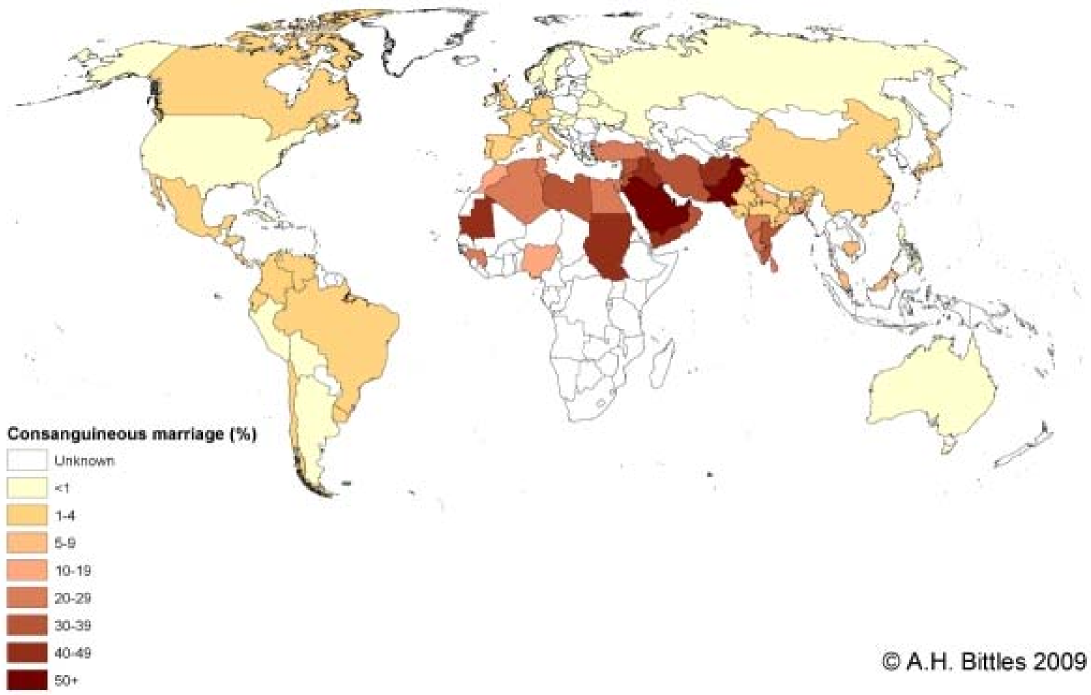
Online Supplementary Materials

I. Supplementary Figures

Figure S1: Global Prevalence of Consanguinity



Source: http://www.consang.net/index.php/Summary, accessed September 5, 2011. Consanguinity is defined as unions contracted between persons biologically related as second cousins or closer.

Figure S2: The Embankment

a: The Embankment: Not Very High and Reinforced with Sandbags

b: Protected Bank from the Top of the Embankment: Agricultural Fields Very Close to the Embankment

Figure S3. Share of Consanguineous Marriages by Protected Status and Year of Marriage

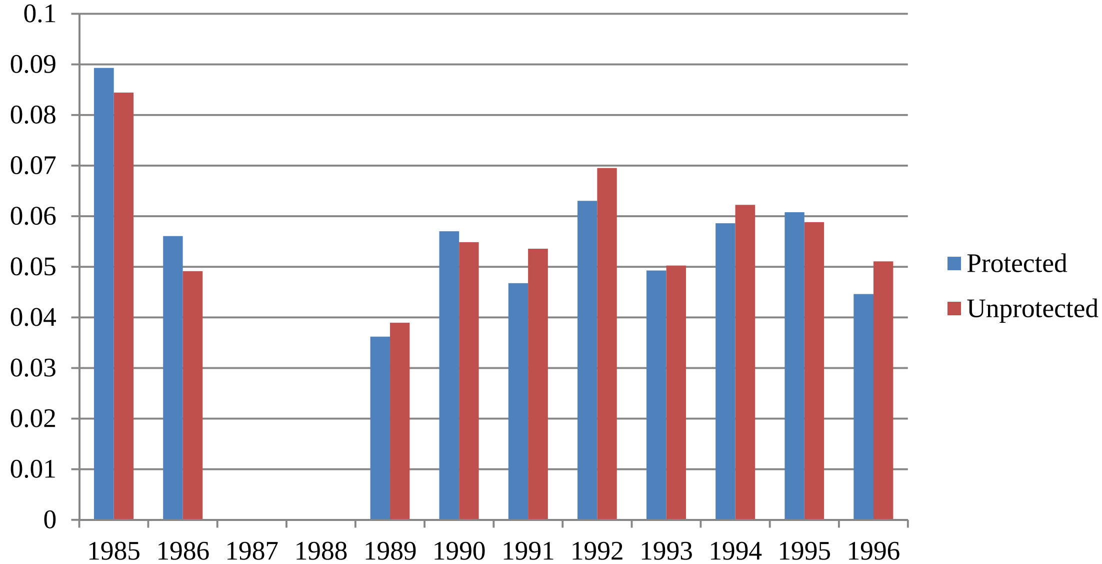
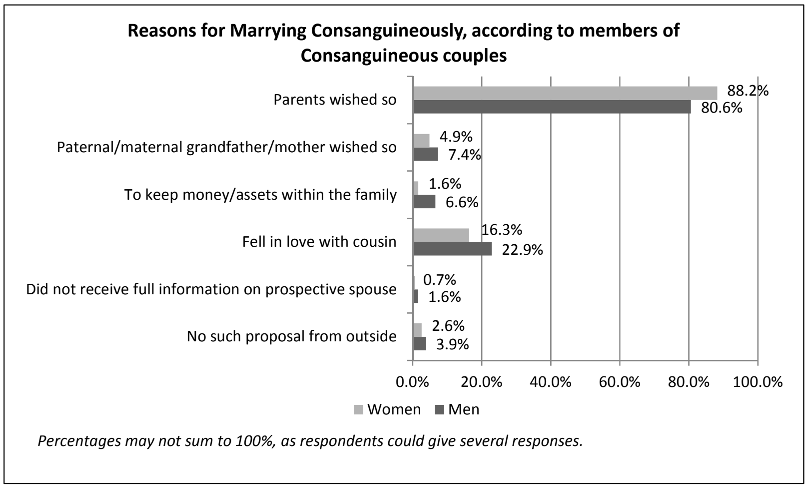
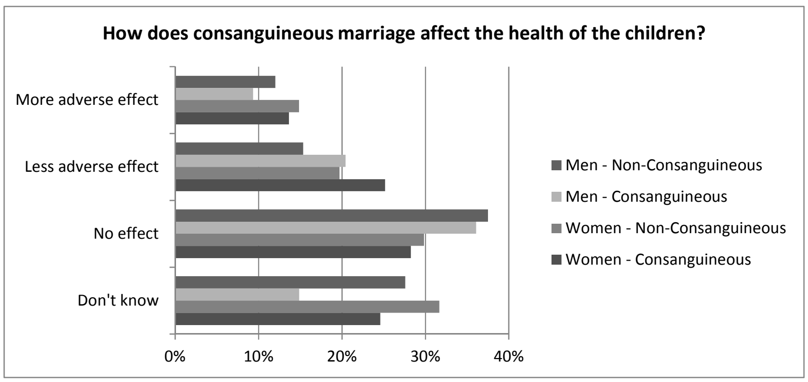


Figure S4 a: Reasons for marrying consanguineously and attitudes toward consanguinity





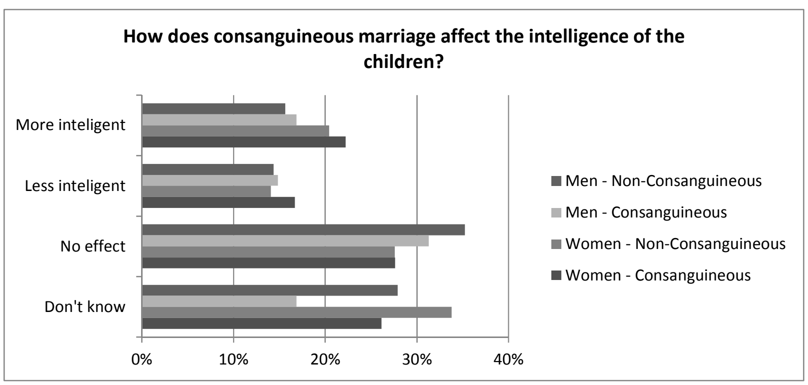
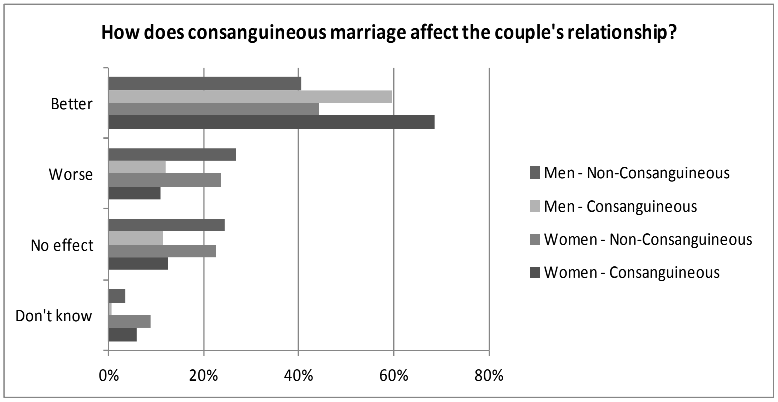
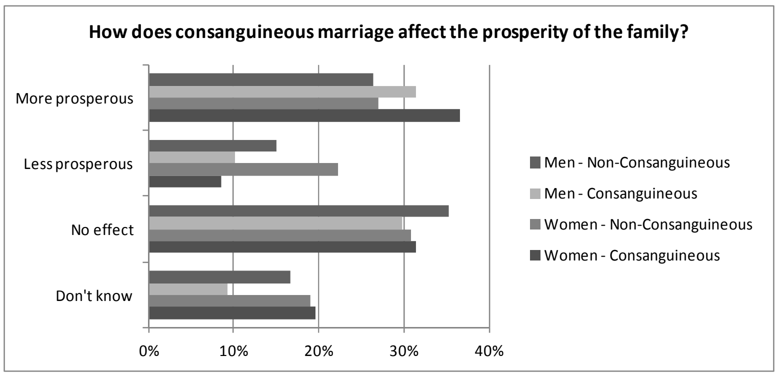
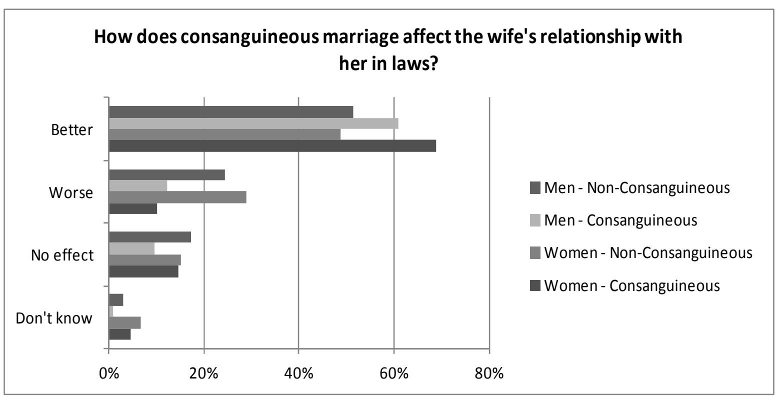
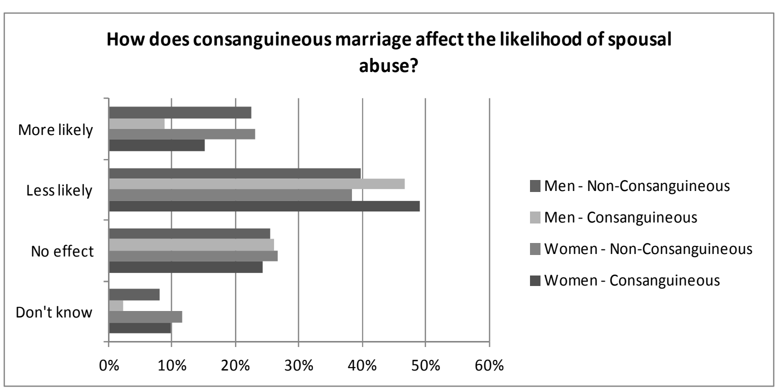


Figure S4 b: Attitudes toward consanguinity









II. Supplementary Tables

Table S1. Variable Definitions

Marriage Outcome	Definition
Size of Dowry	Total estimated cash value of dowry paid to husband in Taka
Consanguineous Marriage	Indicator equal to 1 if individual married first, second, or other cousin; 0 otherwise (observed only for Matlab residents)
Land Owned by Spouse's Household (1982)	Land owned by head of spouse's household in 1982 (measured in decimals)
Spouse Above Average Land	Indicator equal to 1 if spouse's household owns more than the average amount of land
Age at Marriage (Male and Female)	Age of individual at the time of marriage
Spouse Age (at Marriage)	Age of spouse at time of marriage (male and female)
Big Age Difference	Indicator for whether or not male spouse is more than 10 years older than the female marriage observation; 0 otherwise
Spouse Diff Vill	Indicator equal to 1 if spouse is from a different village; 0 otherwise
Spouse for outside of Matlab	Indicator equal to 1 if spouse is from outside Matlab area; 0 otherwise
Marriage Across the River	Indicator equal to 1 if spouse lived across the river (embankemnt) prior to entering marriage; 0 otherwise
Distance to Spouse's Village (OLS)	Distance (in kilometers) between the centers' of spouses' villages (estimated using GPS coordinates)

Explanatory Variables	
Protected	Time-invariant indicator equal to 1 if individual's household is protected by embankment
Post	Indicator equal to 1 if marriage year between 1989-1996 and 0 if marriage year between 1982-1986
Embankment	Embankment effect (interaction of Protected and Post)
Household Land Owned (1982)	Land owned by the household in 1982 (measured in decimals)
Oldest Child	Indicator equal to 1 if individual is the oldest child in the family (missing category is "middle" child)
Youngest Child	Indicator equal to 1 if individual is the youngest child in the family (missing category is "middle" child)
Hindu	Indicator equal to 1 if individual practices Hinduism; 0 otherwise (Muslim and other religions)
MCHP	Indicator equal to 1 if village is part of Maternal and Child Health and Family Planning program; 0 otherwise
MCHP*Post	Interaction variable (MCHP*Post)
Farmer	Indicator equal to 1 if household head is a farmer and 0 otherwise

Table S2: Within-Village Variance in Assets by Embankment Status

	Within-Village Variance in Assets	
	Protected	*Unprotected*
Pre-embankment	0.87	1.02
	(.04)	*(.04)*
Post-embankment	0.91	0.96
	(.04)	*(.02)*
Difference	0.03	-0.06
	(.06)	*(.05)*
Obs.	32	93

Notes. Standard errors are in parentheses. Observations are villages with more than 80% of land on one side of the embankment or the other.

Table S3: Difference-in-Differences Estimates of Consanguinity: Robustness checks

Robustness check:	**Top quarter of distance from the river eliminated**		**Top quarter of distance from the river on the unprotected side is eliminated**		**Control for Religion**		**Muslim Only**		**Control for MCHFP**	
Sample:	(1982-1996)	(1982-1993)	(1982-1996)	(1982-1993)	(1982-1996)	(1982-1993)	(1982-1996)	(1982-1993)	(1982-1996)	(1982-1996)
Protected	0.017**	0.017*	0.018**	0.019**	0.012	0.013	0.015*	0.015*	0.016*	0.016*
	(0.009)	(0.009)	(0.008)	(0.008)	(0.008)	(0.008)	(0.009)	(0.009)	(0.010)	(0.010)
Post	0.011	0.006	-0.027**	0.016**	0.010	0.005	0.012	0.019**	0.004	0.013
	(0.009)	(0.008)	(0.011)	(0.007)	(0.008)	(0.008)	(0.010)	(0.009)	(0.009)	(0.009)
Embankment	-0.023***	-0.021***	-0.027***	-0.026***	-0.022***	-0.021***	-0.027***	-0.024**	-0.021***	-0.020**
	(0.008)	(0.008)	(0.007)	(0.007)	(0.007)	(0.008)	(0.009)	(0.010)	(0.008)	(0.008)
Hindu					-0.046***	-0.042***				
					(0.005)	(0.005)				
MCHFP									-0.004	-0.004
									(0.010)	(0.010)
MCHFP*Post									0.011	0.008
									(0.009)	(0.009)
Observations	21,945	16,440	25,081	18,792	21,945	16,440	18,533	13,916	21,945	16,440

Notes. Difference-in-differences results are estimated using probit where the dependent variable is a binary variable equal to 1 if a marriage is consanguineous, 0 otherwise; marginal effects are reported (estimated at the means). The sample is restricted to marriages for which consanguinity rate, post or protected are non-missing and to marriages from households with more than one marriage over the study period. Year dummies are included but not shown. Standard errors (clustered at the village level in probit models) are in parentheses. *** indicates significance at 1% level; ** indicates significance at 5% level; * indicates significance at 10% level.

III. Model: Effects of the Embankment in Stylized Models of the Marriage Market

A.1 A Transferable Utility Model of the Marriage Market

Since marriages in Matlab are typically arranged by the families of the groom and bride, we assume that preferences of the bride and her family are grouped together, as are the preferences of the groom and his family. Males and females on the marriage market are indexed by *m* and *f*. Each potential spouse has two relevant characteristics: the level of wealth (w_f or w_m), which can be either high (*H*) or low (*L*), and the embankment status (e_f or e_m), which can be either protected (*P*) or unprotected (*U*). Each marriage produces an output z_{fm}, and there exists a medium of exchange (such as a dowry payment, which we denote d_{fm}) that can be used to transfer utilities from the bride to the groom. This assumption (e.g. Weiss 1997, Siow 1998, Anderson 2007) simplifies the matching problem by allowing each person to use z_{fm} in comparing the gains across different types of matches and against the payoff from remaining single. d_{fm} regulates the division between spouses, so that each person's decision is conveniently split into: (1) choose the match that maximizes the surplus generated from marriage, and (2) choose a value of d_{fm} to split that surplus.

The groom's payoff from the marriage is d_{fm}, while the bride's payoff is z_{fm} - d_{fm}.[1] We assume the following general form for z_{fm}: $z_{fm} = \max(e_f, e_m) \cdot \Pi(w_f, w_m)$. This formulation reflects the fact that embankment protection increases the productivity of land by extending the crop season, which is the principal component of wealth in rural Bangladesh. The embankment also protects from flood risk, and it is most important to have at least one side of the newly joined families be protected, an idea embodied in the max(e_f, e_m) function.[2] A woman may gain from starting to live under embankment protection after marriage, and conversely, an unprotected groom's family may gain from forming a marital bond with a protected family where they can take refuge during a flood.

Variables e_f, e_m (which can take on values *P* and *U*) and w_f, w_m (with values *H* or *L*) are all assumed to be strictly positive so that greater wealth can be valuable even in the absence of protection. $P>U$, $H>L$, and $\Pi_f = \frac{\partial \Pi}{\partial w_f}$ and $\Pi_m = \frac{\partial \Pi}{\partial w_m}$ are positive, so that protection and greater wealth are both positive characteristics in the marriage market. Further, we will focus on the case where there are gains to marriage: $\Pi_{fm} > 0$. All couples with any wealth gain from being married relative to remaining single when $\Pi_{fm} > 0$, and for the unprotected there are additional gains from marrying into a family protected by the embankment.

Our task is to uncover a *stable* set of matches for the four types of men and women in this marriage market, such that no married person would rather be single and that no two people, married or single, would prefer to form a new union. Stability implies a participation constraint for each woman which specifies that her payoff from marriage must be as large as her payoff

[1] Another reasonable and important formulation of the distribution of gains from marriage assumes Nash bargaining between spouses over the marital surplus (e.g. McElroy and Horney 1981), and extends to other forms of bargaining (Manser and Brown 1980). The bargaining solution in turn has implications for spousal choice (McElroy 1990), which is the focus of our analysis here.

[2] The max(e_f, e_m) function is an admittedly strong conceptualization of risk mitigation, but the idea is to model the embankment as a substitute characteristic, and the particular form (i.e. the max function) is chosen for convenience. The intuition we develop holds for any form of a substitute characteristic.

from remaining single: $\max(e_f, e_m)\cdot\Pi(w_f, w_m) - d_{fm} \geq e_f \cdot \Pi(w_f, 0)$. Similarly, the participation constraint for each man requires $d_{fm} \geq e_m \cdot \Pi(0, w_m)$. For stable matches, a set of incentive compatability constraints must also be satisfied for each person that specify that the payoff from the chosen match is larger than under alternate matches:

$\max(e_f, e_m)\cdot\Pi(w_f, w_m) - d_{fm} \geq \max(e_f, e_n)\cdot\Pi(w_f, w_n) - d_{fn}, \forall n \neq m$, and

$d_{fm} \geq d_{gm} \;\; \forall g \neq f$.

Since there are only four types of each gender, the above represents three incentive compatibility constraints for women and a further three for men. A final market clearing condition stipulates that for a match of type *f* and type *m* to be feasible in the aggregate, the supply of these types must be equal.

A.2 Solution to the Transferable Utility Model

Under transferable utility and a unique output measure z_{fm} associated with each marriage, the stable assignment is the set of matches that maximizes total output over all possible assignments.[3] It is easy to verify that under complementarity ($\Pi_{fm} > 0$), the only stable set of matches is where type (*P*, *H*) get matched to type (*U*, *H*) of the opposite gender, while (*P*, *L*) and (*U*, *L*) also form bonds. In other words, we observe positive assortative matching in wealth, but negative assortative matching in protection status.

In order to illustrate why these matches are optimal, it is useful to derive the result assuming a market structure where the women can bid for the men and are the residual claimant of the marital surplus generated (the results are analogous when men bid). The maximum willingness to pay for a (*P*, *H*) man by each type of woman is as follows:

By a (*P*, *H*) woman, $WTP_{PH}^{PH} = P\cdot\Pi(H,H) - P\cdot\Pi(H,0)$

By a (*P*, *L*) woman, $WTP_{PL}^{PH} = P\cdot\Pi(L,H) - P\cdot\Pi(L,0)$

By a (*U*, *H*) woman, $WTP_{UH}^{PH} = P\cdot\Pi(H,H) - U\cdot\Pi(H,0)$

By a (*U*, *L*) woman, $WTP_{UL}^{PH} = P\cdot\Pi(L,H) - U\cdot\Pi(L,0)$

Since *P*>*U*, $WTP_{UH}^{PH} > WTP_{PH}^{PH}$ and $WTP_{UL}^{PH} > WTP_{PL}^{PH}$. This is because a protected man offers greater value added to an unprotected woman than he does to a protected woman, and the unprotected woman will therefore be willing to outbid the protected woman. Also, $WTP_{UH}^{PH} > WTP_{UL}^{PH}$ when $\Pi_{mf} > 0$. Under complementarity in the husband's and wife's wealth, a wealthy woman gains greater surplus from a wealthy man than does a low wealth woman, and will therefore be willing to outbid her. Thus the (*U*, *H*) woman can outbid all other types of women in order to match with a (*P*, *H*) man.

The above implies that a (*P*, *H*) man will be feasible for a (*U*, *H*) woman. For this match to occur in equilibrium, we also need to demonstrate that the (*U*, *H*) woman wants the (*P*, *H*) man – that a marriage to this man generates more surplus for her than a marriage to any other man. If the (*P*, *H*) - (*U*, *H*) match is surplus maximizing, then we can find a transfer d_{fm} such that the (*U*, *H*) woman and (*P*, *H*) man are better off under this match than under any other pairing. This is easily established, as we can use the assumptions *P*>*U*, $\Pi_m > 0$, $\Pi_f > 0$, and $\Pi_{fm} > 0$ to show that WTP_{UH}^{PH} exceeds WTP_{UH}^{PL}, WTP_{UH}^{UH}, and WTP_{UH}^{UL}. In other words, a protected, high-

[3] This result is derived in Weiss (1997), pp. 100-101, and in Browning, Chiappori and Weiss (2005), chapter 8.

wealth woman's desire for an unprotected high-wealth man exceeds her desire for any other type of man.

Analogous arguments establish that (*P*, *H*) type women have the highest willingness to pay for (*U*, *H*) type men, and achieve the largest surplus from those matches. So for both men and women, all matches are of the form (*P*, *H*) - (*U*, *H*). Once all these (*P*, *H*) - (*U*, *H*) men and women are paired up, the remaining (*U*, *L*) women in the market place the highest bid for (*P*, *L*) men (their surplus maximizing choice). So the remaining matches for both men and women are of the form (*P*, *L*) - (*U*, *L*).[4]

The general result highlighted by this model is that we should observe positive assortative matching in men's and women's characteristics that are complements (such as wealth) and negative assortative matching in characteristics that are substitutes (such as protection status). Although the transfer payments from wives to husbands are not precisely pinned down in the general model (the participation and incentive compatibility constraints only place upper and lower bounds on the feasible values of d_{fm}), we can also predict changes in dowries following embankment construction under specific market structures, such as the case where women bid for men in a multi-unit English auction setting. If there are multiple (*U*, *H*) women bidding for the same (*P*, *H*) man, the women would compete away the entire surplus generated by this man, and dowry payments would increase with protection status after embankment construction, since the man's contribution to the total marital surplus increases with his protection status.

A.3 Embankment Effects in a Simulated Gale and Shapley (1962) Matching Model

We now relax a number of the restrictive assumptions made in the model outlined above and simulate the dynamics of matching in a more general model. Potential spouses can offer compensating differentials along multiple dimensions in order to secure a desirable match. For example, a family could make up any deficiency in its relative wealth position by offering their candidate at the age most desirable by the opposite sex, or accepting a candidate of a less desirable age. Thus, we now endow each candidate with a continuous characteristic that is complementary to embankment protection (such as the amount of land or wealth), another continuous characteristic relevant to spousal choice which is neither a complement nor a substitute to protection (e.g. age at marriage), a discrete protection status, and an idiosyncratic attractiveness parameter.

A male *m*'s payoff from marrying a female *f* is postulated to be:

$$s_m^f = \max(e_f, e_m)\cdot\Pi(w_f, w_m) + \left[\alpha - \beta(a_f - a_f^*)^2\right] + \varepsilon_m^f \quad (1)$$

e is embankment protection status, *w* is wealth, *a* is age, a_f^* (a constant) is the most desired female age at marriage from a man's perspective, ε_m^f is the idiosyncratic pair-specific attractiveness parameter that measures male *m*'s preference for female *f*, and α and β are constants. Greater wealth and protection status are considered attractive characteristics, and wealth is complementary to protection (e.g. the embankment extends the crop growing season). The insurance benefits of the embankment make the husband's and wife's protection status substitutes. Candidates are penalized if their age at marriage differs from some optimal age at

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[4] These are results for a monogamous society with equal numbers of men and women of each type. Note that *H*-type women can typically outbid *L*-type women, and if there are an excess of *H*-type women (over *H*-type men) in the market, then we will observe some (*U*, *H*) women marrying (*P*, *L*) men (and (*P*, *H*) marrying (*U*, *L*)), which will in turn force some *L*-type women to remain single.

marriage. Female *f* has an analogous scoring function over each male *m* that she uses to evaluate which proposal to accept:

$$s_f^m = \max(e_f, e_m) \cdot \Pi(w_f, w_m) + \left[\alpha - \beta(a_m - a_m^*)^2\right] + \varepsilon_f^m \quad (2)$$

With a total of *M* men and *F* women on the market, we can use (1) and (2) to define an *M* x *F* matrix of scores over all men and women. Since we cannot describe analytical solutions to the matches that occur, we simulate the matches by endowing 2500 men and 2500 women with a distribution of wealth, age, protection and attractiveness characteristics. We assume that initially each individual gets an independent draw on wealth from a truncated normal distribution over positive support, a draw on age from a uniform distribution (on support 16-22 for women with an optimal age at marriage, a_f^* of 19, and on support 21-27 for men, with a_m^*=24), and a draw on preferences for each individual of the opposite gender from a normal (0,1) distribution. Half of all men and all women are randomly assigned to each bank of a river with an embankment on only one side. We add search frictions to this model by assuming that individuals are more likely to see (and propose to) others on the market who are physically closer to them. The Gale and Shapley (1962) algorithm identifies the stable set of matches in this market.[5]

Results of the matching simulation show that for both protected men and women, the wealth (land) distribution of spouses they match with shifts to the right following embankment construction (see figure S5). Conversely, the wealth distribution of spouses shifts to the left for men and women on the other bank of the river (who remain unprotected) following embankment construction. Thus, the protected are able to secure wealthier spouses at the expense of the unprotected. Individuals residing on the two sides of the river are in direct competition in the marriage market, and this result comes about because (a) the protected have an extra desirable characteristic to offer, so their offers are more likely to be accepted and (b) due to complementarity in protection status and land, they are more likely to extend offers of marriage to higher-wealth individuals.

For age at marriage, where no such complementarity exists, figure S6 shows that there no clear trend to indicate that the protected are better able to secure partners at the "optimal" age, or reduce spousal age gaps. Complementarity in inputs is therefore key to understanding the potential effects of the embankment on the variety of possible marriage outcomes. The model also exhibits negative assortative matching in the substitute characteristic – protection status. Within-bank marriages are less likely to occur after embankment construction, even with cross-bank search frictions.

Although dowries are not well defined in this non-transferable utility model, figure S7 plots the surplus accruing to matched men and women if the marital surplus (over the payoff from remaining single) is divided between spouses according to Nash bargaining. The distribution of surpluses shifts to the right for both protected men and women. Since the dowry payment would be a positive function of the difference between the man's surplus and woman's surplus, when protected men (women) marry unprotected women (men), dowry payments increase (decrease). This result would also be predicted by a model where the embankment is thought to shift spousal threat points (McElroy 1990). For protected-protected matches, the prediction on dowry payments is not clear.

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[5] In the Gale and Shapley (1962) algorithm, men propose their most preferred woman, and the woman holds on to the most attractive man while rejecting the rest. The men then propose to their next best option, and so on …, producing a stable set of matches where no two man and woman not paired to each other through the algorithm would be better off by contracting that marriage.

Figure S5: Land Distribution of Spouses of Protected and Unprotected Men in the Simulated Gale-Shapley Marriage Market

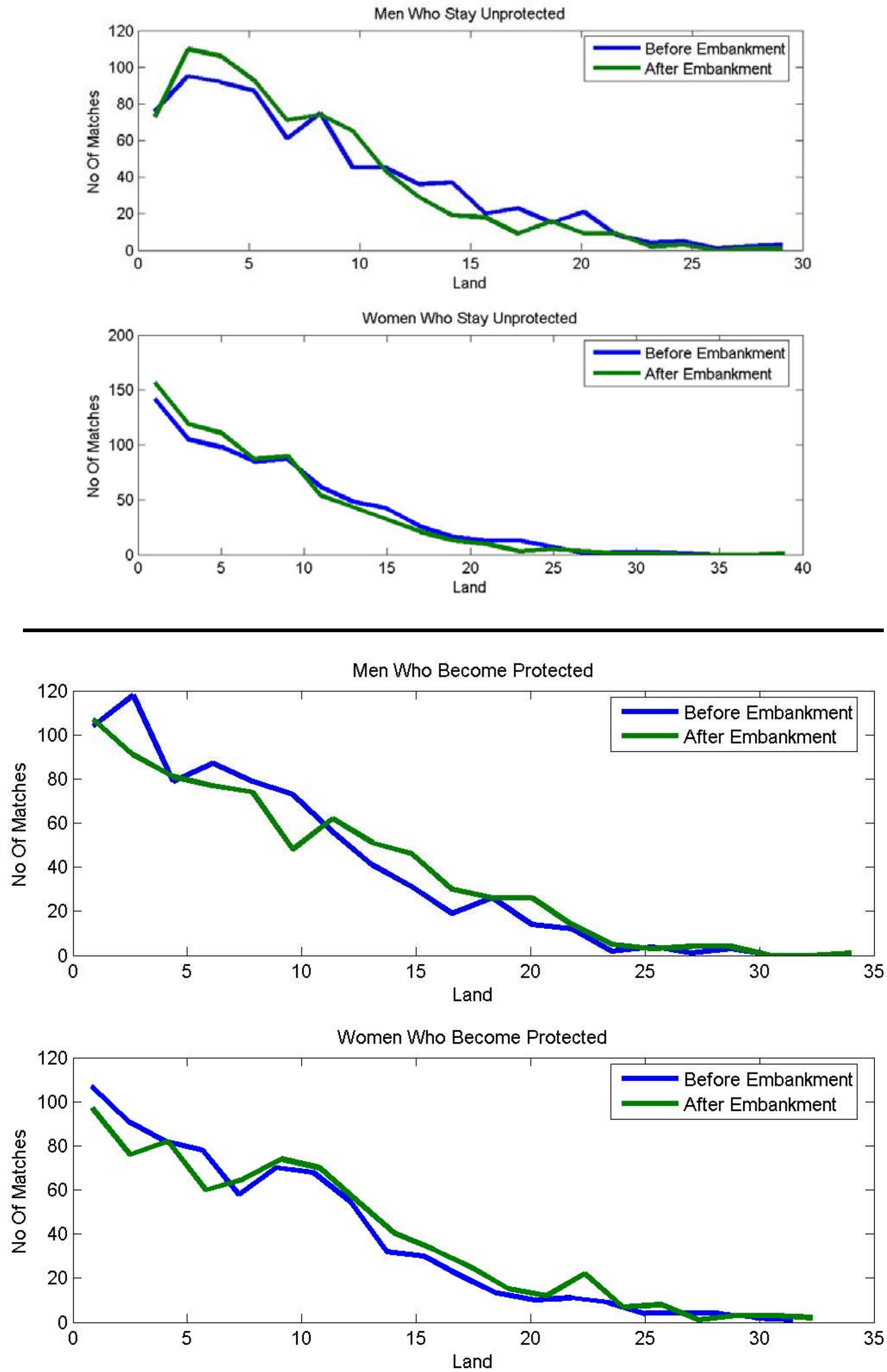

Figure S6: Spousal Age Gap for Protected Men and Women in the Simulated Gale-Shapley Marriage Market

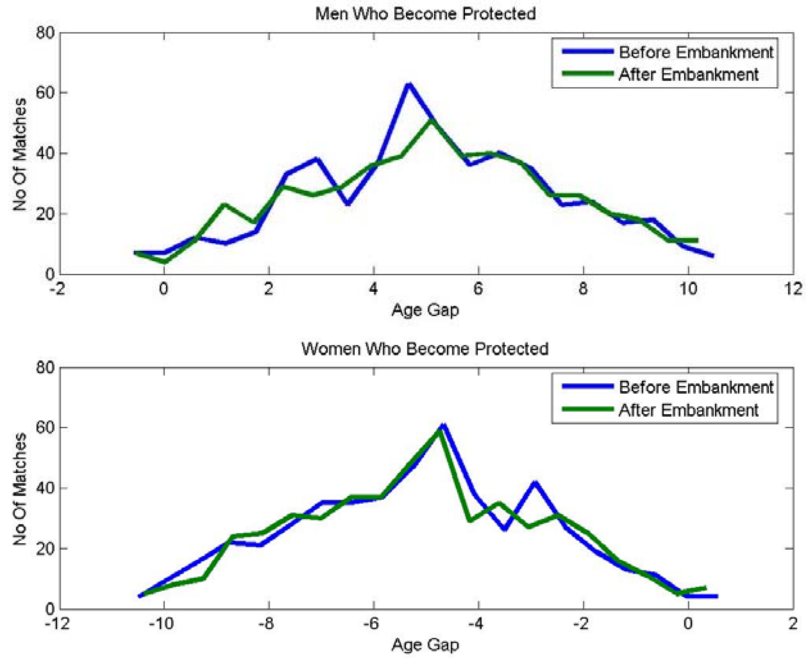

Figure S7: Nash Bargaining Surplus for Men and Women Pre and Post Embankment