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Soil Endowments, Female Labor Force Participation and the Demographic Deficit of Women in India

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Abstract

Differences in relative female employment by soil texture are used to explain the heterogeneous deficit of female children across districts within India. Soil texture varies exogenously and determines the depth of land tillage. Deep tillage, possible in loamy but not in clayey soil textures, reduces the demand for labor in agricultural tasks traditionally performed by women. Girls have a lower economic value where female labor opportunities are fewer. Consistently, higher relative female employment in agriculture improves the ratio of female to male children in districts that have a smaller fraction of loamy relative to clayey soils.

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Soil Endowments, Female Labor Force Participation and the Demographic Deficit of Women in India

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A demographic deficit of women relative to men has emerged as an indicator of severe gender-based discrimination in India (Sen 1990). However, the deficit of women is not equally pronounced everywhere. Sex ratios—defined by the ratio of female to male populations—exhibit remarkable heterogeneity across districts, even within the same state and cultural region (Dyson and Moore 1983; Agnihotri 1996). The deficit of women starts in early childhood. District sex ratios for the 0-to-6 year old population are more skewed in the North than in the South, and range from a minimum of 766 to a maximum of 1035 females per 1000 males.

This study argues that the heterogeneous female to male child ratios can be explained by differences in women's relative employment in agriculture across soil textures. In India, where 72 percent of the population is rural, the ratio of female to male children is inversely related to the difference between the fractions of loamy and clayey soil textures in a district. The soil texture exogenously determines the depth of land preparation (Müller and Schindler 1999). Deep tillage of land, only possible in loamy but not in clayey soil textures, saves labor in transplanting, fertilizing and weeding operations which are typically performed by women (Basant 1987). The lower demand for female relative to male labor reduces the relative economic value of women to a household.

The explanation I offer is informed by existing evidence of an association between agricultural practices and women's gainful employment; it also contributes to a literature on the impacts of adult sex-specific labor market opportunities on sex ratio outcomes. Earlier research documented that specialization along gender lines gives men an advantage in plough relative to shifting agriculture (Boserup 1970; Bardhan 1974, 1988; Miller 1982; Bosen 1989). Norms regarding gender-appropriate production roles are persistent and explain the lower female labor force participation in societies that historically

used the plough (Alesina, Giuliano and Nunn 2013).[1] In present-day plough agriculture, the gender-based division of production remains the same, but the use of labor across tasks and the participation of women vary with the depth of tillage (ASAE 2003).[2]

I link the effect of deep tillage on the demand for female labor in agriculture to the degree of discrimination against them. A low market value of female labor and limited female employment have been associated to fewer births of female children and greater survival differentials between boys and girls (Rosenzweig and Schultz 1982; Qian 2008). Conceivably, more household resources are allocated to female children in response to a higher return when female earnings and market opportunities improve (Rosenzweig and Schultz 1984).[3]

To test the proposed explanation, I use exogenous soil texture as a proxy for the depth of tillage. The physical type or texture of the soil defines the land workability and is not easily modified by land management practices. I exploit the variation in the fractions of loamy and clayey soil textures across districts within the same state, conditional on an exhaustive set of covariates.[4] Across districts within the same state, it is possible to isolate the impact of deep tillage from migration, culture and other channels which operate at higher or lower levels.

The identification strategy relies on the assumption that the exogenous soil texture fractions affect the rural child sex ratio exclusively through the impact of

[1] Shifting cultivation has been abandoned in favor of the plough; nowadays it is 10.1 percent of arable land in America, 7.2 in Africa, 8.3 in Oceania and 2.4 in South Asia. In India, shifting cultivation accounts for 1.3 percent of all cultivation lands (FAO 1985; Ninan 1992; MEF 2011).

[2] In contrast to the use of the plough, the depth of tillage does not determine the gender-based division of labor. The strength required in land preparation is a function of the depth of tillage and the resistance offered by the soil, which are inversely related (ASAE 2003). Deep and shallow tillage have similar strength requirements. Men always prepare the land.

[3] There are limited theoretical and empirical grounds to support a bargaining over a returns model (Rosenzweig and Schultz 1984; Folbre 1984). Although men and women allocate resources to different uses, there is no evidence that women have more benevolent preferences for girls relative to boys (Duflo 2012). Indeed, in India, mothers have a stronger son preference than fathers; and as mothers' education increases, they discriminate more effectively against girls (Das Gupta 1987).

[4] In main regressions, I control for temperature, rainfall and the content of nitrogen, phosporous, potasium and pH in the soil, which determine the soil quality and crop suitability. I also control for the share of population from rural areas and different religions, to account for the economic structure and beliefs about gender roles. In auxiliary regressions, I control for proxies of cropping patterns and income, including the area cultivated and yields of rice and wheat, real per-capita household expenditure, land ownership and district location relative to the direction of river flow.

deep tillage on relative female employment, conditional on state fixed effects and other controls. The empirical analysis confirms that the assumption is plausible. In loamier districts, I find higher stocks of deep-tillage equipment and draft animals per hectare of land as well as lower employment of labor in cultivation than in land preparation. In contrast, I find no differences by soil texture in the pattern of gender segregation of labor, the pattern of crop production or the measures of household income examined.

In reduced form regressions, I find that districts with larger fractions of loamy relative to clayey soils exhibit significantly lower rates of female participation in agriculture and significantly lower rural ratios of female to male children. The estimated impacts are sizable. Point estimates associated with a 10 percentage point difference between the fractions of loamy and clayey soils are comparable to 5.1 percent of the average rate of female participation as agricultural laborers, and 7.2 percent of the average deficit of girls relative to the natural sex ratio. Soil texture fractions also explain up to 23 (12.5) percent of the total (within-state) variation in the share of female agricultural laborers and up to 11 (9.1) percent of the total (within-state) variation in the rural child sex ratios. The results are robust to the choice of specification, sample and year.

Instrumental variable estimates of the relationship between relative female employment and the child sex ratio indicate an important impact of women's participation in the labor market. Using the exogenous fractions of loamy and clayey soils as instruments, I find that erasing the rural deficit of girls in India would require a 5.8 percentage point increase in the average share of female agricultural laborers in the rural work force. In the North, where cultural practices are believed to diminish the status, autonomy and mobility of women, a 7.1 percentage point increase would eliminate the rural deficit of girls.

The focus of this study on a persistent exogenous determinant of the demand for female labor in agriculture does not exclude the role of other economic factors

and cultural influences. The ratio of female to male children has been related to income, agricultural yield, cropping patterns, land ownership, fertility rates, maternal education and the practices of dowry payment, hypergamy and exogamy, among others (Krisanji 1987; Basu 1992; Rao 1993; Das Gupta and Bhat 1997; Rose 1999; Das Gupta et al. 2003). Nevertheless, the impacts of these factors contrast with the deficit of women across geographical units.[5] Large unexplained variation remains after accounting for their influence. Instead, the soil texture explains an important share of the total, within-state and residual variation in the relative employment of women in agriculture and in the ratio of female to male children.

To motivate the empirical work, in the next section, I begin by explaining the relationship between soil texture, depth of tillage and relative female employment. Section II describes the empirical methodology, provides evidence on the role of the depth of tillage and excludes alternative mechanisms. Section III presents reduced form estimates and robustness checks of the relationship between soil texture, relative female employment and rural child sex ratios. Section IV reports instrumental variable estimates of the impact of relative female labor force participation on the rural child sex ratios. Section V concludes.

I. Soil Texture, Agricultural Production and Demand for Labor

The soil texture is a physical property of the soil that varies little over time and is difficult to modify through land use. It is exogenously established over millennia as rock, the mineral parent material, disintegrates into particles of

[5] For instance, there is evidence that a decline in fertility intensifies the preferences for boys. However, the South of India exhibits a lower fertility level, a faster decline in fertility and more balanced sex ratios than the North (Das Gupta and Bhat 1997). The evidence also indicates that girls are normal goods, but sex ratios do not vary in the expected way with regional differences in per-capita income, assets or food availability (Bardhan 1974; Das Gupta 1997; Rose 1999). Female education has a positive effect on the birth and survival of girls, but in the North more educated mothers are more effective at sex-selection (Das Gupta 1987; Miller 1982; Murthi, Guio and Dreze 1995). Transfers at marriage increase the cost of having a daughter, but the dowry custom is spreading from the North to the South without consequences on the sex ratio (Das Gupta 1987).

different sizes. According to the proportion in which small, medium and large particles are combined in the soil, the soil texture can range from very fine clay, to medium loam, to very coarse sand. Finer soils have higher particle density and lower pore space than coarser soils. As a result, they are heavier, tighter and more difficult to work. They have poorer aeration and water intake, but lower percolation and better retention of cations (USDA 1993; Troeh and Thompson 2005).[6]

The workability and mechanical features determined by the soil texture make deep tillage possible in loamy soils but not in clayey soils (Wildman 1981; USDA 1993; Müller and Schindler 1999; Troeh and Thompson 2005; Alamouti and Navabzadeh 2007). When soils are so finely textured as to be classified as clayey, they are unyielding when dry and sticky when wet. Instead, medium loamy soils are easy to break at any moisture level (Müller and Schindler 1999). Suitable aeration, moisture and cation exchange conditions for plant growth are obtained near the ground surface in clayey soils and deeper below the ground in loamy soils (Wildman 1981; Alamouti and Navabzadeh 2007).[7]

Other than the depth of tillage, the quality and crop suitability of a soil are not determined by soil texture and are not exogenous (Doran and Parkin 1994; Karlen et al. 1997; Troeh and Thompson 2005). The quality and crop suitability are the capacity of the soil to meet the nutrient, moisture and aeration needs of one or more plant species. They are shaped by physical, chemical and biological soil traits as well as meteorological, organic, mineral and hydraulic factors (Troeh and Thompson 2005).[8] In order to suit a wider variety of crops and to increase yields, they are frequently modified through land and crop management practices such as

[6] Cation exchange is the innate ability of a soil to retain cations, some of which are plant nutrients.

[7] Clayey soils are prepared by breaking up clods and lumps in the top 2 to 6 inches. Loamy soils are turned over to a depth of 12 inches (Troeh and Thompson 2005).

[8] For instance, a sandy texture is inherently porous and permeable. However, the water retention of sandy soils is determined by the rainfall and temperature levels; the content of organic matter, iron and aluminum oxides; the closeness to a water table and the presence of a hard pan.

irrigation, tillage, fertilizing and fallowing (Troeh, Hobbs and Donahue 1991; Carter 2002). The quality and suitability of a soil are more accurately assessed by the yield of a crop than by single soil markers (USDA 1993; Doran and Jones 1996; Karlen et al. 1997).[9] Conditional on physical, chemical and biological attributes and other exogenous influences, soil texture has no significant impact on a crop yield (Gregorich and Carter 1997; Troeh and Thompson 2005).

Deep tillage of loamy soils reduces the overall use of labor and, disproportionally, the use of female labor in agricultural production (Burton and Reitz 1981; Basant 1987). Deep tillage lowers the demand for labor in transplanting, fertilizing and weeding relative to land preparation (Burton and Reitz 1981; Troeh and Thompson 2005).[10] Land preparation is relatively capital intensive, requires great physical strength and is predominantly done by men. The remaining cultivation activities are relatively more labor intensive and typically performed by women (Basant 1987; Foster and Rosenzweig 1996).[11] Women are equally unlikely to prepare the land in loamy and clayey soils.[12] Given the gender segregation and relative labor intensities of the agricultural tasks, deep tillage reduces both female and male employment and female relative to male employment.

The depth of tillage has no other known effects on agricultural yields, crop mix, cultivation cycles and cultivated area (Wildman 1981; Pingali, Bigot and Binswanger 1987; Alamouti and Navabzadeh 2007). Only the transition from shifting to plough cultivation has been attributed those impacts (Binswanger 1986; Ellis 1992). Deep tillage in loamy soils offers the same conditions for the

[9] For example, although yields increase with soil pH, optimum values are crop-specific and vary with other physical, chemical and biological soil markers. Therefore, the quality and suitability of the soil cannot be assess based on pH alone, but conditional on crop type and other determinants.

[10] Deep tillage helps root development, reintegrates moisture and nutrients, and uproots weeds.

[11] The occupational distribution of workers has been explained by productivity differentials and statistical discrimination (Foster and Rosenzweig 1996).

[12] In contrasts, the strength requirement is greater and the use of female labor in land preparation is lower in plough relative to shifting cultivation (Boserup 1970).

growth and yield of a crop than shallow tillage in clayey soils (Wildman 1981).[13] Similarly, the variation in climate across seasons and the availability of productive soils—not the depth of tillage—determine the length of cultivation, the number and frequency of cropping cycles and the area of cultivated lands (Binswanger 1986; Ellis 1992).[14]

II. Empirical Strategy

To distinguish the effect of deep tillage, I build on the exogenous geographical variation in soil texture. The soil texture is described by the fraction of district area in clayey, loamy and sandy soils. Within a given state in India, I compare districts that have different loamy and clayey soil fractions, holding sandy soils constant. The identification relies on the assumption that the difference between the fractions of loamy and clayey soils is associated exclusively with deep tillage in land preparation and the use of labor across the sequence of tasks.

My empirical analysis starts by corroborating that the identification assumption is plausible. I estimate:

$$Y_{sd} = \alpha_{1s} + \beta_{1Loam} T_{Loam,sd} + \beta_{1Clay} T_{Clay,sd} + \mathbf{X}_{sd}\boldsymbol{\theta}_1 + \varepsilon_{1sd}, \quad (1)$$

where Y_{sd} is the outcome observed in district *d* in state *s*; $T_{Loam,sd}$ and $T_{Clay,sd}$ are the fractions of district area in loamy and clayey soil textures; and $\mathbf{X}_{sd}$ includes temperature, rainfall, soil pH, phosphorus, nitrogen and potassium—which exogenously define the quality and crop suitability of the soil. I control for state

[13] The depth of tillage minimizes the differences in physical functioning between loamy and clayey soils. Deep tillage improves the moisture and nutrient retention of loamy soils, and shallow tillage improves the aeration and drainage of clayey soils (Troeh and Thompson 2005).

[14] This is particularly true in India, where labor is abundant relatively to other agricultural inputs. Although the labor saved by deep tillage could be employed in growing higher value crops or in increasing the area cultivated, no significant impacts have been found.

fixed effects α_{1s} and cluster standard errors at the state level. The difference $\beta_{1Loam} - \beta_{1Clay}$ is the effect of deep tillage.

I construct a district-level dataset that combines information collected from multiple sources (see appendix Data Sources). I match administrative divisions from all datasets to district boundaries from the 2001 census and obtain a sample size of 584 districts, with complete information available for 358 districts.

Data from the 1991 *Soils of India* show a large variation in soil textures across states and across districts within the same state. Clayey soils are rarer than loamy soils in the North compared to the South. In the North, 56 percent of districts have some area in clayey soils, relative to 96 percent of districts with some area in loamy soils. In the South, the percentages of districts with some area in clayey and loamy soils are more similar: 79 and 99 percent, respectively. On an average district, 66 percent of the district area is covered with loamy soils, 22 percent with clayey soils and 11 percent with sandy soils.

Markers of weather and soil chemical traits exhibit geographical variation, but they do not vary by soil texture across districts within the same state. In Table A.1, panels A and B, I provide summary statistics of selected indicators of weather and soil nutrients for all districts and by soil texture, conditional on state fixed effects. Rainfall, temperature and the content of nitrogen, phosphorus and potassium in the soil are not associated with the fraction of loamy relative to clayey soils in a district. There is a significant difference by soil texture in soil pH, an indicator of soil acidity, but the sign cannot be explained by soil texture.[15]

Information on the depth of tillage is not available at the district level. However, the stocks of equipment and draft animals employed in deep tillage are a good proxy. Primary-tillage equipment, mechanical or animal-drawn, can only

[15] In the sample examined, loamier districts are more likely to have acidic soils (pH<7.5) and less likely to have alkaline soils (pH>7.5). If soil acidity were driven by soil texture, loamier areas would have higher pH because loams have inherently lower cation exchange capacity than clays.

be employed in deep tillage in loamy soils. Instead, equipment used in secondary-tillage and other cultivation tasks can be employed in both loamy and clayey soils.[16] In Table 1, panel A, I use data from the 2000/01 *Agricultural Census and Input Survey* to estimate regressions of stocks of selected equipment and livestock on the fractions of loamy and clayey soils. I find that a 10 percentage point higher fraction of loamy to clayey soils is significantly associated with 7.3 percentage points more primary-tillage equipment and 4.1 percentage points more buffalos, the main source of animal traction. In contrast, the stocks of equipment used in secondary tillage, sowing, transplanting, fertilizing, weeding and harvesting as well as the stocks of non-draft animals do not vary with soil texture.[17]

The relative use of male and female labor across agricultural tasks is summarized by the shares of men and women who perform land preparation and other cultivation activities over the total number of agricultural workers.[18] Figures obtained from the 1999/2000 *National Sample Survey* (*NSS*) confirm that the participation of women in land preparation is minimal. Of all agricultural labor, only 1.3 percent is female in land preparation. In comparison, males in the same activity comprise 15 percent. In Table 1, panel B, I estimate the impact of loamy relative to clayey soils on the use of labor across the sequence of tasks. I find that the share of women in land preparation does not vary with soil texture and that the share of men in land preparation is significantly larger in loamier districts. Overall, the share of workers in land preparation is 10 percentage points larger and the share in other cultivation tasks is 11 percentage points smaller in loamier

[16] Secondary-tillage equipment is used after the deep tillage of loams to crush clods and make a firm and smooth seedbed. Primary-tillage equipment is not used in clays because these soils resist being broken, and the power required to break them can damage their hardpan (Wildman 1981).

[17] Primary-tillage equipment: tillers, mouldboards, steel ploughs, wood ploughs and disc harrows. Secondary-tillage equipment: wood ploughs, disc harrows, tooths, rollers, hoes, levelers and kahans. Weeding tools: hoes, weeders, triphalis and forks. Sowing and fertilizing tools: sticks, chisels, drills and planters. Harvesting equipment: harvesters, reapers and threshers. Other livestock: cattle, horses, ponies, mules, donkeys, asses, sheep, goats, pigs and poultry.

[18] Since a worker performs more than one activity, the shares add to more than 100 percent.

areas.[19] The findings suggest that the pattern of gender segregation remains the same across soil textures, but the relative demand for labor across tasks varies. A higher fraction of loamy relative to clayey soils in a district is associated with a decline in total labor use and in the use of female relative to male labor.

The yield and the gross area cultivated in rice relative to wheat, the two dominant crops in India, inform on soil productivity and crop suitability.[20] Although there is considerable spatial variation in soil texture, crop production data from the 1997-2001 *Indian Agricultural Statistics* show that 79 percent of all districts in India cultivate rotations of both rice and wheat.[21] Statistics on GDP or household income at the district level are not produced in India. Instead, the average real per-capita household expenditure, the percentage of households that own land, and the average size of land owned by a household in a district are obtained from the 1999/2000 *NSS*. All monetary values are adjusted using the *Consumer Price Index Numbers for Agricultural and Rural Laborers*. In Table 1, panel C, I estimate regressions for a subset of outcomes on the fractions of loamy and clayey soils. Soil texture has an insignificant impact on the outcomes reported and on the larger set of outcomes examined. I find no evidence that soil texture shapes the productivity of the soil or its suitability for a certain crop. More generally, I find no evidence that households are richer, are more likely to be landed, or hold more land in loamier relative to more clayey districts.

In summary, only the depth of tillage is determined by soil texture and can explain the demand for labor across agricultural production tasks. A number of studies have identified significant effects of meteorological variables, agricultural yield, household wealth and the cultivation of rice and wheat crops on the

[19] I also find that 10 additional percentage points of loamy relative to clayey soils are associated with the employment of 5.4 percent more men-days in land preparation. The numbers of women-days in land preparation and of men- and women-days in cultivation remain unchanged.

[20] The gross area counts the area sown as many times as there are sowings in a year.

[21] The years between 1997 and 2001 correspond to the birth of children under six years old. I obtain 5-year averages of crop production and area cultivated.

participation of women in agriculture and on the child sex ratio (Bardhan 1974; Miller 1982; Rosenzweig and Schultz 1982; Dyson and Moore 1983; Krisanji 1987; Das Gupta and Shuzhuo 1999; Rose 1999; Mbiti 2007).[22] Nevertheless, I find that their influences are independent of soil texture.[23] Likewise, soil texture is not associated with the level of capital, the extent of mechanization or the practice of plough agriculture. I find no differences by soil texture in the overall use of equipment, the use of power operated equipment, the use of ploughs in primary and secondary tillage or the participation of women in land preparation.

III. Reduced Form Impacts of Soil Texture on Agricultural Employment and Child Sex Ratio

Having clarified the association between soil texture, depth of tillage and labor use across tasks, I move to examine the reduced form relationship between soil texture, men and women's employment in agriculture and sex ratio:

$$Y_{sd} = \alpha_{2s} + \beta_{2Loam} T_{Loam,sd} + \beta_{2Clay} T_{Clay,sd} + \mathbf{X}_{sd}\boldsymbol{\theta}_2 + \mathbf{Z}_{sd}\boldsymbol{\delta}_2 + \varepsilon_{2sd}. \quad (2)$$

I measure the employment and sex ratio outcomes Y_{sd} using information from the 2001 *Census of India*. The census reports the district-level enumeration totals of female and male workers of all ages, as well as female and male population of all ages and under six years old. No census micro-data are available. Accordingly, I define the labor force participation rate as the ratio of workers to population of all ages, and the sex ratio as the number of females per 1000 males under six

[22] Rainfall and agricultural yields have positive impacts on the demand for female labor and the ratio of women to men (Rosenzweig and Schultz 1982; Mbiti 2007; Rose 1999). High household income reduces both the supply of female labor and the female to male child sex ratio (Krisanji 1987; Das Gupta and Shuzhuo 1999). Wheat cultivation is associated with lower female labor force participation and a stronger son bias (Bardhan 1974; Miller 1982; Dyson and Moore 1983).

[23] Given soil texture, no significant differences in the tasks performed by men and women are found between rice and wheat cropping in the same plot (Sethi 1991; Varma 1992). On the contrary, keeping crop constant, there are significant differences in tasks and labor use between loamy and clayey soils. In rice cultivation—identified with greater use of female labor—women have a more significant role when rice is broadcast-sown rather than deep-sown (Miller 1982).

years old. I focus on the child sex ratio rather than the population sex ratio because the former is more likely to result from differential treatment than from migration.[24]

On average across all 584 districts in India, the rural child sex ratio is 934 female per 1000 male children, the rural female (male) labor force participation rate is 33 (52) percent, and agriculture employs 76 percent of female rural workers. The figures mask wide heterogeneity. Rural child sex ratios range from 757 to 1038 girls per 1000 boys, and female labor participation rates in agriculture vary from 0.57 to 60 percent.[25] Geographically, the variation in the ratio of female to male children and in the labor force participation rate of women relative to men somewhat resembles the distribution of soils by texture.

I account for a number of factors $\mathbf{Z}_{sd}$ that may shape the preferences for child gender and the level of female relative to male employment. In main regressions, I include the fraction of rural population and the total district area to control for the influence of the structure and the scale of economic activity on the demand for labor. I also include the fractions of Muslims, Sikhs, Jains, scheduled castes and scheduled tribes to control for the beliefs and characteristics of religion and ethnic groups, which may be correlated with gender roles, and the supply of female labor. Since the yield of rice and wheat, the real per-capita household expenditure, the percentage of households that own land and the average area of land owned may be endogenous to $\mathbf{X}_{sd}$, I include them only in auxiliary regressions to control for their independent effect on demographic and labor market outcomes.

Other potential confounders such as migration of workers, culture and institutions operate at levels higher or lower than the district and are less likely to

[24] No information on the sex ratio at birth or at age 0 is available. Birth records in India are deficient and the census does not report population numbers disaggregated by age.

[25] Rural female labor force participation varies substantially across districts, from 4.7 to 64 percent. Male participation exhibits a more limited range of variation, from 40 to 76 percent.

affect comparisons across districts within the same state. If women from loamy areas were employed in clayey areas, household- or village-level estimates of the effect of soil texture would be biased downward. However, district-level impacts can be correctly identified because labor markets and migration are confined within district boundaries (Foster and Rosenzweig 2001). Likewise, if norms or institutions adverse to women emerged in loamier districts, the effect of the depth of tillage could not be distinguished from cultural and institutional channels. However, their influence can be differentiated-out because they are homogeneous across districts within a given state (Dyson and Moore 1983; Agnihotri 1996).[26]

In Table A.1, panel C, I present summary statistics for selected confounders $\mathbf{Z}_{sd}$. I find no significant differences by soil texture in the percentage of rural, Muslim and Sikh populations, in household size, in female and male wages or in migration rates.[27] I find a higher percentage of scheduled tribes and a lower percentage of Jains and scheduled castes in loamier districts, but the child sex ratios for those population groups do not vary with soil texture.[28] To the extent that there are no significant systematic differences by soil texture, conditional on state fixed effects, these confounders do not pose a threat for identification.[29]

In Table 2, I estimate ordinary least squares (OLS) regressions of the child sex ratio, the employment of male and female labor, and the relative employment of women on the fractions of loamy and clayey soils for a sample of districts that have complete data. The specification reported includes all exogenous control variables and states fixed effects. The difference between the coefficients on

[26] If differences in culture and institutions by soil texture remained within a state, the impact of deep tillage would be overstated but the effect of soil texture would still be identified.

[27] On average, only 7.8 (1.6) percent of women (men) in a district are immigrants from a different district within the same state. I do not find significant differences by soil texture in the percentage of immigrants, the location of previous residence or the reason for migration.

[28] If omitted, their influence could attenuate the estimated effect of soil texture because women's social value is high in scheduled tribes and low in Jain and scheduled castes (Agnihotri 1996).

[29] Previously, in Table 1, I showed that rice and wheat crops, agricultural yield and indicators of household wealth were not explained by soil texture conditional on $\mathbf{X}_{sd}$.

loamy and clayey soils is negative and statistically significant at the 0.1 percent level. The F-tests for joint significance and the associated p-values indicate that the soil texture fractions always have strong predictive power.

In Figure A.1, partial correlation plots make evident the order of magnitude of the estimated impacts. The plots show that the sex ratios and relative female labor force participation vary considerably within the boundaries of a state. The estimates are not driven by a few districts and are not only identified from differences across states, but mainly from within-state variation.[30]

In Table 2, col. 1, the outcome variable is the ratio of 0-to-6 year old female to male children who reside in rural areas. To assess the magnitude of the estimated impact, I compare the difference between the coefficients on loamy and clayey soil texture fractions against the average deficit of girls, defined relative to the natural sex ratio outcome of 950 girls per 1000 boys.[31] The estimates indicate that a 10 percentage point higher fraction of loamy relative to clayey soils is associated with a reduction of 1.8 girls per 1000 boys, an impact equal to 7.2 percent of the average deficit of 25 girls per 1000 boys in the estimation sample.[32]

In Table 2, col. 2 to 5, I turn to examine different measures of female and male employment in agriculture. I distinguish between agricultural workers and agricultural laborers. *Agricultural workers* are all workers, landed or landless, employed in their own or in others' land, with or without pay. Agricultural workers comprise agricultural laborers and cultivators. *Agricultural laborers* are employed in others' lands, are engaged during peak period and attend to rush

[30] This can also be observed by comparing regressions with and without state fixed effects (Table 2 and Table A.2). The full specification explains 81, 70 and 67 percent of the variation in the rural child sex ratio and the shares of female agricultural workers and laborers, respectively. The state fixed effects account for 11 to 12 percentage points of the total explained variation.

[31] A natural outcome of 950 girls per 1000 boys is observed in the developed world and societies where sex-selective discrimination is not practiced (Johansson and Nygren 1991; Coale 1991).

[32] The percent change in the deficit relative to the natural sex ratio is (-18.2*0.1)/(950-924.7).

work only.[33] The demand for agricultural laborers has been found to be important for the participation of women in agriculture (Basu and Basu 1991). Of all women (men) in rural areas across all 584 districts in India, 27 (36) percent are agricultural workers and 11 (12) percent are agricultural laborers.

According to regression estimates, a 10 percentage point larger difference between the fraction of loamy and clayey soils reduces the participation rate of female (male) agricultural laborers by 0.76 (0.54) percentage points, which is equal to 5.1 (3.6) percent of the average participation rate as agricultural laborers. The effect on female (male) agricultural workers is a smaller reduction by 0.52 (0.35) percentage points, equivalent to 1.9 (0.92) percent of the average participation rate as agricultural workers in the estimation sample.

The estimates are consistent with the anticipated impacts of soil texture on the demand for labor. The fraction of loamy relative to clayey soils has a negative impact on employment, particularly of women relative to men. The results also reveal that differences in agricultural employment by soil texture are significantly driven by agricultural laborers. There is larger variation by soil texture in the participation of agricultural laborers than in all agricultural workers.[34]

Finally, in Table 2, col. 6 and 7, I examine two measures of relative female labor force participation: the ratio of female agricultural workers to all rural workers and the ratio of female agricultural laborers to all rural workers. Alternative measures such as the ratio of female to male agricultural participation rates give a distorted picture of the relative contribution of women to the labor force across geographical units. They mask important differences in female and male population sizes and district economic structure. For a given number of

[33] Instead, *cultivators* are permanent or attached agricultural workers employed in their own or in others' lands, engaged on annual or seasonal basis and not ordinarily free to seek work elsewhere.

[34] In rural areas, the employment of women is driven by agriculture, but men are more likely to participate in non-agricultural activities. In regressions not reported, the impact of soil texture on total rural female labor was significant and similar to that on agricultural female workers. On the contrary, the labor force participation of rural men is not affected by soil texture.

female and male workers, higher relative female participation rates are recorded in areas that have relatively fewer women. Moreover, greater employment opportunities for men outside agriculture result in artificially high measures of relative female labor participation in agriculture (Miller 1982).

Soil texture has a significant negative impact on the relative labor force participation of women. A 10 percentage point larger difference between the fraction of loamy and clayey soil textures reduces the share of female agricultural laborers (workers) by 0.82 (0.57) percentage points, equivalent to 5.1 (2) percent of their average share in the rural work force in the estimation sample.[35]

A. Robustness to Alternative Specifications

In Tables A.3 to A.5, I show estimation results for alternative specifications. I use the maximum available sample of districts and allow the sample size to vary. Col. 1 and 2 start with raw and fixed-effects regressions on soil texture fractions alone. Col. 3 to 7 gradually introduce control variables, from exogenous rainfall and temperature to potentially endogenous income and crop production. Col. 8 additionally controls for the district location relative to the direction of river flow, a possible exogenous proxy for the latter.

The estimated impacts continue to be negative and statistically significant, and clayey and loamy soil fractions remain jointly significant. The magnitudes of the estimates are fairly stable. Impacts range from -15.4 to -18.3 in fixed effect regressions of the child sex ratio, from -0.046 to -0.077 in regressions of the share of female agricultural workers, and from -0.066 to -0.082 in regressions of the share of female agricultural laborers.[36]

[35] The results remain robust to the use of alternative measures.

[36] Estimates are similar for other measures of female and male labor force participation and when the sample size is kept constant across columns.

A comparison of specifications reveals that the omission of covariates would bias downward the estimated impact of soil texture (col. 2 and 5). Furthermore, the fractions of loamy and clayey soils explain a sizeable share of the total, within-state and residual variation in outcomes. Soil texture accounts for 11, 13 and 11 percent of the total variation—across all districts and states—in the rural child sex ratio and the share of female agricultural workers and laborers, respectively (col. 1). It also accounts for 9.1, 2.3 and 8.8 percent of their within-state variation (col. 2), as well as for 5, 6.2 and 8.3 percent of their residual variation (col. 5)—left unexplained by other control variables.[37] In the sample of districts with complete data, soil texture explains up to 11, 17 and 23 percent of their total variation and 3.2, 6.3 and 12.5 percent of their within-state variation, correspondingly.

B. Robustness to Alternative Samples

In India, historically lower female autonomy and greater neglect of female children in the North and Northwest resemble marked contrasts in kinship structure relative to the South, and less pronounced cultural variations relative to the East (Bose and Kumar 1994; Agnihotri 2000).[38] Similarly, women's labor and demographic outcomes vary with differences in economic opportunities and gender norms between rural and urban areas (Das Gupta, Chung and Shuzhuo 2009), and with differences in the level and variability of agricultural production, as observed between districts located upstream and downstream a river

[37] The share explained by soil texture is the difference between the R-squares in regressions with and without soil texture fractions, divided by the variation left unexplained in the latter. In Table A.3, col. 1, the R-square of a regression on soil texture alone is 0.11. Inclusion of soil texture variables in Table A.3, col. 2 (col. 5), increased the R-squared from 0.67 to 0.7 (from 0.80 to 0.81). Therefore, the share of total variation explained by soil texture is 0.11, the share of within-state variation is 0.091=0.03/(1-0.67) and the share of residual variation is 0.05=0.01/(1-0.8).

[38] The low status of women is attributed to a greater presence of Muslim population and the customs of exogamy, hypergamy, patrilocality, patrilineal inheritance, dowry payments, low age at marriage and female seclusion (Sopher 1980; Miller 1982; Dyson and Moore 1983).

(Rosenzweig and Schultz 1982; Rose 1999, 2001; Duflo and Pande 2007; Duflo 2012).

In Table 3, I verify the extent to which the results are driven by un-modeled differences along those dimensions. I consecutively omit Southern and Eastern districts (panels A and B); and restrict the estimation sample to districts where the population is less than 50 percent urban (panel C), and districts located downstream of a river (panel D).[39] I choose this strategy over the inclusion of proxy variables because the influences of culture, urbanization and direction of river flow cannot be fully captured and are potentially endogenous.[40]

The impact of soil texture is reasonably robust to the choice of sample. The point estimates continue to be negative and statistically significant and their magnitude remains roughly similar. A 10 percentage point larger difference between loamy and clayey soil fractions is associated with 1.4–2.1 fewer girls per 1000 boys, a 5.5–8.7 percentage point lower share of female agricultural workers, and a 7.4–8.5 percentage point lower share of female agricultural laborers.[41]

The results are irreconcilable with un-modeled influences of cultural system, urbanization and direction of river flow. Soil texture has a larger impact and explains a greater share of the total variation in the sex ratio and relative female labor force participation in the patriarchal North than in the South and East, as well as in less urbanized districts of India. Instead, in downstream districts, the estimated impact of soil texture on the child sex ratio is smaller and less precise,

[39] I exclude districts in the South and East, more urban districts, and upstream and neither-upstream-nor-downstream so as to maximize sample size. The standard North-South division of cultural regions in India is defined by the Satpura and Chota Nagpur Hills, and the East-Northwest demarcation by the state border of West Bengal (Dyson and Moore 1983; Sopher 1980).

[40] For instance, the distance of female migration due to marriage—a proxy for patrilocality and the cultural worth of women—is shorter when the labor contributions and local availability of females are higher (Min and Eades 1995). Similarly, dowry payments increase when the contribution of women to the household declines (Kishor 1993). Moreover, industrialization and urbanization take place faster where relative female productivity in agriculture is lower (Goldin and Sokoloff 1984).

[41] I obtained similar results in regressions for the sub-sample of districts that do not have a major urban center, and in full-sample regressions that included dummies for district location relative to river flow and controls for river gradient, length and elevation (Tables A.3 to A.5, col. 8).

the impact on the share of agricultural workers is larger, and the impact on the share of agricultural laborers remains unchanged.

C. Robustness to Alternative Years

The results are also robust to alternative estimation years. In Table 4, I obtain pooled-regression estimates of the impacts of soil texture between 1961 and 2001, for a sample of districts that have complete information.[42] In that period, the average rural child sex ratio in India decreased from 977 to 934 girls per 1000 boys, and the share of female agricultural workers fluctuated between 24 and 29 percent of the rural work force. However, the influence of soil texture is persistent. Point estimates remained negative and highly statistically significant, and their magnitude stayed unchanged. Moreover, the soil texture fractions continued to explain a substantial part of the variation in the child sex ratio and the share of female agricultural workers. Urbanization and employment opportunities in the modern sector have not lessened the impact of soil texture.[43]

IV. Instrumental Variables Estimates of the Impact of Relative Female Employment on the Child Sex Ratio

The findings from the reduced form suggest the following structural relationship:

$$\text{(3)} \qquad SR_{sd} = \alpha_{3s} + \beta_3 FLFP_{sd} + \mathbf{X}_{sd}\boldsymbol{\theta}_3 + \mathbf{Z}_{sd}\boldsymbol{\delta}_3 + \varepsilon_{3sd},$$

$$\text{(4)} \qquad FLFP_{sd} = \alpha_{4s} + \beta_{4Loam} T_{Loam,sd} + \beta_{4Clay} T_{Clay,sd} + \mathbf{X}_{sd}\boldsymbol{\theta}_4 + \mathbf{Z}_{sd}\boldsymbol{\delta}_4 + \varepsilon_{4sd},$$

[42] I use the ratio of female to male 0-to-9 year olds and the ratio of female agricultural workers to total rural workers. The census does not report the population under six years old before 2001 or the number of agricultural workers in 1971 and 1991. Soil texture data are available only for 1991, but it is reasonable to assume that it remained the same over the period examined.

[43] Other factors may explain the fall in female labor and female-to-male child sex ratios. In fact, the child sex ratio and female labor force participation rate are smaller in urban than in rural areas.

where the soil texture fractions $T_{Loam,sd}$ and $T_{Clay,sd}$ influence only the relative female employment $FLFP_{sd}$. In contrast, $\mathbf{X}_{sd}$ and $\mathbf{Z}_{sd}$ influence both $FLFP_{sd}$ and the child sex ratio SR_{sd}. For instance, religion and caste may shape the attitudes towards female children and female labor. Weather, soil quality and crop suitability have a direct effect on the demand for labor but also have indirect effects—through agricultural yields and income—on the supply of female labor and the demand for female children.

In Table 5, I assess the impact of relative female employment on the rural ratio of female to male children. I exploit the fractions of loamy and clayey soils in a district as exogenous instruments. The identification rests on the assumption that soil texture affects the rural child sex ratio exclusively through relative female employment, conditional on state fixed effects. Other controls are not used as instruments as they are not exogenous or do not satisfy the exclusion restriction. Soil chemical and biological attributes that determine the quality and crop suitability of the soil are endogenous; and exogenous rainfall and temperature affect the child sex ratio through channels other than female labor.[44] For comparison, I also obtain ordinary least squares estimates.

In Table 5, col. 1, I report instrumental variable results for the full available sample of districts. In the first stage, the soil texture fractions have strong predictive power (Table 2, col. 6 and 7). I find that 10 additional percentage points in the share of female agricultural laborers (workers) in the rural work force is estimated to increase the relative number of rural 0-to-6 year olds by 44 (28) girls per 1000 boys, from an average ratio of 925 to a ratio of 969 (953). The estimated effect is larger than the average rural deficit of 25 girls per 1000 boys.

[44] Soil chemical and biological attributes that define the soil quality are easily and frequently modified to improve crop yields and crop suitability (Troeh, Hobbs and Donahue 1991).

The deficit could be erased by a smaller 5.8 (9) percentage point increase in the share of female agricultural laborers (workers) in the rural work force, from a sample average of 0.16 to 0.22 (0.29 to 0.38).[45]

In Table 5, col. 2, I report similar estimates for the North of India. The first-stage F-statistics are lower, but the p-values show that the instruments remain jointly significant (Table 3, panel A, columns 2 and 3). A 10 percentage point higher share of female agricultural laborers (workers) in the rural work force would increase the rural child sex ratio by 54 (34) girls per 1000 boys. Effects of this order raise the rural child sex ratio in the North to above the natural outcome, from 912 to 966 (946). In the North, eliminating the outstanding sex ratio imbalance would require a 7.1 (11.2) percentage point increase in the share of female laborers (workers) in the rural work force, from a sample average of 0.12 to 0.19 (0.27 to 0.38).[46]

The instrumental variables results have important implications for policy. Greater relative female economic opportunities lead to higher female labor force participation and higher female-to-male child sex ratios. Economic factors have a more important influence when non-equalitarian perceptions regarding the role and value of women exist.

V. Conclusions

This study provides evidence that deep tillage, only possible in soils with a loamy texture, reduces female relative to male employment in agriculture and has a negative influence on the rural ratio of female to male children.

[45] The required increase in the share of female agricultural laborers is 0.058=(950-924.7)/281.7 and in the share of female agricultural laborers is 0.0898=(950-924.7)/439.2. In a related study, I find that proximate determinants of the child sex ratios include greater pre-natal sex selection and lower vaccination of girls relative to boys in loamier districts, where labor market opportunities for women are fewer (Carranza 2011).

[46] In the South, a 10 percentage point higher share of female agricultural laborers (workers) in the rural work force would increase the rural child sex ratio by 23 (14) girls per 1000 boys, from 948 to 972 (963). Eliminating the deficit of girls would only need a 0.7 (1.1) percentage point increase in the share of female laborers, from a sample average of 0.22 to 0.23 (0.33 to 0.34).

Point estimates indicate that 10 additional percentage points in the share of loamy relative to clayey soils in a district are associated with a 5.1 percent decline in the share of female agricultural laborers and a 7.2 percent increase in the deficit of female to male children. Soil texture fractions also explain a sizeable proportion of the total, within-state and residual variation in the relative female agricultural labor force participation and the 0-to-6 year old sex ratios.

The relationship between the soil texture, the relative female labor force participation and the ratio of girls to boys in rural areas is highly robust to different specifications, samples and estimation years. In particular, the estimated impacts are larger in the less gender-equalitarian and patriarchal North of India. Moreover, the impacts of soil texture have not significantly changed between 1961 and 2001.

Using soil texture fractions as instruments, I find that a 5.8 percentage point increase in the share of female agricultural laborers in the rural work force could eliminate the rural deficit of girls. The result suggests that a reduction of the male-female differential in employment opportunities in rural India can substantially improve the survival chances of girls.

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TABLE 1—CROPPING PATTERNS, AGRICULTURAL YIELDS, INCOME AND DEEP TILLAGE BY SOIL TEXTURE

	(1)	(2)	(3)	(4)
	Mean/ Std. Dev.	Loamy Soils - Clayey Soils	R-Squared	Observations
Panel A: Livestock and equipment per hectare of land				
Buffaloes	0.78	0.41***	0.71	331
	[0.82]	(0.14)		
Primary-tillage equipment	1.78	0.73**	0.71	331
	[2.01]	(0.34)		
Secondary-tillage equipment	0.31	0.033	0.37	331
	[0.27]	(0.068)		
Sowing equipment	0.014	-0.0055	0.19	331
	[0.027]	(0.0077)		
Weeding equipment	0.20	0.11	0.64	331
	[0.40]	(0.076)		
Harvesting equipment	0.22	0.0011	0.54	331
	[0.42]	(0.090)		
Panel B: Workers by task and gender as share of all agricultural workers				
Workers in land preparation	0.16	0.10***	0.18	358
	[0.13]	(0.038)		
Workers in other cultivation tasks	0.87	-0.11***	0.19	358
	[0.13]	(0.039)		
Females in land preparation	0.013	0.0019	0.19	358
	[0.023]	(0.0067)		
Females in other cultivation tasks	0.31	-0.043	0.66	358
	[0.18]	(0.034)		
Males in land preparation	0.15	0.100***	0.19	358
	[0.12]	(0.036)		
Males in other cultivation tasks	0.56	-0.065	0.55	358
	[0.20]	(0.043)		
Panel C: Crops, yield and income				
Rice Yield, in t/ha	1715.4	127.8	0.75	365
	[1014.8]	(155.0)		
Wheat Yield, in t/ha	1821.1	103.6	0.86	365
	[1265.5]	(146.4)		
Rice to Wheat Yield	1.08	0.42	0.47	297
	[1.45]	(0.37)		
Rice to Wheat Area	1659.7	-5593.1	0.10	309
	[16794.6]	(5532.3)		
Per-Capita Expenditure, in real Rs	428.2	6.43	0.74	358
	[98.4]	(15.6)		

Notes: Column 1 reports average and standard deviation across all districts. Column 2 reports the difference between the coefficients on loamy and clayey soils, from the regression of indicated variables on the fractions of district area in loamy and clayey soils and state fixed effects (sandy soils constant). Other controls: Weather: temperature and rainfall. Soil attributes: nitrogen, phosphorus and potassium in the top 25cm of soil, and dummies for soil pH range values.

*** Significant at the 0.1 percent level.

** Significant at the 1 percent level.

* Significant at the 5 percent level.

TABLE 2—RURAL 0-TO-6 SEX RATIO, LABOR FORCE PARTICIPATION RATES AND SHARE OF FEMALE AGRICULTURAL WORKERS AND LABORERS ON SOIL TEXTURE

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Dependent Variable:						
	Rural 0-to-6 Sex Ratio	Female Agricultural		Male Agricultural		Female Agricultural To Total Rural Workers	
		Workers	Laborers	Workers	Laborers	Workers	Laborers
Loamy soils - Clayey soils	-18.2***	-0.052***	-0.076***	-0.035***	-0.054***	-0.057***	-0.082***
	(6.68)	(0.020)	(0.014)	(0.014)	(0.011)	(0.019)	(0.014)
F-test for soil texture	4.37	6.12	15.27	4.00	12.02	8.15	17.58
p-value	0.01	0.00	0.00	0.02	0.00	0.00	0.00
R-squared	0.81	0.73	0.72	0.57	0.68	0.70	0.67
F	41.57	27.51	25.28	13.56	21.18	23.37	20.68
Observations	365	365	365	365	365	365	365
Variable Means							
Dependent variable	924.7	0.27	0.15	0.38	0.15	0.29	0.16
Loamy soils	0.68	0.68	0.68	0.68	0.68	0.68	0.68
Clayey soils	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Weather	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Demographics	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Soil nutrients and pH	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Dependent variables: ratio of females per 1000 males in the 0-to-6 age group; female and male agricultural workers and agricultural laborers as percentage of all-age female and male rural population; ratio of female agricultural workers and agricultural laborers to total workers in rural areas. Agricultural workers are women or men employed in agricultural activities (farming and cultivation, excluding plantation crops) with or without compensation. Laborers are women or men employed in another person's land for wages in kind or cash. Main explanatory variables: fraction of district area in loamy and clayey soils (sandy soils constant). Other controls: weather, soil attributes and demographics. Weather: temperature (30-year average of daily mean temperature, in Celsius) and rainfall (50-year average of daily accumulated rainfall, in mm). Soil attributes: nitrogen, phosphorus, potassium in the top 25cm of soil (in parts per million, ppm) and pH (dummies for pH values of 4.5 to 5.5, 5.5 to 6.5, 6.5 to 7.5, 7.5 to 8.5, and 8.5 to 9.5). Demographics: district area (in ha), percentage scheduled tribes and scheduled castes, and percentage rural, Muslim, Sikh and Jain population.

*** Significant at the 0.1 percent level.

** Significant at the 1 percent level.

* Significant at the 5 percent level.

TABLE 3—RURAL 0-TO-6 SEX RATIO AND SHARE OF FEMALE AGRICULTURAL WORKERS AND LABORERS ON SOIL TEXTURE, ALTERNATIVE SAMPLES

	(1)	(2)	(3)
	Dependent Variable:		
	Rural 0-to-6 Sex Ratio	Female Agricultural To Total Rural Workers	
		Workers	Laborers
Panel A: Omitting districts in the South			
Loamy soils - Clayey soils	-21.0**	-0.071***	-0.074***
	(8.81)	(0.027)	(0.019)
F-test for soil texture	4.22	6.02	8.16
p-value	0.02	0.00	0.00
R-squared	0.85	0.70	0.56
Observations	236	236	236
Mean of dependent variable	911.8	0.27	0.12
Panel B: Omitting districts in the South and East			
Loamy soils - Clayey soils	-24.0***	-0.087***	-0.085***
	(9.29)	(0.030)	(0.020)
F-test for soil texture	3.92	6.08	9.22
p-value	0.02	0.00	0.00
R-squared	0.86	0.71	0.59
Observations	191	191	191
Mean of dependent variable	901.3	0.27	0.12
Panel C: Omitting districts with major urban areas			
Loamy soils - Clayey soils	-19.6***	-0.066***	-0.085***
	(6.87)	(0.019)	(0.014)
F-test for soil texture	5.35	9.76	18.27
p-value	0.01	0.00	0.00
R-squared	0.82	0.71	0.69
Observations	340	340	340
Mean of dependent variable	925.0	0.29	0.16
Panel D: Omitting districts upstream and neither upstream nor downstream of a river			
Loamy soils - Clayey soils	-13.6*	-0.070***	-0.081***
	(7.65)	(0.022)	(0.016)
F-test for soil texture	2.25	7.22	15.24
p-value	0.11	0.00	0.00
R-squared	0.75	0.71	0.69
Observations	285	285	285
Mean of dependent variable	929.0	0.29	0.16
Weather	Yes	Yes	Yes
Demographics	Yes	Yes	Yes
Soil nutrients and pH	Yes	Yes	Yes
State fixed effects	Yes	Yes	Yes

Notes: Dependent variable: ratio of females per 1000 males in the 0-to-6 age group; ratio of female agricultural workers and agricultural laborers to total workers in rural areas. Main explanatory variables: fraction of district area in loamy and clayey soils (sandy soils constant). Other controls: See note from Table 2 for description.
*** Significant at the 0.1 percent level.
** Significant at the 1 percent level.
* Significant at the 5 percent level.

TABLE 4—RURAL 0-TO-9 SEX RATIO AND SHARE OF FEMALE AGRICULTURAL WORKERS ON SOIL TEXTURE, BY CENSUS YEAR

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent Variable:					
	Rural 0-to-9 Sex Ratio			Female Agricultural Workers to Total Rural Workers		
	1961	1981	2001	1961	1981	2001
Loamy soils - Clayey soils	-14.7**	-22.0***	-18.2***	-0.053**	-0.051***	-0.057***
	(7.11)	(8.40)	(6.88)	(0.022)	(0.018)	(0.019)
F-test for soil texture	2.18	3.53	4.12	4.43	6.29	7.68
p-value	0.11	0.03	0.02	0.01	0.00	0.00
R-squared	0.78	0.71	0.81	0.71	0.78	0.70
Observations	365	365	365	365	365	365
Test for change in the effect of soil texture						
F-test for change since 1961		0.23	0.60		0.00	0.12
p-value		0.79	0.55		1.00	0.89
Variable Means						
Dependent variable	971.9	954.5	924.7	0.28	0.24	0.29
Loamy soils	0.68	0.68	0.68	0.68	0.68	0.68
Clayey soils	0.22	0.22	0.22	0.22	0.22	0.22
Weather	Yes	Yes	Yes	Yes	Yes	Yes
Demographics	Yes	Yes	Yes	Yes	Yes	Yes
Soil nutrients and pH	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Dependent variable: ratio of females per 1000 males in the 0-to-9 age group; ratio of female agricultural workers to total workers in rural areas. Main explanatory variables: fraction of district area in loamy and clayey soils (sandy soils constant). Other controls: Weather: temperature and rainfall. Demographics: district area, percentage scheduled tribes and scheduled castes, and percentage rural, Muslim, Sikh and Jain population. Soil attributes: nitrogen, phosphorus, potassium and pH. See note from Table 2 for a more detailed description.

[a] In 2001 the dependent variable is the ratio of females per 1000 males in the 0-to-6 age group.

*** Significant at the 0.1 percent level.

** Significant at the 1 percent level.

* Significant at the 5 percent level.

TABLE 5—IV AND OLS REGRESSIONS OF RURAL 0-TO-6 SEX RATIO ON SHARE OF FEMALE AGRICULTURAL WORKERS AND LABORERS

	(1)	(2)	(3)	(4)
	Dependent Variable: Rural 0-to-6 Sex Ratio			
	IV Regression		OLS Regression	
	All	North	All	North
Panel A: Using share of female agricultural workers as measure of relative female employment				
Share of female agricultural	281.7***	340.6***	86.3***	127.7***
workers to total rural workers	(33.6)	(42.9)	(18.7)	(20.3)
R-squared	0.74	0.79	0.81	0.87
F	36.13	39.76	44.96	54.65
Observations	365	236	365	236
Variable Means				
Dependent variable	924.7	911.8	924.7	911.8
Share of female agricultural workers	0.29	0.27	0.29	0.27
Panel B: Using share of female agricultural laborers as measure of relative female employment				
Share of female agricultural	439.2***	539.3***	130.5***	204.7***
laborers to total rural workers	(55.5)	(105.8)	(24.2)	(28.8)
R-squared	0.72	0.76	0.82	0.88
F	33.30	33.26	46.16	57.45
Observations	365	236	365	236
Variable Means				
Dependent variable	924.7	911.8	924.7	911.8
Share of female agricultural laborers	0.16	0.12	0.16	0.12
Weather	Yes	Yes	Yes	Yes
Demographics	Yes	Yes	Yes	Yes
Soil nutrients and pH	Yes	Yes	Yes	Yes
State fixed effects	Yes	Yes	Yes	Yes

Notes: Dependent variable: ratio of females per 1000 males in the 0-to-6 age group. Main explanatory variables: ratio of female agricultural workers and agricultural laborers to total workers in rural areas. Instruments: fractions of district area in loamy and clayey soils (sandy soils constant). Controls: Excluded: Demographics: district area, percentage scheduled tribes and scheduled castes, and percentage rural population. Included: Weather: temperature and rainfall. Demographics: Muslim, Sikh and Jain population. Soil attributes: nitrogen, phosphorus, potassium and pH. See note from Table 2 for a more detailed description. First stage: see Table 2, col. 6 and 7, and Table 3, panel A.

*** Significant at the 0.1 percent level.

** Significant at the 1 percent level.

* Significant at the 5 percent level.

APPENDIX

DATA SOURCES

Soils of India. National Bureau of Soil Survey & Land Use Planning (NBSS&LUP), Indian Council of Agricultural Research. Data on soil taxonomy, physiography, depth, parent material, particle size, surface texture classification and particle percentage are reported for 9875 soil type divisions. Divisions result from the intersection of a data layer of soil attributes and district boundaries from the 2001 Census of India. Soil inventory follows a three tier approach including remote-sensing, soil survey and chemical analysis, and GIS application for mapping and image interpretation.

Agricultural Census and Input Survey, 2000-2001. Department of Agriculture and Cooperation (DAC), Ministry of Agriculture. Data are compiled by operational holding and reported at the district level as in 1991. Data include district number and area of operational holdings, land utilization, tenancy pattern, cropping pattern, irrigation status, fertilizer, manure and pesticide use, agricultural machinery and equipment, livestock and agricultural credit.

Census of India, Primary Census Abstract and Religion Tables, 2001. Office of the Registrar General of India (RGI) and Census Commissioner. Population and demographic information is available as cross-tabulations. No raw micro-data are available to the public. Enumeration totals are provided for the population of all ages and in the 0-6 age group. Data are reported for 584 districts.

National Sample Survey (NSS), 55th Round, 1999-2000. National Sample Survey Organization (NSSO). The 55th round of the NSS is the sixth quinquennial survey in the series on household consumer expenditure, employment, and

unemployment. It has an all-India coverage and representation at the regional level. Data are reported for 71,417 households in 537 districts and 264 regions as in 1991.

Daily District-wise Normals of Meteorological Parameters. Indian Meteorological Department (IMD). Data include 24-hour cumulative rainfall precipitation and number of rainy days; maximum, minimum and mean temperature; relative humidity; total cloud amount and wind speed. Rainfall normals are computed for 524 districts using 50 years of data (1941-1990). Other normals are prepared for 441 districts using 30 year of data (1971-2000).

Indian Agricultural Statistics, 1997-2001. Department of Agriculture and Cooperation (DAC), Ministry of Agriculture. District-wise data include yearly crop production, yield and area cultivated, land classification, irrigated area source-wise and crop-wise, and farm harvest prices of principal crops.

Consumer Price Index Numbers for Agricultural and Rural Laborers, 1999-2001. Labor Bureau of India. State-wise CPI(RL) and CPI(AL) are constructed using retail prices of 260 items of goods and services. Information is collected on a monthly basis by the National Sample Survey Organization from 600 sample villages in 20 states.

India Administrative Atlas 1872-2001. Office of the Registrar General of India (RGI) and Census Commissioner. This publication contains administrative division maps of India for each decade, historical background on the administrative divisions that occurred, data appendixes and an equivalence table that permits to trace the constituents of a district in different decades.

TABLE A.1—SELECTED DISTRICT CHARACTERISTICS BY SOIL TEXTURE

	(1)	(2)	(3)	(4)
	Mean/ Std. Dev.	Loamy Soils - Clayey Soils	R-Squared	Observations
Panel A: Weather				
Temperature, 30-year normal, in C	25.1	-0.51	0.82	440
	[3.00]	(0.33)		
Rainfall, 50-year normal, in mm	1350.1	113.3	0.65	584
	[898.8]	(117.4)		
Panel B: Soil nutrients and pH				
Nitrogen, in ppm	21874.4	1746.4	0.52	419
	[20102.4]	(3405.8)		
Phosphorus, in ppm	8150.3	-1739.0	0.49	419
	[6696.6]	(1169.3)		
Potassium, in ppm	3316.6	815.4	0.66	419
	[4097.4]	(582.5)		
4.5<pH<5.5, dummy	0.24	-0.012	0.37	419
	[0.43]	(0.084)		
5.5<pH<6.5, dummy	0.22	0.22**	0.18	419
	[0.42]	(0.092)		
6.5<pH<7.5, dummy	0.12	0.32***	0.19	419
	[0.32]	(0.071)		
7.5<pH<8.5, dummy	0.28	-0.57***	0.30	419
	[0.45]	(0.092)		
8.5<pH<9.5, dummy	0.14	0.048	0.28	419
	[0.35]	(0.072)		
Panel C: Demographic and economic				
% Scheduled tribes	0.18	0.100***	0.66	577
	[0.28]	(0.036)		
% Scheduled castes	0.16	-0.026**	0.67	577
	[0.098]	(0.013)		
% Jains	0.0012	-0.0011*	0.25	577
	[0.0034]	(0.00066)		
Household size	6.35	0.18	0.61	561
	[0.91]	(0.14)		
Migration rate of men	0.068	0.0050	0.53	561
	[0.066]	(0.011)		
Migration rate of women	0.39	0.024	0.59	561
	[0.19]	(0.029)		
Wage rural male workers, in real Rs	74.5	7.40	0.67	558
	[35.5]	(4.96)		
Wage rural female workers, in real Rs	53.8	13.7	0.36	543
	[50.0]	(9.87)		

Notes: Column 1 reports average and standard deviation across all districts. Column 2 reports the difference between the coefficients on loamy and clayey soils, from the regression of indicated variables on the fractions of district area in loamy and clayey soils and state fixed effects (sandy soils constant). Other controls: Weather: temperature and rainfall. Soil attributes: nitrogen, phosphorus and potassium in the top 25cm of soil, and dummies for soil pH range values.

*** Significant at the 0.1 percent level.

** Significant at the 1 percent level.

* Significant at the 5 percent level.

TABLE A.2—RURAL 0-TO-6 SEX RATIO, LABOR FORCE PARTICIPATION RATES AND SHARE OF FEMALE AGRICULTURAL WORKERS AND LABORERS ON SOIL TEXTURE (NO STATE FIXED EFFECTS)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Dependent Variable:						
	Rural 0-to-6 Sex Ratio	Female Agricultural Workers	Female Agricultural Laborers	Male Agricultural Workers	Male Agricultural Laborers	Female Agricultural To Total Rural Workers Workers	Female Agricultural To Total Rural Workers Laborers
Loamy soils - Clayey soils	-9.96	-0.087***	-0.11***	-0.063***	-0.070***	-0.080***	-0.10***
	(7.08)	(0.021)	(0.014)	(0.013)	(0.012)	(0.019)	(0.014)
F-test for soil texture	8.71	12.53	34.12	17.51	20.86	14.47	35.78
p-value	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R-squared	0.69	0.60	0.59	0.43	0.47	0.58	0.56
F	42.05	29.40	28.12	14.33	16.81	26.80	24.57
Observations	365	365	365	365	365	365	365
Variable Means							
Dependent variable	924.7	0.27	0.15	0.38	0.15	0.29	0.16
Loamy soils	0.68	0.68	0.68	0.68	0.68	0.68	0.68
Clayey soils	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Weather	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Demographics	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Soil nutrients and pH	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effects	No	No	No	No	No	No	No

Notes: Dependent variables: ratio of females per 1000 males in the 0-to-6 age group; female and male agricultural workers and agricultural laborers as percentage of all-age female and male rural population; ratio of female agricultural workers and agricultural laborers to total workers in rural areas. Main explanatory variables: fraction of district area in loamy and clayey soils (sandy soils constant).Other controls: Weather: temperature and rainfall. Demographics: district area, percentage scheduled tribes and scheduled castes, and percentage rural, Muslim, Sikh and Jain population. Income and assets: median per capita household expenditure (in real Rs), percentage households that own cultivated land and average area owned (in ha). Crop yield: rice yield and wheat yield (in tons/ha). Soil attributes: nitrogen, phosphorus, potassium and pH. River geography: district location relative to river flow. See note from Table 2 for a more detailed description.

*** Significant at the 0.1 percent level.

** Significant at the 1 percent level.

* Significant at the 5 percent level.

TABLE A.3—RURAL 0-TO-6 SEX RATIO ON SOIL TEXTURE

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				Dependent Variable: Rural 0-to-6 Sex Ratio				
Loamy soils - Clayey soils	-24.3***	-7.27	-17.8***	-18.3***	-18.2***	-16.3***	-15.4**	-15.4**
	(7.19)	(5.81)	(6.96)	(6.31)	(6.68)	(6.24)	(6.58)	(6.59)
F-test for soil texture	35.08	27.31	23.65	18.49	4.37	18.66	4.51	4.50
p-value	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01
R-squared	0.11	0.70	0.71	0.77	0.81	0.79	0.82	0.82
F	35.08	35.23	32.63	35.72	41.57	37.47	38.49	37.39
Observations	577	577	436	436	365	421	358	358
Variable Means								
Dependent variable	934.1	934.1	928.7	928.7	924.7	929.1	925.3	925.3
Loamy soils	0.66	0.66	0.66	0.66	0.68	0.66	0.68	0.68
Clayey soils	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Weather	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Demographics	No	No	No	Yes	Yes	Yes	Yes	Yes
Soil nutrients and pH	No	No	No	No	Yes	No	Yes	Yes
Income and assets	No	No	No	No	No	Yes	Yes	Yes
Crop yield	No	No	No	No	No	Yes	Yes	Yes
River geography	No	No	No	No	No	No	No	Yes
State fixed effects	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Dependent variable: ratio of females per 1000 males in the 0-to-6 age group. Main explanatory variables: fraction of district area in loamy and clayey soils (sandy soils constant). Other controls: Weather: temperature and rainfall. Demographics: district area, percentage scheduled tribes and scheduled castes, and percentage rural, Muslim, Sikh and Jain population. Income and assets: median per capita household expenditure (in real Rs), percentage households that own cultivated land and average area owned (in ha). Crop yield: rice yield and wheat yield (in tons/ha). Soil attributes: nitrogen, phosphorus, potassium and pH. River geography: district location relative to river flow. See note from Table 2 for a more detailed description.

*** Significant at the 0.1 percent level.

** Significant at the 1 percent level.

* Significant at the 5 percent level.

TABLE A.4—SHARE OF FEMALE AGRICULTURAL WORKERS ON SOIL TEXTURE

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Dependent Variable: Female Agricultural Workers to Total Rural Workers							
Loamy soils - Clayey soils	-0.16***	-0.050***	-0.072***	-0.077***	-0.057***	-0.053***	-0.046**	-0.047***
	(0.018)	(0.017)	(0.021)	(0.018)	(0.019)	(0.017)	(0.019)	(0.019)
F-test for soil texture	41.78	8.12	11.85	16.24	8.15	11.75	6.97	7.16
p-value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R-squared	0.13	0.58	0.59	0.71	0.70	0.73	0.71	0.71
F	41.78	21.12	18.57	25.29	23.37	26.02	20.53	20.39
Observations	577	577	436	436	365	421	358	358
Variable Means								
Dependent variable	0.29	0.29	0.28	0.28	0.29	0.29	0.29	0.29
Loamy soils	0.66	0.66	0.66	0.66	0.68	0.66	0.68	0.68
Clayey soils	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Weather	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Demographics	No	No	No	Yes	Yes	Yes	Yes	Yes
Soil nutrients and pH	No	No	No	No	Yes	No	Yes	Yes
Income and assets	No	No	No	No	No	Yes	Yes	Yes
Crop yield	No	No	No	No	No	Yes	Yes	Yes
River geography	No	No	No	No	No	No	No	Yes
State fixed effects	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Dependent variable: ratio of female agricultural workers to total workers in rural areas. Main explanatory variables: fraction of district area in loamy and clayey soils (sandy soils constant). Other controls: Weather: temperature and rainfall. Demographics: district area, percentage scheduled tribes and scheduled castes, and percentage rural, Muslim, Sikh and Jain population. Income and assets: median per capita household expenditure (in real Rs), percentage households that own cultivated land and average area owned (in ha). Crop yield: rice yield and wheat yield (in tons/ha). Soil attributes: nitrogen, phosphorus, potassium and pH. River geography: district location relative to river flow. See note from Table 2 for a more detailed description.

*** Significant at the 0.1 percent level.

** Significant at the 1 percent level.

* Significant at the 5 percent level.

TABLE A.5—SHARE OF FEMALE AGRICULTURAL LABORERS ON SOIL TEXTURE

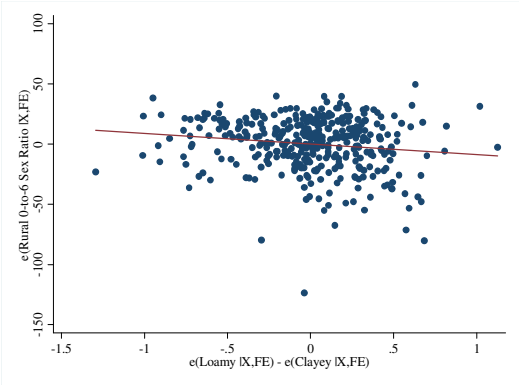
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Dependent Variable: Female Agricultural Laborers to Total Rural Workers							
Loamy soils - Clayey soils	-0.070***	-0.068***	-0.073***	-0.076***	-0.082***	-0.066***	-0.073***	-0.073***
	(0.013)	(0.011)	(0.013)	(0.012)	(0.014)	(0.012)	(0.014)	(0.014)
F-test for soil texture	35.52	21.56	19.38	20.52	17.58	16.58	15.12	15.07
p-value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R-squared	0.11	0.69	0.67	0.71	0.67	0.73	0.71	0.71
F	35.52	32.73	26.10	25.99	20.68	26.88	20.97	20.37
Observations	577	577	436	436	365	421	358	358
Variable Means								
Dependent variable	0.13	0.13	0.14	0.14	0.16	0.14	0.16	0.16
Loamy soils	0.66	0.66	0.66	0.66	0.68	0.66	0.68	0.68
Clayey soils	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Weather	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Demographics	No	No	No	Yes	Yes	Yes	Yes	Yes
Soil nutrients and pH	No	No	No	No	Yes	No	Yes	Yes
Income and assets	No	No	No	No	No	Yes	Yes	Yes
Crop yield	No	No	No	No	No	Yes	Yes	Yes
River geography	No	No	No	No	No	No	No	Yes
State fixed effects	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Dependent variable: ratio of female agricultural laborers to total workers in rural areas. Main explanatory variables: fraction of district area in loamy and clayey soils (sandy soils constant). Other controls: Weather: temperature and rainfall. Demographics: district area, percentage scheduled tribes and scheduled castes, and percentage rural, Muslim, Sikh and Jain population. Income and assets: median per capita household expenditure (in real Rs), percentage households that own cultivated land and average area owned (in ha). Crop yield: rice yield and wheat yield (in tons/ha). Soil attributes: nitrogen, phosphorus, potassium and pH. River geography: district location relative to river flow. See note from Table 2 for a more detailed description.

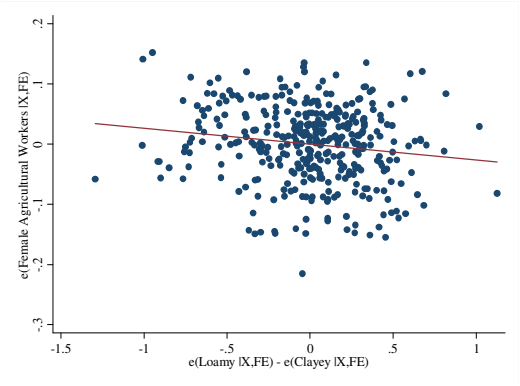
*** Significant at the 0.1 percent level.

** Significant at the 1 percent level.

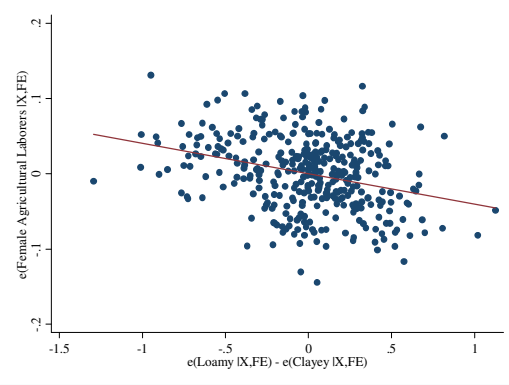
* Significant at the 5 percent level.



(a) Rural 0-to-6 Sex Ratio
and Loamy Relative to Clayey Soil Texture Fractions



(b) Female Agricultural Workers to Total Workers
and Loamy Relative to Clayey Soil Texture Fractions



(c) Female Agricultural Laborers to Total Workers
and Loamy Relative to Clayey Soil Texture Fractions

FIGURE A.1. PARTIAL CORRELATION PLOTS