Appendix

On line supplement to

Contracting without contracting institutions—The “trusted-assistant” loan in 19th century China

Abstract

This document provides a model of trusted assistant lending (Section A), associated proofs (Section B), a sample loan document and a description of our bank-loan book (Section C), as well as robustness analysis (Section D), for “Contracting without contracting institutions—The “trusted-assistant” loan in 19th century China.”

A A model of trusted assistant lending

In this section, we develop an infinite-date, Markovian, Nash bargaining model of trusted-assistant lending. The bargainers are an official and a trusted assistant. The information sets of the assistant and official are identical and commitment in the current period to future surplus divisions is impossible. The gain from reaching an agreement is subject to stochastic shocks which can eliminate the surplus. Thus, our model is a standard complete information, repeated game bargaining model.

The only wrinkle in the model is that we focus on solutions in which some of the surplus is transferred to a third-party, the creditor. This raises some issues not present in a standard repeated bargaining model—is the bargaining surplus net of transfers to the creditor sufficient to make cooperation profitable to the bargaining parties? Is it incentive compatible for the bargaining parties not to deviate to alternative surplus divisions that eliminate the transfer to the creditor? All proofs for results are deferred to Section B of this appendix.

In the model, the rents from provincial tax collection are divided through period-by-period bargaining between the official and assistant. We first derive, in Proposition 1, the conditions for a Cooperative Repayment Solution—a stationary solution to the individual period Nash bargaining problems which implements efficient loan repayment when the parties conjecture that the same solution will be played in all subsequent periods. Next, in Proposition 2, the conditions that must be satisfied for the solution to be renegotiation proof are developed. Finally, in Proposition 3, we consider the effect of parameter variations on the viability of trusted-assistant lending.

A.1 Framework

Consider a world populated by three actors: a bank, an official, and an assistant. Dates are indexed by $d = \{0, 1, 2, \ldots\}$. All actors are risk neutral, patient, expected utility maximizers. The official is a provincial governor and the assistant is his assistant. There is only one good in the economy called "cash." The actors must consume any cash generated in a period during that period. The expected utility of the bank is equal to the sum of its expected future cash flows from the loan. The utility of the official and assistant depends on the sum of expected future cash flows as well as the sum of the expected non-pecuniary costs of collecting tax *revenue* in the province. Consistent with Hypothesis I.A, the loan is not collateralized or guaranteed and the borrowing official faces not reputation costs triggered by default.

The official borrows funds from the bank at date 0. A condition for the loan is that an assistant, an employee of the bank, travel to the province with the official and assist in collection. The face value of the official's debt equals ℓ. At each date at which the official is in post, the official collects tax revenue, t, from the province. The official is required to remit, in each period τ of this revenue to the imperial government in Beijing. We will call this required remittance the center's *tax quota*.

Revenue in excess of the tax quota can be offered to the assistant to ensure the assistant's cooperation in collecting revenue, paid to the lender to satisfy the debt, or consumed by the official. While the two *agents*—the official and assistant—are in post, tax revenue is their only source of cash. All actions of the agents are observable by the agents. The bank only observes loan payments and whether the assistant is "in-post," working for the official in the province, or has returned to the bank. Thus the model is consistent with Hypothesis I.A in the main body of the paper—trusted assistant loans are used when creditors cannot directly observe the actions of borrowers.

At date 0, the official is in post. At the start of each period following the first period, with probability β, the official retains his position and with probability $1-\beta$, the official is *separated* from his position. This probability represents the random exogenous shocks, e.g., mourning the death of parents, that led to officials departing from their posts. At date 0, the official is inexperienced. At the start of each subsequent period in which the official is in post and inexperienced, the official *converts* to being experienced with probability $1-\alpha$, $\alpha \in (0, 1)$. Once an official is experienced, the official stays experienced. Experience affects the non-pecuniary cost of debt collection.[1] At date 0, and all subsequent dates, the assistant is experienced.

In each period, there are two possible *economic conditions* for the province: "bad," B, and "good," G. The probability that the economic condition in a period is G equals p. Thus, the economic condition in each period is independent of the previous and future realizations of the economic condition. The good condition is intended to represent the "normal" situation where collecting revenue is easy and agents profit from collecting revenue in excess of the tax-quota. The bad condition represents an "exceptional" time of hardship, e.g., crop failure, in which revenue collection is onerous.

We assume that, regardless of the cost of collection, the official will always raise sufficient revenue to satisfy the tax quota from the center, $\tau > 0$. The maximum tax revenue the official can raise in any period is given by $\bar{t} > \tau$. The cost of collecting tax revenue depends on (a) the economic condition, (b) whether the official cooperates with the assistant, and (c) on whether the official is experienced.

When the official is inexperienced, the cost of collecting tax revenue, t, without the help of the assistant is $\chi_\omega t$, $\omega = G,B$. If the assistant and official agree to raise tax revenue, t, cooperatively, each bears a cost of $\frac{1}{2} c_\omega t$, $\omega \in G,B$. Whether the assistant cooperates in revenue collection or simply occupies his post without providing any useful aid to the official can only be observed by the agents. If the assistant's cooperation is not obtained in a given period, the official has no incentive to compensate the assistant and the assistant is effectively "fired" for that period. Cooperation requires making a payment, a, to the assistant. This payment must satisfy limited liability, implying that, if the loan is also repaid in the period, $a \in [0, t - \tau - \ell]$ and, if the loan is not repaid in the period, $a \in [0, t - \tau]$.

When the official is experienced, the cost of collecting tax revenue, t, without the help of the assistant is given by $c_\omega t$, $\omega = G,B$. If the assistant and official agree to raise tax revenue, t, each bears a cost of $\frac{1}{2} c_\omega t$, $\omega = G,B$.

In any period following the first, the official and assistant are in one of four possible *states*: *I Indebted*: The official has not repaid the loan and the official is inexperienced. *N Not indebted*: The official has repaid the loan but is still inexperienced. *F Free*: The official is free, i.e., experienced, and has no need for the assistant. *S Separated*: The official is separated.

When the official is separated at the start of the period, state S, the payoff to the official and assistant equals 0. In the first period in which separation occurs, the assistant, being a personal employee of the official, returns (at the start of the period) to the bank.

In state F, when the official is free, it is a weakly dominated strategy for the official to cooperate with the assistant as cooperation would entail at least paying the assistant an amount equal to the assistant's effort costs and might entail paying the assistant more. Repaying the loan

[1] An alternative and equivalent interpretation of "experience" in our model is that the official converts when he is able to identify trustworthy local administrators who are perfect substitutes for the assistant.

is also a dominated action for the official—the loan cannot be legally enforced and paying off the loan lowers the consumption of the official. Thus, when the official is free, the probability of repayment is zero as is the expected share of tax revenues received by the assistant. Because remaining in post is futile, we assume that, at the first date at which the official is free, the assistant also returns to the bank.

In a period in which the state is N, i.e., when the official is not indebted but is still inexperienced, the official has an incentive to make a *cooperation* agreement with the assistant to ensure the assistant's cooperation in tax-revenue collection. Such an agreement will specify a level of tax collection, t, and the share of tax revenue received by the assistant, which we call the assistant's *compensation*, a. The terms of the agreements are determined in each period by bargaining in a fashion to be discussed later. Note our specification for state N assumes that the assistant remains with the inexperienced official even though the loan has been repaid. This assumption is made to conform with documentation in the historical record.

In a period in which the state is I, i.e., when the official is both inexperienced and indebted, bargaining will fix compensation, a, in the period, However, in addition, a cooperation agreement will specify whether the loan is repaid in that period. The period rewards and state transition probabilities specified above are summarized in Tables B-1, B-2, and B-3. Table B-1 in Appendix Section B for the reader's convenience.

Upon returning to the bank, the assistant will receive a *return benefit*. This benefit reflects the change in the assistant's utility produced by return. As the discussion above shows, the assistant only returns after an unsuccessful collection if (a) the official becomes experienced or (b) the official is separated from his post. In these cases, the return benefit has no effect on bargaining between the official and assistant because there is no bargaining. Thus, to reduce notational clutter, we normalize the return benefit to 0 when the assistant returns after an unsuccessful collection.

However, if a cooperation agreement leads to repayment, part of the surplus generated by the agreement is the benefit to the assistant from returning after a successful collection. Thus, the benefit will affect the bargaining solution. In practice, as discussed in Section 2, the benefit to the assistant from returning after successful collection arose from a number of channels: (a) increased utility engendered by rejoining his family, (b) the effect of successful collection on the value of the assistant's human capital (e.g., promotion prospects), (c) performance shares awarded based on successful collection, and (d) the elimination of suspicions of disloyalty, which might lead to termination.

Secondary and primary historical sources, as well as research by financial economists (Morck and Yang, 2010), verify the existence of each of these channels. However, given our information, we have no means distinguishing between them. So, again to avoid excessive notation, we simply assume that the collective effect of these channels produces a return benefit, conditioned on successful collection, equal to $A > 0$.

A.2 Parametric assumptions

In order to simplify the analysis, reduce the number of parameters, and restrict attention to interesting cases, we impose the following restrictions on the marginal cost of collection parameters.

Assumption 1 (Parameters)**.**
(i) $c_G = 0$, (ii) $c_B = c$, $c \in (1,2)$, (iii) $\chi_G = \chi_B = \chi$, $\chi \in (1,2)$, (iv) $\chi > \frac{c}{2-c}$.

Assumption 1.i captures the idea that collecting tax revenue is easy for experienced agents when the condition of the province is G. Assumption 1.ii captures the idea that, even for experienced agents, when the condition of the province is bad, B, tax collection is onerous, i.e., $c > 1$. However, it is not so onerous that the net loss from collecting revenue, $t - ct$, exceeds revenue collected, i.e., $c < 2$. Assumption 1.iii captures the idea that collecting taxes is difficult and onerous for inexperienced agents regardless of economic conditions. Assumption 1.iv implies that the marginal cost of collection is higher for inexperienced agents than experienced agents, $c < \chi$. Assumption 1.iv ensures that the advantage of cooperation is sufficient to offset the increased cost of collection generated by the additional revenue that must be raised to compensate the assistant.

We also impose the following restrictions on the maximum tax capacity of the province, $\bar{t}$. These restrictions ensure that the bargaining solution we develop in the subsequent section is not constrained by the tax capacity constraint, $t \leq \bar{t}$. These assumptions are not required to derive the main results of the paper but greatly simplify the analysis by permitting us to avoid working out all of the "corner solutions" to the bargaining problem.

Assumption 2 (Revenue capacity)**.**
(i) $\bar{t} - \tau > \tau\chi$, (ii) $\bar{t} > \frac{\tau(c+(2-c)\chi)}{c(2-c)}$, (iii) $\bar{t} - \tau - \ell > A - \tau\chi$.

A.3 When the official is free or separated

When the official is separated, the official's payoff is 0. Thus the payoff to the official, the expected sum of the period rewards from the current and all future periods, is given by $v_O^S = 0$.

If the official is free, then, if the economic condition is G, because the marginal cost of collection is 0, the official will collect taxes up to the maximum capacity of the province, $t = \bar{t}$ and remit the tax quota to the center, leaving the official with a surplus of $\bar{t} - \tau$ which equals the official's period reward. When the condition of the province is B, the marginal cost of tax collection $c > 1$. Thus, the official will collect just enough tax revenue to meet the tax quota,

$t = \tau$, and the official's period reward will equal the non-pecuniary cost of collection, $-c\,\tau$. Hence, the expected period reward to the official when the state is F, $\bar{r}_O^F$, is given by

$$\bar{r}_O^F = p\, r_O^F(G) + (1-p)\, r_O^F(B) = p(\bar{t}-\tau) - (1-p)\, c\, \tau.$$

Because the state transition probabilities are stationary, the collection policy of the official is stationary, and economic condition in the current period is independent of future economic conditions, in any period in which the state is F, the payoff to the official satisfies the dynamic programming equation

$$v_O^F = \bar{r}_O^F + \beta\, v_O^F + (1-\beta) v_O^S = v_O^F = \bar{r}_O^F + \beta\, v_O^F,$$

where the official's *continuation payoff*, $\beta\, v_O^F + (1-\beta) v_O^S$ is determined by the transition probabilities. Solving this equation yields:

$$v_O^F = \frac{\bar{r}_O^F}{1-\beta}. \tag{A-1}$$

A.4 When the official is inexperienced: the cooperative repayment solution

When the official is inexperienced, an agreement with the assistant to jointly collect taxes can increase the payoff of both the assistant and the official. We analyze the conditions under which an economic-condition dependent agreement can be implemented by Nash bargaining. Our key assumption is that bargaining is period-by-period. Agents cannot commit, at the given date, to the terms of future agreements. Thus, bargaining in state N centers only on the assistant's compensation, a, in that period, and bargaining in state I centers only on the assistant's compensation in that period and whether the loan will be repaid. Agents take payoffs from future negotiations as given and compute their continuation payoffs based on the conjectured solution to the bargaining problem.

We focus on agreements that lead to loan repayment if and only if economic conditions are good, G. We call such an agreement a *cooperative repayment solution* (CRS). Thus, as discussed in Section 3, we model trusted assistant financing that implements efficient repayment, forbearance when conditions in the period favor repayment, and effective repayment, repayment enforced when collection is efficient. If efficient and effecting repayment can be implemented, implementation should increase the probability of eventual loan repayment (Hypothesis II) in the main body of the paper..

Before the loan agreement is entered into by the scholar, regardless of how the bargaining power in ex ante negotiations is divided between the creditor and the scholar, both parties will prefer an agreement that features efficient and effective repayment (if such agreement is incentive compatible) because efficient and effect repayment maximizes the surplus that the parties are able to split through the terms of the loan.

Definition 1. A CRS is a loan repayment and assistant compensation policy followed by the agents when the official is inexperienced that satisfies the following conditions:

(i) The official and assistant agree to cooperate to raise revenue.

(ii) In any period in which the official is indebted, i.e., the state is I

  (a) The agreement specifies loan repayment in state I when economic conditions are good, G.

  (b) The agreement specifies no loan repayment in state I when economic conditions are B.

(iii) Assistant compensation, a, depends only on the state and the economic condition of the province.

(iv) Assistant compensation is determined by period-by-period Nash bargaining.

A CRS is a payment to the assistant when the official is inexperienced that is the same in every period in which the state and economic conditions are the same. Hence, it can be represented by the vector $a_* = (a_*^N(B), a_*^N(G), a_*^I(B), a_*^I(G))$. Because, the state variable is Markovian and the current future economic condition of the province is independent of its current condition, and the CRS specifies a stationary payment to the assistant, the expected payoff to an agent at the start of any period satisfies the recursive equation of dynamic programming, i.e., if we let v_i^s represent the expected payoff to agent i, $i = \text{Official}, \text{Assistant}$ in state s, then

$$v_i^s(a_*) = \bar{r}_i^s(a_*) + \sum_{s'} p\,\mathbb{P}_*[s'|s,G]v_i^{s'}(a_*) + (1-p)\,\mathbb{P}_*[s'|s,B]v_i^{s'}(a_*), \tag{A-2}$$

where $\bar{r}_i^s(a_*)$ is the expected period payment to agent i,

$$\bar{r}_i^s(a_*) = p\,r_i^s(a_*^s(G)) + (1-p)\,r_i^s(a_*^s(B)),$$

and $\mathbb{P}_*$ represents the state transition probability under the CRS. These state transition probabilities follow from condition (ii) of Definition 1 and the state transition probabilities specified above.[2]

For the reader's convenience, an explicit table of transition probabilities under the CRS is provided in Table B-4 in the Appendix. Using equation (A-2), we derive the payoff function associated with each state. Given the number of states and economic conditions, the derivation of the CRS is somewhat tedious and so we defer the derivation to the Appendix Section B. Our

[2]We assume that in all states, s and for both agents i, $v_i^s(a_*) > 0$ and thus participation is individually rational for the official and assistant. This condition is satisfied for all parameters of the model for the assistant and is satisfied for sufficiently large p for the official.

basic result concerning the existence of a CRS is provided by the next proposition.

Proposition 1. *If*

$$\Sigma_*^I(G) = \frac{(\bar{t} + \tau(\chi - 1))\,(1 - (1-p)\,\alpha\beta) + (1 - \alpha\beta)\,(A - \ell)}{1 - (1-p)\,\alpha\beta} \geq 0,$$

then a cooperative repayment solution (CRS) exists. Under this solution, in each period in which the official is inexperienced payments to the assistant, a_*, are given as follows:

$$a_*^N(B) = a_*^I(B) = \tau\left(\frac{c-1}{2-c} + \frac{\chi}{c}\right), \quad a_*^N(G) = \frac{1}{2}\,(\bar{t} - \tau + \chi\,\tau), \quad a_*^I(G) = \frac{1}{2}\,(\bar{t} - \tau - \ell - (A - \tau\chi)).$$

The economic intuition for the proposition is straightforward. Nash bargaining characterizes the division of *surplus revenue*, revenue in excess of the tax quota and possibly the loan repayment. In each period, this division is based on the payoff gain to the agents from reaching a cooperative arrangement. This payoff gain is determined by the status quo payoff and the cooperation payoff. Since bargaining is period-by-period, the agents' continuation payoff in a given period is the payoff specified in the CRS. Except for economic condition G and state I, when the CRS calls for the loan to be repaid, the continuation payoffs under the status-quo and the cooperative agreement are the same. Thus, the total payoff gain from cooperation to the assistant and official is just the period gain—excess revenue less costs of collection.

When the economic condition of the province is G and the state is I, repayment under cooperation generates a different set of continuation states than non-repayment under the status-quo policy. Repayment leads to the assistant capturing the return benefit upon return from the province (after the official becomes experience) and to a third party, the bank, capturing cash flows from loan repayment. The condition, in Proposition 1, that $\Sigma_*^I(G) \geq 0$ insures that the total gain from cooperation to repay when the condition is G and the state is I is non-negative.

A.5 Renegotiation proofness of the cooperative repayment solution

Next, consider the question of the renegotiation proofness of the CRS: i.e., does there exist an alternative allocation of period gains which makes both the assistant and official better off? When the official is not indebted, the answer to this question is obviously no. As discussed above, when the official is not indebted, the only policy variable is the compensation to the assistant. When a CRS exists, its Nash bargaining allocation maximizes the joint payoff of the assistant and the official. However, when the official is indebted, there is another policy variable—whether to repay the loan. The CRS calls for the loan to be repaid if the economic condition is G, and not repaid if the economic condition is B. Thus, there are two possible alternative policies—not repaying the loan when the state is G and repaying the loan when the state is B. The following proposition, derived in Appendix Section B, characterizes the parameters of the model that support a renegotiation-proof CRS. Thus the proposition implicitly characterizes the conditions under which trusted assistant lending is viable.

Proposition 2. *The CRS agreement is renegotiation proof if and only if $A \geq \ell$ and*

$$\mathscr{R} = \left(\tau\left(\frac{c}{2-c}+\chi\right) - c\,(\ell+\tau)\right) - p\,(A-\ell)\,\frac{\alpha\beta}{1-(1-p)\,\alpha\beta} < 0. \tag{A-3}$$

The conditions for renegotiation proofness have a fairly intuitive interpretation. When economic conditions are good, G, collection is costless. The failure to collect prevents the assistant from capturing the return benefit but increases the revenue that can be split between the assistant and official by decreasing the payment to the bank. Since collection is costless when the economic condition is G, limited liability does not prevent this total gain from being split in a fashion that increases the payoff of both the assistant and official. The net gain to the agents from "stiffing" the bank is $\ell - A$. Thus, the CRS is renegotiation proof in condition G if and only if $A \geq \ell$.

When $A \geq \ell$, the assistant may have an incentive to induce the official to repay the loan even when economic conditions are bad, B. However, when economic conditions are bad, B, collection is onerous. Thus, collecting additional revenue to repay the debt is costly as the cost of repayment includes not only the amount repaid but also increased revenue collection costs. To compensate for these costs to the official, and for the effect of repayment on the bargaining position of the official in future negotiations, the assistant's share of the surplus in the period negotiations must fall. When $\mathscr{R} < 0$ this compensation reduction is so large that it violates the limited liability condition, $a \geq 0$, and thus the CRS is renegotiation proof.

A.6 Comparative statics of renegotiation proofness

Note that $\mathscr{R} < 0$ is a necessary and sufficient condition for renegotiation proofness when $A \geq \ell$ and that the CRS is never renegotiation proof when $A < \ell$. Thus, renegotiation proofness centers on whether $\mathscr{R} < 0$. Shifting a parameter of the model in a way that decreases $\mathscr{R}$ *facilitates* renegotiation proofness and parameter shifts that increase $\mathscr{R}$ *impedes* renegotiation proofness. Thus, to investigate the question of renegotiation proofness, we explore the effect of parameter shifts on $\mathscr{R}$.

In order to make these shifts more relevant to the context of our empirical analysis, it is useful to interpret the parameters of the model in a fashion that can be related to observed characteristics. The features of the economic environment that we would like to capture are the dependence of the inexperienced official on the assistant, the expected tenure of the assistant, and economic conditions.

First consider dependence. Dependence of the official on the assistant, and thus the assistant's bargaining power, depends on the attractiveness of collecting without the aid of the assistant. Assumption 1 bounds the inexperienced official's marginal cost of collection, χ, between $c/(2-c)$ and 2. Thus, we can express χ as a weighed average of these two extreme values as follows:

$$\chi = d2 + (1-d)\frac{2}{2-c}, \quad d \in (0,1), \tag{A-4}$$

where d in equation (A-4), is a *dependency index*.

Using equation (A-4) to substitute for χ in the renegotiation condition (equation (A-3) in Proposition 2) yields the following version of the renegotiation condition:

$$\mathscr{R}' = \frac{\left(2-c+c^2\right)\,\tau - (2-c)\,c\,\ell - 2\,(c-1)\,\tau\, d}{2-c} - p\,(A-\ell)\,\frac{\alpha\,\beta}{1-(1-p)\,\alpha\,\beta} < 0. \tag{A-5}$$

Next, consider $\alpha\beta$. Because the assistant's expected tenure equals $1/(1-\alpha\beta)$, $\alpha\beta$ is a measure of the tenure of the assistant. Finally, given that bad state B represents the realization of an abnormal adverse event such as a crop failure, p can be interpreted as a measure of the economic stability of the province. Under these interpretations, the following results are immediate from differentiating $\mathscr{R}'$, defined in equation (A-5), with respect to the relevant parameters.

Proposition 3. *When $A \geq \ell$, then, holding all other parameters fixed,*

(i) Increasing the dependency index, d, facilitates renegotiation proofness.

(ii) Increasing expected assistant tenure, measured by $\alpha\beta$, facilitates renegotiation proofness.

(iii) Increasing the economic stability of the province, p, facilitates renegotiation proofness.

Proposition 3 is the theoretical foundation for Hypotheses I.B, I.C, and I.D, in the main body of the paper.

B Derivations of results

B.1 Period rewards and transition probabilities

Table B-1 presents the period rewards to the official and assistant assuming a cooperative agreement is struck when the official is inexperienced. Table B-2 presents status quo period payoffs, period rewards when the official is inexperienced and a cooperative agreement is not reached. These rewards will affect the *status-quo* or default payoffs in official/assistant bargaining. Table B-3 presents the state transition probabilities.

	Current state				
	Indebted I		Not Indebted N	Free F	Separated S
	Payment of loan				
	Pay	Not Pay			
$r_A =$	$a - \frac{1}{2} c_\omega$	$a - \frac{1}{2} c_\omega$	$a - \frac{1}{2} c_\omega$	0	0
$r_O =$	$t - a - \ell - \tau - \frac{1}{2} c_\omega$	$t - a - \tau - \frac{1}{2} c_\omega$	$t - a - \tau - \frac{1}{2} c_\omega$	$t - a - \tau - c_\omega$	0

Table B-1: Period rewards, r, to official and assistant if collection agreement is reached when the official is inexperienced and official collects without assistance when the official is free.

	Current state		
	Indebted I		Not Indebted N
	Payment of loan		
	Pay P	Not Pay $\neg P$	
$\delta_A =$	0	0	0
$\delta_O =$	$t - \ell - \tau - \chi_\omega$	$t - \tau - \chi_\omega$	$t - \tau - \chi_\omega$

Table B-2: Period rewards, r, to official and assistant if collection agreement is not reached when the official is inexperienced.

	Current state				
	I		N	F	S
	Payment of Loan				
	P	$\neg P$			
Next State					
I	0	$\alpha\beta$	0	0	0
N	$\alpha\beta$	0	$\alpha\beta$	0	0
F	$(1-\alpha)\beta$	$(1-\alpha)\beta$	$(1-\alpha)\beta$	β	0
S	$1-\beta$	$1-\beta$	$1-\beta$	$1-\beta$	1

Table B-3: Transition probabilities from current state to next state.

B.1.1 The CRS

In this section we provide the transition probabilities, reward, and payoff functions associated with the CRS. These functions will be used repeatedly in the derivations and, so, for ease of reference, they are collected below. All the characterizations in this section follow from the period rewards, specified in Tables B-1 and B-2, the transition probabilities in Table B-3, the definition of a CRS provided by Definition 1, and recursive dynamic programming equation, equation (A-2).

B.1.2 Transition probabilities under the CRS

s	I		N		F		S	
	Condition		Condition		Condition		Condition	
s'	G	B	G	B	G	B	G	B
I	0	$\alpha\beta$	0	0	0	0	0	0
N	$\alpha\beta$	0	$\alpha\beta$	$\alpha\beta$	0	0	0	0
F	$(1-\alpha)\beta$	$(1-\alpha)\beta$	$(1-\alpha)\beta$	$(1-\alpha)\beta$	β	β	0	0
S	$1-\beta$	$1-\beta$	$1-\beta$	$1-\beta$	$1-\beta$	$1-\beta$	1	1

Table B-4: Transition probabilities under a cooperative repayment solution (CRS): $\mathbb{P}_*[\cdot|s,\omega]$

B.1.3 Payoff functions for CRS

Let $a_* = (a_*^N(B), a_*^N(G), a_*^I(B), a_*^I(G))$, represent the candidate CRS solution provided in Proposition 1.

B.1.4 Value in the CRS

$$\begin{aligned}
v_A^S =& 0,\\
v_A^F =& 0,\\
v_A^N(a_*) =& A + \frac{\bar{r}_A^N(a_*)}{1-\alpha\beta},\\
v_A^I(a_*) =& A + \frac{\bar{r}_A^N(a_*)}{1-\alpha\beta} - \frac{A(1-p)(1-\alpha\beta) + \left(\bar{r}_A^N(a_*) - \bar{r}_A^I(a_*)\right)}{1-(1-p)\alpha\beta}.
\end{aligned} \tag{B-6}$$

$$\begin{aligned}
v_O^S &= 0,\\
v_O^F &= \frac{\bar{r}_O^F}{1-\beta},\\
v_O^N(a_*) &= \frac{\bar{r}_O^F}{1-\beta} - \frac{\bar{r}_O^F - \bar{r}_O^N(a_*)}{1-\alpha\beta},\\
v_O^I(a_*) &= \frac{\bar{r}_O^F}{1-\beta} - \frac{\bar{r}_O^F - \bar{r}_O^N(a_*)}{1-\alpha\beta} - \frac{\bar{r}_O^N(a_*) - \bar{r}_O^I(a_*)}{1-(1-p)\alpha\beta}.
\end{aligned} \tag{B-7}$$

B.1.5 Period rewards in CRS

$$\begin{aligned}
\bar{r}_A^S(a_*) &= 0,\\
\bar{r}_A^F(a_*) &= 0,\\
\bar{r}_A^N(a_*) &= \tfrac{1}{2}\,p\,(\bar{t}+\tau\,(\chi-1)) + \tfrac{1}{2}\,(1-p)\,\tau\left(\frac{2-c}{c}\right)\left(\chi-\frac{c}{2-c}\right),\\
\bar{r}_A^I(a_*) &= \tfrac{1}{2}\,p\,(\bar{t}-\tau-\ell-(A-\tau\,\chi)) + \tfrac{1}{2}\,(1-p)\,\tau\left(\frac{2-c}{c}\right)\left(\chi-\frac{c}{2-c}\right).
\end{aligned} \tag{B-8}$$

$$\begin{aligned}
\bar{r}_O^S &= 0,\\
\bar{r}_O^F &= p\,(\bar{t}-\tau) - (1-p)\,c\,\tau,\\
\bar{r}_O^N(a_*) &= \tfrac{1}{2}\,p\,(\bar{t}-\tau\,(\chi+1)) - \tfrac{1}{2}\,(1-p)\,\tau\left(\frac{c}{2-c}+\chi\right),\\
\bar{r}_O^I(a_*) &= \tfrac{1}{2}\,p\,(A+\bar{t}-\ell-\tau\,(1+\chi)) - \tfrac{1}{2}\,(1-p)\,\tau\left(\frac{c}{2-c}+\chi\right).
\end{aligned} \tag{B-9}$$

B.2 Proof of Proposition 1

The proof will compute the Nash bargaining solution for assistant compensation under the CRS. This involves considering all state/condition pairs under which the official is dependent.

Condition B, state I or N Suppose the agents bargain in state N when the condition is B. Under the conjecture that the CRS outcome will characterize payoffs in all subsequent periods, the payoff to the official from the status quo outcome of no cooperation is given by

$$\delta_O^N + \beta\left(\alpha\, v_O^N(a_*) + (1-\alpha)\, v_O^F\right) = t - \tau - \chi\, t + \beta\left(\alpha\, v_O^N(a_*) + (1-\alpha)\, v_O^F\right), \quad t \in [\tau, \bar{t}].$$

Because $\chi > 1$, the official, absent a cooperator agreement, will set $t = \tau$, resulting in a status-quo payoff of

$$-\chi\,\tau + \beta\left(\alpha\, v_O^N(a_*) + (1-\alpha)\, v_O^F\right). \tag{B-10}$$

Note that the marginal cost of cooperative collection in state B, $c > 1$. Thus, if a cooperative agreement is reached surplus revenue above the tax quota will be raised only to fund payments to the assistant, a. The official will not raise surplus funds for personal consumption. Thus $a = t - \tau$ and the official's period payoff under cooperation will equal $-\frac{1}{2}c\,t$ and the official's payoff will equal

$$-c\,t + \beta\left(\alpha\, v_O^N(a_*) + (1-\alpha)\, v_O^F\right). \tag{B-11}$$

Hence, the official's gain from cooperation, the difference between expressions (B-10) and (B-11), equals $-\frac{1}{2}\,c\,t - (-\chi\,t) = (\chi - \frac{1}{2}c)\,t$. Note that, because the continuation payoff is the same under both the status-quo and cooperate outcomes, the gain to the official from an agreement to cooperate is simply the period gain. For the assistant, the period gain from cooperation is the payment received, a, less the cost of collection, $\frac{1}{2}ct$. Again, because the assistant's continuation value is the same under the cooperation and status quo outcomes, the payoff gain from cooperation is simply the period gain. Thus, the payoff gain to the assistant equals $a-\frac{1}{2}ct$. The Nash bargaining solution maximizes the product of the gains to the assistant and official subject to the constraint that the gains to both agents are nonnegative. Thus, the Nash bargaining solution is determined by the program:

$$\begin{aligned}
&\underset{t\in[0,\bar{t}]}{\text{Max}} \left(a-\frac{ct}{2}\right)\left(\chi\tau-\frac{ct}{2})\right)\\
&\text{s.t.}\\
&a-\frac{ct}{2}\geq 0,\\
&-\frac{ct}{2}-(-\chi\tau)\geq 0.
\end{aligned}$$

The revenue collection policy, t that solves this problem is given by

$$t_*^N(B)=\frac{\tau\,(c+\chi\,(2-c))}{(2-c)\,c}.$$

This revenue collection policy implies that the payment to the assistant in state N when the condition is B is given by

$$a_*^N(B)=t_*^N(B)-\tau=\tau\left(\frac{c-1}{2-c}+\frac{\chi}{c}\right). \tag{B-12}$$

Assumption 2.ii ensures that the limited liability condition is satisfied. Next, note that when the state is I and the condition is B, it is never optimal for the official to pay the loan under the status quo policy. In state I, the CRS also calls for no repayment when the condition is B. Thus, the continuation payoffs to both agents are again the same regardless of whether a cooperative agreement is reached. Also, because $\chi>1$ under the status quo outcome, in this case as well, the official will collect revenue just sufficient to satisfy the tax quota, and, under a cooperation agreement, because $c>1$ all revenue raised in excess of the tax quota will be used to fund payments to the assistant. Thus, the Nash bargaining solution in state I when the condition is B is the same as the Nash bargaining solution in state N when the condition is B, i.e.

$$a_*^I(B)=\tau\left(\frac{c-1}{2-c}+\frac{\chi}{c}\right). \tag{B-13}$$

Condition G, state N As in the previous case, the continuation payoffs to the agents are the same under the status quo and cooperative outcomes. Thus the Nash bargaining solution will maximize the product of the period gains to the two agents. Because the marginal cost of collection is 0 in state G. Under the status quo because the marginal cost of collection, $\chi > 1$ the official will collect just enough revenue to satisfy the quota, producing a period gain to the official of $-\chi\,\tau$. Under cooperation, the marginal cost of collection is 0, and thus optimal collection policy is $t = \bar{t}$. Because, in state N, the loan has already been repaid, the limited liability restriction implies that $a \in [0, \bar{t} - \tau]$. Thus, the Nash bargaining solution is given by the solution to the following program.

$$\begin{aligned}
&\operatorname*{Max}_{a \in [0,\bar{t}-\tau]} \left(a\right)\left((\bar{t} - a - \tau) - (-\chi\,\tau)\right) \\
&\text{s.t.} \\
&a \geq 0, \\
&(\bar{t} - a - \tau) - (-\chi\,\tau) \geq 0.
\end{aligned}$$

Solving this program yields

$$a_*^N(G) = \tfrac{1}{2}\,(\bar{t} - \tau + \chi\,\tau)\,. \tag{B-14}$$

Assumption 2.i ensures that the limited liability constraint is satisfied.

Condition G, state I As in the previous case, because the state is G, it is optimal to maximize tax revenue collection, so $t = \bar{t}$ in any solution. The payoff from cooperation to the official is thus given by

$$\bar{t} - \ell - \tau - a + \beta\,\left(\alpha\,v_O^N(a^*) + (1-\alpha)\,v_O^F\right).$$

The status quo payoff is given by not cooperate:

$$-\chi\,\tau + \beta\,\left(\alpha\,v_O^I(a^*) + (1-\alpha)\,v_O^F\right).$$

Thus, the gain from cooperation to the official is given by

$$\bar{t} - a - \ell + \left(v_O^N(a^*) - v_O^I(a^*)\right)\,\alpha\,\beta + \tau\,(\chi - 1).$$

For the assistant, the cooperation payoff is given by

$$a + \left(\beta\,\alpha\,v_A^N + (1-\beta\,\alpha)A\right).$$

The status quo payoff to the assistant equals

$$0 + \beta\,\alpha\,v_A^I.$$

Thus, the official's gain from cooperation equals

$$a+\beta\,\alpha\,\left(v_A^N(a^*)-v_A^I(a^*)\right)+(1-\beta\,\alpha)A.$$

In contrast to the previous cases, the continuation payoffs are different under the status quo and cooperative agreement policies. A necessary condition for a bargaining solution to exist is that the sum of the payoff gains of the assistant and the official is positive. Using the explicit representations of the period reward and value functions presented by expressions the Appendix, simple algebra shows that the sum of payoff gains, $\Sigma_*^I(G)$, is based on algebraic substitutions into equations (B-6), (B-7), (B-8), (B-7) in this appendix.

$$\Sigma_*^I(G)=\frac{(\bar{t}+\tau\,(\chi-1))\,(1-(1-p)\,\alpha\,\beta)+(1-\alpha\,\beta)\,(A-\ell)}{1-(1-p)\,\alpha\,\beta}. \tag{B-15}$$

The Nash Bargaining solution maximizes the product of payoff gains over $a\in[0,\bar{t}-\tau-\ell]$given by

$$\left(\bar{t}-a-\ell+\left(v_O^N(a^*)-v_O^I(a^*)\right)\,\alpha\,\beta+\tau\,(\chi-1)\right)\times \\ \left(a+\beta\,\alpha\,\left(v_A^N(a^*)-v_A^I(a^*)\right)+(1-\beta\,\alpha)A\right). \tag{B-16}$$

At an interior solution of the bargaining problem, the bargaining solution splits the sum of payoff gains equally between the assistant and official. Thus if $\Sigma_*^I(G)\geq 0$ the interior solution produces non-negative payoff gains to both the assistant and the official. Differentiating with respect to a shows that an interior solution must satisfy the condition that

$$a=\tfrac{1}{2}\,\left(\bar{t}-\ell+\left(v_O^N(a^*)-v_O^I(a^*)\right)\right)- \\ \tfrac{1}{2}\,\left(\left(v_A^N(a^*)-v_A^I(a^*)\right)\,\alpha\,\beta+\tau\,(\chi-1)-A\,(1-\alpha\,\beta)\right). \tag{B-17}$$

Since, by definition, the CRS is stationary, it must be the case that $a=a_*^I(G)$. Imposing this condition, and using the solutions to the bargaining problem for the other state/condition pairs derived above, and the explicit period reward and payoff functions provided into equations (B-6), (B-7), (B-8), (B-7) in this appendix, shows that if an interior solution is feasible, the solution to the Nash bargaining problem is given by

$$a_*^I(G)=\tfrac{1}{2}\,(\bar{t}-\tau-\ell-(A-\tau\,\chi)). \tag{B-18}$$

Assumption 2.iii implies that the interior solution is in fact feasible. Because the interior solution is the unconstrained solution to the maximization problem, feasibility implies optimality. Thus, the Nash Bargaining solution when the state is I and the condition is G is given by equation (B-18).

B.3 Proof of Proposition 2

The proof will first consider renegotiation in state I when the economic condition is G. Next, the case of renegotiation in state I when the economic condition is B is considered. As discussed in the body of the paper, the efficiency of the Nash Bargaining solution and the fact that no repayment is made to the lender in other states imply that the CRS is renegotiation proof for all other states.

Condition G renegotiations When the state is I and the condition is G, the CRS calls for repayment of the loan. Consider an alternative agreement between the official and assistant in which the official and the assistant cooperate but agree not to repay the loan. Let a_N be the payment to the assistant under this agreement. The payoff to the official under the alternative agreement equals

$$\bar{t} - \tau - a_N + \beta\, \left(\alpha\, v_O^I a_*) + (1-\alpha)\, v_O^F\right).$$

The payoff gain to the official from the alternative agreement relative to the CRS is thus

$$G_O(G)[a_N] = (a_*^I(G) - a_N) + \ell - \alpha\,\beta\, \left(v_O^N - v_O^I\right). \tag{B-19}$$

The assistant's payoff from the alternative agreement is

$$a_N + \beta\,\alpha\, v_A^I.$$

Thus, the assistant's payoff gain from the alternative agreement relative to the CRS is given by

$$G_A(G)[a_N] = (a_N - a_*^I(G)) - \left(A\,(1-\alpha\,\beta) + \left(v_A^N - v_A^I\right)\,\alpha\,\beta\right).$$

Using the explicit representations of period rewards under the CRS and the payoff functions provided by equations (B-6), (B-7), (B-8), (B-7) in this appendix, we can compute the total payoff gain $G_\Sigma(G) = G_A(G) + G_O(G)$ from the alternative agreement:

$$G_\Sigma(G) = -\frac{(A-\ell)\,(1-\alpha\,\beta)}{1-(1-p)\,\alpha\,\beta}. \tag{B-20}$$

Thus, expression (B-20) shows that, if $A < \ell$, the total gain from the alternative arrangement is positive. Next note that if $a_N = \frac{1}{2}\,(\bar{t} - \tau + \chi\,\tau)$, then $G_A(G)[a_N] = G_O(G)[a_N]$. Because the total gain is positive, $G_A(G) = G_O(G)$ implies that the gain to both the official and assistant is positive. By Assumption 2.i, $a_N = \frac{1}{2}\,(\bar{t} - \tau + \chi\,\tau)$ satisfies the limited liability constraint. Thus, the CRS is not renegotiation proof. If, on the other hand, $A \geq \ell$, expression (B-20) shows that the total payoff gain from the alternative agreement is non-positive and thus the alternative agreement cannot produce a positive payoff gain for both the official and the assistant. Thus, the CRS is renegotiation proof when $A \geq \ell$, the CRS is renegotiation proof in state G.

Condition B renegotiations Since all alternative agreements produce the same continuation value, if any alternative agreement produces a payoff gain for both agents, an efficient alternative agreement, i.e., an alternative agreement that maximizes the total payoff to the agents conditioned on the payment to the assistant will produce a payoff gain for both agents. Because in state B the marginal cost of collection $c > 1$, efficient agreements specify collecting the minimum revenue required to satisfy the center and the payment to the agent. Hence, we restrict attention to efficient alternative agreements. Under such agreements the payoff to the official equals

$$-\tfrac{1}{2} c\,(\tau + a_P + \ell) + \beta\,\left(\alpha\, v_O^N + (1-\alpha)\, v_O^F\right).$$

Thus, the payoff gain to the official from the alternative arrangement is given by

$$G_O(B)[a_P] = \tfrac{1}{2}\left(\tau\left(\frac{c}{2-c} + \chi\right) - c\,(a_P + \ell + \tau)\right) + \left(v_O^N - v_O^I\right)\alpha\,\beta. \tag{B-21}$$

The assistant's payoff under the alternative arrangement is given by

$$a_P - \tfrac{1}{2} c\,(\tau + \ell + a) + \left(\alpha\,\beta\, v_A^N + (1-\alpha\,\beta) A\right).$$

Thus, the payoff gain to the assistant is given by

$$G_A(B)[a_P] = a_P - a_*^I(B) - \tfrac{1}{2} c\,\left(\tau + \ell + (a_P - a_*^I(B))\right) + \left(A\,(1-\alpha\,\beta) + \left(v_A^N - v_A^I\right)\alpha\,\beta\right). \tag{B-22}$$

The total payoff gain from renegotiation is given by

$$G_\Sigma(B) = \frac{(A-\ell)\,(c\,(1-\alpha\,\beta) + (c-1)\,p\,\alpha\,\beta)}{2 - 2\,(1-p)\,\alpha\,\beta}. \tag{B-23}$$

Thus if $A \leq \ell$, the CRS is renegotiation proof in state B. So suppose that $A > \ell$. Because of limited liability, the alternative payment to the assistant must be non-negative, i.e., $a_P \geq 0$. Next note that if $G_O(B)[0] \leq 0$, then, because the official's gain is strictly decreasing in a_P the alternative agreement cannot produce a higher payoff to the official than the CRS, thus the CRS is renegotiation proof. Finally note $\mathscr{R}$, defined in the body of the paper by equation (A-3), is the algebraic simplification, after substituting the definitions of continuation values provided by equations (B-7), of $G_O(B)[0]$, defined by equation (B-21). Thus, if $\mathscr{R} = G_O(B)[0] \leq 0$, the CRS is renegotiation proof in state B.

Next we show that if the agreement is renegotiation proof then $G_O(B)[0] \leq 0$ by proving the contrapositive, i.e. that if $G_O(B)[0] > 0$, then the CRS is not renegotiation proof. So suppose that $G_O(B)[0] > 0$. First consider the case where $G_A(B)[0] > 0$. In this case an alternative agreement that specifies $a_P = 0$ will generate a payoff gain for both the assistant and the official and so the CRS is not renegotiation proof. Now consider the case where $G_O(B)[0] > 0$ but $G_A(B)[0] < 0$. First note that if $a_P \geq a_*^I(B)$, then $G_A(B)[a_P] > 0$. Thus, $G_A(B)[a_*^I(B)] > 0$. If it is also the case that $G_O(B)[a_*^I(B)] > 0$, then again the CRS is not renegotiation proof.

Finally, consider the case where $G_O(B)[0] > 0$ and $G_A(B)[0] \leq 0$ and $G_O(B)[a_*^I(B)] \leq 0$ and $G_A(B)[a_*^I(B)] > 0$. Define the function Δ_G by

$$\Delta_G(a_P) = G_O(B)[a_P] - G_O(B)[a_P], \quad a_P \in [0, a_*^I(B)]. \tag{B-24}$$

Because Δ_G is continuous, and $\Delta_G(0) > 0$ and $\Delta_G(0) < 0$, the intermediate value theorem implies that there exists $a'_P \in [0, a_*^I(B)]$ such that $\Delta_G(a'_P) = 0$, i.e., $G_O(B)[a'_P] = G_O(B)[a'_P]$. Equation (B-23) shows that $G_O(B)[a'_P] + G_O(B)[a'_P] > 0$ and thus

$$G_O(B)[a'_P] = G_O(B)[a'_P] > 0. \tag{B-25}$$

Hence, setting $a = a'_P$ produces a higher payoff to both the assistant and the official. Because $a_P \in [0, a_*^I(B)]$ and both $a = 0$ and $a = a_*^I(B)]$ satisfy the limited liability constraint, $a = a'_P$ is feasible. Thus, expression (B-25) implies that the CRS is not renegotiation proof.

C A sample trusted-assistant loan documents

In order to provide more detailed descriptions of loans to officials, we collected several documents that contain detailed information with regards to various aspects of loans with trusted assistant.

C.1 Sample loan agreement

A typical debt contract (debt receipt) written by the debtor and signed by the creditor and the trusted assistant is presented in Figure C-1. The contract is signed by a an incoming official, Mr Jialin He, with a then influential middle-sized bank "Yu-Sheng-Ji" in the year of 1839 in Beijing. It provides information about the identity of the borrowers: the debtor's name (Jialin He), his official positions, and his jurisdiction (County official candidate in Shanxi Province). The document also provides the loan terms: the type of total amount of silver borrowed (800 Liang, silver with standard purity), the primary and alternative repayment date (next April or when the borrower obtains official certification of appointment), and interest charged given extension, 20%. The family name of the creditor (Zhou), names and signatures of two middlemen also appear in the contract.[3] A repayment of 50 Liang made 13 months after the debt was issued also appears on the list.

The interest rate specified in the debt contract seems quite low. However, the interest rate on the contract only specifies the stated rate interest; the interest rate charged if the borrower paid on time, which was unusual. In fact, ample evidence suggests that the effective nominal interest rate was much higher than the stated rate. First, the proceeds that the borrower obtained from the creditor were usually lower than the principal written on the debt contract. Discounting the principal bypassed the anti-usury laws that imposed an official interest ceiling of 30%. Note that the total proceeds received by the debtor are frequently not stated in the debt contracts. Many sources confirm that principal discounting was a common practice. For most of the early and middle period of Qing dynasty, the proceeds of the loan were only 50%-70% of the contracted principal but, in certain extreme cases in the late Qing, proceeds could be as low as 30% of the principal.[4]

The effective interest rate was also affected by the quality of silver received by the debtor. The silver received by the debtor was usually of lower in quality and purity than the quality of the sliver specified for principal, and thus lower than the quality of the silver that the borrower was obligated to return to the lender. For instance, Fengzhi Du in his diary mentioned that half of the proceeds of his of 2,000 Liang loan were advanced in the form of inferior-quality Songjiang, silver whose value was 20% less than standard silver.(Du, 2008) However the debt contract stipulated that the principal on the Loan was 2,000 Liang of standard silver.

1. The borrower's appointment: Candidate county governor in Shanxi province
2. Name of the borrower: Jialin He
3. Family name of the creditor (owner of "Yushengji" Bank): Zhou
4. Specie: Silver of standard purity
5. Quantity: 800 Liang
6. Repayment date: End of July next year
7. Interest rate after repayment date: 20% per month

[3]Their identities are marked as "middleman." These middlemen are probably the trusted assistants (or associates of the trusted assistant) rather than associates of the official because they appear to poorly educated and of low social class, as evidenced by the fact that their handwritten signatures are quite primitive. Middlemen might also agents who facilitate the loan in some fashion. Many loans had no "middlemen" listed on the contract.

[4]At the beginning of the Qing dynasty, the proceeds-to-principal ratio was about 70%. For instance, in a novel by Ding (2002), the loan proceeds were reported to be equal to 60% of the principal and in the novel of Wu (1958), the reported ratio of proceeds-to-principal ratio was 70%. However, the proceeds-to-principal ratio appears to have declined to about 50% by the middle of the Qing dynasty. For instance, in the case of Fengzhu Du (c. 1860) proceeds equaled 50% of the principal. Liu and Yang (2015) assert that the ratio was sometimes as low as 30%.

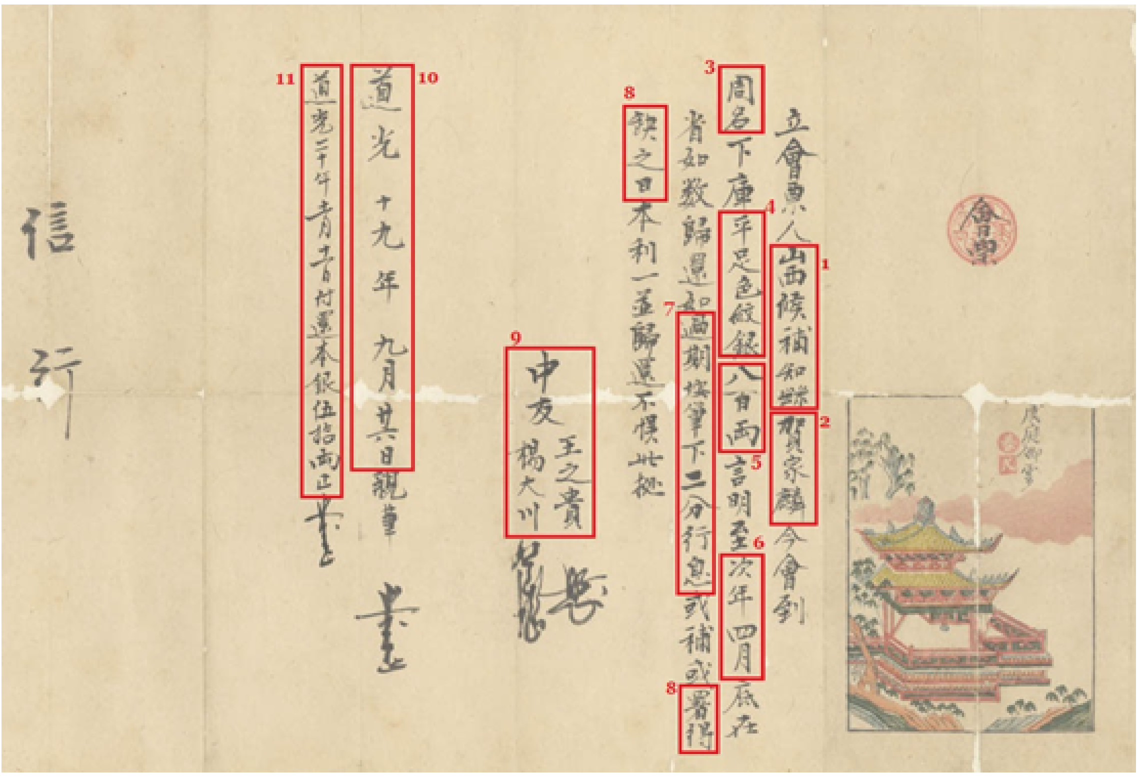

Figure C-1: A trusted-assistant loan document

8. Alternative repayment date: When the borrower obtains appointment
9. Middlemen: Dachuan Yang, Zhigui Wang
10. Date signed: 26th Sep, 1839
11. Repayment signature: On 11th Nov, 1840, the borrower returns principal of 50 Liang of silver

D Alternative specifications and samples

In order to ensure that our result is robust to changes to the regression specification and to rule out some obvious alternative explanations for the effects of our proxy variables, we conduct a series of robustness checks.

D.1 Alternative samples: various samples

Tables D-1 and Table D-2 report the results associated with the discussion in the manuscript of robustness and specification issues (Sections 5.2.1 and 5.3).

D.2 Other robustness checks

The path cost and path time In the baseline specification, we used distance to proxy for the barriers to information transmission associated with spatial separation in Qing China. We implicitly assumed that these barriers were simply a function of physical distance. However, the energy and time required to traverse a given unit of distance might also have been important barriers to information transmission. Because of the large variation in the topography in China, the energy and time consumption rate per unit of distance was far from constant. A waterborne journey, for instance, might entail less energy use but more time compared with the same distance on land. Similarly, a traveling across the hilly terrain might require more time and consume more energy than traveling across a plain. The calories of energy consumed by a journey in Qing China, where transportation was performed by animals, were highly correlated with the journey's cost.

To construct our variables, we take advantage of the geographical information and algorithms provided by the China History Geographic Information System (CHGIS) and simulate the transportation technology of Qing China [5]. We then calculate the travel time and energy consumed by each official traveling from Beijing to their jurisdiction. We use the variables *Path cost*, the logarithm of the energy expended, and *Path time*, the logarithm of travel time, as alternative proxies for debtor/creditor distance. In columns 1-2, Table D-3 we replaced, *Distance to Beijing* with these two proxies. The resulting coefficient estimates are significant and their marginal effects are quite close to our estimates for baseline distance measure, (*Distance to Beijing*).

Distance to other cities In the baseline specification, we implicitly assumed that all creditors were located in Beijing and thus the Beijing-jurisdiction distance captured the extent of information asymmetry. One concern is that Beijing was not the only place there were creditors were

[5]For more information about finding the path cost, see http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/creating-a-cost-surface-raster.htm

located. For instance, a disproportionate share of domestic banks (and all Piaohao banks) were run by Shanxi merchants. These banks often had headquarters or major branches in their hometowns in Shanxi province. Therefore, Shanxi-jurisdiction distances might also be informative measures of debtor/creditor information asymmetry. Computing distance relative to Shanxi, of course, should not be expected to have a major effect on our results as Beijing and Taiyuan, the capital of Shanxi, relatively close to each other (500km apart). Still, to address this concern, we add a new independent variable, *Distance to Shanxi*, the distance between the borrower's jurisdiction and Taiyuan, the capital of Shanxi province. We re-run the baseline specification incorporating *Distance to Shanxi* (See Column 3, Table D-3). When this variable is added, the marginal effect of *Distance to Beijing* increased, from 0.372 to 0.435. The marginal effect of the *Distance to Shanxi* was also positive but its estimated coefficient is not significant. This result suggests that our results are not sensitive to the choice of Beijing vs. Shanxi as one of the terminus points for our distance measures.

As political and business centers coincide in Qing China, the fact that distances to Beijing and Shanxi matter could suggest that the distance to other business centers might also matter. Although the banks that specialize in scholar loans were usually too small to have branches in cities other outside of Beijing and Shanxi (Liu and Yang, 2015), they may have had connections in other cities that could help them monitor loans, decreasing the necessity of sending a trusted assistant to jurisdictions near these business centers. To address this concern, we construct a new variable, the distance between an official's jurisdiction and the two most developed metropolitan areas in south China, *Distance to Shanghai* and *Distance to Guangzhou*. If the business connections of those banks are indeed wide-spread, then one would expect that the distance between a debtors jurisdiction and these metropolitan areas would matter in decisions surrounding whether a trusted assistant is dispatched to monitor the borrower.

We conduct a placebo test and the result is presented in Column 4 of Table D-3. The marginal effect of the distance to Beijing is almost unchanged; the marginal effect of the distance to these southern metropolitan areas is small and insignificant, suggesting that the business activities of these banks specializing in scholar loans were not as wide-spread as this hypothesis implies. Our finding is also consistent with using distance to Beijing as our proxy for distance.

Other explanations for the effect of distance on trusted-assistant deployment In our analysis, debtor/creditor distance was interpreted as the measure of information asymmetry. However, as discussed in the manuscript, the size of the loan required to fund the official would also depend on travel fees, which, in turn, might be affected by the distance traveled. Thus, distance might predict the use of a trusted assistant simply because distance is a noisy proxy for loan size. In column 5 of Table D-3 we report a regression of *Loan amount* on *Distance to Beijing*, and the control variables used in the baseline specification. The coefficient for *Loan amount* is not significant. This result suggests that distance in the baseline specification is not acting simply as a proxy for the loan amount.

Another possible non-information channel through which, distance might affect the use of trusted assistant lending is that distance might be positively related to the administrative workload of local officials, and administrative workload might be positively related to the use of trusted assistants. Towns located on the borders of the Qing Empire were more likely were associated with additional administrative duties, such as immigration control and hunting for cross-border criminals. Thus, distance might predict the use of trusted assistants only because distance is a noisy proxy for administrative workload.

To test whether the distance/trusted-assistant link is driven by the administrative complexity of more far-flung jurisdictions, we use two variables. The first variable, *Heavy workload*, is a dummy variable representing whether the central government classified local administration as "Fan," complicated, and involving a heavy workload. The second variable, *Conjunction* represents whether the county is classified as "Chong," or "at the conjunction of major roads." Officials governing counties located at the junctions of major roads had many additional administrative duties, such as hunting for fugitives, and accommodating traveling officials. In columns 7-8 of Table D-3, we report regressions of the administrative complexity variables on *Distance to Beijing*, and the control variables used in the baseline specification. The insignificant coefficients for the administrative complexity variables suggest that distance, in our baseline specification, is not acting simply as a proxy for administrative workload.

Dependent variables	Pr (Having trusted assistant)				
Key indicator	Baseline	Rebellious tradition	Different dialect	Parents alive	Rice price volatility
	(1)	(2)	(3)	(4)	(5)
Panel A. The loan book sample (N=66)					
Distance to Beijing	0.533***	0.535***	0.576***	0.497***	0.514***
	(0.004)	(0.005)	(0.005)	(0.001)	(0.005)
Key indicator		0.453***	0.563***	−0.371***	−4.504*
		(0.003)	(0.003)	(0.009)	(0.0561)
$Pseudo R^2$	0.435	0.555	0.526	0.503	0.467
Panel B: The lottery sample (N=88)					
Distance to Beijing	0.564***	0.633***	0.459***	0.402***	0.438***
	(0.004)	(0.005)	(0.003)	(0.005)	(0.004)
Key indicator		0.432**	0.534***	−0.352***	−5.653**
		(0.011)	(0.006)	(0.009)	(0.043)
$Pseudo R^2$	0.454	0.564	0.533	0.544	0.526
Panel C:The civil official sample (N=142)					
Distance to Beijing	0.380***	0.379***	0.384***	0.371***	0369***
	(0.002)	(0.002)	(0.001)	(0.002)	(0.000)
Key indicator		0.432**	0.397***	−0.477***	−7.434**
		(0.016)	(0.002)	(0.000)	(0.002)
Control and decade dummy variables	Yes	Yes	Yes	Yes	Yes
$Pseudo R^2$	0.206	0.306	0.326	0.31	0.307
Panel D:The diligent official sample (N=143)					
Distance to Beijing	0.418***	0.735***	0.606***	0.382***	0.275***
	(0.001)	(0.002)	(0.005)	(0.000)	−0.00488
Key indicator		0.453**	0.596***	−0.325***	−4.897*
		(0.011)	(0.006)	(0.009)	(0.0511)
Control and decade dummy variables	Yes	Yes	Yes	Yes	Yes
$Pseudo R^2$	0.247	0.285	0.323	0.378	0.352

Table D-1: *Determinants of using trusted-assistant finance: Alternative samples*. This table presents the regression analysis of the determinants of the using a trusted assistant using alternative samples. The panels contain regression results from the sub-samples of observations A) that are exclusively from the loan-book sample, B) that include only loans to scholars appointed by lottery, C) that exclude military officials, and D) that exclude diarists who were negligent when recording loan transactions. The definitions of all the variables are provided in Table 1. The p-values, calculated using standard errors clustered at the borrower level, are reported in parentheses.*,**,*** indicate significance at the 10%, 5%, and 1% level respectively.

Dependent variables	Recovery rate					
Key variable		Guaranteed loans	Family repuation	Distance to Beijing	Size of the loan	Dialect differs from Official's
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. The loan book sample (N=66)						
Trusted assistant	16.594**	18.116***	16.594**	26.115***	16.481**	19.628***
	(0.014)	(0.005)	(0.014)	(0.001)	(0.015)	(0.002)
Key variable		15.465	8.342	−16.600***	1.622	−20.894*
		(0.238)	(0.243)	(0.004)	(0.204)	(0.058)
Control and decade dummy variables	Yes	Yes	Yes	Yes	Yes	Yes
PseudoR^2	0.38	0.399	0.38	0.472	0.391	0.428
Panel B: The lottery sample (N=88)						
Trusted assistant	11.515**	12.358**	11.515**	23.480***	11.041**	12.688***
	(0.012)	(0.008)	(0.012)	(0.001)	(0.014)	(0.008)
Key variable		13.752	10.992	−21.203***	1.262	−10.727
		(0.433)	(0.323)	(0.001)	(0.339)	(0.371)
Control and decade dummy variables	Yes	Yes	Yes	Yes	Yes	Yes
PseudoR^2	0.305	0.315	0.305	0.459	0.314	0.319
Panel C:The civil official sample (N=142)						
Trusted assistant	11.146**	12.683***	11.924***	13.982**	11.015**	12.722**
	(0.046)	(0.001)	(0.008)	(0.013)	(0.014)	(0.015)
Key variable		5.992	10.992	−11.319	0.644	−6.012
		(0.371)	(0.323)	(0.651)	(0.459)	(0.299)
Control and decade dummy variables	Yes	Yes	Yes	Yes	Yes	Yes
PseudoR^2	0.375	0.378	0.376	0.375	0.377	0.381
Panel D: The diligent official sample (N=143)						
Trusted assistant	11.429***	12.377***	11.329***	13.260**	11.306**	15.441***
	(0.009)	(0.008)	(0.007)	(0.012)	(0.011)	(0.001)
Key variable		11.133	10.313	−13.475	0.446	−15.654*
		(0.151)	(0.395)	(0.304)	(0.607)	(0.050)
Control and decade dummy variables	Yes	Yes	Yes	Yes	Yes	Yes
PseudoR^2	0.403	0.413	0.405	0.407	0.404	0.448
Panel E: The rookie official sample (N=85)						
Trusted assistant	22.275***	22.431***	21.236***	23.044***	22.120***	24.640***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
Key variable		7.549	6.571	−2.17	1.095	−11.767*
		(0.525)	(0.274)	(0.730)	(0.431)	(0.094)
Control and decade dummy variables	Yes	Yes	Yes	Yes	Yes	Yes
PseudoR^2	0.421	0.425	0.428	0.422	0.425	0.445
Panel F:The diary sample (N=99)						
Trusted assistant	10.288**	10.742**	11.662**	11.574**	10.269**	10.573**
	(0.032)	(0.044)	(0.038)	(0.032)	(0.022)	(0.039)
Key variable		10.532*	52.92	-1.967	0.745	-7.966
		(0.058)	(0.124)	(0.564)	(0.445)	(0.370)
Control and decade dummy variables	Yes	Yes	Yes	Yes	Yes	Yes
PseudoR^2	0.22	0.233	0.335	0.223	0.225	0.237

Table D-2: *Determinants of recovery rate: Alternative samples.* This table presents the regression analysis of the determinant of recovery rate of scholar loans using alternative samples. The regressions and control variables are the same as the control variables in Table 4. The panels contain regression results from the sub-samples of observations A) that are exclusively from the loan-book sample, B) that include only loans to scholars appointed by lottery, C) that exclude military officials, D) that exclude diarists who were negligent when recording loan transactions, E) the only include loans to rookie officials, i.e., officials who, at the time of borrowing, had no administrative experience in Beijing or the provinces, and F) that are exclusively from the diary sample. The definitions of all the variables are provided in Table 1. The p-values, calculated using standard errors clustered at the borrower level, are reported in parentheses.*,**,*** indicate significance at the 10%, 5%, and 1% level respectively.

Dependent variables	Pr(Trusted Assistant)					The loan amount	Heavy workload	Conjunction
	Path cost as a proxy	Path time as proxy	Distance to Shanxi	Distance to Beijing or Shanxi	Distance to other large cities			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Distance to Beijing	0.374***	0.333**		0.435***	0.445***	−0.459	0.005	0.03
	(0.001)	(0.032)		(0.002)	(0.001)	(0.299)	(0.852)	(0.515)
Distance to Shanxi			0.177*	-0.112				
			(0.060)	(0.227)				
Distance to Guangzhou					−0.0672			
					(0.101)			
Distance to Shanghai					−0.0356			
					(0.747)			
Control and decade dummy variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	165	165	165	165	165	165	165	165
$PseudoR^2$	0.196	0.152	0.265	0.259	0.306	0.191	0.174	0.213

Table D-3: *Determinants of using trusted-assistant finance: Robustness tests.* This table presents the regression analysis of the determinants of the using a trusted assistant. The dependent variable in columns 1–5 is whether the loan is a trusted assistant loan. Columns 1-2 report the marginal effects when *Distance to Beijing* is replaced with the *Path cost* or *Path time* measures of distance from Beijing. Column 3 and 4 report marginal effects when *Distance to Shanxi* is added to the probit estimation equation. Column 5 reports marginal effects when *Distance to Guangzhou* and *Distance to Guangzhou* are added to the probit estimation equation. In Column 6, the dependent variable *Loan amount*. In Column 7, the dependent variable is *Heavy workload*. *Heavy workload* equals 1 if and only if *Easy to tax* equals 0. In Column 8, the dependent variable is *Conjunction*. The control variables are *Salary*, *Ruggedness*, *Distance to coast*, *Distance to Yangtze River*, and *Latitude*. The definitions of all the variables are provided in Table 1 in the manuscript. The p-values, calculated using standard errors clustered at the borrower level, are reported in parentheses. *,**,*** indicate significance at the 10%, 5%, and 1% level respectively.

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