The Roots of Modern Sex Ratios

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November 17, 2016

Abstract

While most measures of female empowerment have improved with development, sex ratios in many countries have become increasingly male. We exploit countries' prior history of plough-based agriculture to identify cultural variation in patriarchal norms following Boserup (1970) and Alesina, Giuliano, and Nunn (2013). Using detailed birth records from 76 countries between 1970 and 2010, we show that the cultural legacy of plough use explains a large portion of variation in modern sex ratios, and present evidence that plough countries' male-skewed sex ratios are achieved through a mix of in-utero sex-selection, son-based stopping rules, and increased mortality suggestive of neglect or infanticide. This cultural bias intensifies with lower fertility, even when controlling for a suite of economic and historical controls, a pattern that is not found in non-plough countries.

Keywords: Sex ratio, plough, agriculture, fertility, gender.

JEL Codes: D03, J16, N30.

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Many measures of female empowerment have improved with global development but a notable exception is the sex ratio at birth, which has become more male with time (Kishor and Gupta (2009); Jayachandran (2015)). A component of the larger population-level "missing women" phenomenon, male-favoring sex ratios at birth well in excess of the natural range of 103–107 can now be found many countries, in some notable cases (e.g., India and China) exceeding 115 male births for every 100 female (Sen (1989); Coale (1991); Anderson and Ray (2010)).[1] In addition to being of inherent interest as a measure of gender equality, imbalanced sex ratios influence a range of economic outcomes over time, including human capital accumulation (Jensen (2002)), marriage markets (Angrist (2002); Stopnitzky (2016)), fertility (Jayachandran (2014)), crime/violence (Edlund et al. (2013)), and savings behavior (Wei and Zhang (2011)). Further, the problem of sex imbalance often worsens rather than improves with economic development, as rising incomes and access to technology allow for greater household expression of cultural son preference rather than simply leading to more egalitarian norms (Duflo (2012)).

In this paper we exploit a geographic source of heterogeneity in gender norms to shed light on the cultural drivers of male-skewed sex ratios at birth. Specifically, we leverage Ester Boserup's 1970 "plough hypothesis" that attributes differences in gender roles to differences between shifting (i.e., using a hoe or digging stick) and plough-based cultivation techniques (Boserup (1970)). We combine Alesina, Giuliano and Nunn (2013)'s country-level measures of plough agriculture with birth record data from the Demographic and Health Surveys to generate a dataset comprised of 4.8 million children born in 76 countries between 1970 and 2010. Our individual-level data set allows us to estimate country-level sex ratios over time, as well as exploit child- and mother-level variation, which sheds light on mechanisms driving sex selection in plough countries.

Our results suggest that a substantial portion of the present-day imbalance in global sex ratios is due to the cultural legacy of plough agriculture. We estimate that plough countries have sex ratios at birth roughly 2–3 males per 100 females higher than in non-plough countries, and that this relationship is largely unchanged when controlling for contemporaneous fertility or income per capita, or for a suite of historical and bio-geographical controls.[2] We find that the plough effect is largely driven by rural households, consistent with the agricultural nature of the plough hypothesis, and further that it is a particularly strong predictor of the sex ratio of last birth. We estimate that plough countries' sex ratio of last birth is skewed by 10–15 more males per 100 females than non-plough countries, consistent with widespread adherence to son-based stopping rules.

A key contribution of our approach is the ability to examine directly the interaction between declining fertility, birth order, and sex composition of children at the household level. We demonstrate that sex ratios varies strongly with fertility in plough countries, with male-skewness of sex ratios increasing with lower levels of total fertility, a pattern not found in non-plough countries (see Figure III). We interpret this relationship as a meaningful empirical estimate of the conditional

[1] Recent evidence suggests that the sex ratio at *conception*, however, displays parity between males and females (Orzack et al. (2015)).

[2] This set of controls is the same included in Alesina, Giuliano and Nunn (2013)'s original analysis

intensity of son preference, which theories of gender bias suggest should be non-homothetic in fertility. In this light, the global increase in male-skewness of sex ratios seems to be heavily driven by development-driven decreases in fertility in countries with strong son preferences, and not a change in the preferences *per se*.

We examine children's outcomes to show that historical plough use predicts not only the quantity of female and male children but also the relative care and human capital investments for each group. We provide evidence of male-biased preferences in plough countries for outcomes ranging from breastfeeding duration, to succeeding birth intervals, to anthropometrics. We demonstrate that plough countries betray evidence of sex selection across birth order, with families in plough countries far more likely to have a son if previous births are all female. We lastly show that female children in plough countries face a comparative increase in mortality rates compared to their non-plough counterparts. This mortality bias in plough countries extends beyond infancy, consistent with mortality being the result of preferential female neglect, and is sufficiently strong that the plough penalty to mortality among girls aged one to five more than outweighs the female advantage in mortality that exists in the broader population.

Together our results suggest that historical use of the plough identifies a central axis of patriarchal cultural norms, one where technological choices in production evolved endogenously with male-biased cultural practices, such as son preference and male-biased funeral rites. These existing cultural norms, in turn, have interacted with the demographic transition and modern sex-selection technology in a way that explains a significant portion of modern sex ratios. In this way, the underlying economic and agricultural roots of contemporary cultural practices continue to shape global demography and women's well-being.

1 Background

1.1 The Plough Hypothesis

Boserup (1970)'s original articulation of the plough hypothesis argues that variation in gender norms across societies can be partly explained by the legacy of differential returns to gendered labor in historical agricultural societies. Boserup divides traditional agricultural practices into two types: shifting cultivation, which uses hand-held tools such as a hoe for soil preparation, and plough cultivation, which is both more capital-intensive and requires more upper-body strength and burst power to pull the plough or control the animal that is pulling it. This strength requirement gives men in plough societies a comparative advantage in soil preparation, one of the most important and time-consuming activities in agricultural production, and further reduces the need for weeding, a task which does not have gender-differentiated productivity. Plough cultures thus see increased returns to male as compared to female labor, which influence gendered property rights over income streams and thus the gender balance of power within the household (e.g., Basu (2006)).

Boserup traces the influence of this differential increase in expected returns to male labor through a variety of endogenous social responses. Men in plough societies specialize in agricultural labor outside the home, pressuring women to increase specialization in domestic work within the home, reinforcing a male-reliant family structure and male-favoring interactions between the household and society. Marriage markets become more male-favoring, with women seen as a cost to be supported, increasing the likelihood of dowry payments. Gendered land tenure favors the development of patrilocal norms, leading to differential investments in children as parents' livelihoods become preferentially tied to sons' outcomes over daughters'. Core attitudes towards the relative value of the genders reflect these changes, leading to an equilibrium disadvantage for women in social norms.

Alesina, Giuliano and Nunn (2013) provide the first major test of Boserup's hypothesis using modern data. Using a variety of rich historical data, the authors determine preindustrial societies' legacy of plough use and estimate modern ethnic groups' relative exposure to the legacy of plough agriculture. Across countries in the global sample, within countries across districts, and within districts across ethnicities, the authors find that plough agriculture is strongly associated with more male-favoring norms and increased gender inequality, even after controlling for a broad suite of historical and social characteristics and the endogeneity of plough adoption. Separately, Alesina, Giuliano and Nunn (2011) demonstrate that plough countries tend to have lower fertility, a phenomenon they attribute to lower returns to children's on-farm labor.

In a study closely related to ours, Carranza (2014) studies how variation in plough agriculture explains male-biased sex ratios within modern India. She shows that parts of India with loamy or sandy soils favor plough use more than clayey soils, and uses variation in these soils as an instrument for plough uptake, showing that loamy soil predicts worse labor market participation for women and more male-skewed sex ratios, consistent with Boserup's core hypothesis. Our study differs from Carranza's both by looking at an international sample of dozens of countries as well as by using microdata to explore the demographic mechanisms through which sex ratio preferences are realized.

1.2 Cultural Transmission and Persistence

The link between historical agricultural practices and modern cultural norms requires an explanation of mechanism and transmission. We focus on simple cultural heuristics, i.e. shorthand "rules of thumb" to reduce the cognitive load, regarding women's role in society (Boyd and Richerson (1988); Alesina, Giuliano and Nunn (2013)). In this formulation, costly or imperfect information acquisition makes it desirable for individuals to develop heuristics for decision-making. Subsequently, these heuristics are strengthened by other mutually reinforcing conventions, such as dowry (Das Gupta et al. (2003)), religious traditions such as sons playing prominent roles in Confucian ancestor worship or in organizing funeral pyres in Hinduism (Arnold, Choe and Roy (1998)), and patrilocal and patrilineal kinship systems more generally (Dyson and Moore (1983); Das Gupta et al. (2003); Ebenstein (2014)). The cumulative effect of these deeply rooted, interconnected cultural heuristics and conventions is that, once established, they often exhibit substantial path dependence even when confronted with substantial changes brought on by economic development or through assorted shocks (Easterlin (1967)).

Evidence in favor of such cultural persistence can be found in a variety of studies, including research on contemporary labor outcomes for women (Fernández and Fogli (2006); Alesina, Giuliano and Nunn (2013)), on collectivism versus individualism (Gorodnichenko and Roland (2011)), on historical shocks to generalized trust (Nunn and Wantchekon (2011)), and on gender attitudes among migrants who have left their home countries (Almond, Edlund and Milligan (2013)).[3] Alesina, Giuliano and Nunn (2013) show direct evidence on the "stickiness" of cultural gender norms by showing second-generation immigrants from plough societies to the US and Europe have less equal views on female labor force participation than their non-plough counterparts.

Also closely related is the literature that argues that the broadening and intensification of agriculture caused a shift from matrilineal kinship patterns (in hunter-gatherer societies) to patrilineal norms of inheritance. Today these changes are associated with increased patrilocality and male-skewed sex ratios positively correlated with the co-residence of sons with parents (Engels (1902); Ebenstein (2014)).

While persistent, these norms do not seem immutable, and evidence suggests they may not only be changed, but may specifically be influenced in the short run by changes in the relative returns to gendered labor. Qian (2008), for example, shows that fluctuating economic conditions that increase the relative returns to female labor can attenuate son preference and cause the sex ratios to become more balanced. Conversely, D'Agostino (2016) shows that the adoption of Green Revolution technologies within India led to increased returns to agricultural labor favoring males, resulting in increases in male wages and decreases in female wages, with women shifting towards own-farm and domestic work.

1.3 Sex Ratios

Sex ratios both at birth and later in life have been an object of study in human populations for centuries. Early estimates of a small bias in favor of male births were documented as early as 1710 by demographers in London, and most estimates currently place 'natural' sex ratios at birth (i.e., ones were parents are not explicitly selecting for child sex) in the range of 105-107 males per 100 females, with preferential male mortality leading to more balanced sex ratios in older cohorts (Hesketh and Xing (2006); Drevenstedt et al. (2008)).

While evidence of son-favoring practices and skewed sex ratios abound in the anthropological literature, population-level evidence of systematic selection for sons is generally attributed to Sen (1989), who estimated a global deficit of approximately 100 million "missing women" in 1990. In marked contrast with most other measures of global gender equality, this gap has worsened over time (Kishor and Gupta (2009); Jayachandran (2015)), consistent with the complex and non-monotonic relationship between development and female empowerment, as well as the enduring

[3] Alesina and Giuliano (2015) and Nunn (2012) provide overviews of the economics of historical and cultural development.

nature of male-favoring (and female-disfavoring) preferences and norms (Duflo (2012)). Further evidence supporting cultural preferences as a driver of sex ratios includes Almond, Edlund and Milligan (2013), who show that immigrants from countries with strong son preferences practice sex selection at higher parities when earlier-born children are female.

Of particular note is Jayachandran (2014)'s work on the interaction between declining fertility and missing women. Differentiating between son preference, or the preferred number of sons at any fertility level, and family size preference, or the overall number of desired children, Jayachandran argues that declining preferences for family size increases male-bias in sex ratios when son preferences are held fixed, and presents empirical evidence to support this argument. This interaction leads to a reliance on son-based stopping rules, i.e., families being more likely to complete fertility after having a son than a daughter. This, alongside Alesina, Giuliano and Nunn (2011)'s evidence that plough societies have lower fertility, suggests that accounting for cultural determinants of the global imbalance in sex ratios requires examining how sex ratio outcomes vary with fertility at the family level.

2 Data

For our empirical analysis we use data from three sources: (1) multiple rounds of the Demographic and Health Surveys from 76 countries, (2) data on historical plough use and societal characteristics as first assembled by Alesina, Giuliano and Nunn (2013), and (3) country-level control variables from the World Bank Development Indicators. This section describes key features of each of these data sources.

The Demographic and Health Survey (DHS) program conducts household-level surveys in a large sample of developing countries, focusing on women and children's health. We identify all standard DHS surveys for which estimates of plough culture exist in Alesina, Giuliano and Nunn (2013), generating a sample of 76 countries surveyed between 1986 and 2014. We extract information from the individual recode files for these countries to create a global birth record dataset, containing over 2.1 million mother-level and over 5 million child-level observations. Additional data on investment and anthropometrics are available for a subset of young children (under the ages of 3–5 at time of survey, depending on country).

We use the DHS to estimate country-level sex ratios at birth by calculating the weighted proportion of total births that were female for both the entire pooled sample (all births between 1970 and 2010) as well as by decade, weighting our country-level estimates using DHS sample weights and reweighting observations from different surveys using population estimates from the World Development Indicators. We report sex ratio at birth as the number of male births per 100 female births. The same method was used to construct the sex ratio of first birth (SRFB) variable and the sex ratio of last birth (SRLB) variable, which is the sex ratio of last born child for those women who report in the DHS data that they have completed their desired fertility.

The variable we utilize to measure historical plough use is identical to that used by Alesina, Giuliano and Nunn (2013). The authors construct this country-level measure by using the Ethnographic Atlas dataset, which reports whether 1,265 distinct ethnic groups utilized the plough for agriculture in the pre-industrial period. The authors then link traditional plough use with current distributions of descendants using the 15th edition of the Ethnologue: Languages of the World, a reference that maps the geographic population distribution of 7,612 languages, which is then matched to the Landscan 2000 database, a map of the global population in 2000. This novel approach yields an estimate of contemporary populations' proportional descent from traditional societies that practiced plough agriculture across the globe.

To create their plough variable at the country level, Alesina, Giuliano and Nunn (2013) use modern national boundaries to estimate:

$$Plough_c = \sum_e \sum_i \frac{N_{e,i,c}}{N_c} * I_e^{plough} \tag{1}$$

where I_e^{plough} is equal to 1 if ethnic group e practiced plough agriculture and 0 otherwise[4], $N_{e,i,c}$ is the total number of individuals of ethnicity e living in Landscan grid cell i in country c, and N_c is the total population of country c. This equation generates the variable $Plough_c$, the population-weighted average of I_e^{plough} for all ethnic groups living in country c, net of observed migration. Due to the way the variable is constructed, the values of $Plough_c$ are contained within the closed interval $[0, 1]$, though we note that the measure is highly bimodal and that most societies are either strongly plough (i.e., close to 1) or not at all. Figure I shows variation in the plough variable within our sample.

The third source of secondary data, the World Bank Development Indicators, provides annual series at the country level for a wide variety of variables. We use these data, such as real GDP per capita and yearly averages of total fertility rates, as controls in our main analyses and robustness checks.

Table II provides summary statistics for both the overall country-level sample, as well as broken up into "plough" and "non-plough" societies, defining any society with a weighted average plough measure of $> 95\%$ to be a plough country and non-plough otherwise. Sex ratios are higher in plough countries regardless of how measured, with a population average sex ratio of 106.3 males per 100 females compared to a non-plough average of 103.5. This difference is heightened in first-borns (108.3 vs 104.5) and extremely large in last-borns (113.7 vs 103.7), underlying the importance of focusing on son-based stopping rules. Average total fertility is lower in plough countries, echoing Alesina, Giuliano and Nunn (2011), and plough countries are if anything somewhat more developed than non-plough countries, with slightly higher levels of per capita GDP and longer histories of jurisdictional hierarchy.

[4] This measure does not distinguish whether the plough was developed aboriginally or imported after contact with other societies, or the duration of time the plough was utilized in the pre-industrial period.

3 Methods

3.1 Empirical Approach

Our empirical approach studies the relationship between plough use and sex ratios at three levels of observation: the country-level aggregate to examine broad demographic associations with the plough; the mother level to study the conditional relationship between sex ratios and fertility; and the child level to examine family behavior conditional on gender of realized births.

Country-Level Regressions To examine the effect of historical plough use on contemporary sex ratios, we estimate ordinary least squares regressions of the following form:

$$Y_{ct} = \alpha + \beta Plough_c + \delta A_{ct} + X_{ct}^C + X_c^H + \epsilon_{ct} \tag{2}$$

where Y_{ct} is a measure of sex ratio for country c during decade t. We focus on three dependent variables: overall sex ratio at birth, sex ratio of firstborn children, and sex ratio of lastborn children. A_{ct} is the average total fertility of country c in decade t, X_{ct}^C is log GDP per capita and log GDP per capita squared, and X_c^H is a vector of historic controls used in Alesina, Giuliano and Nunn (2013) and Alesina, Giuliano and Nunn (2011). This vector of historic variables controls for other differences in traditional societies potentially correlated with plough use and includes: a measure of political complexity proxied by jurisdictional hierarchy, a measure of settlement density, agricultural suitability for the adoption of plough-based agriculture, and the fraction of land that is tropical. In some specifications we collapse births to generate an overall sample value of sex ratios; when we do this we also collapse other time-varying controls (GDP per capita and average total fertility) for those periods as well.

Mother-Level Regressions We estimate the conditional dependence of sex ratios on fertility in plough countries at the mother-level using OLS regressions of the following form, which we estimate on a sample of all mothers who stated they have completed fertility at time of survey:

$$\Phi_{ict} = \alpha Plough_c + \rho \kappa_i + \sigma Plough_c * \kappa + X_i + \epsilon_{ict} \tag{3}$$

where Φ_{ict} is the percentage of total children born to mother i that are female. κ is a $7x1$ vector of dummy variables that are equal to one for mother i's total number of children (total fertility), and is equal to zero otherwise. X_i is a vector of historical controls. All levels of total fertility greater than or equal to seven have been coded as 7+ to simplify the regression output.[5] We interact $Plough_c$ with each of the total fertility dummy variables in order to explore heterogeneous treatment effects across different levels of fertility, as suggested by evidence of non-homothetic son preference in India discussed in Jayachandran (2014). The conditional average effect of traditional

[5] We also ran this regression using a compete set of dummy variables for all fertility levels up to the maximum of 22, which has no bearing on our results.

plough agriculture on the sex composition of children to a given mother will be $\alpha + \sigma$, conditional on the mother's total level of fertility. We also run regressions using a host of individual controls X_i as a robustness check on omitted variable bias; X_i includes a vector of dummy variables for the highest level of education attained by both mothers and fathers.

Child-Level Regressions In order to see conditional changes in sex ratio at birth by sex of previous births, we estimate a linear probability model at the level of individual children using the following specification:

$$F_{ijdt} = \alpha + \beta_1(SC'_{ij} * Plough_c * L) + \beta_2(SC'_{ij} * Plough_c) + \beta_3(SC'_{ij} * L) + \beta_4(Plough_c * L) + \gamma_1 SC'_{ij} + \gamma_2 Plough_c + \gamma_3 L + \epsilon_{ijdt} \quad (4)$$

where the dependent variable F_{ijdt} is an indicator variable for sex of child j, born to mother i, birth order d, in time period t. SC'_{ij} is a vector of dummy variables capturing all possible combinations of the gender composition of the previous siblings of child i to mother j up through fourth-borns.[6] L is a dummy variable equal to one if child i is the lastborn child to mother j and mother j has indicated that she does not prefer to have any more children in the DHS questionnaire.

The coefficient of primary interest is the triple interaction, $(SC'_{ij} * Plough_c * L)$, i.e, the plough-related change in the likelihood that a non-last born child will be born male as the gender composition of older siblings changes. For example, for birth order of two, and restricting ourselves to non-lastborn children to attenuate selection bias imposed by son-based stopping rules,[7] we compare gender outcomes for all second-born children who are descendants of non-plough societies, all second-born children who have one older brother (regardless of ancestry), and all second-born children with one older brother in plough societies. This regression specification mirrors Almond, Edlund and Milligan (2013)'s exploration of immigrant sex ratios in the United States, and allows us to determine to what extent sex selective technology such as abortion have allowed descendants of plough societies to realize their latent son preference.[8]

We lastly explore evidence of gendered mortality and disinvestment mechanisms by estimating variants of equation 4 using child-level outcomes including mortality, anthropometrics, and other measures of human capital investment. In these specifications our variable of interest $female_{ij} * Plough_c$ identifies differential outcomes in female children associated with being in a plough society.

[6] We study children in birth orders $d = 2, 3, 4$ only as the results for the mother level specification (Figure III) show sex ratios in plough societies to only be measurably male-skewed at levels of total fertility less than or equal to four.

[7] That is, children with younger siblings or children whose mothers say they plan on having more children.

[8] We note that under reporting of female mortality will also generate changes in the marginal likelihood of a birth being male.

4 Results

4.1 Male-Biased Sex Ratios in Plough Societies

Table III reports the results of OLS regressions of country-level average sex ratios at birth on our plough variable following specification (2). We first explore this relationship in the cross-section, pooling the entire sample of births between 1970-2010. Column (1) provides evidence that the unconditional relationship between plough and male-skewed sex ratios is strong and significant; absent any controls, plough countries have 2.42 extra males born per 100 females relative to a baseline of 103.7. Including quadratic controls for per capita income averaged over the 1970–2010 period (column (2)) generates a very similar coefficient of 2.33, suggesting that income has little influence on the underlying cultural relationship captured by the plough variable. Column (3), however, shows that the coefficient on plough becomes small and insignificant when expanding our specification to include the full set of historical controls used by Alesina, Giuliano and Nunn (2013) as well a measure of average total fertility averaged 1970-2010. Fertility is negatively and significantly associated with sex ratios in this specification, suggesting that results in the pooled country-level sample may be driven by the endogenous relationship between plough agriculture and fertility decisions, while plough-suitable agriculture is also negatively associated with sex ratios, suggesting that underlying geographical suitability may be partially driving our results in the cross-section.

Columns (4)-(6) of Table III re-estimate the regressions in columns (1)-(3) as a panel, with decadal average versions of all non-historic control variables replacing 1970-2010 averages. Columns (4) and (5) demonstrate that our panel estimates of the unconditional and per-capita income-conditioned relationship between plough and sex ratios are largely unchanged relative to the specifications in columns (1) and (2), being if anything slightly stronger at 2.92 and 2.95 extra males per 100 females born. Column (6) demonstrates the importance of using contemporaneous controls: here we find that the coefficient on our plough variable is somewhat attenuated at 2.00 extra males per hundred females, and significant at the 5% level. The coefficient on the plough-suitability of agriculture is slightly weaker than in column (3), though still negative, and we further find that tropical agriculture is associated with less male-biased sex ratios. Contemporaneous fertility, meanwhile, no longer predicts sex ratios, lending credence to a view of fertility as a slow-moving outcome of gender norms rather than an influence on them per se.

We explore the interaction between fertility and sex ratio at birth by rerunning our decadal panel specification on sex ratio of first and last births in Table IV while restricting last births to mothers who say they want no more children at time of survey.[9] Columns (1)–(3) show that plough agriculture predicts male-favoring sex ratios at birth among first borns, a relationship robust to including our full vector of controls that is if anything stronger than the whole sample effect in Table III, albeit insignificantly so. Since bias in first-born sex ratios cannot, by definition,

[9] Our results are broadly similar except slightly attenuated when reestimated while designating all youngest children as firstborns, consistent with the expected increase in measurement error.

be a result of son-based stopping rules, we interpret this as evidence of either sex selective abortion or under-reporting of first-born female births following cases of neglect or infanticide.

Columns (4)-(6) of Table IV show that the association of male-bias with the plough is particularly strong in last-born children, with the unconditional effect in Column (4) indicating that plough agriculture increases excess male births by 10.56 per 100 girls born. Notably, the constant term in columns (1) and (4) is very close, suggesting that once plough differences are accounted for, non-plough countries' sex ratios do not vary between first and last births, a result mirrored by our results across fertility levels in Section 4.2. Further, the inclusion of controls seems to strengthen rather than attenuate this relationship, with the specification with full controls in column (6) suggesting that plough countries see 15 excess male births for every 100 females compared to their non-plough counterparts. We interpret this result as strong evidence of plough countries reliance on son-based stopping rules, though note that underreporting of female births or sex-selective abortion are likely contributing to this effect as well. While it may seem counterintutive for both the first and last born plough effects to be stronger than the average effect, this is consistent with Jensen (2002)'s observation that girls have on average more siblings than boys in son-based stopping rule societies, as well as with a simple model of choice over methods in achieving desired number of sons. Families employing sex-selective abortion to limit fertility and simultaneously prefer male births will drive up bias at low parities, while families practicing son-based stopping rules will have higher fertility overall with male-biased last births but patterns less discernible over birth parities.

We explore whether our results differ substantially in urban and rural areas in Table V, following the DHS designation of respondents into binary urban or rural categories. Column (1) shows that the unconditional relationship between the plough and urban sex ratios remains is positive and significant at the 5% level, albeit at a somewhat reduced intensity of 2.25 male births per 100 females. Consistent with this relationship being generally weaker, we find that the addition of the full set of controls reduces the plough effect to an insignificant 1.08 excess male births per 100 girls overall (column 2), an effect that persists even among last born children where the coefficient is a large but insignificant 5.27 excess male births per 100 girls.

Columns (4)-(6) of Table V repeat the specifications from columns (1)-(3) for the rural sample and make clear that rural areas are driving the general population result. The unconditional OLS estimate of plough agriculture on sex ratio is 3.41 excess male births per 100 females, significant at the 1% level. The addition of controls somewhat attenuates this effect to 2.50 at the 5% level. Focusing on last borns we see that plough agriculture is overwhelmingly associated with male-biased sex ratios at 21.95 excess births per 100 females, or approximately six last born males for every five last born females.

A strong rural bias is unsurprising given that agricultural production occurs in rural areas, though other features of these areas may also be driving these outcomes. Rural areas may still see this gendered division of labor in practice but may also be more likely to have those structures reinforced through norms such as marriage market conventions. Rural areas are also generally less exposed to cultural mixing than urban areas, suggesting there may be a role of cosmopolitanism vs. traditional norms.

We examine dynamic variation in our results in Figure II, which shows decadal coefficients calculated by estimating equation (2) with our full set of controls on a sample restricted to births born in each decade. Our results hold broadly across time, with plough agriculture associated with more male-biased first born, last born, and overall sex ratios[10]. The notable exception to this rule are the 1990s, where the plough predicts male skewness in last-born sex ratios but not otherwise. This is partly an artefact of controls; during the 1990s, and only during the 1990s, average total fertility is a strong predictor of *less* male-skewed sex ratios. We interpret this as likely evidence of the roll out of ultrasound: if ultrasound was in general only used to reduce fertility in cases where families were trying to alter sex ratios at birth, and if many families had unmet demand for sons when ultrasound arrived, then it seems plausible for fertility to be an endogenous control during this period. Testing this, we find that the coefficient on plough for first and all borns during the 1990s is positive, significant, and comparable in size to the coefficient from the 1980s and 2000s samples when estimated without fertility as a control.

4.2 Male-Biased Sex Ratios By Total Fertility

We explore the relationship between fertility, sex ratios, and the plough by estimating equation (3) at the individual level, separating the 1.7 million women in our sample by different levels of total fertility (number of children) at time of survey. Since we are no longer trying to identify effects on last-born children, we include all women in our sample, i.e. we do not exclude women who have not completed fertility. We include the same vector of historical controls as in our main specification but drop average total fertility since it is constant within each group as well as GDP controls because they neither meaningfully explain variation nor alter our estimates.

Figure III depicts the relationship between male-favoring sex ratios and fertility in plough versus non-plough countries. Within plough countries, the composition of smaller families are proportionally much more male-biased than larger ones. While families of five or more children tend to have sex ratios at the natural rate of 105 males per 100 females, families with four or fewer children show a marked and statistically significant bias favoring male births. We estimate the sex ratio of families with three children in plough countries to be 112 males for every 100 females, approximately the same as the population sex ratio for India. This bias increases to 119 males for every 100 females in two child families (in excess of any country's sex ratio, even China's, though comparable to sex ratios in various sub-national areas with the greatest imbalance), and then falls slightly to 115 males for every 100 females in one child families. Non-plough countries, meanwhile, see no variation of sex ratio with fertility, with estimated sex ratios for families of at all fertility levels in the range of 102–105.

[10] We test for and find no evidence of a trend in plough effect intensity over time.

4.3 Family-Level Evidence of Mechanisms

Figure IV shows coefficients from estimating equation (4), interpretable as the difference in the probability that a child is born female between plough and non-plough countries, conditional on different combinations of older siblings' genders. We find that birth outcomes become systematically more male-biased in plough societies as the proportion of female older children increases, mirroring Almond, Edlund and Milligan (2013)'s findings suggestive of sex selective abortion among immigrants in the United States. In two child families in plough countries, the likelihood that a child will be born female drops over 12 percentage points if the first child was female, relative to non plough countries. In three child families in plough countries, girl-girl older sibling dyads decrease the likelihood of a third birth's being female by over 10 percentage points.

Table VI shows the result of child-level regressions of investment and health outcomes on the plough and controls following equation 4, modified to include birth order and birth-year fixed effects as well as quadratic controls in GDP per capita for year of birth. We find that plough history predicts broadly worse investments in girls, with girls followed by succeeding birth intervals 0.96 months shorter in plough countries than non-plough ones, and girls breastfed 0.3 months less on average. Further, we find evidence that these and other female-disfavoring investment behaviors have a material cost as seen in worse anthropometric indicators. Female children in plough countries are 2.02 percentage points likelier to be stunted according to WHO guidelines, or 6.1% of the baseline female stunting prevalence of 32.9%. Wasting is 1.47 percentage points likelier among females in plough countries, a 7.4% of the baseline female prevalence of 19.8%.[11]

Table VII shows evidence of heightened female mortality in plough societies, estimated using a linear probability probability of mortality following equation 4, modified to include birth order and birth-year fixed effects as well as quadratic controls in GDP per capita for year of birth. We find that female children in plough societies face a differential increase in the likelihood of mortality relative to their counterparts in non-plough countries across all age categories, with a 2.62 per 1000 increase in mortality risk among neonates that increases to 4.74 for infant mortality, and 7.08 for under-five mortality. Notably, at younger ages this plough-related mortality effect is small relative to the naturally occurring female mortality advantage: $(2.62/10.8) = 24\%$ for neonates. Once past infancy, however, the plough effect swamps the native female advantage and if anything reverses it, with plough-associated female mortality for children aged one to five of $(2.34/1.25) = 187\%$ of the native female mortality advantage. This is strong evidence of systematic disinvestment in female children in plough countries.

[11] The WHO guidelines for stunting and wasting are measures of height-for-age and weight-for-age, respectively, two standard deviations below the mean.

5 Discussion

5.1 Culture, Demography, and Sex Ratios

Consistent with findings on other contemporary gender norms (Alesina, Giuliano and Nunn (2013)), our results provide evidence of long-standing persistence of patriarchal norms in places where the historical division of agricultural labor favored males. However, our family-level results reveal that such gender norms on their own appear insufficient to explain sex ratios. We find that the effect of plough-driven variation in son preference is relatively unchanging over the several decades of our sample, and that the increase in global sex ratio imbalance is driven by the interaction of lowering fertility with existing cultural preferences. As countries progress through the demographic transition and fertility falls, gender norms and son preference interact with smaller family sizes to drive increase maleness of births.

Our findings provide additional, complementary evidence on the importance of declining fertility levels in skewing sex ratios, as in Jayachandran (2014), and in particular underscores the tight relationship between son-preference and the early development legacies of historical plough use. In this sense, the specific cultural practices associated with son preference —patrilocal and patrilineal kinship systems (Dyson and Moore (1983); Das Gupta et al. (2003)), religious traditions such as sons organizing funeral pyres in Hinduism (Arnold, Choe and Roy (1998)), Confucian ancestor worship, etc.—appear to share common roots in historical plough use and the ensuing gender division of labor to which it led. Our results further provide window into Alesina, Giuliano, and Nunn (2011)'s finding linking the plough with low fertility.

5.2 Gendered Preferences Over Quantity and Quality of Children

Our analysis shows that the cultural axis of patriarchal norms identified by the plough influences the quantity of girls worldwide, but notably also influence post-birth investments in girls' human capital quality. Tables VII and VI demonstrate that plough-associated cultural preferences for sons result in disinvestments in daughters, and that these disinvestments cause female mortality risk to increase substantially as the child ages. In this regard, we find substantial basis for culturally-determined variation by gender in demand for quality and quantity of children. Our results suggest future researchers may wish to explicitly model gendered components of preferences over quantity and quality of children.

5.3 The Case of China

China has a large and heavily sex-imbalanced population and is also almost entirely a plough country. A natural question to consider then is what role it plays in our analysis. There are no Demographic and Health Surveys conducted in China, so it is excluded from the empirical results presented here, but China nevertheless serves as an excellent case study of the interaction between son preference, fertility and plough use.

When China adopted the One Child Policy in 1979, it imposed an exogenous restriction on the number of children that was binding (with variable enforcement) for most Chinese households. In the context of the strong cultural son preferences, this decline in fertility fueled a massive increase in male-skewed sex ratios (see, e.g., Yi et al. (1993)). The experience of worsening sex ratios in China as a response to declining fertility is therefore consistent with the main argument in this paper.

Moreover, additional evidence exists that the cultural norms of son preference are persistent enough to affect behavior even after the economic context changes. For example, male-biased sex ratios persist even among the children of immigrants to the US (Almond and Edlund (2008)) and the UK (Almond, Edlund and Milligan (2013)), especially if preceding births were female. Cultural norms on son preference appear to be quite resilient to major social changes, lending additional credibility to the primary mechanism by which, we argue, the plough affects contemporary sex ratios.[12]

6 Conclusion

Historical plough use separates societies around the world in a way meaningful for understanding present day sex ratios. In non-plough countries, the sex ratio at birth is near demographers' best estimates of the "natural" sex ratio at birth. In these societies, female children have lower mortality than do males at all ages and are cared for, on average, slightly better than their male counterparts as well, as indicated by time spent breastfeeding, birth spacing, weight-for-age, and height-for-age.

In plough countries, however, each of these empirical relationships is overturned. In these places, sex ratios are more male-biased at birth, which suggests that households are sex-selecting aborting female fetuses (and in some cases, committing infanticide and failing to report the birth). Then, conditional on being born, parents in plough societies invest less in their girls than in boys, which results in girls relatively stunted and wasted compared to girls in non-plough countries. This differential care, explained almost entirely by variation in historic plough use, results in higher neonatal, infant, and child mortality rates for females as compared to males.

While all societies experience greater or lesser degrees of discrimination against women, male-skewed sex ratios are unusual in that they, like dowry payments or female genital mutilation, are only found in a subset of societies. Our results suggest that this difference, at least in the case of sex ratios, can be understood as the culturally persistent legacy of a gendered division of agricultural labor. In cultures where traditional agricultural practices favored men, a cluster of gender norms that favored men and sons emerged, including specific norms of patrilocality, ancestor worship, etc. These norms persist today in the form of cultural and religious practices which lead to strong son preferences, which in turn interact with declining fertility to worsen sex ratios as households

[12] An interesting counterexample in which sex ratios at birth respond relatively quickly to economic conditions is provided by Qian (2008), who studies changing returns to female agricultural labor in China.

strive harder to meet their preferred number of boys. The roots of cultural preferences for sons are thus revealed and intensified by the development process, implying that policy responses that aim to address sex balance of births must pay attention to both cultural and economic factors.

TABLE I: SUMMARY STATISTICS, PLOUGH VS. NON-PLOUGH COUNTRIES

	Plough	Non-Plough
Sex Ratio at Birth	106.340	103.540
	(4.729)	(3.958)
Sex Ratio of Firstborn Children	108.330	104.533
	(6.571)	(6.795)
Sex Ratio of Last Birth	113.712	103.683
	(25.889)	(21.718)
Sex Ratio of Urban Births	105.831	104.006
	(7.579)	(6.282)
Sex Ratio of Rural Births	107.116	103.656
	(6.469)	(5.789)
Average Total Fertility	4.144	5.676
	(1.875)	(1.469)
% Plough-Suitable Agriculture	0.514	0.573
	(0.321)	(0.301)
% Land Tropical/Subtropical	0.868	0.976
	(0.311)	(0.151)
Large Animals	0.999	0.893
	(0.002)	(0.219)
Jurisdictional Hierarchy	4.084	2.564
z	(0.531)	(0.977)
Settlement Patterns	6.583	6.207
	(0.632)	(1.059)
Avg GDP per capita	7.166	6.628
	(0.733)	(0.957)
Observations	70	170

Notes: Unweighted sample averages reported with standard deviations in parentheses. Sex ratio of last birth determined by most recent birth for mothers who state they want no more children.

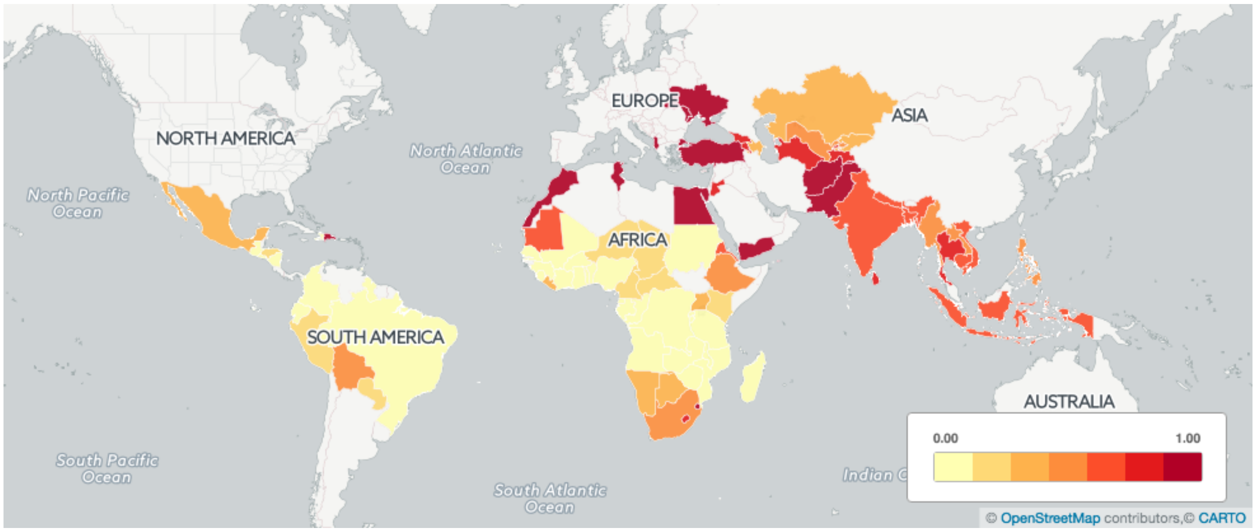

FIGURE I: Plough Intensity in the Sample of DHS Countries

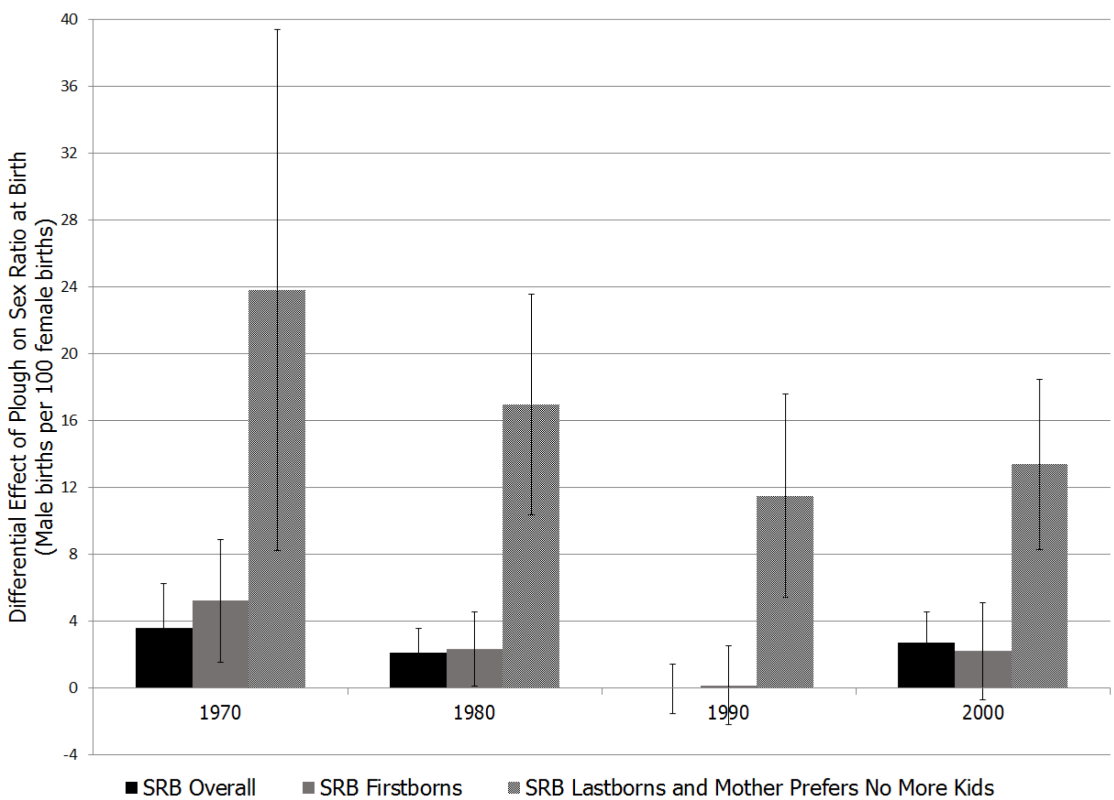

FIGURE II: Plough vs. Non-Plough Differences in Overall, First, and Lastborn Sex Ratios by Decade

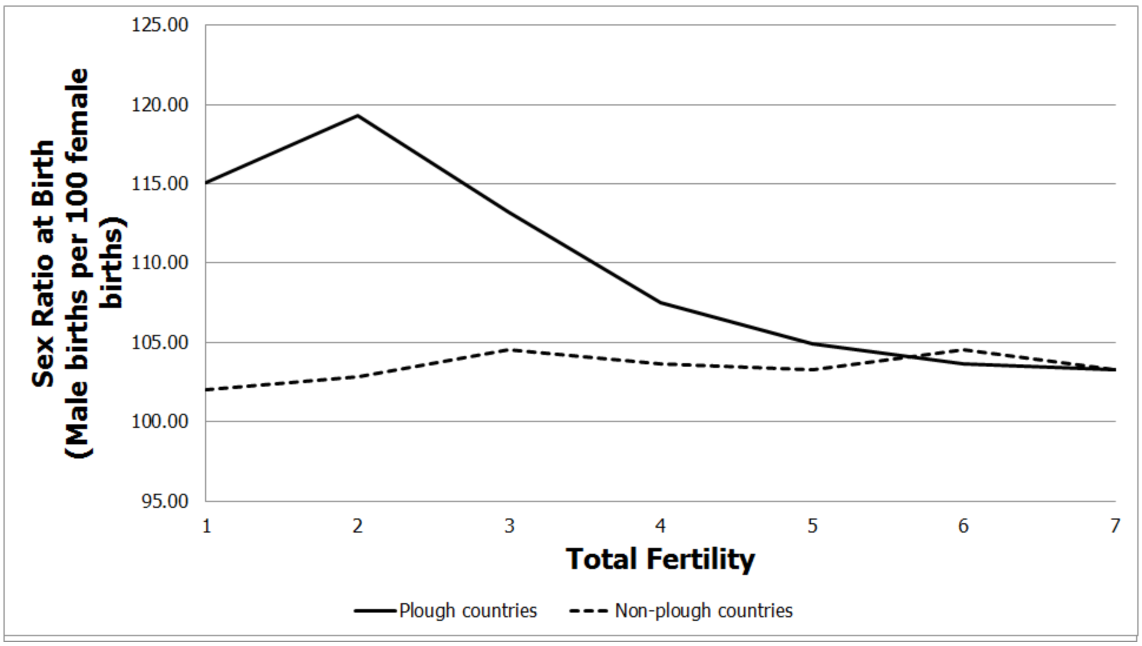

FIGURE III: Sex Ratio At Birth by Total Fertility, Plough and Non-Plough Countries

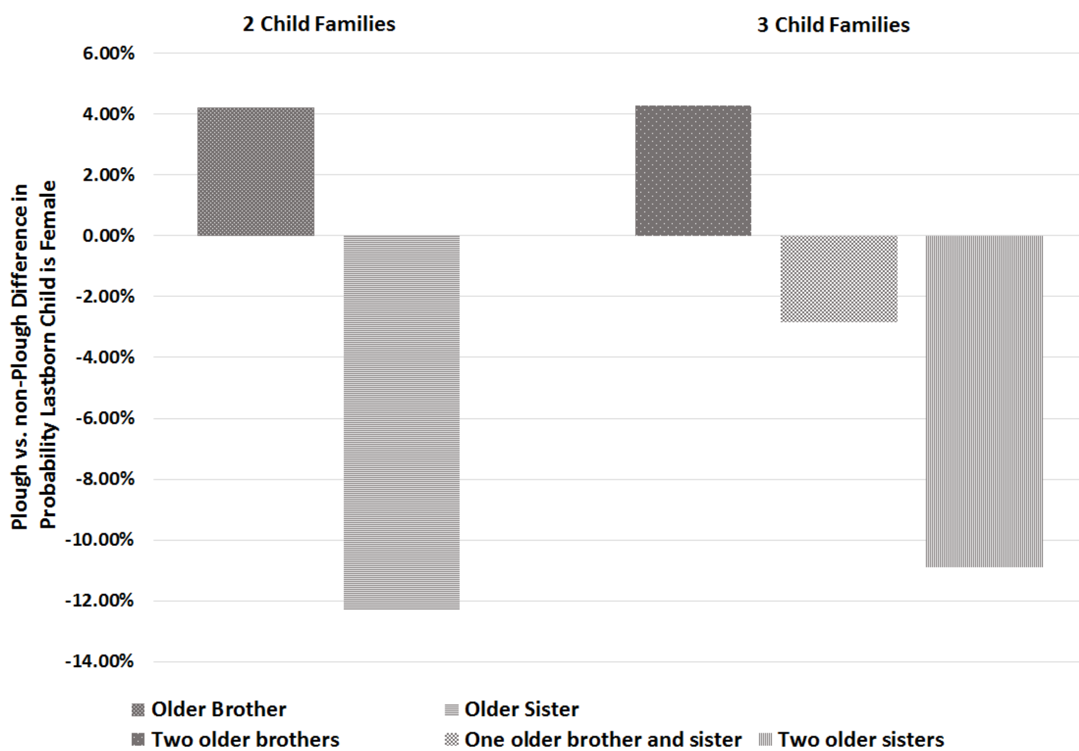

FIGURE IV: Influence of Plough on Gender of Last Birth by Sibling Composition

TABLE II: SUMMARY STATISTICS, PLOUGH VS. NON-PLOUGH COUNTRIES

	Plough	Non-Plough
Sex Ratio at Birth	106.0	103.7
	(2.7)	(1.9)
Diff in SRB	0.5	-2.2
	(7.2)	(6.7)
Sex Ratio of First Birth	107.2	104.7
	(3.8)	(3.2)
Diff in SRFB	-1.1	-1.9
	(11.2)	(10.8)
Sex Ratio of Last Birth	115.3	102.8
	(15.7)	(5.2)
Diff in SRLB	7.1	-3.4
	(31.7)	(36.5)
Sex Ratio at Birth, Urban	105.3	103.8
	(4.1)	(2.6)
Diff in SRB - Urban	-1.7	-4.8
	(13.0)	(10.6)
Sex Ratio at Birth, Rural	106.4	103.8
	(3.1)	(2.2)
Diff in SRB - Rural	0.6	-1.3
	(7.7)	(10.6)
Average Total Fertility	4.4	5.8
	(1.4)	(1.1)
Diff in Avg Total Fertility	-2.6	-1.7
	(1.0)	(1.1)
% Plough-Suitable Agriculture	0.5	0.6
	(0.3)	(0.3)
% Land Tropical/Subtropical	0.8	1.0
	(0.3)	(0.2)
Large Animals	1.0	0.9
	(0.0)	(0.2)
Jurisdictional Hierarchy	4.1	2.6
	(0.6)	(1.0)
Settlement Patterns	6.6	6.2
	(0.7)	(1.1)
Avg GDP per capita	7.2	6.6
	(0.7)	(0.9)
$(\text{Avg GDP per capita})^2$	52.0	44.7
	(10.1)	(12.7)
Observations	18	43

Notes: Unweighted sample averages reported with standard deviations in parentheses. Sex ratio of last birth determined by most recent birth for mothers who state they want no more children.

TABLE III: SEX RATIOS AT BIRTH

	(1)	(2)	(3)	(4)	(5)	(6)
	Pooled Sample (1970-2010)			Decadal Panel Sample		
Historic Plough Intensity	2.42***	2.33***	0.38	2.92***	2.95***	2.00**
	(0.65)	(0.67)	(0.91)	(0.60)	(0.59)	(0.89)
Avg GDP per capita		4.52	1.55		4.22	2.42
		(4.45)	(4.34)		(3.27)	(3.53)
(Avg GDP per capita)^2		–0.32	–0.16		–0.30	–0.19
		(0.32)	(0.31)		(0.24)	(0.26)
Average Total Fertility			–0.89**			–0.10
			(0.44)			(0.26)
% Plough-Suitable Agriculture			–2.09**			–1.58**
			(0.86)			(0.80)
% Land Tropical/Subtropical			–0.86			–4.83**
			(2.46)			(2.20)
Large Animals			1.06			0.23
			(1.60)			(1.71)
Jurisdictional Hierarchy			0.36			0.11
			(0.33)			(0.34)
Settlement Patterns			0.10			0.43
			(0.53)			(0.50)
Constant	103.74***	88.22***	105.15***	103.63***	89.24***	99.22***
	(0.34)	(15.31)	(14.97)	(0.31)	(10.80)	(11.33)
Adj. R^2	0.149	0.138	0.281	0.082	0.094	0.136
N	76	76	76	278	248	248

Notes: OLS estimated associations with population sex ratios for DHS countries. Columns (1)-(3) are estimated using the average population sex ratio in each country for all births between 1970 and 2010, while Columns (4)-(6) are estimated on a panel of each country's decadal average sex ratio. Robust standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE IV: SEX RATIO OF FIRST AND LAST BIRTHS

	(1)	(2)	(3)	(4)	(5)	(6)
	First Born Children			Last Born Children†		
Historic Plough Intensity	3.53***	3.42***	2.64*	10.56***	13.47***	15.03***
	(0.88)	(0.88)	(1.42)	(3.34)	(2.95)	(3.92)
Avg GDP per capita		–0.34	–1.62		14.07	10.31
		(5.15)	(5.62)		(13.80)	(14.56)
(Avg GDP per capita)^2		0.01	0.07		–1.04	–0.76
		(0.38)	(0.41)		(0.98)	(1.02)
Average Total Fertility			–0.10			–0.55
			(0.36)			(1.13)
% Plough-Suitable Agriculture			–1.02			–3.74
			(1.26)			(4.31)
% Land Tropical/Subtropical			–4.36*			–13.27*
			(2.38)			(6.92)
Large Animals			–2.90			15.68**
			(3.03)			(7.80)
Jurisdictional Hierarchy			0.28			–3.24*
			(0.55)			(1.67)
Settlement Patterns			0.42			–1.50
			(0.62)			(1.47)
Constant	104.63***	106.41***	116.85***	104.95***	56.84	90.51*
	(0.51)	(17.23)	(18.39)	(1.86)	(46.98)	(52.69)
Adj. R^2	0.050	0.046	0.050	0.031	0.078	0.112
N	278	248	248	277	247	247

Notes: OLS estimated associations with population sex ratios for first and last births for DHS countries. † Sex ratio of last births shown only for women who state they do not plan to have more children at time of survey. Robust standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE V: URBAN AND RURAL SEX RATIOS AT BIRTH

	(1)	(2)	(3)	(4)	(5)	(6)
		Urban			Rural	
	All	All	Last Borns†	All	All	Last Borns†
Historic Plough Intensity	2.25**	1.08	5.27	3.41***	2.50**	21.95***
	(0.97)	(1.67)	(5.62)	(0.82)	(1.15)	(5.77)
Average Total Fertility		0.05	0.83		–0.10	0.93
		(0.39)	(1.74)		(0.31)	(1.74)
Avg GDP per capita		4.60	3.78		3.00	2.30
		(5.20)	(21.37)		(4.61)	(23.99)
(Avg GDP per capita)^2		–0.38	–0.36		–0.23	0.03
		(0.38)	(1.52)		(0.34)	(1.73)
% Plough-Suitable Agriculture		–2.01	–9.12		–1.88	–4.11
		(1.48)	(5.57)		(1.16)	(5.86)
% Land Tropical/Subtropical		–1.78	–8.72		–7.85**	–22.71**
		(2.23)	(7.45)		(3.29)	(9.53)
Large Animals		–1.17	10.42		–0.79	11.25
		(2.44)	(9.17)		(2.58)	(11.48)
Jurisdictional Hierarchy		1.18**	2.30		–0.19	–5.23**
		(0.58)	(3.43)		(0.46)	(2.17)
Settlement Patterns		0.46	–3.12*		0.57	–1.11
		(0.53)	(1.78)		(0.60)	(2.02)
Constant	103.97***	88.11***	108.30	103.73***	101.17***	118.30
	(0.48)	(17.58)	(73.78)	(0.44)	(15.13)	(85.00)
Adj. R^2	0.018	0.044	0.028	0.060	0.118	0.101
N	278	248	247	278	248	246

Notes: Results from OLS regression of country-level sex ratios of DHS urban and rural subsamples for all births as well as last borns only. † Sex ratio of last births shown only for women who state they do not plan to have more children at time of survey. Sample restricted to observations with at least 200 births. Robust standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE VI: CHILD ANTHROPOMETRICS

	(1)	(2)	(3)	(4)	(5)
	Succ. Birth Interval (mos)	# Months Breastfed	WHO Stunted (%)	WHO Wasted (%)	
Female	0.13**	0.19***	–4.09***	–2.93***	
	(0.05)	(0.03)	(0.23)	(0.23)	
Plough	1.18	0.69	–2.89	1.53	
	(1.19)	(0.88)	(3.12)	(3.49)	
Female # Plough	–0.96***	–0.30**	2.02***	1.47***	
	(0.28)	(0.11)	(0.49)	(0.44)	
% Plough-Suitable Agriculture	0.74	0.58	–1.04	–1.80	
	(1.35)	(0.94)	(3.43)	(3.43)	
% Land Tropical/Subtropical	–4.68*	3.82***	10.18***	11.75***	
	(2.73)	(0.89)	(3.23)	(3.72)	
Large Animals	–0.98	–0.26	11.45	10.21*	
	(3.28)	(1.84)	(8.01)	(5.35)	
Jurisdictional Hierarchy	–0.46	0.29	–0.41	–0.13	
	(0.44)	(0.31)	(1.14)	(1.17)	
Settlement Patterns	0.71	–0.30	–0.53	0.20	
	(0.45)	(0.23)	(0.67)	(1.00)	
GDP per capita	–1.18	1.55	–17.34	–18.69*	
	(3.74)	(2.61)	(10.94)	(10.14)	
(GDP per capita)^2	0.11	–0.27	0.69	0.84	
	(0.29)	(0.20)	(0.80)	(0.74)	
Constant	36.40***	10.94	152.47***	133.35***	
	(13.02)	(8.43)	(37.36)	(33.95)	
Adj. R^2	0.009	0.080	0.050	0.046	
N	5131353	1463997	1056996	1090302	

Notes: Results from OLS regression of child-level outcomes for children in DHS countries, calculated using DHS survey weights. Regressions include fixed effects in birth order and year of birth. Robust standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE VII: INFANT AND CHILD MORTALITY

	(1)	(2)	(3)	(4)
	Neonatal (<1 m.o.)	Infant (< 1 y.o.)	Child <5 y.o	Non-Infant Child > 1 & <5 y.o.
Female	–10.80***	–13.89***	–15.14***	–1.25***
	(0.68)	(0.68)	(0.78)	(0.39)
Plough	–4.60	–20.12***	–42.48***	–22.36***
	(4.08)	(7.26)	(11.36)	(5.05)
Female # Plough	2.62**	4.74***	7.08***	2.34***
	(1.27)	(1.51)	(1.64)	(0.69)
% Plough-Suitable Agriculture	2.75	2.92	6.91	3.99
	(3.45)	(8.30)	(12.22)	(5.02)
% Land Tropical/Subtropical	7.78**	14.90*	32.10**	17.20*
	(3.60)	(7.71)	(13.73)	(8.89)
Large Animals	10.79	36.64	81.36**	44.71***
	(9.18)	(23.44)	(32.28)	(11.35)
Jurisdictional Hierarchy	–0.56	–4.59	–7.43	–2.83
	(1.57)	(3.45)	(5.23)	(2.28)
Settlement Patterns	2.41**	2.67	1.76	–0.92
	(0.98)	(2.61)	(4.90)	(2.55)
GDP per capita	–24.91*	–92.70***	–132.08***	–39.38*
	(14.11)	(30.00)	(47.90)	(20.37)
(GDP per capita)^2	1.24	5.32**	7.51**	2.18
	(1.01)	(2.20)	(3.50)	(1.49)
Constant	163.15***	491.50***	685.76***	194.26***
	(48.43)	(101.29)	(162.30)	(69.08)
Adj. R^2	0.005	0.014	0.028	0.015
N	4684841	4684841	4684841	4684841

Notes: Mortality rates shown per 1000 live births. Results from an OLS linear probability model of child-level mortality outcomes for children in DHS countries, calculated using DHS survey weights. Regressions include fixed effects in birth order and year of birth. Standard errors are clustered at the country level and reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

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