constructed a new head temple in Kyoto. By the end of the sixteenth century, TPL had become the largest sect.

The geographical spread of TPL was influenced by several factors, including the distance from the head temple (see Fig. 3) and where the sect's talented monks were born. Monks who received training at the head temple returned to their hometowns to establish their own temples with the head temple's approval (Chiba, 1980; Honganji Shiryō Kenkyūjo, 1997, 1998).

During the Tokugawa era (1600–1867), the government disarmed temples and held head temples responsible for their affiliated temples. Christianity was banned and individuals were required to register at a Buddhist temple, clearly identifying their religious affiliation.

In 1868, pressure from Western powers led to the establishment of a Western-style centralized government. While the government initially attempted to promote *Shintō* as a state religion, this prioritization of *Shintō* resulted in a harsh attitude toward Buddhism, including the destruction of some temples.[8] This approach created social instability, leading to religious freedom in 1875. Buddhism quickly regained its position and many temples were rebuilt.

From the late nineteenth to the early twentieth century, Buddhism exerted a significant influence, with a majority of people reporting Buddhism as their religion (Appendix B.2).

3.3. Abortion, infanticide and Buddhism

From the seventeenth to the nineteenth century, Japan experienced stagnant population growth, partly due to repeated famines and a low fertility rate driven by households seeking to maintain their living standards (Kurosu, 2002; Saito and Takashima, 2015). This low fertility rate is the result of various family control methods, including abortion and infanticide (Hardacre, 1997). Although the authorities issued repeated orders prohibiting these practices, enforcement remained weak (Takahashi, 1936), demonstrating their ineffectiveness and indicating widespread abortion and infanticide use. Whether these family control practices lead to distortions in the MF ratio is unclear, because the extent of male preference in Japan likely varies depending on specific regional conditions and historical periods (Kurosu, 2002; Tsuya and Kurosu, 2010; Drixler, 2013). Consequently, this discussion underscores the importance of controlling for baseline sex preferences in each area by incorporating prefecture fixed effects in the regression analysis.

Infanticide is typically administered by a family member or a midwife. Traditional midwives played a substantial role in pregnancy and childbirth by contributing to child-selection practices (Takahashi, 1955; Hardacre, 1997; Drixler, 2013). With the establishment of a modern legal system in the late nineteenth century, both abortion and infanticide were officially declared illegal. Nevertheless, weak enforcement of the law has led to limited convictions from abortion providers, including parents and midwives (Hardacre, 1997, pp.48–50). Additionally, as Drixler (2013, 2016) argue, the extremely high stillbirth rate in this period reflects the deliberate practices of abortion and infanticide.

A more fundamental question arises: why are abortions and infanticide prevalent among practicing Buddhists? Modern Buddhism strictly prohibits abortion and infanticide based on the belief that the first of the five precepts in Buddhism is to refrain from harming living creatures (Keown, 2007b) and to interpret that life starts with fertilization (Keown, 2007a). However, this has not been the case historically. As Hardacre (1997, p. 25) summarizes, "There is much evidence to suggest the fetus was not regarded as fully human", and "contraception, abortion, and infanticide existed along a continuum, corresponding to the level of the fetus or newborn".

Infanticide is sometimes referred to as "kogaeshi", which translates to "returning a child". Newborns were considered humans only after reaching a certain age; before that, they were perceived as living in a border region between birth and prebirth (LaFleur, 1992). Infant deaths are often interpreted as a return to the pre-birth period. Given this belief, parents sometimes "helped" a baby "return" when the timing of its birth did not align with the family's intentions.[9] The returned child was thought to have been reborn elsewhere. Buddhism itself provides justification for such practices, rooted in the fundamental Buddhist belief of a continuous cycle of birth and death (LaFleur, 1992).

[8] Throughout this time, the current Kagoshima prefecture eradicated all temples. The total number of temples in Kagoshima prefecture in 1888 was 39, and the total number of temples per person was 0.00004, far below the second-lowest (Kochi prefecture, 0.0003). Kagoshima prefecture was also special. TPL was officially prohibited by the local lord during the Tokugawa period, when the official number of TPL temples was zero. Nevertheless, many people still followed to TPL (Takahashi, 1955). In this sense, temple data for Kagoshima Prefecture have a measurement problem. For robustness, I ran regressions without Kagoshima Prefecture.

[9] Kawaguchi (2002) compiled a diary from an affluent farmer in northeastern Japan in the early nineteenth century, noting the farmer's experience of "returning" three of his 10 children: a child of unknown sex, a boy, and a girl.

Most Buddhist sects, along with other religions, did not explicitly oppose infanticide use. As Hardacre (1997) points out, “Buddhism, Shinto, and Shugendo had virtually nothing to say about contraception, abortion, and infanticide” (Hardacre, 1997, p. 26). However, TPL took an exceptionally strong stance. For example, in 1791, on behalf of the TPL head temple, a high-ranking monk sent letters to monks in the Kanto area (near Tokyo) in response to an inquiry from the Tokugawa government.

> I hear that in the Kanto area many parents mercilessly kill a baby if they already have three or so children ... If you notice followers who do the above-described things, you must expel them. We heavily penalize the monk who connives the followers into doing such things (p.446, 448, Kōzon, 1791, translated by HI).

TPL followers accepted this teaching, and contemporaneous individuals acknowledged the specificity of TPL. For example:

> In many areas, parents may conduct infanticide and the population is declining. However, in areas where the TPL is dominant, people have a strong belief and refrain from conducting infanticide (p. 683, Buyō, 1816, translated by HI).

This strong prohibition may not align with Shinran’s original teaching that one moment of faith is sufficient for rebirth in the Pure Land. This teaching transition was established in the seventeenth century (Arimoto, 1995). The underlying concept originates from people’s fear of going to hell after death, with the belief that evil deeds lead to hell. This idea was repeatedly communicated through religious, daily and folk events, encouraging people to avoid evil, including acts such as killing, which were viewed as significant transgressions.

Takahashi (1955), Sekiyama (1957), and Arimoto (1995) collect many other anecdotes about this stringency from historical documents. Drixler (2013) provides a summary of the literature, stating that “[m]ost of these were strongholds of Jōdoshinshū, the True Pure Land sect of Buddhism, which condemned infanticide more consistently than other Buddhism sects ...” (Drixler, 2013, p. 32). However, since Drixler (2013) use data from eastern Japan, where the influence of the TPL is limited, he does not empirically assess this hypothesis.

4. Empirical strategy and data

This section discusses the empirical strategies and data, a concise overview, while Appendix B.3 provides information in detail on the data sources.

4.1. Estimation equation

Basic identification relies on a two-way fixed-effects model; hence, the idea is similar to the difference-in-differences (DID) estimation. For each fire-horse episode in 1846 and 1906, I examine the outcome variable, the MF ratio of the cohort, in the fire-horse year relative to the surrounding normal years, and relate this difference to the area’s TPL ratio. I estimate the two fire-horse episodes separately, as socioeconomic conditions differed in two episodes.

The estimation differs from typical DID approach. First, for the time-series dimension, the change occurred in only one year and was simultaneous for all prefectures. Second, I assume that the magnitude of the changes in the value for girls is common across prefectures, whereas the outcome varies based on the *observable* characteristics of the prefecture (specifically, the prevalence of TPL). Although interpreting the two-way fixed-effects model for this setting requires caution, the development of an alternative is an ongoing research agenda (Callaway et al., 2021; de Chaisemartin and D’haultfœuille, 2023). As a baseline estimation, I use a two-way fixed-effects model with continuous measure of the prevalence of TPL. Appendix C.3 provides the results based on a binary version of the prevalence of the TPL variable, and the main message is similar to the baseline findings.

The baseline estimation equation is:

$$y_{irt} = \alpha FH_t \times TPL_i + (FH_t \times \boldsymbol{z}_i)'\boldsymbol{\beta} + \gamma_t + \delta_i + \varepsilon_{irt},$$

where y_{irt} represents the outcome variable in prefecture i of region r in cohort t, FH_t is a dummy variable taking the value 1 if the cohort was born in the fire-horse year (1846 or 1906), TPL_i is a measure of the prevalence of TPL in i, $\boldsymbol{z}_i$ is a set of time-invariant control variables, γ_t denotes the year fixed effects, which include the fire-horse year, δ_i is the prefecture fixed effects, and ε_{irt} represents the error term. Following standard practice, I cluster the covariance matrix at the prefecture (i) level to account for any form of autocorrelation structure in ε_{irt}.

The prefecture fixed effects δ_i account for the baseline differences in the prefecture’s attitude toward girls and other time-invariant socioeconomic characteristics that affect the outcome level. For example, high-income areas might exhibit stronger or weaker preferences for girls. The year-fixed effects γ_t capture year-specific effects. For example, the Russo-Japanese War (1904–05) may have influenced fertility decisions.

Because the average impact of the fire-horse year is captured by the year fixed effect γ_t, the main coefficient α indicates how much the TPL ratio affects the difference in the outcome. A negative coefficient is expected if TPL is more stringent for sex-selective infanticide.

Several socioeconomic characteristics correlated with TPL may respond to the fire-horse year. For example, an area that relies heavily on female labor (typically, textile industries) may experience a weaker fire-horse effect (c.f., Qian, 2008). Another confounding factor is the presence of midwives and medical institutions, which play an important role in the reproductive process.

Table 1
Descriptive statistics of main variables.

	Mean	SD	Min	Max	Obs.
1846 episode					
Male-to-female ratio	1.08	0.063	0.91	1.54	559
Male-to-female ratio (age 45–47 as age 46)	1.07	0.046	0.95	1.22	473
Unmarried/Total female	0.22	0.048	0.13	0.43	559
TPL ratio	0.28	0.22	0.010	0.80	43
ln (temple/pop)	−6.50	0.82	−10.1	−5.30	43
ln time to Naoetsu	4.46	0.68	2.67	5.58	43
ln time to Yoshizaki	4.37	0.75	1.72	5.38	43
Male-to-female ratio, 1846 cohort	1.19	0.099	1.05	1.54	43
Male-to-female ratio, 1840 cohort	1.08	0.047	0.99	1.17	43
1906 episode					
Male-to-female ratio, birth statistics	1.04	0.022	0.96	1.20	585
Male-to-female ratio, born March–October	1.12	0.067	0.90	1.35	585
Male-to-female ratio, 1918 Population statistics	1.03	0.027	0.95	1.18	585
Unmarried/Total female	0.092	0.087	0.017	0.55	585
TPL ratio	0.28	0.22	0.0095	0.79	45
ln (temple/pop)	−6.59	0.74	−9.68	−5.39	45
ln time to Naoetsu	4.47	0.67	2.67	5.58	45
ln time to Yoshizaki	4.36	0.74	1.72	5.38	45
Abortion conviction/1K pop	0.0080	0.011	0	0.049	45
Male-to-female ratio, 1906 cohort	1.08	0.038	1.02	1.20	45
Male-to-female ratio, 1900 cohort	1.05	0.018	1.01	1.08	45

See Section 4.2 for the data source. The full version is reported in Appendix B.4.

These socioeconomic characteristics can potentially influence the effects of TPL. Hence, I include the interaction terms of the fire-horse year dummy and a set of control variables ($\boldsymbol{z}_i$) to disentangle these confounding effects from the impact of religion. Finally, some specifications include a prefecture-specific time trend ($t\delta_i$) and a full set of the region-year dummies (γ_{rt}) to further control for various unobservable characteristics.[10]

4.2. Data

The baseline estimation relies on annual prefecture-level data obtained from population statistics and other statistics published between 1870 and 1920. Hokkaido and Okinawa prefectures were excluded from the analysis for both 1846 and 1906. Until the late nineteenth century, the two prefectures were politically and culturally independent. Table 1 provides the summary statistics for the key variables. Appendix B.4 presents the summary statistics of the other control variables.

For the 1846 episode, most of the variables are taken from the statistics of the 1870–80s. The limited availability of data is the reason for using data from three decades after the episode. Readers may question the stability of socioeconomic conditions over 30 years as well as post-treatment bias. Regarding stability, I cannot fully reject the possibility of the problem, but the problem occurs only if changes in socioeconomic variables are systematically correlated with the TPL effect, conditional on the time-invariant prefecture fixed effects. Moreover, the fire-horse effect occurs only in one year, and, as shown in Fig. 1, the population statistics bounce back. Hence, the timing of the data period is unlikely to cause post-treatment bias. For the 1906 episode, the variables are taken from data for the 1890s to early 1900s.

4.2.1. Population

For the 1846 episode, vital statistics are unavailable. Instead, I use population statistics from 1886.[11] The statistics include the prefecture-level population for each birth year, sex, and marital status. Thus, the data included cohorts that survived until 1886. The population statistics for 1886 show data for the 43 prefectures from that time.[12] Thus, the cross-sectional dimension is 43 for the 1846 episode. One issue is that the data reflect the location of the registered residents, which is not necessarily the same as their birthplace. This number includes the effects of inter-prefecture migration, and measurement errors may contaminate empirical results.

For the 1906 episode, I use vital statistics from 1900 to 1912 that report the prefecture-level number of births for each sex.[13] At this time, the number of prefectures was 47. After excluding Hokkaido and Okinawa, 45 cross-sectional dimensions for the 1906

[10] Japan is divided into six major regions: Tohoku, Kanto, Chubu, Kinki, Chugoku and Shikoku, and Kyushu. Therefore, the specifications with γ_{rt} include the 1903-Kanto dummy, 1905-Kinki dummy, and so on.

[11] Kurosu (1992, 1994) also uses this data to examine the cross-prefecture difference in the effect of the fire-horse. Hayami (1987) and Kurosu (1992, 1994) carefully examine the reliability of this data.

[12] Compared with the current number of 47 prefectures, the data from 1886 are missing Hokkaido and Okinawa prefectures. Nara was then a part of Osaka, and Kagawa a part of Ehime prefecture. The western part of current Tokyo was included in Kanagawa prefecture.

[13] About 5% of births are reported in the years after the birth year. I include the birth numbers reported 1–12 years after the birth year in the original report. See Appendix B.3 for details.

episode remained. For robustness, I also checked regression results using MF ratio in the 1918 population statistics. Using the 1918 population statistics reflects any potential child selection at birth as well as the selection when children are young. In this sense, the regressions using the 1918 population statistics are more similar to the 1846 data.[14]

The main dependent variable is male-to-female ratio. For the 1846 episode, the variable is the current (as of 1886) number of males born in a particular year per 100 females born in that year. For the 1906 episode, the primary dependent variable is the number of males per 100 females.

4.2.2. TPL ratio

I use a ratio based on the number of temples to measure the prevalence of each sect in each prefecture. The data source for the 1846 episode is the earliest available issues of the prefecture's statistical yearbooks. The period ranges from 1875 to 1888, and most values are obtained around 1880. For the 1906 episode, I use the value for 1898 from the 1898 Statistical Yearbook of the Ministry of the Interior. These yearbooks include the number of temples in each prefecture for the 13 sects.[15] From this, I derive the ratio of the number of TPL temples to the total number of temples.

An ideal measure of TPL influence would be the number of believers in the sect relative to the total population; however, data on the number of TPL believers do not exist for most prefectures. This information is available for only a few years for a limited number of prefectures. Therefore, I could not use the data on believers for the main estimations. However, when I compare the ratios based on believers and temples for the available cases, these two ratios are highly correlated (see Appendix B.2). Thus, the ratio based on the number of temples is a good proxy variable.

Another concern is the effect of religions other than Buddhism. However, the data on believers indicate that the number of those affiliated with a religion other than Buddhism was very small in these periods (see Appendix B.2). Hence, I exclusively focus on Buddhist temples.

To control for the general prevalence of Buddhism in the area, I include the natural log of the total number of temples per capita as a control variable.

4.2.3. Other socioeconomic characteristics

Using population statistics, I calculate the total population and number of households. I also take the location and geographical characteristics from modern sources.

A larger household size, which may be the result of refraining from birth control, may affect attitudes toward girls born in a specific year. Another variable is the proportion of households whose heads are female. Female-headed households may have different preferences from male-headed households. I also include the marriage rates for males and females aged 15. Marriage tends to occur earlier in Eastern Japan than in Western Japan (Kurosu, 1992, 1994). Kurosu (1992, 1994) speculates that this different marriage pattern across regions could be a factor explaining the different effects of the fire-horse across prefectures. Another control variable is the logarithm of population density. People may hesitate to commit infanticide if they have a lot of neighbors.

I include two distance-related variables: logs of walking time from Tokyo and Kyoto to the prefecture capitals.[16] These two cities are political, economic, and cultural centers of Japan. Tokyo is the origin of the Oshichi episode and fire-horse superstition was likely stronger in areas closer to Tokyo. At the same time, TPL is relatively scarce in Tokyo and surrounding prefectures (see Fig. 3). Failure to control for the distance variable may lead to an overestimation of the TPL effect. Compared to straight-line distance or mileage, time reflects the actual cost and burden of travel in mountainous countries like Japan.

Another variable controlled for is the city dummy variable. The situation might differ in the prefectures of the three major cities – Tokyo, Kyoto, and Osaka – and I simply include a dummy for these three prefectures.

I control for several other economic and medical conditions. I construct the variables using industrial production data from Yuan et al. (2009). For the 1846 episode, I use the 1874 data, and for the 1906 episode, 1890 data. General economic prosperity is captured as the total manufacturing value divided by the population in 1884 for the 1846 episode and in 1898 for the 1906 episode. In addition to total manufacturing production, agricultural and textile production are included. These two industries may employ many women. In areas relying more on textile industries, the change in attitude toward valuing baby girls, even in the fire-horse years, might be weaker.[17] I include the number of midwives, doctors, and hospitals per capita in each prefecture in 1885 (for the 1846 episode) and 1901 (for the 1906 episode).[18] Midwives play an important role in the reproductive process. Doctors and hospitals capture formal medical conditions.

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14 After 1918, the population statistics were replaced by the population census. However, the census reports the cohort-level data based on age as of October 1 of the census year, not the person's birth year. The 1918 data is the last data using the birth year.

15 Depending on issues, a few small sects are also included.

16 These variables are based on the current road using Google Map's walking time. See Appendix B.3 for details.

17 Qian (2008) suggests that the expected income of women is an important determinant of missing women in China.

18 Although population statistics and the number of temples are 1898 values, I use 1901 values for medical variables. This is because there are multiple zeros for various medical variables in 1898–1900.

5. Results

5.1. Casual observation and baseline estimations

Fig. 2 shows the regional variations in the MF ratio in 1846 and 1906 relative to normal years. For the 1846 episode, the normal year value is the mean MF ratio from 1840 to 1852, excluding 1845–1847. I exclude 1845 and 1847 because of the drop in Fig. 1. Similarly, the normal year value for the 1906 episode is based on the values from 1900 to 1912, excluding 1905–1907. As discussed in Section 1, the maps suggest the fire-horse effects have regional variation. The spatial pattern shows some clustering, but is not necessarily explained by income or population density.

Columns (1) and (5) in Table 2 show the results of the simple two-way fixed-effects regressions. Here, I regress the MF ratio on the year dummies, prefecture dummies, and the interaction of the fire-horse year dummy and the TPL ratio. Among the year dummies, I show the coefficients for fire-horse years, which indicate the effects of the fire-horse relative to the initial years (1840 or 1900).[19] For the 1846 episode, the MF ratio increased by 16 percentage points. The magnitude is weaker for the 1906 episode, yet the change is still statistically significant; the MF ratio increased by 6.4 percentage points.

The coefficient of the interaction between the fire-horse and TPL ratio (number of TPL temples relative to all temples) is -0.13 for the 1846 episode. Because there is wide variation in TPL ratios, the difference between the first and thrid quartiles (9% and 44%, respectively) is associated with a 4.6 percentage point ($=0.13 \times (0.49 - 0.09)$) difference; thus, nearly one-third ($\approx 4.6/16$) of the total effect is erased. Similarly, in the 1906 episode, the coefficient of the TPL ratio was -0.077. The differences between the first and third quartiles (9.7% and 44%, respectively) correspond to 2.6 percentage points; thus, one-third of the total effects are eliminated. The weaker result in 1906 is reasonable because formal institutions (legal and enforcement) had already prohibited infanticide, and there was less room for informal institutions to play a role.

Fig. 4 shows event-study type regression coefficients, where the MF ratio is regressed on the year dummies interacting with the TPL ratio after partialling out year fixed effects and prefecture fixed effects. The adjacent lines show 1.96 standard errors. The coefficient is normalized to zero in 1840 for the 1846 episode, and to zero in 1900 for the 1906 episode. As shown in Table 1, the MF ratios in these initial years are close to the overall averages.

An observation from the figure is that the coefficients for the fire-horse years are very close to those reported in columns (1) and (5) of Table 2. Thus, the baseline regression is not driven by an abnormal deviation in the TPL effect in any other year. Consistent with this observation, the coefficients for other than fire-horse years are close to zero. Thus, the overall male preference, if any, is not systematically correlated with the TPL ratio. These near-zero coefficients include those for the years immediately before and after the fire-horse years. False reporting affects the overall change in the MF ratio (Fig. 1), but the contribution of false reporting is unrelated to TPL.

5.2. Additional control variables

Columns (2) and (6) in Table 2 include prefecture-specific time trends, interaction terms with control variables, and the fire-horse dummy. Columns (3) and (7) further incorporate region-year fixed effects. Because the control variables also interact with the fire-horse year dummy, the fire-horse coefficients in these regressions substantially differs in columns (1) and (4). The coefficient now reflects the residual variation of the fire-horse year that is not captured by these interactions. In the remaining columns, I focus only on the interaction between the fire-horse and TPL. The results are robust for the 1846 episode and somewhat less pronounced, but still somewhat robust, for the 1906 episode.

Columns (4) and (8) include the interaction terms of the TPL ratio and the year before or after the fire-horse, as well as the year dummies interacting with the control variables. As the control variables are time-invariant, the inclusion of these additional interaction terms does not affect the main coefficient. The intention here was to check whether false reporting was systematically associated with TPL. If false reporting is the primary explanation, these two years should have opposite signs to the main interaction term. Moreover, the sum of the coefficients must approximate the magnitudes of the main coefficients.

The main coefficients are negative for both the 1846 and 1906 episodes. The coefficients of the interaction terms with the surrounding year dummies are close to zero except in 1845. This suggests that while false reporting may contribute to the overall change, its effect does not differ significantly between TPL and non-TPL areas.

The number of temples per capita also has a negative impact, but is statistically significant only in 1846. This indicates that the main driver is TPL rather than the overall number of temples. Appendix C.1 shows the coefficients of the interaction terms of the fire-horse dummy and the other control variables. Most coefficients do not show any coherent pattern for the 1846 and 1906 episodes.

[19] Choice of the reference does not qualitatively change the figures.

Table 2
Male-to-female ratio, fire-horse, and TPL.

M/F	1846				1906			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
FH	0.16***	1.05**	1.09**	1.04**	0.064***	0.036	−0.17	−0.16
	(0.023)	(0.43)	(0.45)	(0.43)	(0.011)	(0.15)	(0.22)	(0.20)
FH × TPL ratio	−0.13**	−0.49***	−0.50***	−0.49***	−0.077***	0.0024	−0.053*	−0.056**
	(0.052)	(0.11)	(0.094)	(0.092)	(0.025)	(0.021)	(0.030)	(0.028)
FH−1 × TPL ratio				0.12***				−0.017
				(0.030)				(0.019)
FH+1 × TPL ratio				0.013				−0.021
				(0.033)				(0.022)
FH × ln (Temple/pop)		−0.058***	−0.060***	−0.060***		0.0081	−0.0011	−0.00091
		(0.021)	(0.018)	(0.017)		(0.0069)	(0.0073)	(0.0068)
Other cntrl × FH		✓	✓	✓		✓	✓	✓
Cntrl × FH+1, FH−1				✓				✓
Prefecture FEs	✓	✓	✓	✓	✓	✓	✓	✓
Pref-time trend		✓	✓	✓		✓	✓	✓
Year FE	✓	✓			✓	✓		
Region × year FE			✓	✓			✓	✓
Obs.	559	559	559	559	585	585	585	585

Numbers in parentheses are standard errors clustered at the prefecture level, and asterisks indicate the significance levels: *** 1%, ** 5%, and * 10%. Male-to-female ratio was used as the dependent variable. The control variables are log temple per capita, household size, female head ratio, male marriage rate at age 15, female marriage rate at age 15, log population density, log of time to Tokyo, log of time to Kyoto, city dummy, log manufacturing value-added per capita, log textile value-added per capita, log agricultural value-added per capita, log midwife per capita, log doctor per capita, and log hospital per capita. See Section 4.2 for data sources.

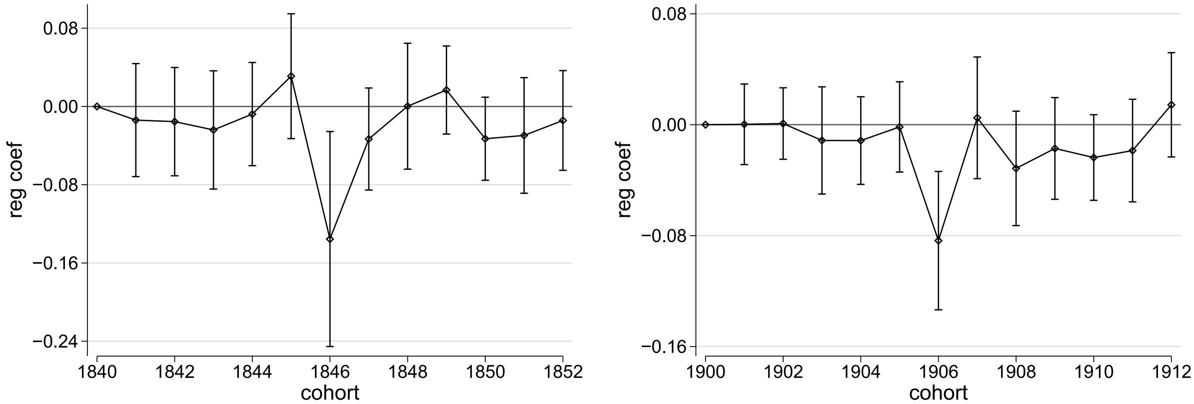

Fig. 4. Regression coefficients of the male-to-female ratio on the year dummies interacted with TPL ratio. Regressions partial out the TPL ratio, year fixed effects, and prefecture fixed effects. (Left panel: 1846 episode, right panel: 1906 episode)

5.3. Other sects

Historical documents suggest that other sects were largely silent on abortion and infanticide (Hardacre, 1997). To investigate the specificity of TPL, I conduct similar regressions by replacing the key explanatory variable with the interaction term of the fire-horse year dummy and the prevalence of one of the six other major sects (*Tendai*, *Shingon*, *Jōdo*, *Rinzai*, *Soto*, and *Nichiren*).

Table 3 lists the results. Column (1) shows the coefficients for TPL, which are listed in Table 2. The remaining rows report the results for the different sects using analogous specifications.

These findings indicate that the effects of the other sects on the MF ratio are not uniform. Some sects are positively associated with the fire-horse effect, whereas others are negatively associated. For example, the *Jōdo*, *Rinzai*, and *Sōtō* sects are positively associated with the fire-horse effect, whereas the *Shingon* sect is negatively associated with the fire-horse effect. However, compared to those of TPL, the effects of these other sectors are relatively small and unstable.

5.4. Instrumental variables

The baseline regression results may be subject to several problems. One of the key concerns is that religion is measured by the ratio of temples rather than by the number of affiliated people. This gap between the number of temples and that of the actual religious followers may lead to measurement error problems (c.f., 4.2.2 and Appendix B.2). Another concern is that the popularity

Table 3
The effect of other sects on the fire-horse effect.

	(1) TPL	(2) *Tendai*	(3) *Shingon*	(4) *Jōdo*	(5) *Rinzai*	(6) *Sōtō*	(7) *Nichiren*
1846 episode							
w/o cntrl	−0.13**	0.19	−0.019	0.43	0.32	0.10	0.016
	(0.052)	(0.19)	(0.083)	(0.27)	(0.22)	(0.12)	(0.24)
w/ cntrl	−0.50***	0.065	−0.072	0.55*	0.53**	0.63***	−0.14
	(0.094)	(0.29)	(0.083)	(0.31)	(0.21)	(0.084)	(0.31)
1906 episode							
w/o cntrl	−0.077***	0.066	0.051	0.096	0.16	0.0054	0.28**
	(0.025)	(0.094)	(0.034)	(0.10)	(0.10)	(0.042)	(0.12)
w/ cntrl	−0.053*	−0.0014	−0.10***	0.14*	0.10	0.086***	0.079
	(0.030)	(0.063)	(0.034)	(0.073)	(0.066)	(0.032)	(0.070)

Numbers in parentheses are standard errors clustered at the prefecture level, and asterisks indicate the significance levels: *** 1%, ** 5%, and * 10%. Each cell reports the coefficient and standard error of the main explanatory variable for each regression. Row (1) is the same as that in Table 2. Rows (2)–(7) replace the TPL ratio with the ratios of other sects. Male-to-female ratio was used as the dependent variable. The main explanatory variable is the interaction term between the fire-horse dummy and ratio of the sect in the second column. The "w/o cntrl" column reports the regressions include the main explanatory variable, year fixed effects, and prefecture fixed effects. The "w/ cntrl" column reports the regressions including the main explanatory variable, the interaction terms of the fire-horse year fixed effect and a set of control variables, prefecture-specific time trend, and region-year fixed effect. See Table 2 for a list of control variables. See Section 4.2 for the data source.

of a specific sect may be correlated with an unobservable attitude toward infanticide, potentially causing an endogeneity issue. As discussed in Section 3.2, the spread of TPL is a series of historical, random events; hence, the resulting distribution of TPL is likely not causing the endogeneity issue. However, it is worthwhile to check using an instrumental variable approach.[20]

The idea behind the instruments follows Becker and Woessmann (2009), who use distance from the location where the new teaching originated. I use two distance measures: one from Naoetsu, where Shinran, TPL founder, was exiled, and the other from Yoshizaki, to which Rennyo, the prominent leader, fled. As clearly shown in Fig. 3, the prefectures around these areas tend to have a high TPL ratio. This correlation justifies the relevance conditions for the instrumental variables. Importantly, the choice of the location of neither Naoetsu nor Yoshizaki can be correlated with the potential popularity of TPL: the government selected Naoetsu as the location for Shinran's exile based on political decisions, and Rennyo chose Yoshizaki because his teacher had land there. I use the logs of the walking time from Naoetsu and Yoshizaki, both interacting with the fire-horse dummy.[21]

Table 4 reports the results for the MF ratio using instrumental variables via two-stage least-squares estimations. Columns (1) and (4) provide the first-stage equations, showing that the instruments exhibit reasonable correlations with the TPL ratio. Columns (2) and (5) present the reduced-form specifications. The reduced-form coefficients are expected to be positive. Here, two distance measures are used simultaneously, which introduces some multicollinearity, resulting in one negative coefficient. However, the remaining coefficients have the expected positive sign. Columns (3) and (6) report the second-stage results. Regarding the diagnostic statistics of the instrumental variable methods, the Kleibergen-Paap test rejects the null hypothesis of less than full rank at the 10% level. Hansen's J statistic does not contradict the current specification.

However, the first stage F is smaller than the conventional level of 10 for the 1846 data. This low F-statistic is not surprising because the variation comes from only one year, and I include several control variables. Given the potential weak instrument problem, I report the two-step identification-robust confidence sets using Sun's (2018) implementation of Andrews (2018).

The coefficients for the 1846 episode are similar to those in the baseline case. As indicated by CS_R, the coefficient falls outside the 95% confidence interval. For the 1906 episode, the coefficients are close to zero and have opposite signs. Again, the results for the 1846 episode are reasonably robust, while those for the 1906 episode are less robust.

5.5. *False reporting*

An important concern in the analysis is the possibility of false reporting of the birth year. To further investigate the importance of false reporting, the dependent variables are modified as follows. For the 1846 episode, I aggregate individuals born between 1845 and 1847. For 1906 episode, I use monthly data. Since false reporting is likely to occur in adjacent months (for example, those born on January 5, 1906, are falsely reported as being born on December 30, 1905), I focus on birth records from March to October, and use the sum of the numbers of people born during these months as the year's total births.[22]

Columns (1)–(4) of Table 5 presents modified versions of the regression results. Owing to these modifications, some of the main interaction terms became smaller and were no longer statistically significant. However, the signs of these coefficients remain negative.

[20] In Appendix C.5, I also check an alternative instrument—the establishment of temples before the arrival of the fire-horse superstition. The results are robust.

[21] However, the use of distance as an instrument has a limitation. The variation in the instrument comes from nationwide geography, which makes it difficult to include region-year fixed effects in the estimation equations. If region-year fixed effects are included, the instrumental variables may not satisfy the relevance condition.

[22] For this, the data comes from the corresponding year's report. As the delayed birth report does not show the month disaggregation, I cannot include the delayed reports.

Table 4
IV estimations of the TPL effect.

	1846			1906		
	(1) FH × TPL ratio	(2) M/F	(3) M/F	(4) FH × TPL ratio	(5) M/F	(6) M/F
FH		−0.088	1.27**		−0.016	−0.032
		(0.45)	(0.56)		(0.15)	(0.17)
FH × TPL ratio			−0.51***			0.0025
			(0.15)			(0.033)
CS_R			[−0.85, −0.16]			[−0.06, 0.08]
FH × ln time to Naoetsu	−0.073**	0.040		−0.036	0.014**	
	(0.029)	(0.031)		(0.053)	(0.0073)	
FH × ln time to Yoshizaki	−0.093**	0.044**		−0.12***	−0.0088*	
	(0.036)	(0.021)		(0.027)	(0.0050)	
Cntrl × FH	✓	✓	✓	✓	✓	✓
Pref-time trend	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓
Cluster-robust first-stage F.			5.52			12.2
$\hat{\gamma}$ of CS_R			5.00			5.00
Kleibergen-Paap rk LM			8.89			5.49
p-value			0.012			0.064
Hansen's J			0.025			2.42
p-value			0.88			0.12
Obs.	559	559	559	585	585	585

Numbers in parentheses are standard errors clustered at the prefecture level, and asterisks indicate the significance levels: *** 1%, ** 5%, and * 10%. The dependent variable is the fire-horse year dummy interacting with the TPL ratio for (1) and (4), and the male-to-female ratio for (2), (3), (5), and (6). (3) and (6) are 2SLS regressions, and (2) and (5) are the first stages of the 2SLS for (5) and (6), respectively. The numbers in the square brackets below the main coefficient (CS_R) show LC Robust confidence set. $\hat{\gamma}$ of CS_R shows the initial coverage distortion of CS_R. See Table 2 for a list of control variables and Section 4.2 for data sources.

Table 5
Modified measures of the male-to-female ratio.

M/F (modified measure)	Avg 1845–47		1906 (Mar–Oct)		1906 (1918 Pop stat)	
	(1)	(2)	(3)	(4)	(5)	(6)
FH	0.019**	0.067	0.041***	−0.18	0.058***	0.20
	(0.0073)	(0.14)	(0.0093)	(0.25)	(0.011)	(0.23)
FH × TPL ratio	−0.019	−0.067***	−0.053***	−0.045	−0.075***	−0.055
	(0.018)	(0.020)	(0.020)	(0.033)	(0.022)	(0.036)
Cntrl × FH		✓		✓		✓
Prefecture FEs	✓	✓	✓	✓	✓	✓
Pref-time trend		✓		✓		✓
Year FE	✓		✓		✓	
Region × year FE		✓		✓		✓
Obs.	473	473	585	585	585	585

Numbers in parentheses are standard errors clustered at the prefecture level, and asterisks indicate the significance levels: *** 1%, ** 5%, and * 10%. Male-to-female ratio was used as the dependent variable. See Table 2 for a list of control variables and Section 4.2 for data sources.

5.6. Gap between the 1846 and 1906 episodes

The coefficients substantially differ between the 1846 and 1906 episodes. One obvious reason for this, as shown in Fig. 1, is that the overall impact of the fire-horse distortion was smaller in 1906, and hence any remedy had smaller impacts in 1906. Another reason for the difference may be the timing of the data; data for the 1846 episode are based on population statistics at around age 40, while data for the 1906 episode come from birth statistics. To determine if this difference in timing is the main cause of the difference in coefficients, I run the same regressions for the 1906 episode using the population statistics from 1918. If there is a large discrepancy from the baseline, it would indicate that the distortion in the MF ratio in the population data includes the effects of maltreatment (e.g., child neglect) and other unfavorable life course outcomes. However, as columns (5) and (6) of Table 5 show, the coefficients are almost identical to those in Table 2. Thus, the effect of child neglect and other maltreatment is minimal.

Yet another potential explanation is the difference in formal institutional enforcement. Around 1846, the authorities prohibited infanticide, but there were no legal penalties and enforcement was lax (Arimoto, 1995). The modern government made infanticide a legally actionable crime. Compared with later years (e.g., around the 1966 episode), the enforcement was weaker, but it is reasonable to assume that the formal enforcement in 1906 was stronger than in 1846. To statistically check the impact of the formal institution, I use the 1906 episode and examine the interaction between religion and the formal institution.

Table 6
Formal institution and religion.

M/F	1906							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
FH	0.045***	0.048	−0.11	−0.10	0.088***	0.11	0.0068	0.00063
	(0.0091)	(0.15)	(0.21)	(0.20)	(0.015)	(0.14)	(0.17)	(0.15)
FH × TPL ratio					−0.13***	−0.064***	−0.11***	−0.11***
					(0.033)	(0.021)	(0.027)	(0.025)
FH−1 × TPL ratio								0.0032
								(0.019)
FH+1 × TPL ratio								−0.0041
								(0.024)
FH × CNVCTpc	−0.42	−0.16	−0.21	−0.20	−4.10***	−4.19***	−3.86***	−3.58***
	(0.46)	(0.33)	(0.33)	(0.31)	(1.23)	(0.77)	(0.67)	(0.63)
FH−1 × CNVCTpc				0.013				1.54***
				(0.18)				(0.49)
FH+1 × CNVCTpc				0.16				1.77***
				(0.25)				(0.62)
FH × TPL ratio × CNVCTpc					8.96***	8.86***	8.75***	8.17***
					(2.55)	(1.53)	(1.48)	(1.37)
FH−1 × TPL ratio × CNVCTpc								−3.30***
								(0.94)
FH+1 × TPL ratio × CNVCTpc								−3.42**
								(1.36)
FH × ln (Temple/pop)		0.0085	0.0072	0.0078		0.0073	−0.0014	−0.0014
		(0.0062)	(0.0064)	(0.0061)		(0.0060)	(0.0068)	(0.0063)
Other cntrl × FH		✓	✓	✓		✓	✓	✓
Cntrl × FH+1, FH−1				✓				✓
Prefecture FEs	✓	✓	✓	✓	✓	✓	✓	✓
Pref-time trend		✓	✓	✓		✓	✓	✓
Year FE	✓	✓			✓	✓		
Region × year FE			✓	✓			✓	✓
Obs.	585	585	585	585	585	585	585	585

Numbers in parentheses are standard errors clustered at the prefecture level, and asterisks indicate the significance levels: *** 1%, ** 5%, and * 10%. Male-to-female ratio was used as the dependent variable. The strength of the formal institution, "CNVCTpc", is measured by the number of cases of abortion convictions per million people. The control variables are log temple per capita, household size, female head ratio, male marriage rate at age 15, female marriage rate at age 15, log population density, log of time to Tokyo, log of time to Kyoto, city dummy, log manufacturing value-added per capita, log textile value-added per capita, log agricultural value-added per capita, log midwife per capita, log doctor per capita, and log hospital per capita. See Section 4.2 for data sources.

One problem here is that no perfect data exist to measure institutional enforcement, even for the 1906 episode. Ideal data might include detected and undetected infanticide cases for each prefecture just before the data period (e.g., 1898). However, neither the number of undetected cases nor any comprehensive data for detected infanticide are available.

As a proxy, I use the number of abortion convictions. As discussed in Section 3.3, people did not firmly distinguish between infanticide and abortion. Abortion was also a legal crime in the late nineteenth century. Due to the difficulty of distinguishing abortions from questionable stillbirths, legal enforcement was not very strong (see Section 3.3). Nonetheless, there were some cases of criminal charges. Specifically, I utilized data on abortion convictions compiled by Okamoto (1920, 1929), who collected conviction cases from court records. The data spans 1899 to 1918. It is the most comprehensive dataset available for that era (Onishi, 2012) although it includes years after the fire-horse period and varies in timing across prefectures.

Table 6 presents the regression results. The measure of formal institution strength is the number of abortion convictions per one thousand people ("CNVCTpc"). Areas with higher conviction rates are expected to have a stronger stance on both abortion and infanticide, making this variable a proxy for formal institutional enforcement. Columns (1)–(4) show the regressions focusing on the formal institution. The coefficients are negative as expected, but the standard errors are large.

Columns (5)–(8) examine the interactive impacts of the formal and informal institutions. After controlling for the formal institution, the coefficient for the interaction between the fire-horse effect and TPL is now twice as large as in the baseline case shown in Table 2. In areas where potential legal penalties are minimal, TPL significantly mitigates the fire-horse distortion. However, these coefficients remain smaller than those for the 1846 episode, suggesting that the effect of TPL has weakened.

The coefficient for the interaction between the fire-horse year and abortion convictions is now negative and precisely estimated, indicating that areas with stronger formal institutions experience a weaker fire-horse effect. This measure is in levels, so the sizes of the coefficients between the TPL ratio and "CNVCTpc" are not directly comparable. In areas where the abortion conviction rate is one standard deviation higher (0.011), about half of the fire-horse effect ($0.045 = -4.1 \times 0.011$) is mitigated. However, the effect of the formal institution may be partially explained by false reporting. Column (8) reveals that the interaction terms between "CNVCTpc" and periods one year before or after the fire-horse year are positive, with their sum being close to the coefficient for the interaction between "CNVCTpc" and the fire-horse year itself. By contrast, the interactions between TPL and these lead and lag terms are negligible.

Finally, the triple interaction term exhibits a positive coefficient; the mitigation effects of the formal and informal institutions are substitutable rather than complementary. When the formal institutional enforcement is strong, the influence of religion is weaker compared to when enforcement is less stringent. In other words, if the formal institution is sufficiently strong, the role of religion becomes minimal.

5.7. Mechanism

Two potential mechanisms can explain the weaker fire-horse effect in the TPL area. First, the area where TPL dominates strongly rejects fire-horse superstitions. Since people do not believe in superstition, there is no distortion in the MF ratio. Second, people in the TPL area believed in fire-horse superstition, but the strong prohibition of infanticide prevented them from carrying out child selection. The regression results thus far are silent about which view is the main effect, although historical documents are favorable to the second explanation. As it is difficult to separate these two effects, I provide additional statistical results.

5.7.1. Marriage

One aspect of fire-horse superstition is that women born in a designated year make trouble for their husbands. This aspect of superstition leads to avoidance in the marriage market for females born in the fire-horse year. Consequently, the number of unmarried females is expected to increase. However, if people did not believe in the fire-horse superstition, the unmarried rate would not be high. There is a complication because the number of females in the fire-horse cohort was smaller than the number of females in other cohorts and smaller than the number of fire-horse males. The limited supply of fire-horse females may make them more likely to find partners than other cohorts in other years, positively affecting the probability of marriage. Thus, predicting marital status remains elusive. Nonetheless, I check the effects of the fire-horse year and TPL on marital status.

For the 1846 episode, I check marital status in 1886. In these data, individuals born in this fire-horse year are around 40 years old, and the data show their marital status at the time of being married or unmarried. These data do not distinguish between those who have never been married, those who are married and divorced, or those who are widowed.

For the 1906 episode, I used data from the 1935 census. In this census, individuals born in 1906 were approximately 29 years old. I calculate the ratio of never-married females to the total number of females in each age group. There are two measurement problems with the data. First, being based on the residential location as of 1935, the data are affected by migration. Second, and more critically, the 1935 census recorded age on October 1, not the birth year (c.f., footnote 14). I assume those aged 29 to be part of the 1906 cohort, those aged 30 to be part of the 1905 cohort, and so on. This rule implies that a quarter of the people were mis-assigned.

Another complication of the data that are not in the MF ratio is that the marriage rate has a clear nonlinear time trend. People were 34–52 years old in the 1846 data. Given the difference in death rates between males and females, older females tended to be recorded as unmarried. By contrast, for the 1906 data, people were aged 23–35 years. Some young people might not have been married. To account for the nonlinear time trend in marriage rates, the regressions include the quadratic term of the prefecture-specific time trend in addition to the prefecture-specific time trend. Furthermore, baseline male preferences may affect marital patterns. To account for this male preference, I include the MF ratio one year before the first sample year in the 12-year period (1839 for the 1846 episode and 1899 for the 1906 episode). Keeping these measurement and specification issues in mind, Table 7 shows the regression results analogous to those in Table 2.

In the simple regression, which includes only year dummies and prefecture-specific linear and quadratic time trends, the coefficient for the fire-horse year dummy is positive for 1846 but negative for 1906. However, the statistical significance of the positive coefficient in 1846 is not robust and the sign is unstable across specifications. For 1906, the fire-horse cohort tends to be more likely married. More importantly, the prevalence of TPL does not strongly correlate with marital status. The coefficients are negative for 1846, but their magnitudes are small and not precisely estimated after controlling for other variables. For 1906, the sign of the coefficients of the interaction term varies across specifications.

Overall, TPL affiliation does not play an important role in changing marital status. Marriage status regressions do not support the hypothesis that TPL followers do not believe the fire-horse superstition more than others do.

5.7.2. Superstition revealed in 1946 survey

In 1946, the Japanese government conducted a survey to investigate people's attitudes toward various forms of superstition (Meishin Chōsa Kyōgikai, 1949).[23] Prefecture-level results are available for four questions, and the analysis focuses on 45 prefectures, excluding Hokkaido and Okinawa.[24] These prefecture-level results are used as dependent variables in the following cross-sectional regressions.

The first question was, "Has your family ever avoided a fire-horse female?" This question asked about the experience of avoiding a female fire-horse. If someone did not make a marriage or fertility decision, then the question is irrelevant. Partly owing to the specificity of the question, the mean value for this question was much lower than that for the other questions. The second question

[23] For each prefecture, three elementary schools were selected: one each from an urban area, an agricultural village, and a fishing/forestry village. In each school, the questionnaires were distributed to students in one class, of approximately 50 students from the sixth grade. The respondents were the parents of these students. The results at the prefecture-level represent an average of approximately 150 responses.

[24] The following explanations about the superstitions are based on *Encyclopedia Nipponica* and *Encyclopedia of Japan* through Japan Knowledge (https://japanknowledge.com/library/) accessed on Oct 18, 2021.

Table 7
Ratio of unmarried to married females.

	1846				1906			
	OLS (1)	OLS (2)	OLS (3)	IV (4)	OLS (5)	OLS (6)	OLS (7)	IV (8)
FH	0.0083***	0.015***	0.10	−0.078	−0.26***	−0.26***	−0.22***	−0.51***
	(0.0020)	(0.0044)	(0.16)	(0.12)	(0.0012)	(0.0017)	(0.048)	(0.13)
FH × TPL ratio		−0.018**	−0.013	−0.018		−0.0023	−0.0055*	0.036*
		(0.0081)	(0.017)	(0.029)		(0.0024)	(0.0030)	(0.020)
CS_R				[−0.11, 0.05]				[0.06, 0.14]
Cntrl × FH			✓	✓			✓	✓
Pref-time trend	✓	✓	✓	✓	✓	✓	✓	✓
Pref-time trend sq.	✓	✓	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓	✓	✓
Region × year FE			✓				✓	✓
Cluster-robust first-stage F.				3.97				13.7
$\hat{\gamma}$ of CS_R				7.75				6.92
Kleibergen-Paap rk LM				7.25				6.07
p-value				0.027				0.048
Hansen's J				2.28				4.58
p-value				0.13				0.032
Obs.	559	559	559	559	585	585	585	585

Numbers in parentheses are standard errors clustered at the prefecture level, and asterisks indicate the significance levels: *** 1%, ** 5%, and * 10%. The dependent variable is the number of unmarried females for 1846 and never-married females for 1906, divided by that of the married females. The control variables are log temple per capita, household size, female head ratio, male marriage rate at age 15, female marriage rate at age 15, log population density, log of time to Tokyo, log of time to Kyoto, city dummy, log manufacturing value-added per capita, log textile value-added per capita, log agricultural value-added per capita, log midwife per capita, log doctor per capita, log hospital per capita, and male-to-female ratio in the 1839 or 1899 cohorts. See Section 4.2 for data sources.

Table 8
Effects of TPL on superstitions, homicides, and suicides.

	1946 survey				1884–1885 data	
	(1) FH	(2) Marriage	(3) Funeral	(4) Direction	(5) Homicide	(6) Suicide
TPL ratio	−0.20	−0.45*	−0.32**	−0.16	−0.44**	−0.19**
	(0.18)	(0.24)	(0.15)	(0.15)	(0.18)	(0.093)
ln Temple/Pop	−0.48**	−0.31	−0.43***	0.31**	−0.42**	0.077
	(0.19)	(0.19)	(0.15)	(0.13)	(0.20)	(0.072)
Other cntrl	✓	✓	✓	✓	✓	✓
Region FE	✓	✓	✓	✓	✓	✓
Adj. R^2	0.59	0.48	0.69	0.69	0.47	0.79
Obs.	45	45	45	45	43	43
Mean	15.6	61.0	63.1	65.5	21.8	159.5
SD	4.7	12.3	12.1	13.9	8.6	63.0

Standardized beta coefficients are reported. Numbers in parentheses are robust standard errors, and asterisks indicate the significance levels: *** 1%, ** 5%, and * 10%. The dependent variables are: (1) the fraction of people who avoided female fire-horses, (2) the fraction of people checking the marriage compatibility of cosmology, (3) the fraction of people who avoid holding funerals on specific dates, (4) the fraction of people who avoid a specific direction, (5) the number of homicide cases (identified by police) per one million population, and (6) the number of suicide cases (identified by police) per one million population. The control variables for equations (1)–(4) are those of the 1906 episode data. The control variables for (5) and (6) are those of the 1846 episode. See Table 7 for a list of control variables and Section 4.2 for data sources.

was, "Do you check compatibility upon considering marriage?" Compatibility is based on the Chinese cosmology. The person's type is determined based on the year, month, and day of birth, and compatibility is the good or bad agreement implied by the couple's type. The third question was, "Have you ever avoided holding a funeral on a *tomobiki* day?" *Tomobiki* is one of the six-day cycles designating the luck of the days. *Tomobiki* literally means "going with friends". People avoid funerals because it is believed that those who died will "invite" attendants. The fourth question was "Do you avoid *kimon* direction?" The *kimon* direction was northeast. People often considered this direction inauspicious and avoid, for example, setting up the entrance to the house in this direction.

The bottom rows of Table 8 report the mean and standard deviation for each superstition. The mean for avoiding a fire-horse female is more than 15%, indicating that a non-negligible fraction of respondents had indeed avoided fire-horse women, likely in the context of marriage. The respondents were born around the 1906 fire-horse year, and while it was their parents who made fertility decisions, it is reasonable to assume that these respondents were influenced by their parents' beliefs. Superstitions, such as the fire-horse superstition, likely transmit across generations (Kurosu, 1992, 1994). Therefore, the 1946 survey provides valuable insights into area-specific attitudes toward the fire-horse superstition.

Given that the 1946 measures area-level belief in the fire-horse, a more important issue is that whether the prevalence of the superstition is systematically associated with TPL. Table 8 presents the results. These are simple cross-sectional regressions. I show the standardized beta coefficients to ease comparison across different outcomes. The TPL rate has no impact on the attitude toward the fire-horse superstition but is associated with two of the other superstitions. This means that people in the TPL area believed in the fire-horse superstition as much as people in the non-TPL area did even in 1946.

5.7.3. Homicides and suicides in 1884–85

The key argument is that TPL prohibited killing more stringently than other sects did. To verify this assertion, Table 8 shows the effects of the TPL ratio on the homicide and suicide rates in 1884–85. The explanatory variables are taken from the 1846 episode regressions with the numbers of homicides and suicides per capita as dependent variables. Homicides and suicide data are obtained from the earliest available year. These years are not fire-horse years, and hence, the regressions show the overall correlation between the TPL ratio and homicide (or suicide) based on cross-sectional data. I again report the standardized coefficients to ease comparison across outcomes.

The regression results suggest that TPL is associated with lower homicide and suicide rates. Note that these are simple cross-sectional regressions. Hence, I do not argue that the prevalence of TPL causally reduces homicide and suicide rates. However, the regressions show that TPL-influenced areas had lower homicide and suicide rates.

5.8. Robustness checks

Appendix C.2 examines the changes in cohort size as the dependent variable. The fire-horse negatively affects the size of the cohort, but TPL mitigates this negative effect. Thus, the results for the cohort size are consistent with those for the MF ratio.

Appendix C.3 provides the tables reporting the robustness checks: (1) excluding Kagoshima Prefecture from the sample (see footnote 8), (2) prevalence measured by a dummy variable where the cutoff is based on the Fisher-Hartigan algorithm (Cox, 2007), (3) prevalence measured by a dummy variable that takes one if TPL has the largest share in the prefecture, and (4) prevalence measured by the relative share of other sects. Appendix C.4 presents a table similar to Table 3 using the relative shares. All these regression results are not largely different from baseline values.

6. Concluding remarks

Historical data from Japan suggest that religious teachings affect demographics. In particular, TPL mitigated the effects of fire-horses on infanticide. The effect of religion is strong when formal institution is weak. Additional regressions suggest that people believed in the fire-horse superstition, but TPL mitigated sex-selective infanticide.

The research findings emerge from a careful examination of the specific features of a sect in Japanese Buddhism rather than general religiosity. Although this context is specific to Japanese history, there is a general lesson that can be applied to other contexts. The specific nature of a subdivision of religion can have socioeconomic consequences; thus, statistical examinations based on a deep understanding of religious teachings across different subdivisions are meaningful.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author used ChatGPT 3.5 and Grammarly in order to edit the text. After using these tools, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication.

Declaration of competing interest

The author declares that the author has no relevant or material financial interests that relate to the research described in this paper.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jebo.2024.106823.

Data availability

Data will be made available on request.

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