Regular Article

Sweet unbinding: Sugarcane cultivation and the demise of foot-binding☆

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ARTICLE INFO

ABSTRACT

We analyze the economic motives for the sudden demise in foot-binding, a self-harming custom widely practiced by Chinese females for centuries. We use newly-discovered Taiwanese data to estimate the extent to which females unbound their feet in response to the rapid growth in sugarcane cultivation in the early 20th century, growth which significantly boosted the demand for female labor. We find that cane cultivation significantly induced unbinding, with the IV estimations utilizing cane railroads – lines built exclusively for cane transportation – support a causal interpretation of the estimated effect. This finding implies that increased female employment opportunities can help eliminate norms that are harmful for females. Further analysis suggests that the need for human capital improvement was more likely to have driven the effects of cane cultivation, rather than the increased intra-household bargaining power for females.

1. Introduction

People's interactions with others around them, as well as their decisions on education, employment, marriage, and fertility, are framed by social norms. Several studies have found that some gender norms are so deep-rooted in society that even females studying in top-notch US universities (Bursztyn et al., 2017), those who are medical doctors in the US (Sarsons, 2017), and those who live in societies with leading levels of gender equality (Kleven et al., 2019) are not exempt from their influence.[1] These findings suggest that our behaviors may be governed by gender-specific beliefs and values in much more profound ways than generally perceived.

An important area in which progress has been made recently is the research investigating the origins of gender norms, where a number of studies have focused on various factors, such as traditional forms of farming or husbandry (Hansen et al., 2015; Becker, 2019), politico-economic regimes (Campa and Serafinelli, 2019; Booth et al., 2019), the pre-industrial variations in gender-specific productivity (Alesina et al., 2013; BenYishay et al., 2017; Brown and Satterthwaite-Phillips, 2018), and historical events leading to substantial changes in local gender ratios (Fernández et al., 2004; Grosjean and Khattar, 2019; Teso, 2019). A common feature of the gender norms identified in these studies is that once formed, a norm tends to persist, even after the original conditions giving rise to it have changed. The persistence helps explain why some ancient norms have survived major industrial and social changes and remained popular in modern societies. This also raises questions relating to how existing gender norms may undergo substantial change, and in particular, when certain harmful

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[1] Based upon field experiments on students in an MBA program in the US, Bursztyn et al. (2017) found that single female students reported lower desired salaries and a willingness to travel and work for long hours when it was expected that their male classmates would see their preferences, whereas there were no such concessions in the responses of male or married female students. Sarsons (2017) found that when referring a patient to a surgeon, physicians in the US evaluated the performance of a surgeon differently depending largely on the gender of the surgeon; the death of a patient led to physicians being more pessimistic about the ability of a female surgeon as compared to that of a male surgeon, leading to fewer referrals to female surgeons. Using Danish data, Kleven et al. (2019) found that after their first birth, mothers tended to experience reductions of around 20 percent in their participation rate, wage rate and the number of hours worked, whilst such 'child penalties' were not experienced by fathers.

norms, such as the practice of 'female genital mutilation' (FGM), could be brought to an end.

Our primary goal in this study is to examine the economic motives behind the quick demise of a prominent gender-specific norm behavior, the practice of foot-binding, an ancient custom followed by females in China and Taiwan. The practice applied tight wrapping of girls' feet at a very young age, resulting in permanent deform in their shape and size. The disappearance of foot-binding in Taiwan provides an interesting setting for the goals of this study for the following two reasons. First, foot-binding was widely practiced in both China and Taiwan for centuries prior to its demise; however, in contrast to China, the practice in Taiwan disappeared within a much shorter period of time. From 1905 to 1920, the proportion of adult females with bound feet in Taiwan declined from around 68 percent to just 11 percent. Although the elimination of foot-binding started earlier in China, it took a much longer period of time to complete (See Section 2.1 for details). The abrupt ending of foot-binding in Taiwan may serve as a valuable template for the elimination of other harmful gender norms, such as FGM. Second, the decade from 1905 to 1915 also witnessed a booming sugar industry in Taiwan, providing a unique opportunity to estimate the extent to which females stopped binding their feet in response to the surged demand for female labor brought about by cane cultivation. The estimated effect will shed light on the role played by economic incentives for foot-binding/unbinding.

Our investigation begins with documenting the demise of foot-binding in Taiwan in the early 20th century. From the start of the Japanese occupation of Taiwan in 1895, the colonial government launched a series of public campaigns and sponsored social movements led by local elites in the hope of eradicating it. However, prior to 1905, whilst this bottom-up approach had been quite effective in discouraging parents from binding the feet of their young girls, it had failed to encourage bound females to unbind their feet. Although most females were able to partially restore their mobility and physical strength after unbinding, they had to endure significant pain during the rehabilitation process. So females' reluctance to unbinding during this period was likely because the benefit from unbinding was outweighed by the disutility of the procedure. It was not until 1905–1915 that a large wave of unbinding occurred, coinciding with the timing of sugar boom, which drastically increased demand for female labor and thus offered an additional benefit for unbinding.

We then move on to developing a research design for estimating the effects of cane cultivation on this wave of unbinding. The rapid development of the sugar industry was engineered and sponsored by the Japanese colonial government. As compared to rice farming, cane cultivation required much more female labor. This raised the opportunity cost of practicing foot-binding, which impeded the physical strength and mobility. Our study estimates the extent to which females in townships which experienced higher growth in cane cultivation between 1905 and 1915 were more likely to unbind their feet. Given that farmers adopted cane cultivation voluntarily, using the OLS method to estimate the effect of cane cultivation raises a concern about selection. To address the concern, we employ a special type of railroad – cane railroad – as the instrumental variable (IV). Unlike ordinary railroads which transported passengers and various types of freight, the cane railroads, built and owned by the sugar corporations, were used exclusively for the transportation of cane. This feature implies that unbinding would only have been affected by the rise in cane cultivation induced by cane railroad, lending credit to the cane railroad as a valid IV and highlighting its advantage over ordinary railroads.[2]

Given that the exact locations of cane railroads were not randomly selected, there may be some concerns relating to the validity of the IV. For example, if the sugar corporations had disproportionately built railroads in townships with a higher propensity for abandoning foot-binding so as to engage in cane cultivation, then the local railroad density would be an outcome of some omitted variable directly affecting foot-binding, which would clearly be a violation of the exclusion assumption. We therefore carry out examinations aimed at gauging the extent of this potential influence, and find that the initial prevalence of foot-binding was not a valid predictor of later railroad density within a locality, a finding contradicting the argument that sugar corporations chose where to build railroads based upon the propensity for unbinding. We also find that the major predictors of local railroad density were naturally existing conditions (such as the landscape and suitability for sugarcane planting), whereas no significant predictive power is found for demographic characteristics (such as the gender ratio, racial composition and population size). These results add further support for railroad density as a valid IV.

Our estimation results suggest strong and robust effects of cane cultivation, with a one standard deviation increase in the proportion of land used for cane cultivation leading to: a significant increase of 18.9 percentage points in unbound women; and a significant decrease of 12.8 percentage points in women remaining bound in 1915, controlling for their initial foot-binding status in 1905. These substantial estimates confirm the importance of economic incentives in ending norms harmful for females.

We then go on to evaluate the relative importance of two mechanisms, intra-household bargaining and human capital investment, which could potentially deliver the effects of cane cultivation on foot-binding/ unbinding. The intra-household bargaining mechanism may have been at play because cane cultivation enhanced the bargaining power of females, relative to males, through an implicit increase in the income share of females within the household. This would have encouraged females to unbind if they resented foot-binding more than males. The human capital investment mechanism may also have been in effect because an increase in female involvement in agricultural productivity brought about by cane cultivation would have encouraged the abandonment of foot-binding, which was regarded as a negative form of human capital for agricultural production.

In order to gauge their roles, we investigate the two mechanisms on a set of additional outcomes and find that cane cultivation significantly reduced the mortality rates for both males and females, with the two effects sharing similar magnitudes. Furthermore, cane cultivation did not seem to alter the gender ratio of children, thereby implying equal effects on the survival rates of young boys and girls. Both of these findings contradict the predictions of the intra-household bargaining hypothesis. As regards the human capital investment mechanism, we find supporting evidence based upon the geographical correlation between the growth in cane cultivation and health improvement for girls aged below 10 years; however, it should be noted that in the absence of proper controls, the evidence is only suggestive.

Our empirical analyses contribute to a broader understanding of the motives behind the practice of foot-binding. Although the focus in our study is specifically on the demise of the practice of foot-binding, our findings complement prior studies in which economic incentives were proposed as being the driving force behind the *origin* of foot-binding (Blake, 1994; Gates, 2001; Bossen et al., 2011; Brown and Satterthwaite-Phillips, 2018). The argument pursued in these studies was that, by reducing the mobility of females, foot-binding increased their productivity in sedentary household work, such as handcrafting,

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[2] Railroads have been shown to have increased real income (Keller and Shiue, 2008; Donaldson and Hornbeck, 2016; Donaldson, 2018) and enhanced factors mobility (Sequeira et al., 2020; Banerjee et al., 2020) in various countries. Both are alternative channels that may had direct impacts on unbinding, thereby violating the exclusion restriction requirement.

cotton spinning and weaving, thereby providing an economic incentive for parents to bind daughters' feet.[3] However, statistical evidence on the economic motives for foot-binding remains extremely scarce.[4] To the best of our knowledge, our study is the first to provide causal evidence of such economic motives.[5]

Our study also adds to the extant related literature by providing evidence on the ways in which any changes in gender-specific labor productivity or employment opportunities can affect gender roles (Alesina et al., 2013; Teso, 2019; BenYishay et al., 2017), female decision power (Majlesi, 2016), gender-based violence (Aizer, 2010; Bulte and Lensink, 2019), sex ratio (Qian, 2008; Carranza, 2014; Xue, 2018), restrictions on women's sexuality (Becker, 2019), female's education (Jensen, 2012) and health (Jensen, 2012; Majlesi, 2016). The design of our test on the economic motive for unbinding is similar to Qian (2008), who used crop production favoring gender-specific labor as a source of the variations in gender-specific income. Qian showed that tea cultivation, which favored female labor, raised female income and their within-household bargaining power in rural China. This in turn improved the survival rates for young girls. Our study focuses on another important crop, sugarcane, the cultivation of which warranted much higher female labor inputs than that required for rice cultivation. Our findings agree with those of Qian (2008), among others, on the importance of female labor productivity in determining the well-being for females.

Our study also relates to recent studies assessing the role played by a railroad network in the early stage of a country's economic development. The primary findings of these studies suggest that railroad network construction had the effect of altering the industrial landscape by integrating markets and facilitating factor mobility (Donaldson and Hornbeck, 2016; Donaldson, 2018; Banerjee et al., 2020). We extend the scope of this literature to privately own railroads. Consistent with the existing evidence, we find that the railroad network built by the entrepreneurs gave rise to a leading industry in the early stage of modern economic development of Taiwan.

The remainder of this paper is organized as follows. Descriptions of the historical background on foot-binding, the sugar industry, and the railroad network in Taiwan are provided in Section 2, followed in Section 3 by a description of the conceptual framework of this study. Section 4 provides explanations of the data and the key variables used in this study, followed in Section 5 by the introduction of our estimation strategy and the justification of the IV. Section 6 presents the estimated effects of cane cultivation on foot-binding/unbinding, as well as its effects on other outcomes which we use to evaluate the potential mechanisms. Finally, the conclusions drawn from this study are presented in Section 7.

2. Background

The practice of foot-binding involved the tight wrapping of young girls' feet, usually starting at the age of 5 or 6 years, and lasting for up to 10 years. It was a painful process that permanently deformed feet, jeopardizing the ability of women to engage in activities requiring physical strength. Historians commonly believed that foot-binding in China originated in the royal court in the Five Dynasties around the 10th century, with the practice later spreading to the entire upper class as a sign of gentility in the Song Dynasty (960–1279) and gaining popularity among the lower classes during the Ming (1368–1644) and Qing (1636–1912) Dynasties. The prevalence of foot-binding varied across regions and ethnic groups in China, and indeed, it was widely practiced among most Han Chinese women, whereas it was rarely seen among the Hakka, a subgroup of Han Chinese.[6] The Hakka account for around 4.4 percent of China's current population, and in 1905 accounted for around 13.1 percent of Taiwan's population.

2.1. Foot-binding and its demise in Taiwan

Throughout the 17th to 19th centuries, the main flow of settlers to Taiwan came from the southern Fujian Province of China and, to a lesser extent, the eastern Guangdong Province, both of which are geographically close to Taiwan. By 1905, which marked the completion of the first population census in Taiwan, 95.1 percent of the island's residents had migrated from these two provinces, with Fujian accounting for 82 percent and Guangdong for the remaining 13.1 percent. The Fujian immigrants were ethnically Hoklo, whilst the Guangdong immigrants were Hakka. Since the practice of foot-binding was inherited from their ancestors in China, it was common among Hoklo women, but was rarely seen among Hakka women.[7]

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[3] Examples include Blake (1994), Gates (2001), Bossen et al. (2011) and Brown and Satterthwaite-Phillips (2018). Blake (1994) pointed out that as opposed to completely eliminating the ability of women to engage in production, foot-binding actually diverted women's labor activities towards home production. Similarly, Gates (2001) argued that by reducing their mobility, foot-binding increased young women's productivity in sedentary light work within the household. This merit, as argued by Bossen et al. (2011), may have been exemplified by the development of the textile industry in rural China during the Ming and Qing Dynasties, providing a potential explanation for the increased popularity of foot-binding in rural areas.

[4] Some studies have shown a geographical correlation between the prevalence of foot-binding and the development of the textile or handcraft industries in China (see, for example, Bossen et al., 2011; Fan and Wu, 2020). However, the only study employing rigorous econometric analysis was that of Brown and Satterthwaite-Phillips (2018), who analyzed a sample of 7683 individuals collected from a field survey in China and found that women with experience of foot-binding were more likely to have participated in home handicraft production for commercial purposes, a correlation which provides support for the 'economic motive' hypothesis. Following their development of a theory on foot-binding, Fan and Wu (2020) carried out a test of such economic motives; however, since their empirical work was based on only a small sample retrieved from an archival dataset reporting respondents' retrospective, unformatted descriptions of the local prevalence of foot-binding, quantitative analysis was difficult.

[5] Other studies have provided evidence linking foot-binding to 'marriage-ability'. Using the data from Taiwan's Census of 1915, Shepherd (2018) showed that in 1915, among Hoklo females (the majority ethnic group in Taiwan), the mean age at first marriage for those with no experience of foot-binding was 20.4 years, much higher than that for previously-bound females (18.6 years), thereby providing a clear indicator of better marriage prospects for those with experience of binding. Brown et al. (2012) collected a sample of around 5000 people from a retrospective survey carried out in Sichuan, China, and found that the previously-bound women were more likely (34% versus 30%) to marry upward into an economically better-off family than women with no experience of foot-binding, and less likely (20% versus 23%) to marry downward into an economically worse-off family. Using household registration data in Taiwan during the colonial era, Wolf and Huang (1980) revealed a lower foot-binding rate for adopted daughters (78%) than that for biological daughters (85%), possibly because parents were more reluctant to invest in the marriageability of adopted daughters.

[6] Whilst researchers have proposed various theories on the resistance of Hakka people to foot-binding, very little evidence has been put forward to justify these theories. Historians, such as Zhang (1993), proposed the following three diverse hypotheses on the unwillingness of the Hakka to engage in foot-binding: (i) prior to the Five Dynasties when foot-binding first emerged in northern China, the Hakka people had migrated to the south, which geographically distanced them from the practice; (ii) after their long-distance migration, the majority of the Hakka settled in mountainous areas where physical mobility was desirable, perhaps even a prerequisite, for both men and women; and (iii) as compared to other Han groups, Hakka women tended to play a more active role in farming.

[7] Following their natural-foot custom in the Mainland, Hakka women in Taiwan rarely bound their feet; the 1905 Taiwan Descriptive Statistics Report shows that the proportion of foot-bound Hakka women was only 0.75 percent in that year, in sharp contrast to the 68 percent of foot-bound Hoklo women.

In the early years of Japanese rule, the authorities did not resort to edicts prohibiting foot-binding. Instead, the government adopted several strategies aimed at discouraging foot-binding. First, starting in late 1895, the government launched a public health media campaign against foot-binding through articles published in newspapers and magazines (Chang, 2008). This was a continuous effort aimed at raising public awareness of the disadvantages of foot-binding. Second, visits to schools by health professionals and intellectuals were arranged to advocate the natural growth of feet and discourage female students from agreeing to be foot bound. Third, the government sponsored civil organizations, such as the Natural Foot Society and Foot-binding Liberation Society, which were established and operated by local elites including medical doctors, local leaders, businessmen and scholars.

The goal of these campaigns was two-fold: (i) to discourage parents from binding the feet of young girls, and (ii) to encourage unbinding among existing bound women. In the first ten years of these campaigns (1895–1904), very little had been achieved in terms of encouraging unbinding; by 1905, only 0.72 percent of ever-bound women had engaged in unbinding, with 68 percent of the Hoklo women remaining bound. However, despite the minimal effect on unbinding, it is likely that these campaigns reduced the number of young girls engaging in foot-binding. Fig. 1 presents the proportion of bound women across age groups, using data from the Census of 1905. The curve in Fig. 1 shows that the proportion of foot-bound women was fairly constant (ranging between 75 and 80 percent) for those aged 26–30 or older in 1905. Since in 1895 these cohorts were already older than 10 years old, prior to which the process of foot-binding must start, so their decisions on entering into the foot-binding process were not affected by the anti-foot-binding campaigns or movements occurring after 1895. Thus, we can consider their foot-binding rates, around 75–80 percent, as a benchmark that indicates the prevalence prior to 1895. For younger cohorts, the scenario is different. Fig. 1 shows that the proportions are 54.6 percent for girls aged 11–15 and 67.9 percent for those aged 16–20 in 1905, both of which are significantly lower than the benchmark foot-binding rate. The lower rates suggest that the number of girls who entered the foot-binding process decreased between 1895 and 1905, arguably due to the anti-foot-binding campaigns.

Why did the campaigns persuade some parents not to bind their daughters' feet and yet fail to encourage already bound women to unbind their feet? One possible answer is that the two decisions involve different cost-benefit considerations. For unbinding, a major cost was that once the feet were bound and reshaped, attempting to reverse the process by unbinding incurred disutility given the pain involved. On the other hand, however, a benefit for women was that unbinding could partially restore their mobility and physical strength (DeMello, 2007). If people act rationally, unbinding would have been undertaken only if the cost of the procedure was outweighed by the benefit. To shed some light on this, we examine the association between unbinding and the age of females in 1915 when 63.1 percent of ever-bound women had unbound their feet. The ever-bound women were comprised of those undertaking unbinding and those remaining bound in 1915. On the cost side, unbinding was biologically easier for younger females whose feet were still soft, such that the rehabilitation process involved less pain. On the benefit side, unbinding was more desirable for younger females whose lifetime return to improved mobility and physical strength was higher. Combined, the higher benefit and the lower cost would have encouraged more unbinding among younger females than older ones, and indeed, our data reveal such a correlation as suggested by Fig. 2.

Despite the resistance to unbinding between 1895 and 1905, such inertia did not persist after 1905. Indeed, the 1905–1915 decade witnessed a dramatic wave of unbinding, with the proportion of unbound women among all ever-bound women rising from 0.7 percent in 1905, to 63.1 percent in 1915. Binding young girls' feet was finally outlawed in 1915, marking the onset of a new stage of the government's overall anti-foot-binding plan. By 1920, the proportion of bound women among all Hoklo women had further declined to just 11 percent, and the practice

ultimately died out completely in the years thereafter.

This raises a question concerning what it was that triggered such a land-slide shift towards unbinding after 1905, the outcome of which was so different from the pre-1905 decade. As argued above, the social movements and public campaigns in the pre-1905 decade had little impact on unbinding; thus, although this anti-foot-binding effort continued into the post-1905 era, it was unlikely to have been the driving force behind the unbinding wave. A more likely scenario is that certain other factors changing the cost-benefit structure for unbinding had come into play. In the following section, we document the rapid development of cane cultivation in the post-1905 era and evaluate its impact on female participation in agricultural production, and thus, their decisions on unbinding.

2.2. The modern sugar industry in Taiwan

At the start of the Japanese occupation of Taiwan, agricultural production was dominated by rice cultivation, whilst cane cultivation was relatively rare, accounting for only 3.9 percent of all arable land in 1905.[8] At that time, the extraction of raw sugar was processed in traditional, small, household-based, stone-built mills, which were powered by ox carts. The development of the modern sugar industry in Taiwan commencing in the 1900s was planned out by the colonial government, closely following the Empire of Japan's goal to replace sugar imported from other countries for sugar from Taiwan. The sugar industry in Taiwan featured the establishment of mechanized sugar refinery factories powered by electricity, and unlike the traditional family-based mills, investment in new factories was undertaken by large, private corporations from Japan, with subsidy from the government. The two decades after 1905 witnessed the rapid expansion of such modern factories, and at its peak, 42 sugar refinery factories had been established and brought into operation.

Each sugar factory was assigned a catchment area by the colonial government within which the factory became the only buyer of the canes planted inside the area; thus, each catchment area was essentially a local monopsony market, a scenario which was designed to mitigate any competition between the sugar corporations. Such a system incentivized sugar corporations to invest in railroad construction within the catchment area. In stark contrast to the systems in Java and the Caribbean, where farmers were coerced into growing cane, cane cultivation in Taiwan operated under a system of contract farming. Since farmers were free to choose between crops, in order to promote cane farming, the sugar corporations often offered a guaranteed purchase price before the plantation began, with the price being set at a sufficiently high level to make cane farming at least equally profitable than the alternatives.[9]

Annual cane production, measured in thousands of tonnes, are provided in Fig. 3, with panel (A) showing that total cane production experienced enormous growth from the 1900s to the 1930s; production rose from 410 million tonnes in 1903, to over 8 billion tonnes in 1935, almost a 20-fold increase.[10] From 1903 to 1918, growth had been driven primarily by continuous expansion in the amount of land used for cane cultivation. As shown in panel (B), the land used for cane cultivation (blue curve) grew from 16,526 Jia in 1903 to 150,450 Jia in 1918, a

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Fig. 1. Proportion of foot-bound women by age group in 1905. Source: Census of 1905, General Volume of Statistics Tables, pp.388-389.
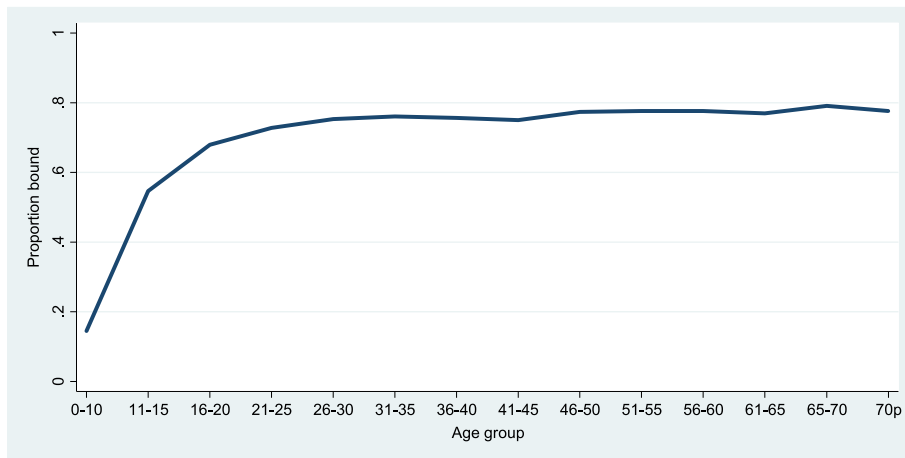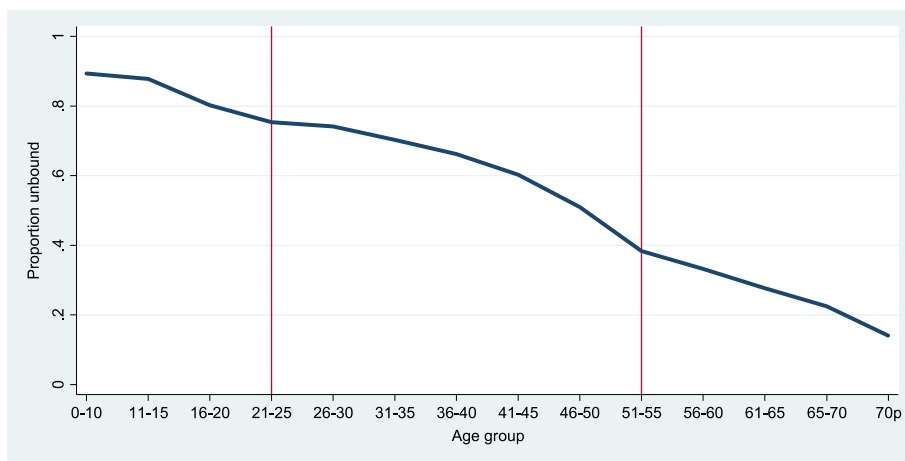

Fig. 2. Proportion of unbound women by age group in 1915. Source: Census of 1915, General Volume of Statistics Tables, pp.442-443.
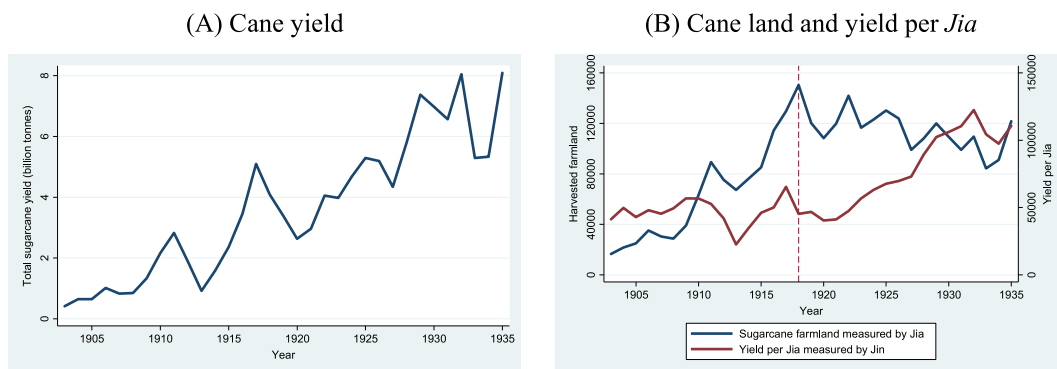

Fig. 3. Development of cane cultivation in Taiwan, 1903–35. Notes: Data are from the 27th Taiwan Sugar Industry Statistics, 1938, pp.15. A Jia is a unit of land area which is equivalent to 0.9699 acre.

nine-fold increase. A Jia is a unit of land area equal to 0.9699 acre. However, the output per Jia increased only slightly over the same period, from 41,338 to 45,314 Jin (A Jin is a unit of mass equal to 600 g), which indicates that there was only a limited gain in productivity. The scenario changed in 1918, a year which heralded the start of a decline in the land used for cane cultivation, leading to a 19 percent reduction by 1935 (from 150,450 to 121,628 Jia). During that same period, however, the amount of cane produced per Jia increased by 146 percent (from 45,314 Jin to 110,807 Jin).[11] The period prior to 1918 has much greater relevance to the present study, since it was a period which exhibited a rapid increase in the land used for cane farming, leading to a rise in demand for labor. As noted earlier, a wave of unbinding was witnessed over the same period, and thus, this period offers a unique opportunity to estimate the effects of cane cultivation on unbinding.

2.3. Sugarcane cultivation and female labor

There are two features of cane farming in Taiwan distinguishing it from rice farming. Firstly, cane cultivation induced a much greater demand for female labor, and male and female labor complements each other by specializing in different tasks in the production of cane. Secondly, railroads were indispensable for transporting canes to the refineries.

For the same area of land, cane cultivation required much higher labor inputs, form both males and females, than rice cultivation. To show this, we use the data reported in the *Agriculture Fundamental Survey No. 5: The Second Report on Farming Household Economy,* which collected production information from a sample of 68 rice-farming and 25 cane-farming households in 1919.[12] The number of days of work spent by adult males and females on a Jia of land for the two types of farming households are reported in Table 1, which shows that 94.4 days of male labor and 15.8 days of female labor were devoted to rice cultivation on a Jia of land. If male and female labor are considered comparable and addable, then the proportion of female labor accounted for 14.4 percent of the total labor input (male and female days combined). In contrast, cane cultivation on a Jia of land used 138.4 days of adult male labor and 78.9 days of adult female labor, with female labor accounting for 36.3 percent of the total labor input. This implies that female labor, in either absolute and relative terms, had a much more important role to play in cane cultivation than in rice cultivation. In absolute terms in particular, the female labor input for cane cultivation was more than five times that required for rice cultivation for the same area of land.

Where did the extra manpower come from to meet the labor demand boosted by the expansion of cane cultivation? Back in the 17th century, when the sugar industry was booming in Brazil and the Caribbean, the

Table 1
Days of work spent cultivating a Jia of land.

	(1) Male	(2) Female	(3) Female labor (%)
Rice farming	94.4	15.8	14.4
Cane farming	138.4	78.9	36.3

Notes: The statistics are calculated based on data obtained from the Agriculture Fundamental Survey No. 5 (1923): The Second Report on Farming Household Economy, which collected information from 68 rice-farming and 25 cane-farming households. The numbers in the Male and Female columns indicate the total number of days spent cultivating a Jia of land during the year of the survey. A Jia is a unit of land area which is equal to 0.9699 acre.

Table 2
Days of work per household member and total hired labor.

	Per household member		Total hired labor	
	(1) Adult male	(2) Adult female	(3) Adult male	(4) Adult female
Rice households	165.2	69.7	216.1	31.2
Cane households	176.7	110.0	255.8	79.4

Notes: The statistics are calculated based on data obtained from the Agriculture Fundamental Survey No. 5: The Second Report on Farming Household Economy, which collected information from 68 rice-farming and 25 cane-farming households. The numbers in the table cells indicate the total number of days spent cultivating crop during the year of the survey.

surge in labor demand was satisfied by the massive inflow of enslaved men from Africa. Such a solution, however, was not an option for Taiwan. Alternatively, cane farmers in Taiwan came up with two solutions. First, they toiled female household members to spend more time in farming. Second, they employed more part-time workers, both males and females, triggering domestic migration.

Table 2 provides comparisons between rice-farming and cane-farming households in terms of the days of work undertaken by adult household members and hired workers (listing males and females separately).[13] It should be noted that since the days of work are measured here at the individual level, they do not refer to the days of work required to cultivate a Jia of land, as reported in Table 1. The results reported in column 1 of Table 2 show that an adult male in a rice household spent 165.2 days on rice farming in 1919, which is only slightly below the 176.7 days spent by an adult male in a cane household. The corresponding figures for adult female members, as shown in column 2, are 67.7 days for rice households and 110 days for cane households. Column 3 further reveals that rice households hired a total of 216.1 days of adult male labor, which was around 40 days less than the 255.8 days required by cane households. The difference is even greater for hired female labor, as rice households hired just 31.2 days of adult female labor, whilst cane households hired a total of 79.4 days of adult female labor, a difference of 48.2 days (column 4).

The details reported in Table 2 on hours worked in the different households indicate that when a household decided to switch from rice farming to cane farming, the increase in the labor demand would have been supplemented primarily by its own female household members, along with hired male and female workers. Aggregately, the expansion of cane farming in the early 20th century greatly enhanced the role of females in agricultural production. Females within a farming household were not only required to work harder on agricultural production, but they were also more likely to be hired by nearby farms as temporary workers.

When entering into sugar cane production, females were employed in certain specialized tasks, which essentially complemented male labor inputs, with this male-female labor division primarily being determined by the gender difference in upper-body strength. As noted by Wu (2021), males generally took on those tasks which demanded greater strength (deep hoeing, packing, carrying and transporting canes), whilst females tended to carry out the lighter tasks (such as planting the stem cuttings, weeding and removing the dry leaves from the cane stalks). The three photographs shown in Fig. A2 in the Appendix illustrate the gender labor division and cooperation during the harvesting process. Fig. A2-A shows males cutting down mature cane stalks; these stalks are more than twice as tall as an adult man and apparently quite heavy. After being cut, the stalks would have been placed on the ground for the females to take over to remove the leaves from the stalks (Fig. A2-B), before being loaded onto a rail cart. As illustrated in Fig. A2-C, this final packing and loading process, which again required more physical strength, was then

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[11] The increase in productivity was driven by a combination of factors, including improvements in plant breeding, soil quality, plantation methods, and fertilizer usage.

[12] These households were collected from all the seven different prefectures in Taiwan.

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[13] The data source for Table 2 is the same as that for Table 1.

carried out by the male workers.

2.4. Sugarcane cultivation and railroad

As noted earlier, traditionally sugar processing operated in household-scale mills, so long-distance transportation of canes was not necessary. However, following the establishment of the large-scale modern factories, sugar processing became centralized, and in order to ensure sugar quality, the harvested canes had to be promptly conveyed to a refinery factory, which could be miles away from the farmland. Since no traditional transportation methods could accommodate the movement of a large volume of canes over long distances, the sugar corporations built a dense railroad network for cane shipping.

Prior to 1895, the railroad system was almost non-existent. The only available railroad was a line connecting two main cities in northern Taiwan, and it was subsequently replaced for the Western Trunk Line (WTL) completed by the Japanese colonial government in 1908. The WTL connected all major cities in western Taiwan, offering transportation of both passengers and freights. Following the assignment of catchment areas in the 1900s, the sugar corporations embarked on the construction of railroads within their own catchment territory. These privately-owned railroads were designed exclusively for cane transportation. As shown in Appendix A (Fig. A1), the flatbed cars ran on narrow-gauge rails, so they were not safe or stable enough for the transportation of passengers or other types of cargo. Fig. 4 illustrates the total length of railroads in Taiwan. The blue curve refers to the length of cane railroads which experienced four-fold growth between 1909 and 1941, from 451 km to 2182 km. The red curve shows the total length of another type of railroads, referred to as the multi-purpose railroads, which were also constructed by the sugar corporations, but used for the transportation of passengers and various types of freight, including canes. Although the total length of these railroads increased rapidly from 1909 to 1918, there was no further expansion thereafter, presumably due to the development of the good quality roads that were replacing the functions of the railways.

As compared to the multi-purpose railroad, the cane railroad is a more suitable IV for our attempts to estimate the causal effects of cane cultivation on unbinding decisions. Given that the multi-purpose railroads may have been important for local economic development and social change, they may have had a direct impact on unbinding without operating through cane cultivation, thereby violating the exclusion restriction requirement for a valid IV. Since the cane railroads were unrelated to the transportation of passengers or non-cane freight, it is unlikely that they would have affected unbinding decisions without working through facilitating cane cultivation.

3. Conceptual framework: foot-binding as a social norm

The practice of foot-binding exhibits the key features of a norm behavior as specified by researchers, and indeed, time persistence is often observed among such features with regard to social norms and culture (Belloc and Bowles, 2013; Borowiecki, 2015). Foot-binding, which had been practiced for centuries in both China and Taiwan, obviously exhibited time persistence. In addition, it also exhibited another feature referred to by Young (2015) as 'local conformity and global diversity'. Young argued that two similar groups in a society might end up with two separate equilibrium points with sharply different levels of the norm, an outcome which is likely to be caused by some random events in history that projected the two groups along different trajectory paths. This feature is helpful in explaining why the Hakka and the Hoklo, both of which are ethnically Han, developed contrasting norms relating to foot-binding.[14]

Perhaps the most intriguing feature exhibited by foot-binding is the pattern of tipping. Nyborg et al. (2016), for example, argued that adherence to a social norm by one individual can help reinforce adherence to the same norm by other individuals, which in turn helps compel adherence by the first individual. This forms a vicious cycle that makes a norm stable and self-reinforcing. The tipping point is where a vicious cycle turns into a virtuous one, which is why when a norm starts to shift, and once the proportion of non-followers passes a critical threshold, people start changing rapidly until a new equilibrium point is reached (Schelling, 1960; Nyborg et al., 2016). Indeed, such a tipping point is discernible among foot-binding followers in Taiwan.

Fig. 5 plots the correlation between the proportion of bound Hoklo women and the proportion of the Hakka population, based upon the data from the Census of 1915. Our sample is comprised of 2716 villages and districts, which were categorized into 25 bins with an equal bin width of 4 percentage points. The mean for each bin was obtained using the proportion of Hoklo women in all the villages and districts within the bin. Although the figure indicates a decline in the foot-binding rate among Hoklo women with an increase in the population share of the Hakka within the village/district, this negative correlation is not linear, as there is a tipping point where the Hakka population share reached around 6 percent. This is to say, the foot-binding rate was much higher for Hoklo women living in a village/district where the Hakka accounted for less than 6 percent of the population, but once the Hakka population share passed the tipping point, there was a dramatic reduction in the Hoklo foot-binding rate. Although the evidence is only suggestive, the existence of the tipping point helps explain why the demise of foot-binding was sudden, rather than incremental.

Foot-binding can be best understood as a costly norm because it inflicted pain on followers and impaired their labor productivity. Thus, the immediate incentive provided by cane cultivation would seem to be evident – unbinding facilitated participation in agricultural production that requires better physical mobility and upper-body strength, thereby raising the cost of remaining bound. Nevertheless, females may not have been responsive, because deviating from a norm can attract criticism and even punishment (Jindani and Young, 2020). Combined, the effect of cane cultivation on unbinding was reliant on the number of females whose gain from unbinding surpassed the loss. Furthermore, the pattern of tipping implies that the marginal effect of cane cultivation on unbinding may have been amplified if the effect resulted in inducing sufficient females to cross the tipping point.

The cost-benefit analysis discussed above implies a potential channel through which cane cultivation may have affected foot-binding/unbinding. For brevity, we refer to this channel as the 'human capital investment mechanism', which posits that foot-binding was considered to be a negative entry to the human capital of females for agriculture production, with the growth in cane cultivation then incentivizing females to raise their human capital by abandoning foot-binding. Importantly, this consideration was not limited to adult females, since an increase in returns to human capital would have also reduced the

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[14] Splitting paths can be observed in the experiments carried out by Baronchelli et al. (2006) and Centola and Baronchelli (2015). Using naming games, they investigated how naming conventions arose through a trial-and-error coordination process within a network of subjects. Each subject was encouraged to come up with the same name with a paired subject within the same network in a series of trials. When cross-network interactions were banned, this resulted in different networks converging to completely distinct names; however, when the network was enlarged to involve the entire available subjects, only one name became the dominant choice.
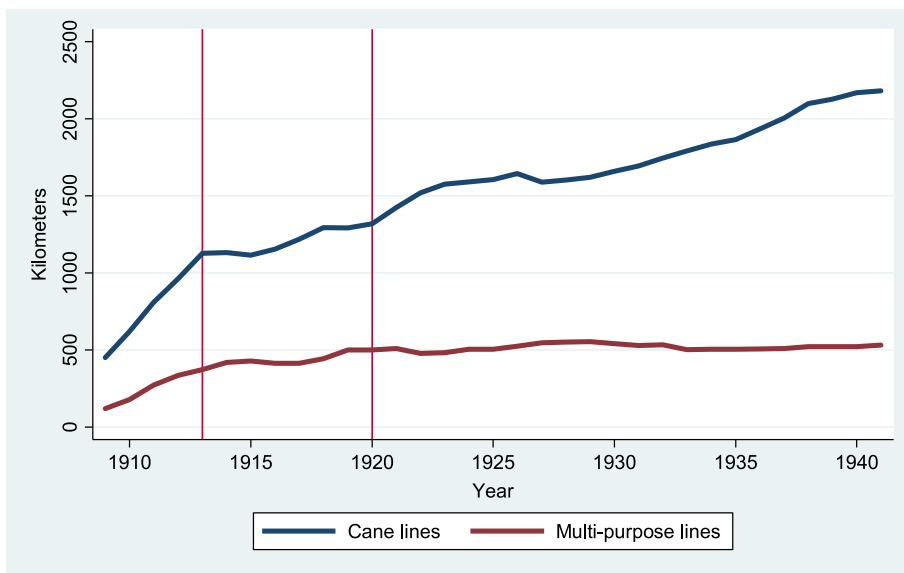
Fig. 4. Length of cane railroads and multi-purposed railroads. Source: Data are from Ministry of Railroads Annual Report, 1941, p.543.
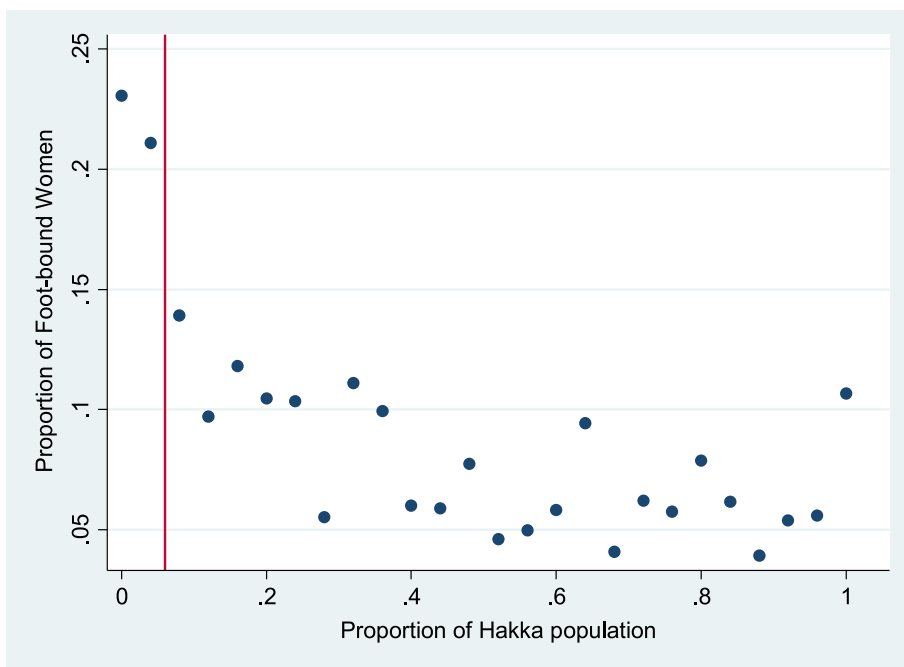

Fig. 5. Foot-binding exhibits tipping. Notes: Data are obtained from the Census of 1915, General Volume of Statistics Tables. All the 2716 villages and districts are categorized into 25 bins, each of which has an equal bin-width of 4 percentage points. The mean for each bin is obtained using the proportion of Hoklo women of all the villages and districts within the bin.

willingness of parents to bind the feet of their daughters if they had not already been engaging in the process of foot-binding, and to continue the process for those daughters who were already engaging in it.

Another mechanism potentially affecting the practice may have operated through intro-household bargaining. Given that cane cultivation may have increased the (implicit) income share of female members within the household, relative to males, it may also have increased their bargaining power (Becker, 1973). This would have led to more un-binding if females resented binding more than males, and would have also helped to prevent young daughters from engaging in the process of foot-binding if the mother was more concerned about the daughter's disutility than the father. In this study, we refer to this channel as the 'intra-household bargaining mechanism'.

Later, in Section 6.2, we estimate the effects of cane cultivation on other outcomes, including mortality, the child gender ratio, health of children, and education, and attempt to identify any differences in these effects between males and females. We use these results to evaluate the relative importance of the two potential mechanisms and find that, as opposed to increasing bargaining power for females, the need for human capital improvement was more likely to have been the channel delivering the effects of cane cultivation on foot-binding.

4. Data and sample

Demographic and foot-binding data were collected from the Census of 1915, General Volume of Statistics Tables, carried out by the Japanese

colonial government.[15] The data are reported at the village/district level, which was the third level of administrative division in 1915, just below township. The key variables of interest are the number of unbound women (who had originally bound their feet but subsequently had them unbound prior to 1915) and the number of women remaining bound in 1915. Also available within the data are the populations by gender, age group and ethnicity (Hoklo, Hakka, and aborigine). For estimating the effect of cane cultivation on unbinding, the village/district-level data were aggregated at township level to accommodate our primary outcome variable, the proportion of land used for cane cultivation, which was reported only at the township level. Following the exclusion of ten special administrative townships located in the aboriginal territory, as well as four townships with no foot-binding records, our final sample for analysis is comprised of 197 townships.

We use two different outcome variables for our regression analysis. The first is the proportion of unbound women among ever-bound women, who ever experienced foot-binding regardless their binding status in 1915. The proportion is expected to be higher for a township that witnessed a higher growth in cane cultivation from 1905 to 1912, if the economic incentive was effective in determining foot-binding/unbinding. Our second outcome variable was simply the proportion of foot-bound women among all Hoklo women in 1915. If the economic incentive worked, we would expect this proportion to be lower for townships with higher growth in cane cultivation between 1905 and 1912, conditional on the initial state on foot-binding. It should be noted that the effect on the second outcome variable, if detected, can be attributed to: (i) more unbinding prior to 1915, and (ii) fewer young girls engaging in initial foot-binding prior to 1915.

Township-level foot-binding statistics for 1905, which should be controlled for as the initial foot-binding status in our regressions, were not available from our data. To address this, we used the number of ever-bound women in 1915 divided by the number of Hoklo women in 1905 as a proxy for the proportion of bound women for each township in 1905. This proxy is obviously problematic because it ignores occurrences of both inbound flows (newly bound women) and outbound flows (bound women who had died) between 1905 and 1915. This limitation is harmless only if the outbound flow minus the inbound flow is proportional to the actual number of bound women in 1905, but evidence of such proportionality is absent. As a precautionary measure, in Section 5, we examine the robustness of our estimates by running regressions with and without controls in place for this imputed variable, and find only minor differences between the two results.

It is worth noting that the censuses conducted during the colonial period were implemented with high accuracy. Barclay (1954) examined the accuracy by counting the individuals at each age in the Census of 1905, and comparing them to the counts at the corresponding ages (15 years older) in the Census of 1920. He found that the differences can be almost perfectly explained by the registered births, deaths, and migrants recorded in the vital statistics conducted annually between 1905 and 1920. He concluded that "With very few exceptions, these events – births, deaths, and presence at each census date – were nearly all recorded and were recorded accurately."

The data on cane cultivation are contained in the annual Governor General of Taiwan Statistics Books, which report land used for cane, rice and other crop cultivation at the township level. Our treatment variable is defined as the change in the proportion of land used for cane cultivation between 1905 and 1912, which is the last year of the data availability. It should be noted that due to the lack of data, we are unable to determine the number of unbound women in 1912 to 'synchronize' our treatment variable (change in the percentage of cane land between

Table 3
Summary statistics.

	(1) Mean	(2) Standard deviation
A. Township-level data (Observations: 197)		
Proportion of unbound women, 1915	0.61	0.28
Proportion of bound women, 1915	0.25	0.21
Proportion of cane land, 1912	0.11	0.11
Log population, 1915	9.13	1.09
Township characteristics, 1905:		
Male-to-female gender ratio	1.12	0.08
Proportion of Hoklo female population	0.94	0.48
Log population	9.05	1.09
Proportion of cane land	0.05	0.08
Imputed percent bound females	0.59	0.22
Proportion of Plain landscape	0.89	0.22
Cane railroad density	9.91	13.05

Notes: Demographic variables and foot-binding data are collected from the 1915 Taiwan Census Primary Statistics Tables. Railroad data are from the Sugar Industry Annual Report, 1919. Land cultivation data are from the Governor General of Taiwan Statistics, 1905 and 1912.

1905 and 1912) and outcome variables (percentages of bound and unbound women in 1915). We should bear in mind that this will inevitably result in measurement errors unless the cross-township variation in the percentage of unbound women in 1912 was proportional to that in 1915. The summary statistics on the main variables used in our analysis are presented in Table 3, which reports the township-level data used for our examinations on foot-binding and other outcomes.

Fig. 6 illustrates the geographical correlation between cane cultivation and unbinding in Taiwan, with panel (A) showing the changes between 1905 and 1912 in the proportion of arable land used for cane cultivation at township level. For simplicity, we focus solely on townships in southwest Taiwan, where cane cultivation was most prevalent. Since townships surrounding the local capital city, Tainan, are shown in a lighter color, this suggests relatively slow growth in the proportion of land used for cane cultivation between 1905 and 1912. Radiating from Tainan, the color turns darker for townships located farther away, indicating a higher 1905-12 growth in cane cultivation. A similar radiation pattern is also observed in panel (B), which indicates the proportion of unbound women in 1915. The proportion is found to be particularly low in townships near Tainan, and becomes larger with an increase in the distance from Tainan. Obviously, the similarity in the radiation pattern demonstrates a geographical correlation between the development of cane cultivation and unbinding.

Finally, we were able to obtain the exact location of each cane railroad by digitizing a detailed raw map of railroads published in the Sugar Industry Annual Report, 1919, using QGIS, a geographical information system (GIS) application. This map was the earliest one with good quality we could find from all existing colonial government archives. The digitized railroad lines are presented in Fig. 7, which shows an intensive network of cane railroads (red curves) in the southwest of Taiwan where the sugar industry flourished. Our digitization provides a total of 1122 km of cane railroad. All the geographic measures, including the railroad length, township area, adjacent villages and districts, border length, and location of the centroid are constructed using the geospatial vector data provided by Center for GIS, Research Center for Humanity and Social Sciences, Academia Sinica. We generated a cane railroad density for each township, which was measured as the total length of cane railroad within the township divided by the area of the township, and then used this variable to instrument the cane cultivation within our regressions.

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[15] Data collected by the Census of 1915 are reported in several different official reports. The township-level data used in this study were obtained from one of these four reports, the General Volume of Statistics Tables.
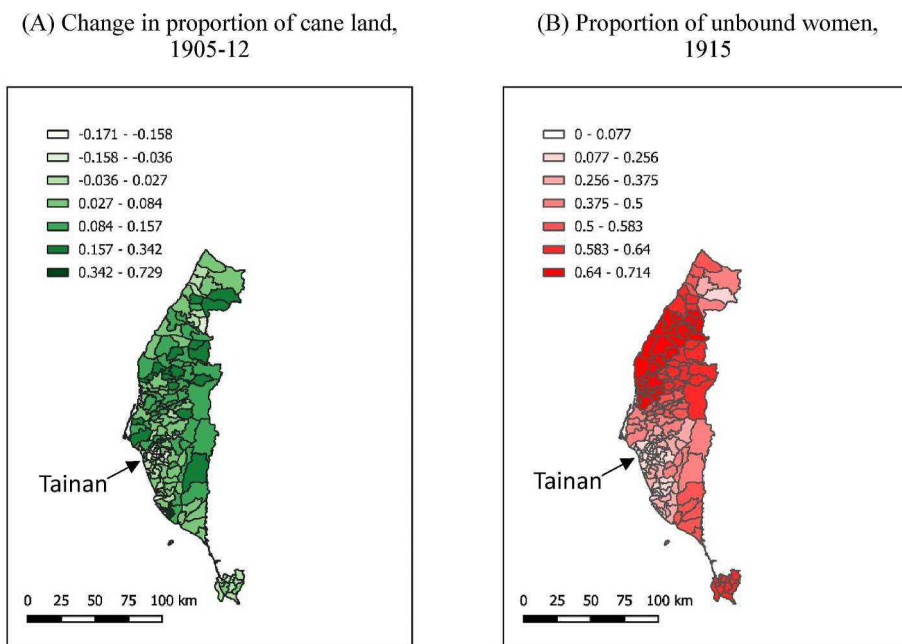
Fig. 6. The geographical correlation between cane cultivation and foot unbinding. Notes: The geospatial vector data are provided by Center for GIS, Research Center for Humanity and Social Sciences, Academia Sinica, Taiwan. Data in panel (A) are from the Governor General of Taiwan Statistics Books, 1905 and 1912. Data in panel (B) are from the Census of 1915, General Volume of Statistics Tables.

5. Estimation strategy

Our primary task in this section is to estimate the causal effect of cane cultivation on unbinding by estimating the following regression:

$$UBR_{1915, k} = \alpha + \beta \Delta Sugar_k + X_{1905,k}\gamma + X_{natural, k}\delta + \rho FBR_{1905,k} + \varepsilon_k \quad (1)$$

where the dependent variable, $UBR_{1915, k}$, refers to the proportion of unbound women in township k in 1915 as our first outcome variable, or the proportion of women who remained bound in 1915 as our second outcome variable; $\Delta Sugar_k$ is the change in the proportion of land used for cane cultivation between 1905 and 1912; $X_{1905,k}$ is a vector of controls measured in 1905, which is comprised of the male-to-female gender ratio, proportion of Hakka among the female population, logarithm of township population, and the proportion of arable land used for cane cultivation in 1905 as its initial status; $X_{natural, k}$ refers to a set of controls indicating natural conditions of township k, including proportion of plains in the landscape and two dummies indicating whether township k is located in the North, Central, or South (omitted group) Taiwan; $FBR_{1905,k}$ is the proxy for the proportion of bound women in 1905 (refer to Section 4 for details on the construction of this proxy), which is used to control for the initial state of foot-binding; ε_k refers to the error term. The coefficient of interest is β, which indicates the marginal effect of the growth of cane cultivation on the corresponding outcome variable. Since the population size is quite variable across the different townships, all of the regressions based upon Equation (1) are weighted by township population in order to improve the precision of our estimations. As recommended by Solon et al. (2015), however, we also report the unweighted regression results later in this section (Table 7) as a test for the robustness of our model specification.

Given that farmers were free to choose between crops, the OLS estimate of β is potentially plagued by the omitted variables bias. One possible confounder, for example, is conservativeness: Consider a conservative male household head who worshipped traditional values and customs; he would be reluctant to adopt the cultivation of sugarcane as a modern crop, and he would ask female household members to stick to the practice of foot-binding. This drives positive correlation between $UBR_{1915, k}$ and $\Delta Sugar_k$, leading to a spurious estimate of β. To address this selection, we exploit the instrumental variable strategy using the cane railroad density as the IV.

As noted earlier, given that the cane railroads were used exclusively for the transportation of cane, the exclusion restriction requirement is arguably satisfied, since unbinding would only have been affected by cane cultivation induced by the cane railroad. However, in order to shed more light on the quality of our IV, we investigate whether the sugarcane corporations may have disproportionately constructed railroads in townships where they anticipated a more rapid cultural change that would lead to more foot unbinding; if this was the case, then the decision to construct dense railroads was an outcome of some omitted variable that might directly affect the practice of foot-binding, thereby presenting a violation of the exclusion assumption.

In an attempt to address this concern, we investigate whether the initial prevalence of foot-binding, measured in 1905, was capable of predicting the railroad density measured in 1919. Given that almost all of the cane railroads were built after 1906, the foot-binding rate in 1905 would reflect the prevalence of the practice prior to any potential impact that the cane railroads could have had on foot-binding. Thus, any strong correlation between the two variables, if detected, raises a concern about selection. Using the same working sample as that used for our main regressions on unbinding, we estimate this correlation by running a regression of 1919 railroad density on 1905 foot-binding rate, along with a set of controls. The results are presented in Table 4.

Column 1 of Table 4 shows that 1905 foot-binding rate has a significant coefficient (6.69), thereby indicating a strong *unconditional* correlation between the 1905 foot-binding rate and the 1919 railroad density; however, when controls are included in the regression for the proportion of plain landscape within the township territory (column 2), the coefficient reduces to 4.34 and turns insignificant. It is unsurprising to find plain landscape being a vital determinant for railroad density
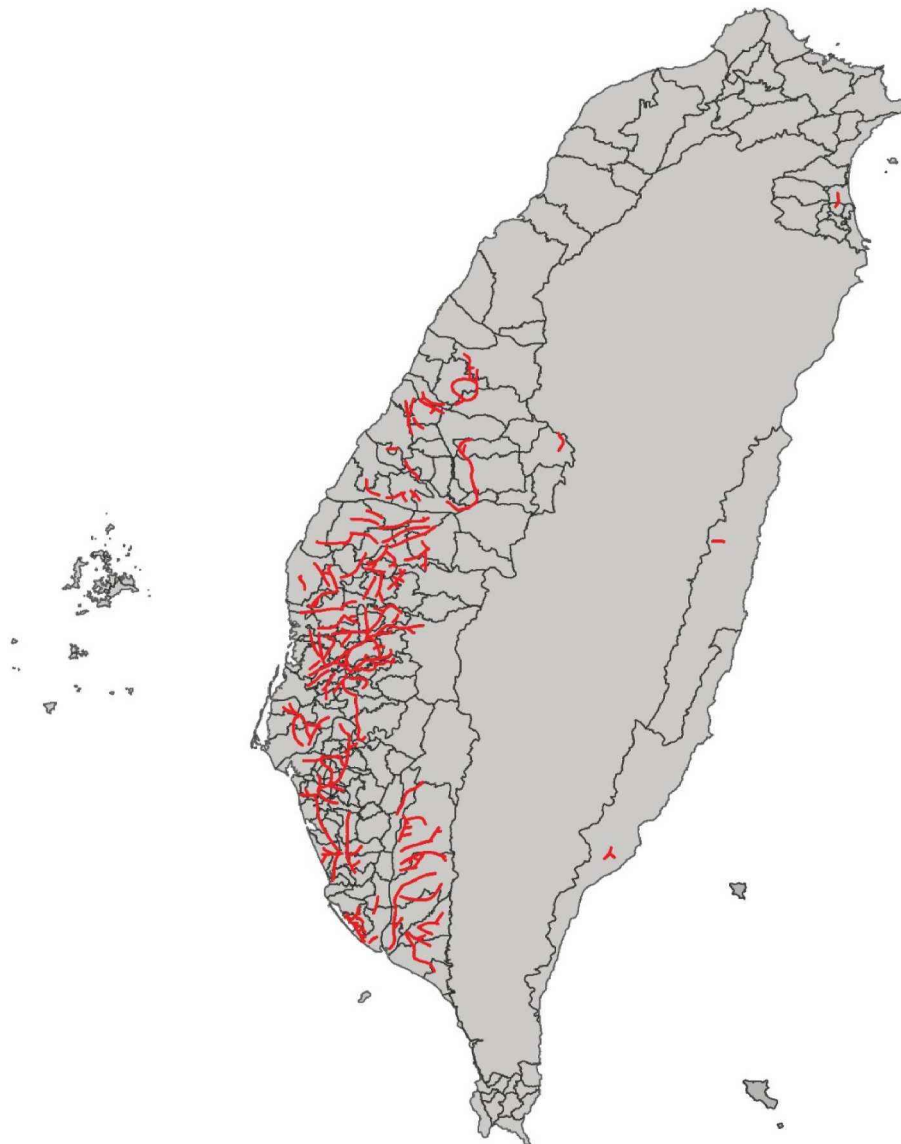
Fig. 7. Cane railroads in 1919. Notes: The geospatial vector data are provided by Center for GIS, Research Center for Humanity and Social Sciences, Academia Sinica, Taiwan. Each cane railroad is digitalized using a raw map published in the Sugar Industry Annual Report, 1919.

since it is technically difficult to build rails on slopes. Furthermore, cane grows well in the plains, but not so well on mountain slopes. In column 3, we see a further decline in the coefficient, to 1.35, with continuing insignificance, when region dummies are controlled for in the regression. The coefficients on the Central Taiwan and Southern Taiwan dummies are both significantly positive, which indicates a higher railroad density in these two regions, as compared to that in Northern Taiwan (the benchmark region). These results are also consistent with the regional differences in climate, as the tropical climate in Central and Southern Taiwan is more suitable for cane cultivation than the cooler weather in Northern Taiwan. In column 4, three different demographic township characteristics are included in the regression, all measured in 1905; none of the corresponding estimates is significant, thereby suggesting that the 1905 demographic characteristics had no predictive power on subsequent railroad density.

The results provided in Table 4 would seem to suggest that natural conditions, such as the landscape and suitability for cane cultivation, were the major considerations when the sugar corporations were

contemplating where to construct railroads, with the cultural or demographic characteristics of the locality, including the prevalence of foot-binding, apparently having less importance.

Next, we examine historical archives providing information on the criteria considered by the sugar corporations when deciding where to construct their sugar factories. Since the factories were the hubs of the cane railroad network, the selection of the factory sites is obviously informative, as it provides a basis for the understanding of where the sugar corporations decided to construct their railroads. Shinji Kono (1930), a prominent researcher on Taiwan's sugar industry, listed four factors that were considered by the sugar corporations as important in determining their sugar factory sites: (i) proximity to a river, since sugar factories were steam-powered, with some of them relying on hydro-electricity; Fig. 8 shows that, in South-Western Taiwan, almost all of the sugar factories (marked as solid dots) were built along a river (indexed as blue lines); (ii) sufficient neighboring land suitable for cane cultivation; (iii) proximity to transportation routes; and (iv) the availability of sufficient labor. Consistent with the regression results presented in

Table 4
The determinants of cane railroad density.

	(1)	(2)	(3)	(4)
Imputed percent bound	6.69**	4.34	1.11	2.89
females, 1905	(3.12)	(3.04)	(1.33)	(2.58)
Township natural conditions:				
Proportion of plain		17.84***	8.44***	7.81***
landscape		(3.18)	(1.99)	(2.00)
Located in Central Taiwan			−12.05***	−12.42***
			(1.34)	(2.18)
Located in Southern Taiwan			−6.70***	−6.73***
			(1.93)	(2.49)
Township demographic characteristics, 1905:				
Male-to-female gender ratio				−7.22
				(10.97)
Proportion of Hokko female population				−0.01
				(1.08)
Log population				0.51
				(1.28)
Population weighted	Y	Y	Y	Y
Mean dependent variable	9.907			
Observations	197			
R-squared	0.025	0.149	0.350	0.352

Notes: All of the regressions, which are estimated at township level, are population weighted. The dependent variable is cane railroad density, measured in 1919, which is defined as the length of cane railroad within the township divided by the township land. The percent bound females in 1905 is imputed using data from the Census of 1905; details are provided in Section 4. Robust standard errors are in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 4, these four criteria suggest that geographical factors were cited as the primary considerations when determining where to build the factories, with no mention of any cultural factors. So once again, the foot-binding status of females, or their propensity for unbinding, was unlikely to have been important determinants of local railroad density.

6. Results

The estimated effects of cane cultivation on unbinding are presented in Table 5, with column 1 showing that when controlling for only the 1905 variables (with the exception of the proxy for the 1905 foot-binding rate), the coefficient on the change in the proportion of cane land is 1.06, which is statistically significant. This estimate implies that a one standard deviation increase (0.1068) in the proportion of cane land is associated with an 11.3 percentage points increase in unbound women in 1915. This coefficient estimate declines to 0.76 when natural condition controls are added into regression (column 2), and declines slightly further to 0.75 when the proxy for the 1905 foot-binding rate is controlled for in regression (column 3), although both remain statistically significant.

Columns 4 to 6 of Table 5 respectively report the first-stage, reduced-form and second-stage results of the 2SLS estimation using cane railroad density as the IV. The 2SLS estimate of interest is 1.77, which is much larger than the corresponding OLS estimate shown in column 3. The large 2SLS estimate suggests that a one standard deviation increase in the proportion of cane land led to an 18.9 percentage points increase in unbound women in 1915. The effect is sizable when compared to the mean proportion of unbound Hoklo females (60.7 percent) in the sample.

Multiple possible reasons may explain why the 2SLS estimate is larger than the corresponding OLS estimate, one of which is that the 2SLS estimate captures the treatment effect on the compliers – those farmers who shifted to cane cultivation in response to the provision of railroad access. Compared to the never-takers who persisted in rice
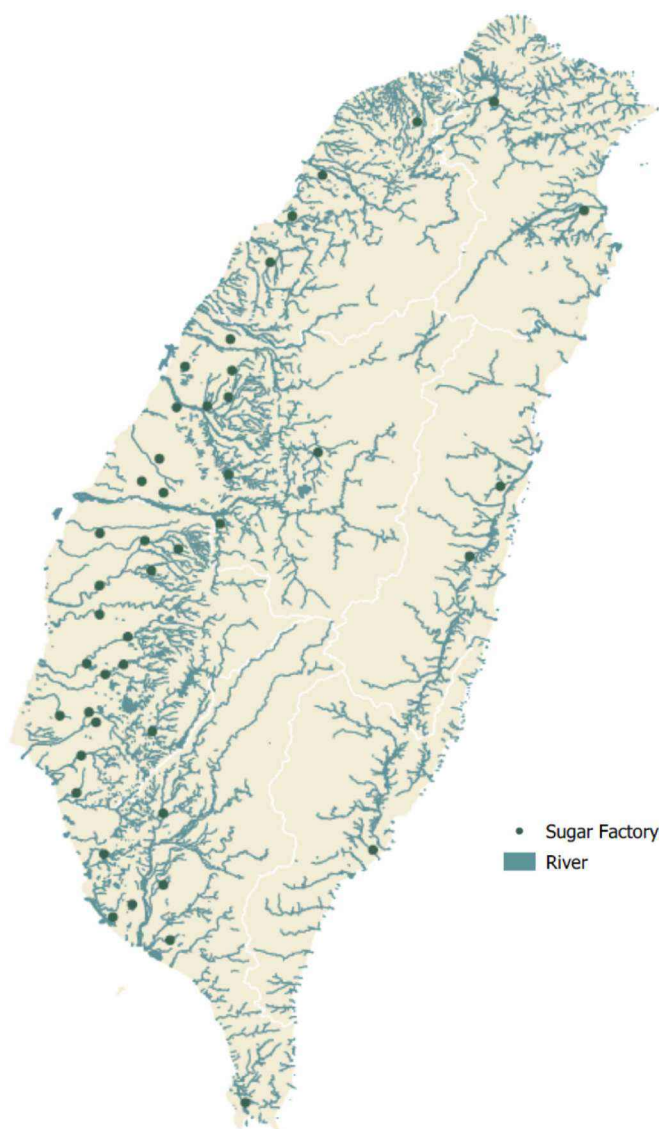
Fig. 8. The sites of sugar factories. Notes: The geospatial vector data, as well as the digital sites of sugar factories, are provided by Center for GIS, Research Center for Humanity and Social Sciences, Academia Sinica, Taiwan.

cultivation (the conventional crop) regardless of any railroad access, the compliers were likely to be more adaptive and less devoted to traditional ways of life, including the practice of foot-binding. In that case, the compliers would have been more inclined to engage in unbinding in response to the adoption of cane cultivation, which would mean that cane cultivation had a greater effect on unbinding.

Table 6 presents the estimation results using the proportion of the remaining foot-bound women in 1915 as the outcome variable. The estimates confirm the main findings drawn from Table 5, that the growth in cane cultivation discouraged the practice of foot-binding, leading to a lower proportion of bound women in 1915. Specifically, the OLS estimates in columns 1 to 3 suggest that a one standard deviation increase in the proportion of cane land is associated with a 4.9 to 7.2 percentage points reduction in bound women in 1915, depending on various controls. Again, these OLS estimates are smaller than the 2SLS estimate, as shown in column 6, which suggests that a one standard deviation

Table 5

The effects of cane cultivation on unbinding.

	OLS			2SLS		
				1st-stage	Reduced form	2nd-stage
	(1)	(2)	(3)	(4)	(5)	(6)
Change in proportion of cane land (1905–12)	1.06***	0.76***	0.75***			1.77***
	(0.19)	(0.20)	(0.20)			(0.58)
Township characteristics, 1905:						
Male-to-female gender ratio	0.89***	0.57*	0.39	−0.021	0.382	0.42
	(0.32)	(0.30)	(0.31)	(0.098)	(0.296)	(0.33)
Proportion of Hokko female population	−0.02	−0.02	−0.04	−0.006	−0.047	−0.04
	(0.04)	(0.03)	(0.04)	(0.007)	(0.033)	(0.04)
Log population	−0.01	−0.41**	−0.43**	−0.195***	−0.655***	−0.31
	(0.02)	(0.20)	(0.19)	(0.062)	(0.199)	(0.21)
Proportion of cane land	0.77***	0.74**	0.74**	−0.530***	0.062	1.00***
	(0.27)	(0.32)	(0.32)	(0.136)	(0.264)	(0.34)
Township natural conditions:						
Proportion of plain landscape		0.01	−0.01	−0.038	−0.065	0.00
		(0.06)	(0.06)	(0.030)	(0.074)	(0.07)
Located in Northern Taiwan		−0.10	−0.11	−0.059***	−0.104*	0.00
		(0.07)	(0.07)	(0.017)	(0.063)	(0.09)
Located in Central Taiwan		0.16***	0.16***	−0.021	0.160***	0.20***
		(0.05)	(0.05)	(0.020)	(0.049)	(0.06)
Log population, 1915		0.41**	0.44**	0.202***	0.670***	0.31
		(0.20)	(0.19)	(0.062)	(0.195)	(0.21)
Imputed percent bound females, 1905			0.12	0.011	0.116	0.10
			(0.08)	(0.024)	(0.074)	(0.09)
Cane railroad density				0.004***	0.008***	
				(0.001)	(0.002)	
Population weighted	Y	Y	Y	Y	Y	Y
Mean dependent variable	0.607					
Observations	197					
R-squared	0.243	0.411	0.419	0.422	0.439	0.315

Notes: All of the regressions, which are estimated at township level, are population weighted. The dependent variable is the proportion of ever-bound Hoklo females whose feet were unbound prior to 1915. The instrumental variable is cane railroad density, which is defined as the length of cane railroad within the township divided by the township land. Robust standard errors are in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1.

increase in the proportion of cane land in 1915 would have led to a 12.8 percent reduction in the proportion of bound women.

We carry out two tests on the robustness of our results in Table 7, with column 1 replicating the 2SLS estimation on unbinding without population weighting. Although the estimate of interest (β) is reduced to 1.37 – from the weighted estimate of 1.77 reported in column 6 of Table 5 – it remains both statistically and economically significant. Column 2 reports the estimation results using a sample which excluded 14 townships that were located either on the east coast or the Penghu Islands, both of which are relatively remote areas of Taiwan. The estimate of interest is 1.36, which implies a smaller effect of cane cultivation on unbinding, although the difference from the full-sample estimate is somewhat limited.

6.1. Verifications

In this section we use data at more aggregate levels to verify our main finding, that unbinding was driven by the increased demand for female labor due to the expansion in cane cultivation. We begin by presenting the geographical correlation between changes in unbinding and the growth in cane land. Figs. A3-A and A3-B in the Appendix illustrate the proportion of unbound Hoklo females, aged 21–50, across different prefectures in 1905 (panel A) as compared to 1915 (panel B). It should be noted that the white area in the central territory is the uninhabited mountainous region, and thus lacks data, and also that major changes were made to the administrative division in 1912, such that there are differences in the boundaries of the two maps. We focus on females aged

between 21 and 50 because, as noted in Section 2.1, younger girls had been discouraged from entering the process of foot-binding by the anti-foot-binding campaigns, whereas adult females had remained largely unaffected. Although unbinding was extremely rare across the whole of Taiwan in 1905 (as shown in Fig. A3-A), the proportion of unbound females had increased dramatically by 1915 (as shown in Fig. A3-B). More importantly, the pace of unbinding was much more rapid in Central and Southern Taiwan, as compared to Northern Taiwan, a pattern which fits well with the territorial distribution of cane cultivation growth over a similar period. Fig. A3-C illustrates the changes in the proportion of land used for cane cultivation between 1905 and 1912, which was also concentrated in Central and Southern Taiwan.

Next, if physical strength was indeed vital for cane cultivation, then we would expect to find unbinding being concentrated among certain age groups (particularly those assumed to have greater physical strength). Support is already provided for this pattern by Fig. 2, which shows that the unbinding rate in 1915 appeared to be declining with female age. Fig. A4 in the Appendix also shows that the overall unbinding rate was substantially higher for females aged 21–50 (panel A) as compared to those aged 50 or above (panel B), thereby corroborating the age pattern presented in Fig. 2.

If the growth in cane cultivation was indeed driving unbinding, then those females participating in agricultural production should exhibit a stronger propensity towards unbinding than those working in the non-agricultural sectors. Fig. A5 in the Appendix illustrates this disparity by showing that the proportions of unbound females among those participating in agricultural production in 1915, either through home

Table 6
The effects of cane cultivation on foot-binding in 1915.

	OLS			2SLS		
				1st-stage	Reduced form	2nd-stage
	(1)	(2)	(3)	(4)	(5)	(6)
Change in proportion of cane land (1905–12)	−0.68***	−0.46***	−0.50***			−1.21***
	(0.13)	(0.13)	(0.13)			(0.40)
Township characteristics, 1905:						
Male-to-female gender ratio	−0.14	0.14	−0.39	−0.022	−0.385*	−0.41*
	(0.26)	(0.23)	(0.24)	(0.098)	(0.225)	(0.25)
Proportion of Hokko female population	0.07*	0.06*	0.01	−0.006	0.017	0.01
	(0.04)	(0.04)	(0.02)	(0.007)	(0.019)	(0.02)
Log population	−0.03**	0.56***	0.48***	−0.194***	0.632***	0.40***
	(0.01)	(0.14)	(0.14)	(0.061)	(0.141)	(0.15)
Proportion of cane land	−0.43*	−0.44*	−0.44**	−0.529***	0.016	−0.62***
	(0.23)	(0.26)	(0.22)	(0.136)	(0.194)	(0.23)
Township natural conditions:						
Proportion of plain landscape		0.02	−0.05	−0.038	−0.006	−0.05
		(0.05)	(0.05)	(0.030)	(0.059)	(0.05)
Located in Northern Taiwan		0.07	0.05	−0.059***	0.049	−0.02
		(0.05)	(0.04)	(0.017)	(0.042)	(0.06)
Located in Central Taiwan		−0.10***	−0.11***	−0.021	−0.111***	−0.14***
		(0.04)	(0.04)	(0.020)	(0.034)	(0.04)
Log population, 1915		−0.59***	−0.48***	0.201***	−0.636***	−0.39***
		(0.14)	(0.14)	(0.062)	(0.140)	(0.15)
Imputed percent bound females, 1905			0.35***	0.012	0.347***	0.36***
			(0.05)	(0.024)	(0.050)	(0.06)
Cane railroad density				0.004***	−0.005***	
				(0.001)	(0.001)	
Population weighted	Y	Y	Y	Y	Y	Y
Mean dependent variable	0.235					
Observations	197					
R-squared	0.153	0.344	0.467	0.422	0.485	0.377

Notes: All of the regressions, which are estimated at township level, are population weighted. The dependent variable is the proportion of Hoklo females remaining bound in 1915. The instrumental variable is cane railroad density, which is defined as the length of cane railroad within the township divided by the township land. Robust standard errors are in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

farming or paid employment, exhibited a higher unbinding rate in Central and Southern Taiwan (panel A), a pattern consistent with the geographical distribution of cane cultivation growth shown in Fig. A3-C. For comparison, Fig. A5-B presents a much lower unbinding rate for females employed in the non-agricultural sectors. This provides further support for our primary hypothesis that cane cultivation induced unbinding.[16]

Finally, we carry out a back-of-the-envelope exercise to gauge the aggregate impact of cane cultivation on the total supply of female labor. Between 1905 and 1915, the land used for cane cultivation grew from 24,977 to 114,451 Jia; based upon the results reported in Table 1, the shift from rice farming to cane farming warranted an additional 63.1 days per year of female labor per Jia, and thus, the growth in cane land implies a total increase of 5,645,809 days of female labor. This equates to an additional 51,326 full-time females participating in cane farming based upon Table 2, which indicates that a female member of a cane-farming household spent a total of 110 days per year in farming. Such a shock to the female labor demand is exceptionally large, given that in 1905, the total number of employed females in the agricultural sector in Central and Southern Taiwan (where cane land was concentrated) was only 247,688, with 160,551 (64.8 percent) of them working in home production, and a further 76,195 (30.8 percent) working in paid employment. It is extremely unlikely that the demand for 51,326

additional female workers could have been supplemented by unbound females in 1905, because at that time there were only 189,271 unbound females aged 15–50, the majority of which (158,740) were Hakka women who lived in Northern Taiwan and did not participate in cane cultivation. As for the remaining 30,531 unbound women, many of them worked as maidservants in wealthy households in the city, and thus, were virtually irrelevant to agricultural production.

6.2. Other outcomes

In this section, we set out to extend our regression analysis to evaluating the impacts of cane cultivation on other outcomes, including mortality, child gender ratio, health of children, and literacy. Armed with this additional evidence, we attempt to assess the relative importance of the potential mechanisms (intra-household bargaining and human capital investment) through which cane cultivation operated to affect foot-binding/unbinding.

6.2.1. Intra-household bargaining

We begin by testing whether cane cultivation had differential effects on the mortality rates of males and females. The rationale behind this test is that if females value their own wellbeing more than males, then an increase in the bargaining power of females brought about by their participation in cane cultivation would have led to health improvements for females relative to males, which would in turn be reflected in a

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[16] Given the similar geographical patterns shared by Fig. A5-B and Fig. A5-A, it may be somewhat puzzling as to why females in the non-agricultural sectors exhibited higher unbinding rates in Central and Southern Taiwan than those in Northern Taiwan, since none of them were involved in cane farming. Although we do not have a definitive answer to this point, we speculate that Fig. A5-B reflects a spillover effect of the shift in the norm emanating from the agricultural sector to other sectors.

Table 7
Robustness examinations.

	2SLS	
	(1)	(2)
	Unweighted	Excluding remote townships
Change in proportion of cane land (1905–12)	1.37**	1.36**
	(0.53)	(0.55)
Township characteristics, 1905:		
Male-to-female gender ratio	0.86***	0.14
	(0.22)	(0.08)
Proportion of Hokko female population	−0.02	0.11
	(0.02)	(0.34)
Log population	−0.25	−0.05
	(0.15)	(0.04)
Proportion of cane land	0.97***	−0.18
	(0.34)	(0.19)
Township natural conditions:		
Proportion of plain landscape	0.09	0.58
	(0.09)	(0.37)
Located in Northern Taiwan	−0.05	−0.02
	(0.08)	(0.06)
Located in Central Taiwan	0.14***	−0.05
	(0.05)	(0.09)
Log population, 1915	0.29*	0.19***
	(0.15)	(0.06)
Imputed percent bound females, 1905	0.15**	0.17
	(0.07)	(0.19)
Population weighted	N	Y
Mean dependent variable	0.607	0.650
Observations	197	183
R-squared	0.321	0.359

Notes: Both regressions are estimated at the township level. The dependent variable is the proportion of ever-bound Hoklo females whose feet were unbound prior to 1915. The instrumental variable is cane railroad density, which is defined as the length of cane railroad within the township divided by the township land. Robust standard errors are in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Table 8
The effects of cane cultivation on mortality rate by gender.

	Change in mortality rate from 1906 to 1913		
	(1)	(2)	(3)
	Females	Males	F-M
Change in proportion of cane land (1905–12)	−52.15**	−53.52**	1.38
	(24.48)	(22.87)	(9.27)
Township characteristics, 1906:			
Male-to-female gender ratio	−0.01	−0.05	0.04
	(0.10)	(0.09)	(0.05)
Proportion of Hokko female population	0.71	1.62	−0.91
	(1.11)	(1.38)	(0.86)
Log population	−31.06***	−17.42	−13.64*
	(10.47)	(11.76)	(8.14)
Proportion of cane land	−24.28	−21.35	−2.93
	(14.95)	(13.02)	(8.74)
Township natural conditions:			
Proportion of plain landscape	2.77	1.62	1.15
	(2.61)	(2.61)	(2.34)
Located in Northern Taiwan	3.51	0.35	3.15*
	(3.27)	(3.09)	(1.72)
Located in Central Taiwan	−0.17	−1.64	1.47
	(2.27)	(2.12)	(1.32)
Log population, 1913	31.29***	18.06	13.22
	(10.61)	(11.79)	(8.03)
Imputed percent bound females, 1905	−4.85*	−3.57	−1.28
	(2.76)	(2.44)	(2.07)
Population weighted	Y	Y	Y
Mean dependent variable	−10.14	−8.50	−1.64
Observations	197	197	197
R-squared	0.203	0.072	0.104

Notes: All of the regressions, which are estimated at township level, are population weighted. The dependent variable is the change in mortality rate from 1906 to 1913. The instrumental variable is cane railroad density, which is defined as the length of cane railroad within the township divided by the township land. Robust standard errors are in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

relative reduction in female mortality rates. To carry out this examination, we merge township-level mortality data from Taiwan's Vital Statistics, an annual report dating back to 1906, with our main dataset containing information on cane cultivation. The pooled data enable us to apply our IV approach to separately estimate the effects of cane cultivation on the mortality rates for males and females. The mortality rate is measured as the number of deceased females (males) during the year divided by the entire female (male) population (times 1000) at the beginning of the same year. The estimated effects, by gender, are presented in Table 8. The dependent variable in column 1 refers to the change in mortality rate for the entire female population from 1906 to 1913, where the estimated coefficient of the change in the proportion of cane land is −52.15, which is statistically significant.[17] The magnitude of the estimate implies that between 1906 and 1913, a one standard deviation increase (0.1068) in the proportion of cane land was associated with a reduction of 5.57 deaths per 1000 females. When compared to the average decline in the female mortality rate (10.14) over the same period, the effect is clearly quite large. As indicated by column 2, the corresponding estimate for males was a reduction of 5.7 deaths per 1000 males, which is only slightly higher than that for their female counterparts. Column 3 shows that the male-female difference in the decline in

mortality rate is minimal and insignificant.[18]

To shed more light on the role of intra-household bargaining, we go on to estimate the effects of cane cultivation on the gender-specific survival rates of children. If the growth in cane cultivation did indeed raise the bargaining power of mothers, and if, relative to the fathers, the mothers placed greater value on the wellbeing of their daughters, then we should observe a positive effect of cane cultivation on the survival of girls, relative to that of boys. However, our township-level data unfortunately lack survival rates specific to children. Alternatively, we examine the male-to-female gender ratio for children under a certain age, which reflects the survival rate of boys relative to that of girls. Table 9 presents the results obtained from repeating the 2SLS estimation of Equation (1), with the dependent variable being replaced by the male-to-female gender ratio for children aged 0–15, 0–10, and 0–5, as reported respectively in columns 1 to 3. For all three age groups, the effects of cane cultivation are positive but insignificant.

The results obtained from our examinations of gender-specific mortality and gender ratios for children are inconsistent with the predictions obtained from a model of intra-household bargaining. One possible interpretation of this result is that there are no differences between male and female household members in their preferences towards total

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[17] Rather than using the change in the mortality rate from 1905 to 1912 (which matches the time window for our treatment variable, the change in the proportion of cane land), we use the change from 1906 to 1913, for two reasons. Firstly, 1906 is the start year of our mortality data, and secondly, since the growth period for sugar cane in Taiwan ranges from 12 to 18 months, the potential effect of cane cultivation on mortality might be lagged by around one year if the effect functioned through increasing income.

[18] There may be multiple channels through which cane cultivation operated to reduce mortality, but we speculate here that it is very likely that income played a major role. Using 1918-21 household survey data, Yeh (2014) showed that cane-farming households were much better off than rice-farming ones; the average income per capita for cane households was 136.19 Yuan (then circulating currency), around 20 percent higher than that for rice households with an average of 113.85 Yuan. The higher income brought by cane cultivation may have improved nutritional intake and healthcare, and thus, reduced mortality.

Table 9
The effects of cane cultivation on child gender ratio.

	Male-to-female gender ratio		
	(1) Ages 0-15	(2) Ages 0-10	(3) Ages 0-5
Change in proportion of cane land (1905–12)	0.091 (0.091)	0.042 (0.087)	0.063 (0.103)
Township characteristics, 1906:			
Male-to-female gender ratio	0.243* (0.145)	0.152 (0.104)	0.135* (0.071)
Proportion of Hokko female population	−0.007 (0.009)	−0.007 (0.007)	−0.014 (0.009)
Log population	0.143*** (0.046)	0.134*** (0.046)	0.111** (0.054)
Proportion of cane land	−0.115 (0.081)	−0.110 (0.079)	−0.108 (0.092)
Township natural conditions:			
Proportion of plain landscape	−0.004 (0.020)	−0.005 (0.018)	0.006 (0.019)
Located in Northern Taiwan	0.016 (0.017)	0.015 (0.013)	0.014 (0.014)
Located in Central Taiwan	0.003 (0.014)	0.005 (0.011)	0.010 (0.013)
Log population, 1913	−0.142*** (0.047)	−0.130*** (0.047)	−0.112** (0.055)
Imputed percent bound females, 1905	0.060*** (0.020)	0.063*** (0.018)	0.031 (0.020)
Population weighted	Y	Y	Y
Mean dependent variable	1.078	1.057	1.040
Observations	197	197	197
R-squared	0.273	0.228	0.110

Notes: All of the regressions, which are estimated at township level, are population weighted. The dependent variable is male-to-female child gender ratio measured in 1915. The instrumental variable is cane railroad density, which is defined as the length of cane railroad within the township divided by the township land. Robust standard errors are in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

household spending on health or the distribution of health-related spending across household members; however, this interpretation goes against the findings of the prior studies, such as Duflo (2003) and Qian (2008), who presented evidence consistent with intra-household bargaining among families in developing countries. Perhaps a more serious interpretation is that the changes brought about by cane cultivation in intra-household bargaining power were insufficient to trigger any significant changes in household bargaining power in favor of females.

6.2.2. Human capital investment

The human capital investment mechanism asserts that by raising the return to human capital for females, cane cultivation motivated them to abandon the practice of foot-binding as a method of increasing their human capital. In order to assess this mechanism, we use child mortality data, since this is the only health indicator that we have been able to identify for children; however, the lack of township-level child mortality data also prevents us from carrying out any regression analysis. Thus, as an alternative, we follow the approach adopted in Section 6.1 to examine the geographical correlation between cane cultivation and child mortality, with Figs. A6-A and A6-B in the Appendix respectively illustrating the average mortality rates in 1906 and 1916 for girls aged 0 to 10 across different prefectures. In Fig. A6-A, Central and Southern Taiwan exhibits a much higher mortality rate for girls aged 0–10 as compared to that for Northern Taiwan; however, Fig. A6-B shows that Central and Southern Taiwan also experienced greater improvements in the mortality rates between 1906 and 1916, as the color flattens out across all regions. This dynamic pattern coincides with the geographical distribution of the growth in cane cultivation, as previously illustrated in Fig. A3-C. It must be stressed that whilst the geographical correlation exhibited in Fig. A6 is not necessarily causal, it does provide suggestive evidence in support of the hypothesis that parents were induced by cane cultivation to invest more in the health of their girls.

We now move on to an examination of another form of human

Table 10
The effects of cane cultivation on literacy rate by gender.

	(1) All	(2) Females	(3) Males	(4) F-M
Change in proportion of cane land (1905–12)	0.011 (0.036)	0.002 (0.012)	0.015 (0.059)	−0.014 (0.049)
Township characteristics, 1906:				
Male-to-female gender ratio	−0.000** (0.000)	−0.000 (0.000)	−0.001*** (0.000)	0.001*** (0.000)
Proportion of Hokko female population	−0.001 (0.002)	−0.000 (0.001)	−0.003 (0.003)	0.002 (0.002)
Log population	−0.037* (0.022)	−0.012 (0.008)	−0.061* (0.035)	0.049* (0.027)
Proportion of cane land	−0.007 (0.032)	−0.009 (0.012)	−0.010 (0.051)	0.001 (0.041)
Township natural conditions:				
Proportion of plain landscape	−0.005 (0.004)	−0.002 (0.002)	−0.009 (0.007)	0.007 (0.006)
Located in Northern Taiwan	0.004 (0.007)	−0.000 (0.003)	0.008 (0.011)	−0.008 (0.009)
Located in Central Taiwan	0.007 (0.005)	−0.001 (0.002)	0.015* (0.008)	−0.015** (0.006)
Log population, 1913	0.040* (0.024)	0.013 (0.009)	0.066* (0.037)	−0.053* (0.029)
Imputed percent bound females, 1905	0.001 (0.005)	0.004** (0.002)	−0.001 (0.009)	0.006 (0.007)
Population weighted	Y	Y	Y	Y
Mean dependent variable	0.0167	0.0023	0.0306	−0.0283
Observations	197	197	197	197
R-squared	0.240	0.175	0.273	0.308

Notes: All of the regressions, which are estimated at township level, are population weighted. The dependent variable is the proportion of literate individuals in the township. The instrumental variable is cane railroad density, which is defined as the length of cane railroad within the township divided by the township land. Robust standard errors are in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

capital, education. Conceptually, an increase in agricultural productivity would encourage parents within a farming household to involve their children in home production activities, and would therefore discourage them from making any investment in the education of their children. In the case of cane cultivation, however, the development of the sugar industry created a number of non-agricultural jobs, which might well have motivated educational investment. Thus, when combined, the aggregate effect may be ambiguous. In order to gauge the effect of cane cultivation on education, we leveraged the data from the 1915 Census which reports the numbers of 'literate' males and females in each township. Although the data description does not provide any exact criteria based upon which an individual is identified as 'literate', it is the only township-level educational indicator that we have been able to retrieve from the archives. We repeat the 2SLS estimation of Equation (1), with the dependent variable being replaced by the proportion of literate individuals in the township. The results are presented in Table 10, which shows a minimal and insignificant effect of cane cultivation on the literacy rate for males and females combined (column 1), separate results on females (column 2) and males (column 3), and female-male difference (column 4).

7. Conclusions

In this study, we examine the demise of foot-binding in Taiwan. Given that cane cultivation was substantially more demanding for female labor than traditional rice cultivation, the expansion of the sugar industry in the early 20th century induced a considerable amount of female labor into agricultural production. Using unique historical data on Taiwan, we show that the shift to cane cultivation incentivized bound females to unbind their feet, a finding which confirms the role of economic motives behind the ancient custom.

It is important to note that our test on economic incentives focuses on the demise in foot-binding that mainly occurred in the first two decades of the 20th century. Our results confirm the importance of economic incentives in determining unbinding, although it must be noted that we have been unable to identify any clear association between economic considerations and the origin of foot-binding. Furthermore, our findings do not rule out the possibility that other motives were coming into play. Indeed, foot-binding has been widely considered as a means of marriage competition: given that men in the marriage market had a preference for women with bound feet, foot-binding was used as a form of investment made by parents to enhance the marriageability of their daughters (Shepherd, 2018).

Although foot-binding has now been consigned to the distant past, other costly, gender-specific norms still prevail. Among these the most heinous is the practice of female genital mutilation, experienced by more than 200 million African females still alive today (UNICEF, 2016). Our findings in the present study reveal that an increase in the demand for female labor accelerated the abandonment of a persistent custom that was costly for females, although the mechanisms delivering the effect remain unclear. To the extent that the cane effect functioned through enhanced women's expected life-time income that prompted parent's investment on girls' health, our findings imply that the development of female-labor-favoring crops (such as tea and coffee) or industries (such as textiles and electronics assembly) may also be helpful in eliminating the practice of FGM in the future.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

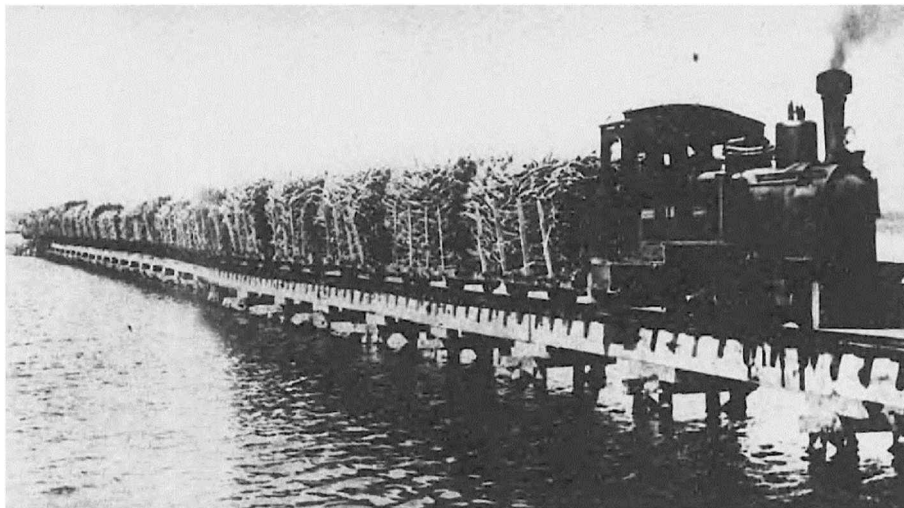Data will be made available on request.

Appendix

Fig. A1. Historical photograph of the cane railroad train. Note: The photo was taken during the colonial period with the exact year being unknown. Source: Ito (1939). .

(A)

(B)

(C)

Fig. A2. Gender labor division for cane harvesting. Note: The photos were taken during the colonial period with the exact year being unknown. Source: Ito (1939). .
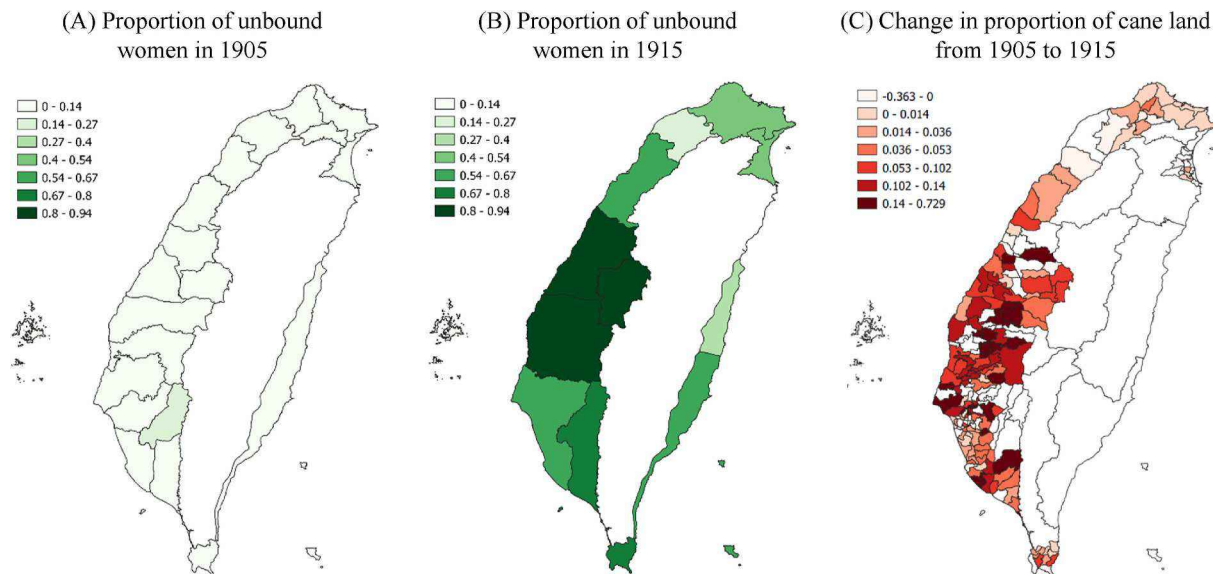
Fig. A3. Unbinding and cane cultivation at the aggregate level. Notes: The geospatial vector data are provided by Center for GIS, Research Center for Humanity and Social Sciences, Academia Sinica, Taiwan. Data in panel (A) are from Census of 1905, General Volume of Statistics Tables, pp.390-391. Data in panel (B) are from Census of 1915, General Volume of Statistics Tables, pp.442-443. Data in panel (C) are from the Governor General of Taiwan Statistics Books, 1905 and 1912. .
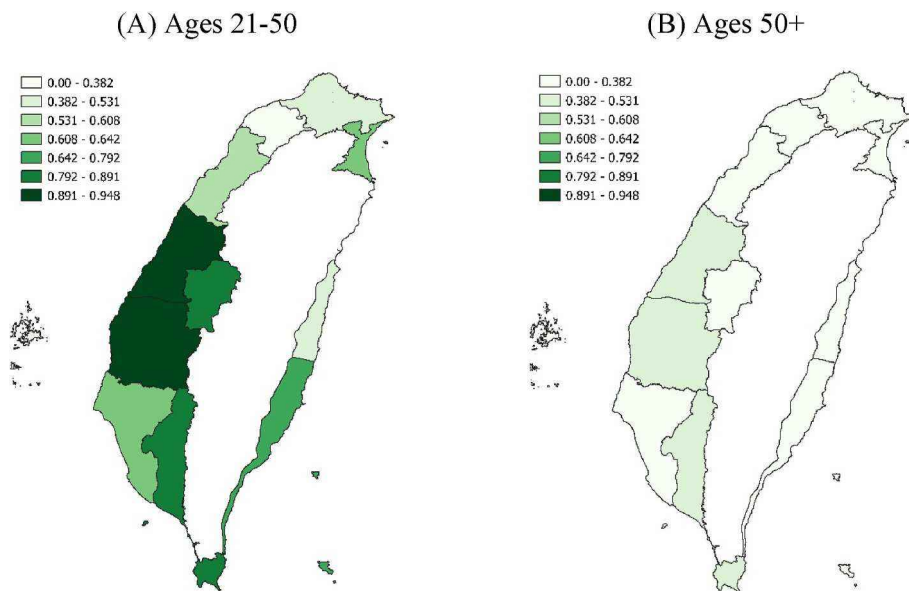

Fig. A4. Proportions of unbound females at ages 21–50 versus ages 50+ in 1915. Notes: The geospatial vector data are provided by Center for GIS, Research Center for Humanity and Social Sciences, Academia Sinica, Taiwan. Unbinding data are from Census of 1915, General Volume of Statistics Tables, pp.442-443. .
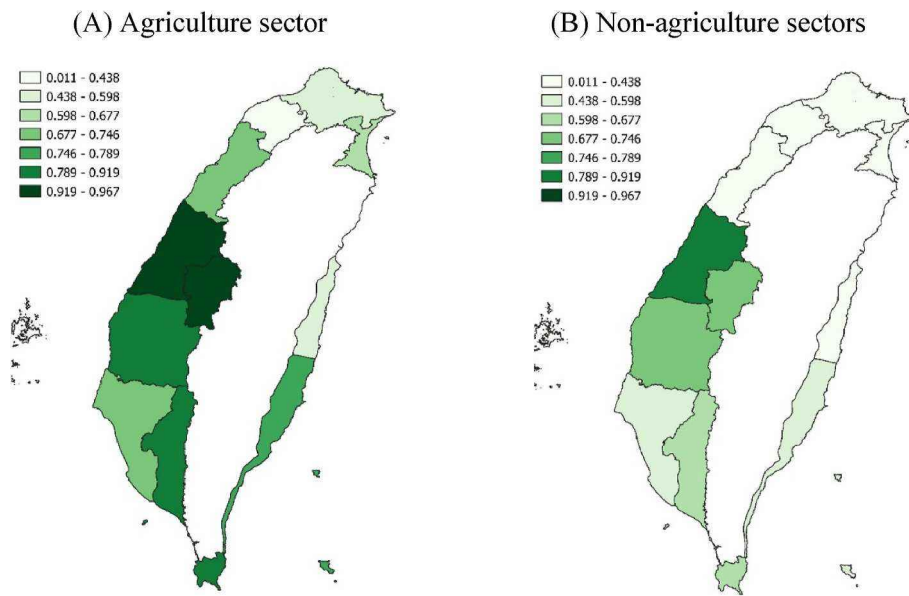
(A) Agriculture sector   (B) Non-agriculture sectors

Fig. A5. Proportions of unbound females by sector in 1915. Notes: The geospatial vector data are provided by Center for GIS, Research Center for Humanity and Social Sciences, Academia Sinica, Taiwan. Unbinding data are from Census of 1915, General Volume of Statistics Tables, pp.442-443. .
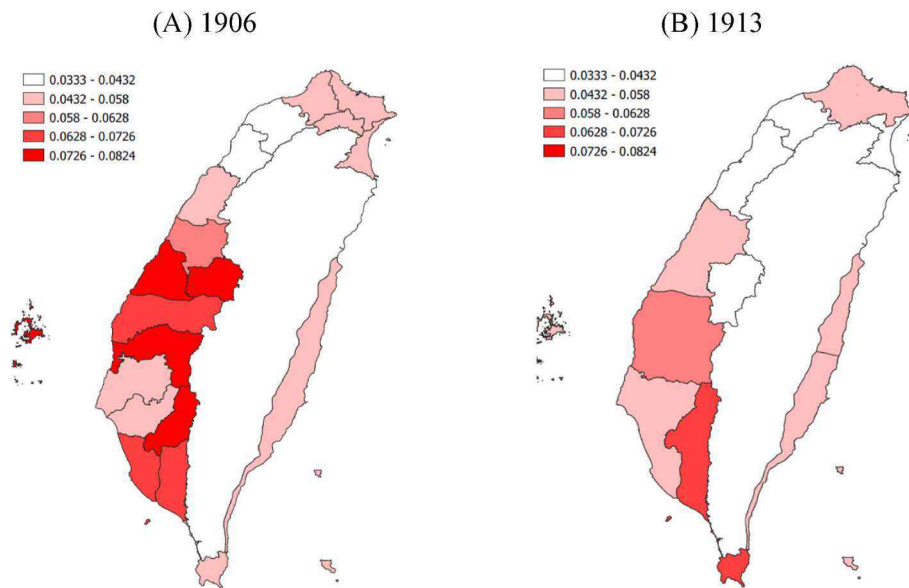
(A) 1906   (B) 1913

Fig. A6. Mortality rates for girls aged 0 to 10 in 1906 versus 1913. Notes: The geospatial vector data are provided by Center for GIS, Research Center for Humanity and Social Sciences, Academia Sinica, Taiwan. Mortality data are from Taiwan Vital Statistics, 1906 and 1913. .

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