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Asymmetric Information and Adverse Selection in Mauritian Slave Auctions*

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Abstract

Information asymmetry is a necessary prerequisite for testing adverse selection. This paper applies this sequence of tests to Mauritian slave auctions. The theory of dynamic auctions with private and common values suggests that when an informed participant is known to be active, uninformed bidders will be more aggressive and the selling price will be higher. We conjecture that observable family links between buyer and seller entailed superior information and find a strong price premium when a related buyer purchased a slave, indicative of information asymmetry. We then test for adverse selection using sale motivation. Our results indicate large discounts on voluntary as compared to involuntary sales. Consistent with adverse selection, the market anticipated that predominantly low-productivity slaves would be brought to the market in voluntary sales.
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1 Introduction

Information asymmetry is a necessary condition for adverse selection to take place. If information is symmetric among market participants, then buyers and sellers share a common information set and competitive markets will ensure that prices correctly reflect the fundamentals of the object's ownership. If information is asymmetric, then adverse selection is possible, but remains to be proven. This suggests a sequential procedure whereby information asymmetry is tested before adverse selection. We propose to apply this procedure in the particular context of nineteenth century Mauritian slavery.

Analyzing information asymmetry and adverse selection in slave markets is relevant for a number of reasons. First, a long-standing view is that slavery was an economically profitable and thus viable institution. However, if potential adverse selection is not factored in, the returns on slavery may be over-estimated. Second, given the high degree of uncertainty associated with purchasing a human being and the imperfections of slave sales laws (Fede, 1987; Wahl, 1996), the presence of information asymmetry and adverse selection has long been suspected. Nonetheless, the empirical evidence presented thus far remains inconclusive. Third, slaves were often sold in public auctions with oral ascending bids. Observing the behavior of better informed buyers in dynamic auctions can reveal information to less informed participants and affect their strategies. Moreover, a slave was often purchased for reasons unrelated to productivity considerations (common value), such as personal affection or a desire for manumission (private value). Dynamic auction theory confirms that both elements (open auction and private value) are conducive to measurable impacts of information asymmetry on bids and equilibrium prices.

This paper asks (i) how the behavior of better informed bidders might have affected that of the less informed slave auction participants and (ii) what would have been the impact of such inter-dependent bidding on slave prices. If we find that the second effect is negligible, then information was either symmetric or it was asymmetric, but inconsequential. On the other hand, if information is found to be asymmetric, then adverse selection is possible and additional tests can be performed.

We depart from previous analysis in many important ways. First, we use an auction theory model to derive pricing implications from the active presence of informed bidders in English auctions with common and private values (Section 3). This model predicts more aggressive bidding by uninformed bidders when an informed bidder is present which would consequently force the informed bidder to pay a higher price if he wins the auction. Moreover, it also predicts that the premium he ends up paying would be independent of the number of participants. An active informed bidder tends to signal a potentially large common value and thus induces higher uninformed bids through a loser's curse effect. This enthusiasm is however dampened by a winner's curse effect whereby the informed bidder may also bid because of a high private value. The model predicts that, for a wide range of parameter values, the first effect will be stronger than the second. Increasing the number of participants also increases the probability there will be more high-signal bidders, and consequently higher prices. However, this effect obtains whether or not an informed bidder is present; the informed bidder premium therefore remains unaffected when the number of participants increases.

Second, we test for the presence of informational asymmetry using a unique data set of notarial acts of the auction sales of Mauritian slaves in the early nineteenth century

(Section 4.1). Importantly, in addition to prices, motivation for sales and slave characteristics, these data document the identities of the sellers and buyers of slaves. We conjecture that family ties between the two were publicly known and likely entailed superior information for the buyer. Since we do not observe the actual bidding process, we cannot test for more aggressive bidding in the presence of a related (and better informed) bidder. Nonetheless, we can test its direct consequence that a related bidder pays a higher price when he ends up winning an auction compared to instances where an unrelated bidder won. Controlling for numerous observable characteristics, we find a statistically significant premium on the related bidder in succession sales (Section 4.3). Due to data limitations, the related variable might be measured with error, or could be endogenously determined. We consequently instrument it with the recorded number of heirs, a variable which is unlikely to be affected by measurement errors and/or simultaneity. The results remain qualitatively similar.

Third, having established the presence of informational asymmetries, we then turn to the issue of adverse selection (Section 4.4). By focusing on the motivation for the sale, we join a large strand of empirical adverse selection literature in detecting an Akerlof (1970) lemons' effect. Hence, a seller with surplus holdings of goods for which he has scant alternative uses should sell all of his stocks, good and bad quality alike. Conversely, a seller with alternative uses and low surplus should sell only the low-quality goods, keeping the high-quality items for himself. To the extent that observable characteristics of the seller provide information as to which case applies, this culling behavior is anticipated by the market and the goods he sells voluntarily are discounted.

In our slavery context, we test for adverse selection by comparing prices in involuntary (succession) sales with those in voluntary auctions. Again controlling for observable characteristics as well as the presence of informed bidders, we find that the succession sales premium is positive and statistically significant. Having shown previously that information is asymmetric, we may safely conclude that the effect measures residual adverse selection.

2 Related literature

2.1 Asymmetric information and adverse selection

Our main findings are consistent with an informed bidder inducing more aggressive uninformed bidding and consequently higher equilibrium prices in slave auctions. Similar competition-enhancing effects of informed bidding are also obtained in the literature on asymmetric information in private value auctions. In this case, uninformed bidders interpret the informed bidder's presence as indicating that either common and/or private values are high. This significantly reduces the dampening impact of the winner's curse and augments the loser's curse effect. For example, Hernando-Veciana and Tröge (2004) consider English auctions where, in the spirit of Wilson (1998), private and common values can be observed separately. An insider who perfectly observes common and private values induces aggressive bidding among uninformed bidders who find it profitable to gamble that their private value is higher and therefore outbid the insider. In a signal setup similar to ours where private and common value cannot be distinguished, Hernando-Veciana

(2008) shows that a bidder acquiring better information on the common value induces more aggressive bidding by uninformed bidders in open than in sealed bid auctions.

Perhaps unsurprisingly, an opposite competition-dampening effect can also obtain under a different auction model and set of assumptions. Hence, in the pure common value environment, Engelbrecht-Wiggans et al. (1983) show that the informed bidder never lets uninformed bidders win at a price less than the common value in static sealed-bid auctions.[1] Consequently, equilibrium expected profits are positive for the informed bidder but zero for uninformed bidders. Put differently, the winner's curse is fully operational and deters uninformed bidders from participating when the informed bidder is active.[2] The empirical evidence on common value auctions generally confirms that the winner's curse is important and that insider information is valuable. Hendricks and Porter (1988) find evidence that a strong winner's curse will have a detrimental impact on drainage lease prices when better informed bidders are present. Similarly, Hendricks et al. (1994) find that returns for better informed (less informed) firms are positive (negligible) when the seller's reservation price is stochastic.[3] In short, although competition dampening can occur in other environments, our choice of auction model (English auctions) and assumptions (common-cum-private values) is dictated by the characteristics of the slave market we analyze and is consistent with the competition-enhancing effect of informed bidding that we identify.[4]

[1]See also Milgrom (1981) for a discussion.

[2]We numerically verify and confirm the competition-dampening impact of informed bidding in a special case of our model where private values are on average zero and the informed bidder is perfectly informed about the common value. This highlights the importance of private valuations in obtaining the competition-enhancing effects that we identify.

[3]Hendricks et al. (2003) also confirm that the winner's curse is empirically important in a sealed-bid setup with symmetric information. See also Hong and Shum (2002) for evidence of winner's curse effects in procurement auctions.

[4]Although the settings are different, note that a competition-enhancing effect can still obtain in other pure-common value setups, including one-shot, first-price, with different information specifications

This paper draws from tests of asymmetric information in other settings. As surveyed by Chiappori and Salanié (2003), this literature tests for residual asymmetric information in realized prices while controlling for observable characteristics. The conclusions on the presence of asymmetric information in different markets (insurance, labor and financial markets) are mixed and depend of the mechanisms these markets use to obtain information.[5]

The paper is also related to tests for adverse selection using observable seller's characteristics. As suggested by Genesove (1993), the propensity to sell (often proxied by the reasons for selling) should be inversely related to adverse selection. In a well-known application, Gibbons and Katz (1991) consider the labor market to test lemons' effects in layoffs.[6] They compare displaced workers from two sources: voluntary layoffs and plant closures. As the less informed market anticipates that voluntary layoffs are also lower skilled workers, the post-displacement wages should be lower for these workers than for those displaced after a plant closure. Their empirical results confirm this intuition. Nonetheless, they refrain from concluding that adverse selection is indeed proven because the market could learn about productivity at the same time as the firm.

2.2 Adverse selection in slave markets

Whether or not informational asymmetry and adverse selection were indeed present in slave markets does matter to the extent that *not* taking it into account may bias evalua-

(Campbell and Levin, 2000), multiple units, second-bid (Hernando-Veciana, 2004), or repeated first-price (Hörner and Jamison, 2006) settings.

[5]For example, automobile insurers often make efficient use of risk classification to mitigate asymmetric information in their portfolio. The evidence is less conclusive in testing for residual asymmetric information in labor markets.

[6]Other applications of this framework are found in the markets for used cars (Genesove, 1993) and for thoroughbred yearlings (Chezum and Wimmer, 1997) among others.

tions of the profitability of slavery. A prevailing view is that slavery was an economically profitable institution that would have remained viable in the absence of exogenous intervention such as anti-slavery legislation or the Civil War (Conrad and Meyer, 1958; Fogel and Engerman, 1974; Fogel, 1989). However, in the presence of adverse selection, it becomes hazardous to infer the productive capacity of the general slave population from the market prices of slaves who might actually be inferior ones culled by their owners (e.g. Greenwald and Glasspiegel, 1983; Choo and Eid, 2004, among others).

Although adverse selection is likely to have been present in slave markets, the empirical evidence concerning its incidence remains inconclusive. Studying the New Orleans market for local and imported slaves, Greenwald and Glasspiegel (1983) rely on the origin of the slave as an observable seller characteristic to gauge the degree of adverse selection. They conjecture that owners from low-productivity areas (e.g. Old South, or Border States) would have had a higher marginal propensity to sell and therefore little or no interest in keeping only the best slaves and selling the low quality ones. In comparison, owners from high-productivity states (e.g. Louisiana) would cull low-productivity slaves for resale purposes. Consequently, prices for imported slaves would be higher than for local slaves in anticipation of that behavior. Their empirical results, as well as those of Choo and Eid (2004), confirm this intuition.

However, Pritchett and Chamberlain (1993) criticize the argument that higher prices for imported slaves reflected adverse selection. First, they maintain that one setting in which adverse selection ought to be minimized was that of estate sales where assets (including slaves) were liquidated following the death of the owner. In comparison, voluntary sales should be more subject to the practice of culling bad slaves and should therefore exhibit lower prices. Yet, they find no statistically significant difference between prices observed during estate and voluntary sales. They conjecture that higher prices fetched by imported slaves on the New Orleans market simply reflected the fact that they were of higher quality compared to local slaves and did not result from an adverse-selection discount applied against local sellers.

3 Theoretical analysis

3.1 An auction model with an informed bidder

One theoretical setting which is particularly well suited to our empirical analysis is the open-bid, single-good, ascending English auction model, with private and common values and asymmetric information across bidders. This framework is useful in that bidders can learn about the quality of the object during the bidding process and can change their reservation prices (Milgrom, 2004; Maskin, 2004).[7]

Wilson (1998) considers a specific case of English auctions introduced by Milgrom and Weber (1982) and labeled as the button (or Japanese) auction in which the dropping-out decision is both public and irrevocable. Under the joint assumption of log normal, multiplicative values and information asymmetries, the equilibrium strategies are log-linear and can be computed as a function of the chosen parameters. Hong and Shum

[7]In the presence of interdependent values, Maskin (1992) shows that an equilibrium with one-dimensional signals can still be efficient in ascending auctions with interdependent values and asymmetric bidders (different value functions) if interpersonal crossing conditions hold. These conditions are verified in the Wilson (1998) additive log-normal model (Krishna, 2003, p. 262). When signals are multi-dimensional, efficiency is no longer possible (for a general proof of inefficiency see Jehiel and Moldovanu (2001)).

(2003) consider a generalized version of the Wilson model and their formulation will be discussed here.

Specifically, agents denoted $i = 1, \ldots, N$ are characterized by an unobservable valuation V_i and a privately observed imperfect signal of that valuation X_i concerning an object sold at an ascending, open-bid auction. The valuation of that object is determined by both a private A_i and a common V component. Each round of the auction consists in agents submitting bids, with the lowest bid being dropped out and a new round being started. At each round k, agents can observe the signal of the exiting bidder, but need to infer that of the $N-k$ other bidders who remain active. Given price P, the equilibrium bidding strategy β_i^k of agent i at bid round k must satisfy:

$$P = \mathrm{E}[V_i \mid X_1 = (\beta_1^k)^{-1}(P), \ldots, X_{N-k} = (\beta_{N-k}^k)^{-1}(P), X_{N-k+1}, \ldots, X_N], \tag{1}$$

for $i = 1, \ldots, N-k$. Under general monotonicity conditions, it can be shown that such an equilibrium exists and is obtained by solving (1) for the $N-k$ inverse bidding functions $(\beta_{N-k}^k)^{-1}(P)$ (Hong and Shum, 2003, Proposition 1, p. 331).

Importantly, it is possible to derive closed-form expressions for the Bayesian-Nash equilibrium bidding functions when the stochastic process is log-normal. Assume that log valuation $v_i \equiv \log(V_i)$ and log signal $x_i \equiv \log(X_i)$ are distributed as follows:

$$v_i = a_i + v, \tag{2}$$

$$x_i = v_i + \epsilon_i, \tag{3}$$

$$[a_i, v, \epsilon_i] \sim N.I.D. \left([\bar{a}_i, m, 0], \mathrm{Diag}\left[t_i^2, r_0^2, s_i^2\right] \right).$$

The valuation for each agent v_i in (2) is the sum of private value a_i and common value v; the signal x_i in (3) is a noisy measure of that valuation. Private and common value as well as noise are assumed to be i.i.d. Gaussian with t_i (r_0) being the standard error of the private (common) value and s_i that of the signal error. All the distributional parameters $\{\bar{a}_i, m, t_i, r_0, s_i\}$ are public knowledge. It can be shown that the equilibrium bid of agent i at round k satisfies:

$$b_i^k \equiv \log(\beta_i^k) = 1/A_i^k(x_i + D_i^k x_d^k + C_i^k), \tag{4}$$

where x_d^k is the ex-post observable vector of signals from exited bidders and where A_i^k, D_i^k, C_i^k are functions of the distributional parameters $\bar{a}_i, t_i, m, r_0, s_i$ (Hong and Shum, 2003, eq. (12), p. 334). This model is convenient for analyzing the impact of the presence of an informed bidder on equilibrium bids. An informed bidder, $i = I$, could be thought of as one whose signal is precise compared to others:

$$s_i = 0 \text{ if } i = I, \text{ and } s_i > 0 \text{ if } i \neq I. \tag{5}$$

Combining (5) and (3) implies that only the informed bidder I is able to observe his own valuation directly, i.e. $x_i = v_i$ for $i = I$ only.[8] Note that this is not equivalent to I observing the common value, as a_i and v are not individually identifiable in (2). Rather, perfect information on v by I obtains under two special cases of the model. First, a similar outcome of $x_I = v$ would obtain under the pure common-value models ($a_i = 0, \forall i$) in the spirit of Engelbrecht-Wiggans et al. (1983), or Hendricks and Porter (1988). Second,

[8] Recall that the distributional parameters are known and, consequently, that the identity of the informed bidder ($s_I = 0$) is publicly known.

Wilson (1998) assumes a diffuse prior (corresponding to $r_0 = \infty$) whereby each agent separately observes his own a_i and $v + e_i$. In this case our informed trader assumption $s_I = 0$ would then be tantamount to I observing the common value. However, because we focus on a market for human beings, the pure common value and diffuse prior assumptions – whereas undoubtedly reasonable in other settings – both appear excessive in our case.

First, assuming away private value for slaves is excessive. Private valuation is usually associated with differences in cost structures, matching synergies or tastes across bidders. Empirical evidence suggests that private values are not negligible.[9] All of these factors behind private valuation were certainly applicable to slave auction participants, but personal feelings towards slaves were also very likely. Evidence of these can be found in the fact that numerous slave purchases were made for reasons unrelated to productivity motives such as manumission, keeping slave families together or on a particular estate. Consequently we follow a large branch of auction theory in allowing $a_i \neq 0$ in our model to accommodate private valuation.

Second, it would seem doubtful that experienced slave owners, who constituted the bulk of auction participants, would have completely uninformative priors on a slave's common productivity. Moreover, it would seem reasonable to expect that common and private valuation would be intertwined and not separably observed. Evaluation of a slave's productivity could very well be influenced and distorted by personal feelings toward that slave and vice versa.

[9]Hong and Shum (2002) provide evidence of strong private value components in procurement auctions for road and bridge construction and maintenance.

An analytical evaluation of the effect of restriction (5) is complicated by the nonlinearities in the distributional parameters found in A_i^k, D_i^k, C_i^k in (4). Alternatively, we may resort to numerical approaches to which we now turn.

3.2 A Monte-Carlo Experiment

To ensure the independence with respect to parametric choices, we stochastically generate all of the model's distributional parameters at each replication (see Appendix A.1 for details) and verify and confirm the robustness to the other parameters in Appendix A.2.

Specifically, for agent $i = 1, \ldots, N$ active in bidding round $k = 1, \ldots, N$ of the Monte-Carlo experiment replication $j = 1, \ldots T$, we define $\hat{\pi}(i,k) \equiv \text{Median}(\pi(i,k,:))$ as the median of the difference between all agents' bids with $b^1(i,k,j)$ and without $b^0(i,k,j)$ informed bidder:[10]

$$\pi(i,k,j) \equiv b^1(i,k,j) - b^0(i,k,j), \quad \forall i,k = 1,\ldots,N, \quad \forall j = 1,\ldots,T. \tag{6}$$

Figure 1 plots the median premium $\hat{\pi}(i,k)$ against the bidding round number k. The identities i for some bidders are indicated.[11] Moreover, the round number where I retires is a random event in the simulations since the distributional parameters are drawn at each replication. We evaluate the median retirement round for the informed bidder at

[10]More precisely, for each replication j consisting of a given set of parameters $\boldsymbol{\theta}_j = \{\bar{a}_i, t_i, m, r_0, s_i\}_j$ and draws for the stochastic shocks $\boldsymbol{\epsilon}_j = \{\epsilon_{a_i}, \epsilon_v, \epsilon_{x_i}\}_j$, we compute two equilibrium bidding strategies: one where an informed bidder $i = I, s_i = 0$ is present to get $b^1(i,k,j)$ and one where the informed is replaced by an uninformed bidder $i \neq I, s_i > 0$ who is otherwise identical to obtain $b^0(i,k,j)$ for all bidders i and all bidding rounds k. We then subtract the second from the first to obtain the excess bid in (6).

[11]Recall that bids are re-sorted at each round in descending order. The bidder's identity should be interpreted as his position in the sorted bids. Hence, for $N = 30$ participants, bidder $i = 17$ at round $k = 5$ is the 17^{th} highest bid of the remaining $N - k = 25$ bidders.

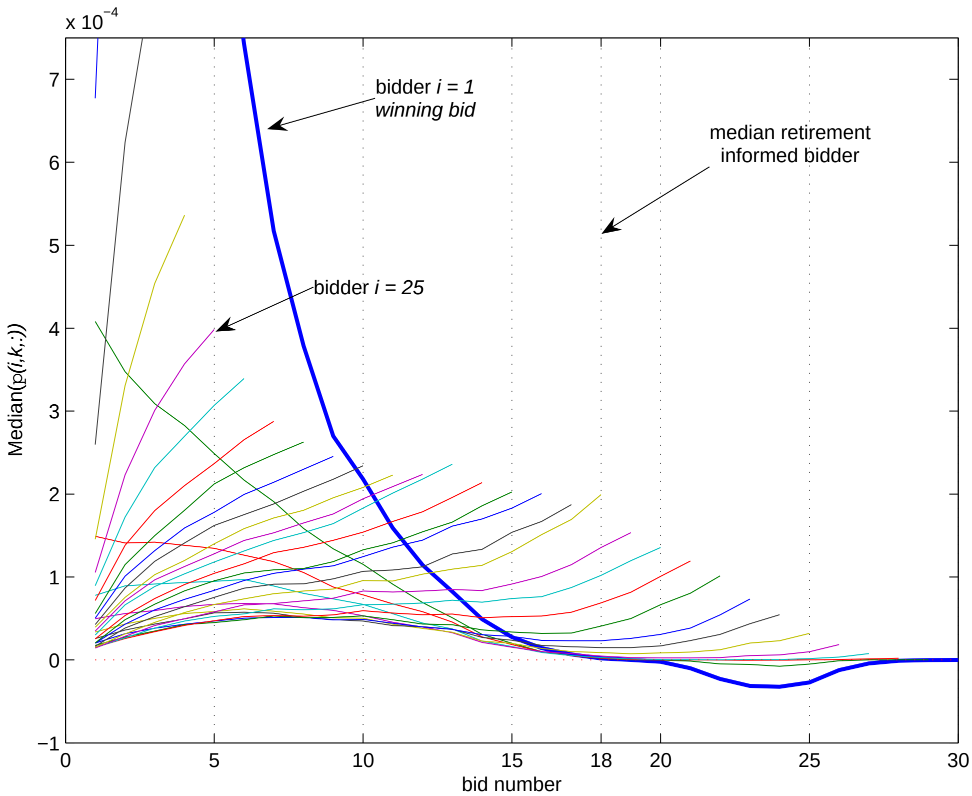

Figure 1: Median informed bidder premium. Each line corresponds to the median informed bidder premium Median($\pi(i,k,:)$), where $\pi(i,k,j)$ is given in (6) and the premium is calculated for each agent $i = 1, \ldots, 30$, and at each round k.

round 18 out of $N = 30$. We observe that, for all agents, the median informed bidder premium remains strictly positive until round 18. Specifically,

Result 1 *The median informed bidder premium is positive until the median retirement round where the informed bidder retires from the bidding process.*

For those high-value bidders remaining after I has left, the premium is negative and becomes negligible as we approach the end of the process; for medium- and low-value bidders, the premium is positive until they retire. Furthermore, the premium for the highest bidders are similar in shape and decline with the intensity of the bids. In addition, for median- and low-value bidders, the premium increases until they retire. Finally, the premium is largest for the lowest bidders who retire early on in the bidding process (located to the left of the graph).

In ascending auctions such as the ones considered here, the equilibrium price is equal to the second highest bid in the next-to-last bidding round (Wilson, 1998). Consequently, a corollary of Result 1 is that, if I remains active until the end to win the auction, then the second highest bidder will also bid more aggressively and I will end up paying a higher price. To verify this claim, we therefore compute the equilibrium price (informed-bidder) premium conditional on I winning the auction:

$$\begin{aligned}&\pi(i=2,k=N-1,j \mid I=1,k=N,j)\\&\qquad\equiv b^1(i=2,k=N-1,j \mid I=1,k=N,j)-b^0(i=2,k=N-1,j) \qquad (7)\end{aligned}$$

This corresponds to the difference in price the informed bidder would have to pay given that he ended up winning the auction. Panel A of Figure 2 plots the distribution of the equilibrium price premium.[12] It clearly indicates that the premium is non-negative, with a mean of 0.0663. This allows us to conclude that:

Result 2 *The equilibrium price (informed-bidder) premium* (7) *is positive when the informed bidder wins the auction.*

The more aggressive bidding when the informed bidder I remains active arises from the interaction of the winner's curse and the loser's curse. The fact that I remains

[12] In our Monte-Carlo experiment, the informed bidder won the auction (i.e. $b^1(I=1,k=N,j)$) a number $T_I = 418$ times out of $T = 5,000$ replications. Selecting only those 418 replications, we therefore compute the second highest bid $b^1(i=2,k=N-1,j \mid I=1,k=N,j)$ with the informed bidder being present and winning the auction. Then, for the same set of parameters, we replace the informed bidder by an uninformed bidder who is equivalent in all other respects to compute $b^0(i=2,k=N-1,j)$ and its associated premium (7), i.e. the difference between the two. Figure 2 plots the distribution of those 418 cases.

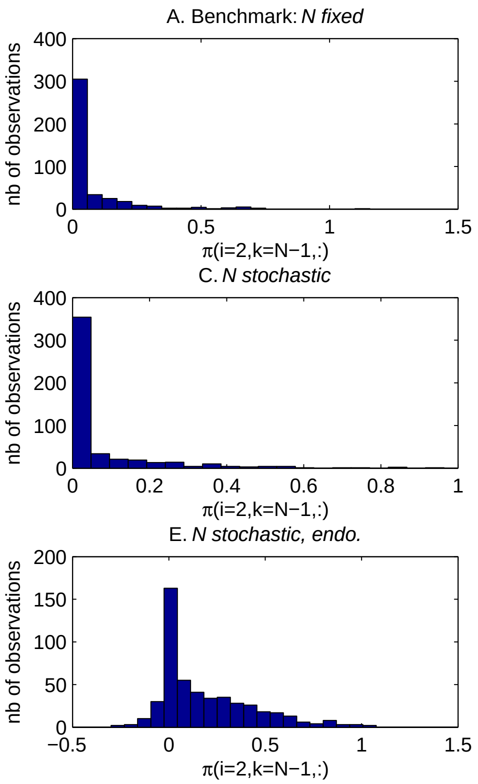

Figure 2: Distribution of equilibrium price premium conditional on I winning the auction. The equilibrium price premium (7) is the second highest bid premium $\pi(i = 2, k = N-1, j \mid I = 1, k = N, j)$, conditional on the informed bidder winning the auction. A. Benchmark case, $N = 30$, bidders, $s_I = 0$; B. Imperfect information $s_I = 10^{-3} \times \min(s), N = 30$. C. $N \sim U[10, 50]$ stochastic; D. $N \sim U[30, 50]$ stochastic; E. $N \sim U[10, 50]$ stochastic and $N_0 = 1/2N$ if I absent.

Table 1: Median equilibrium prices and premium conditional on I winning the auction

b^0	b^1	π	nb. obs.
A. Benchmark: N fixed			
1.9869	2.0649	0.0004	418
B. I imperfect info			
1.9092	1.9989	0.0006	409
C. $N \sim U[10, 50]$ stochast.			
1.8383	1.8973	0.0013	490
D. $N \sim U[30, 50]$ stochast.			
2.1058	2.1748	0.0003	339
E. $N \sim U[10, 50]$ stochast., endo			
1.7093	1.8842	0.0988	501

active could be because of a high common value. Then, an uninformed bidder retiring from the auction incurs a loser's curse. However, I could remain active because of a high private value. Remaining active therefore implies the risk of a winner's curse. Our results indicate that, for a wide range of parametric specifications, the loser's curse effect is higher, such that bidders are willing to bid more aggressively knowing that the informed bidder remains active.

Panels B-E of Figure 2 plot various robustness checks for Result 2. The corresponding sample medians are reported in Table 1. First, in Panel B, we relax the hypothesis that the informed bidder has perfect information ($s_I(j) = 0, \forall j$), by allowing for better (but imperfect) information ($s_I(j) = 10^{-3} \times \min \boldsymbol{s}(j), \forall j$), i.e. the better but not fully informed bidder has a 1,000 times lower standard error on his signal x_I than does the individual with the lowest variance in simulation j. The impact on the results is negligible; the equilibrium-price premium remains positive.

In Panels C and D, we consider the impact of allowing for a stochastic number of bidders N by computing the equivalent of the price premium in Panel A, but where N is drawn randomly at each replication from a uniform distribution $U[10, 50]$ (panel C) and $U[30, 50]$ (panel D) instead of being fixed at $N = 30$. As can be seen by comparing Panels A with C and D, allowing for a random N has no qualitative impact on Result 2. Increasing the mean value of N by increasing its support to $N \sim U[30, 50]$ again leaves the main results unaffected with the mean premium virtually unchanged. We can therefore conclude that

Result 3 *The equilibrium price premium* (7) *is independent of the number of participants* N*.*

The informed bidder who wins an auction pays a higher price owing to the more aggressive bidding by uninformed bidders induced by his presence. However the additional amount he ends up paying does not depend on the number of uninformed bidders. This result can be rationalized as follows. As the number of participants increases, the probability of having a bidder with a high signal increases and so does the equilibrium price. This effect is independent of whether or not an informed bidder is present. Consequently, the premium (i.e. the difference in the two prices) remains unaffected and is independent of N.

In Panel E, we again consider a stochastic number of participants $N \sim U[10, 50]$, but where it is positively correlated with the presence of the informed bidder I. More specifically, we draw N at each replication of the Monte-Carlo experiment and halve it in the absence of I. Although some caution should be exercised in interpreting these results, the equilibrium prices plotted in Panel E of Figure 2 are clearly higher, with a mean value of 0.1860.[13]

Two interpretations of this result are possible. First, we may argue that (I, N) are systematically correlated, in that observing I is informative and attracts potential bidders who were otherwise inactive. Heuristically, equilibrium prices could be affected through an extensive and intensive effect: more bidders bid more aggressively because of the presence of the informed bidder. This interpretation would be consistent with the larger premium observed in Panel E compared with Panel A.

Second, (I, N) may also be positively but unsystematically correlated through the presence of a third, omitted variable. Hence, a given type of auction in which informed bidders are more active than otherwise could also attract more potential bidders for reasons unrelated to informational asymmetry. For example, in our setting, a succession sale (in which better informed related bidders are most likely active) could attract more potential bidders wanting to acquire other goods (e.g. furniture, agricultural equipment, ...). As more bidders may induce a potentially more competitive auction, a higher equilibrium price would obtain in succession sales where I is also more active. This higher price would be unrelated to informational asymmetry but would be exclusively caused by the omitted variable.

Fortunately, this is unlikely to be a problem in our estimation for two reasons. First, in what follows, we focus initially on succession sales exclusively for both our treated (I

[13]Contrary to all the experiments conducted so far, this one does not involve a given set of parameters and draws of shocks per replication, for both cases of with and without an informed bidder. Indeed, we select only half the parameters and shocks for the "without" case and the full set when I is present. This means that the equilibrium bidding processes are for two different sets of primitives. As such, this violates the comparative-statics principle used in computing the informed bidder premium. A different set of players' characteristics could explain the difference in price.

present) and control (I absent) groups. That is, compared to other regular slave auctions, we likely have a larger number of bidders in succession sales, whether or not the informed bidder is active. Our estimated premium is the excess price in those succession sales where the informed bidder ended up acquiring the good, compared with succession sales where an uninformed bidder won the auction. An omitted-variable effect similar to the one just described is thus fully taken into account and should not affect our results.

Second, in the estimation robustness analysis in Section 5, we refine this analysis by incorporating slave-lot (a particular seller selling multiple slaves at a given date) fixed effects. This fixed effect controls for unobserved heterogeneity at the auction level, such as the weather, output price and/or the number of participants. Heuristically, the number of bidders may vary across slave lots but not within a slave lot. Our results confirm that the informational effect of related buyers is maintained when an uncertain N is thus taken into account.

Summarizing, the theoretical auction model predicts that an informed bidder's presence induces more aggressive uninformed bidding (Result 1) and, consequently, a higher equilibrium price when the informed bidder wins the auction (Result 2), independently of the number of participants (Result 3). As the following discussion will make clear, we do not observe the actual bidding process such that Result 1 cannot be tested using our slave auctions data set. However, we do observe the winning price as well as the identity of the winning bidder. This provides a basis for testing Result 2 in Section 4. Finally, as the number of participants is not observed, we cannot test Result 3 directly, but provide an indirect test in Section 5.

4 Empirical analysis

4.1 Data

Although Mauritius remained an important French and subsequently British slave colony until slavery was finally abolished in 1835, Mauritian slavery has not been as extensively studied as other slavery institutions. Chenny et al. (2003) show that Mauritian slavery displayed remarkable parallels with its better known counterparts elsewhere. Valuation of physical strength, skills and reproductive capacities were just as prevalent as those found in the Americas. On the other hand, compared to the New Orleans market, the Mauritian slave market can safely be regarded as purely local, with slave imports effectively banned by the British. In 1807, 85% of the island's total population of 78,000 were slaves of African, Indian and indigenous origins and no external influx of slaves were supplied on local markets.

The information on the sale of Mauritian slaves is obtained from the notarial acts in the Mauritius Archives. Our data base was constructed from 580 auctions involving over 4,200 slaves. A more detailed description is presented in Appendix B. Under Mauritian colonial law, notaries played a key role in the public auctions of slaves (Government of Mauritius, 1824, Proclamation of July 16, pp 122-125). In particular, notaries certified the ownership titles of the sellers and subsequently publicized and organized the public auction. These auctions were conducted as oral (open) ascending bids, following a slave inspection period. After the auction took place, the notaries recorded transactional information between the seller and the buyer of the slave, including date, names of parties involved as well as the slave's price and observable characteristics.

In addition, the acts document the reason for the sale of slaves, either voluntary or involuntary (for instance following the slave owner's bankruptcy, or death, i.e. succession sales). In the latter case, the acts also provide a list of heirs. Under the French Civil Code (adapted for Mauritius under Code Decaen, 1804), following a bankruptcy, all the assets (including slaves) of the individual or company had to be liquidated through an auction. Succession laws (also specified in the Civil Code) prescribed that the succession should be divided among heirs following the death of the owner(s). Complete liquidation of assets through an auction was automatic whenever a heir was minor, absent or legally ineligible. Similarly, auction sales would have been organized whenever heirs failed to reach an agreement concerning the valuation and distribution of the assets among themselves. In this case, the value of the proceeds from the auction would have been divided among the heirs.

Table 2 verifies and confirms our sample's representativeness of the slave population in Mauritius by comparing it with the 1826 partial census data from the *Greffe de l'Enregistrement des Esclaves* in the Mauritius Archives (Teelock, 1998; Valentine, 2000). Overall, gender, ethnicity, as well as age distributions by ethnic group in our sample are quite close to those obtained from the census. We therefore conclude that our sample is reasonably representative of the general slave population.

Panel A of Table 3 reports the average prices across gender, occupation and ethnic group. Our main findings may be summarized as follows: (i) female slaves consistently fetched lower prices; (ii) price differences across ethnic groups are significant, with Creole (i.e. indigenous) slaves fetching the highest prices; and (iii) premiums are associated with

Table 2: Comparison with the 1826 Partial Census.

	Number of slaves				**Average age**			
	1826 Census		**Notarial acts**		**1826 Census**		**Notarial Acts**	
	Nb.	%	Nb.	%	Avg.	Std. Dev.	Avg.	Std. Dev.
All sample	20,467		4,013		25	14.3	28	15.0
Gender								
Male	11,671	57	2,724	64	26	14.0	30	14.5
Female	8,762	43	1,521	36	23	14.5	24	15.2
Missing			33					
Ethnic group								
Creole	10,364	51	2,015	52	17	12.1	19	12.9
Mozambican	5,581	28	995	26	34	10.8	38	9.7
Madagascan	3,666	18	717	19	31	11.3	34	9.9
Indian	669	3	135	3	44	12.6	47	10.4
Missing			424					

skilled occupations. These findings are consistent with those of Chenny et al. (2003) for the 1825-1827 period.

We use the nominal information to construct a "Related" binary index equal to one when family ties link buyers and sellers.[14] The distribution of the links between the buyer and seller across reasons for sales is reported in Table 4. In our data set, the vast majority (75%) of auctions took place to liquidate the estate of a deceased person, while only 6.7% were because a slave owner voluntarily wanted to sell his or her slaves. The remaining auctions occurred because of bankruptcy (9.9%). We find a link between buyers and sellers for 1,003 slaves (3,307-2,304). In the case of succession sales, conditional on being related to the deceased, the widow(er) is the modal buyer. The second group of related buyers is composed of the former owner's children. The share of related buyers is lower in the case of bankruptcies (4.6%) or voluntary sales (12.6%) than in succession sales (38.5%). In the case of voluntary sales, the modal related buyer is the original owner

[14] See Appendix B for an example.

Table 3: Average slave prices are in current *piastres* (5 *piastres* = £1 = $4.94US in 1827, Officer (2001)). A prime-aged field slave is a male of age 15 to 35 who works in agriculture (*pioche* or other agricultural related tasks). The T-test is for the null hypothesis that prices for related and unrelated buyers (Panel B), succession and voluntary sales (Panel C), are equal.

A- Gender, occupation and ethnicity

		Ethnic group										**All ethnic groups**	
Gender	Occupation	Creole		Mozambican		Madagascan		Indian		Unknown			
		Price	Num.	Price	Num.	Price	Num.	Price	Num.	Price	Num.	Price	Num.
Female	Skilled	108	2			229	8	106	1			196	11
	Laborer	378	64	188	49	298	19	109	13	126	5	274	150
	Household	345	203	243	36	354	63	197	23	313	20	325	345
	Unknown	246	69	149	17	216	16	111	11	219	14	214	127
	All	330	338	201	102	313	106	152	48	255	39	288	633
Male	Skilled	427	167	349	155	371	152	131	10	411	59	382	543
	Laborer	397	196	298	495	315	237	194	22	238	25	318	975
	Household	373	210	305	65	405	71	188	33	311	17	350	396
	Unknown	305	70	271	93	310	47	261	12	314	58	294	280
	All	387	643	305	808	344	507	193	77	337	159	337	2,194
All	Skilled	423	169	349	155	364	160	128	11	411	59	378	554
	Laborer	392	260	289	544	314	256	163	35	219	30	313	1,125
	Household	360	413	283	101	381	134	191	56	312	37	338	741
	Unknown	276	139	252	110	286	63	189	23	295	72	269	407
	All	367	981	294	910	339	613	177	125	321	198	326	2,827

B- Related and unrelated buyers

	Related buyer		**Unrelated buyer**		**T-test**	**Premium**
	Avg. price	Nb. of obs	Avg. price	Nb. of obs		
All males						
1825-1835	390	512	330	1,221	5.87	18%
1825-1830	442	317	368	884	5.56	20%
1831-1835	305	195	229	337	6.32	33%
Prime-aged field slaves	489	118	373	236	5.95	31%

C- Succession and voluntary sales

	Succession sales		**Voluntary sales**		**T-test**	**Premium**
	Avg. price	Nb. of obs	Avg. price	Nb. of obs		
All males						
1825-1835	355	1,598	247	146	9.22	44%
1825-1830	400	1,080	267	117	9.81	50%
1831-1835	259	518	163	29	5.90	59%
Prime-aged field slaves	334	687	231	61	6.58	45%

Table 4: Related buyers and motivations for sales. Children sold with their mother are coded as single sale. We exclude group sales of slaves, i.e. heterogeneous bundling of adult slaves. Other informed buyers include: a creditor, husband of the niece of the deceased, the notary, the testament executor (*fondé des pouvoirs*).

		Reasons for the sale			
Link between	**Voluntary**	**Invol.**		**Unknown**	**Total**
seller and buyer		**Bankrupt.**	**Succes.**		
Family					
Wife			286		286
Husband	9		189		191
Son	1		177		178
Son-in-law	1		76		77
Daughter			69		69
Grand-children			9		9
Nephew and niece			9		9
Brother		3	5		8
Father			8		8
Sister			7		7
Brother-in-law			2		2
Cousin			2		2
Minor children			2		2
Father-in-law			1		1
Mother			1		1
Non-family					
Original slave owner	14	7		7	28
The slave		2	4		6
Tenant			3		3
Business partner			7		7
Same last name	3	3	97	2	105
Other			4		4
No apparent link	200	314	1,530	260	2,304
Total	221	329	2,488		3,307

himself (14 purchases).[15] This highlights a fundamental difference between voluntary and involuntary sales in our sample. Related buyers (other than original owner) were active in involuntary sales and mainly absent from voluntary sales. Unrelated buyers were active in both.

Panels B and C of Table 3 present price differentials for sub-samples stratified by the type of buyers (related vs unrelated, Panel B) and the type of sales (succession vs voluntary, Panel C). To obtain a more homogenous slave group, we focus on male slaves and on prime-aged male field hands.[16] The results can be summarized as follows: slaves bought by related buyers or in succession sales fetched higher prices.

4.2 Methodology

We saw earlier that our data set allowed us to gauge whether or not slave sellers and buyers were related. Moreover, we showed that the presence of better informed bidders in public auctions resulted in a higher price being paid by the better informed bidder in those instances where he wins the auction (Result 2). We now regroup these two elements to obtain a testable restriction by making the following two assumptions:

Assumption 1 *Compared to other bidders, a related bidder has superior information on the slave's value.*

and

Assumption 2 *A related bidder's identity is known by other bidders.*

[15] Note that, as was the case in New Orleans, the original owner could buy back his own slaves (Freudenberger and Pritchett, 1991). These owners may have decided to buy back the slave given that the proposed bid was less than their reservation value, or in order to cancel prior sales and return the purchase price to the buyer.

[16] Defined as males aged 15-35 working in agriculture (*pioche* or other agricultural related tasks)

The first assumption appears realistic. We saw in Table 4 that the vast majority of related buyers were either the spouse or children of the deceased owner in succession sales. It would seem natural to suppose that these bidders would have had sufficient time to acquire privileged information on the slave being auctioned.

The second assumption is also reasonable. The small size of the Mauritian market, both in its limited number of participants and geographical concentration, would make it likely that bidders would have known each other. It is of course entirely possible that a related bidder would have preferred to hide the informational content of his bidding strategy by hiring an agent in order to conceal his identity. Again, we do not have access to the actual bids so that we cannot verify the actual impact of this. Nonetheless, three elements lead us to argue that it probably would not have affected our results much. First, from an econometric standpoint, the implications are that our "Unrelated" variable would have been measured with error (since some related winners would have been wrongly classified as unrelated). If that classification error were correlated with the pricing error, then biased estimates would have been obtained. We control for this possibility below by instrumenting-out the related variable without qualitative changes in our results. Second, the notary acts we use were legal documents; any misrepresentation would have implied serious consequences in terms of titles of ownership, guarantees, compensation in case of emancipation, ... A prospective related buyer would have undoubtedly weighted the cost of a higher price by letting his identity be public against the costs of mis-representation. Finally, given the small size of the Mauritian market, it appears doubtful that such hiding strategies would have been successful.

The direct consequence of combining Assumptions 1 and 2 with Result 2 is straightforward. If the related buyer acquires the slave at the end of the bidding process and if other bidders believe his actions are somehow motivated by a high common value, then the price paid by the related buyer will be higher, reflecting the informational asymmetry.

More formally, let I_s denote whether the winner of the auction for slave s is related ($I_s = 1$), or not ($I_s = 0$). We are interested in testing if I_s has some predictive power for the winning bid $p_s \equiv \log(P_s)$. If f denotes some probability function and $\boldsymbol{X}_s$ a vector of exogenous variables which explain the winning bid, then we say there is no residual information asymmetry if I_s has no predictive power for p_s:

$$f\left(p_s \mid \boldsymbol{X}_s, I_s\right) = f(p_s \mid \boldsymbol{X}_s). \tag{8}$$

Assuming a simple hedonic price function we have that:

$$p_s = \boldsymbol{X}_s \boldsymbol{\beta} + I_s\, \gamma + \varepsilon_s. \tag{9}$$

where $\boldsymbol{\beta}$ and γ are parameters and ε_s is an error term. A test of the null hypothesis of no residual information asymmetry is then simply a test of $H_0 : \gamma = 0$.[17] Note that this is a one-sided test. Rejecting the null is consistent with finding asymmetric information;

[17]One way to apply our test to the Hendricks and Porter (1988) data would be to estimate the hedonic price (winning bid) function (9) as a function of control variables and a dummy indicating whether the winner is a neighbor firm or not. This variable would likely have to be instrumented, which is always the most difficult task when applying this test. In particular, it remains unclear which available variable is correlated with the probability of being a neighbor, yet is not correlated with the error terms in the hedonic price function. Two additional difficulties would have to be considered: First, the competition between the bidders and, second, how to integrate the randomization behavior of the non-neighbors. A more general test would be to use all the available bids instead of the winning bids only, since this information is available in their data set.

however, not rejecting it could still entail asymmetry among unrelated bidders and/or that the identity of better informed bidders is not public.

However, I_s is potentially correlated with the unobservable characteristics of the slave in which case ordinary least square estimates of the parameters in (9) would be biased. For example, related bidders could be more present in succession auctions where other items on sale might have attracted a different set of bidders. Alternatively, I_s could be measured with error. For instance, we rely primarily on family names to construct our related index; it is possible that related agents with different names could have been omitted. One approach is therefore to find a valid instrument for I_s. Letting $\boldsymbol{Z}_s$ denote the vector of explanatory variables which determine whether the winner of the auction s is a related buyer and ν_s an i.i.d. random error term, we have that:

$$I_s = 1 \text{ if } \nu_s > -\boldsymbol{Z}_s\boldsymbol{\theta}, \text{ and } I_s = 0, \text{ otherwise.} \tag{10}$$

In other words, a related buyer wins the auction if there are net positive benefits for him or her.

The vector of explanatory variables $\boldsymbol{Z}_s$ must contain identifying variables which are correlated with I_s but are not correlated with the error term in (9). The winning bid should reflect the expected lifetime productivity of the slave. In this case, variables which do not measure the slave's productivity and which appear in the notarial act should not influence the value of the winning bid. One such possible identifying variable is the number of heirs: *ceteris paribus* observing more or fewer heirs should not affect a slave's productivity. However, if there are more heirs, it is more likely that one of them would be willing or would have the means to buy the slave.

For robustness reasons we extend our empirical analysis to the tests for residual information asymmetry proposed by Chiappori and Salanié (2000) and Dionne et al. (2001) in the context of insurance markets. An adaptation of the Chiappori and Salanié (2000) test means we would have to estimate simultaneously (10) and

$$p_s = \boldsymbol{X}_s \boldsymbol{\beta} + \eta_s.$$

A correlation between I_s and p_s given, $\boldsymbol{X}_s$, would then be equivalent to ν_s and η_s being correlated. Moreover, Dionne et al. (2001) point out that (8) is equivalent to:

$$f\left(I_s, p_s \mid \boldsymbol{X}_s\right) = f\left(I_s \mid \boldsymbol{X}_s\right) f\left(p_s \mid \boldsymbol{X}_s\right). \tag{11}$$

This additional relationship shows the symmetry in I_s and p_s of the conditional independence in our context. In a parametric formulation of the distribution of winning auction prices as given by (9), the conditional independence between I_s and p_s, given $\boldsymbol{X}_s$, is obtained when $\gamma = 0$ in (9). Nonetheless, the null hypothesis of no residual information asymmetry can be rejected because (9) is misspecified. Dionne et al. (2001) show that one way to avoid this problem is to add the conditional expectation of I_s as an explanatory variable in (9). In our case, this means we should estimate:

$$p_s = \boldsymbol{X}_s \boldsymbol{\beta} + I_s \gamma + \mathrm{E}(I_s | \boldsymbol{Z}_s) \delta + \varepsilon_s, \tag{12}$$

where E is the expectation operator and δ is a parameter. Again, a test of the null hypothesis of no information asymmetry can be devised as a test for $H_0 : \gamma = 0$.

The control variables in $\boldsymbol{X}_s$ that we include are mainly determined by the availability of data, existing literature and likely relevance. For slave-specific characteristics, we expect prices to be increasing and concave in age and lower for female as well as for handicapped slaves, thus reflecting the valuation of physical strength. Moreover, we expect that prices will vary across ethnic origin, reflecting adaptability to conditions and that prices will increase with the skill levels. As for sale-specific elements, the presence of children sold with their mother should have a positive influence on price. Finally, we control for quarterly and yearly effects reflecting seasonality in the agricultural activities of slaves and medium-term fluctuations in output prices.

Since related buyers were found to be mainly absent from voluntary sales, we focus on succession sales in a first step. We later consider the impact of adding voluntary sales. From the original sample of 4,286 slaves, we are left with 1,812 sales for which the information on all the variables (winning bids, related bidder, slave characteristics, motivation for sale) is complete and 1,212 cases where, in addition, we have the information on the number of heirs which is used as the instrument.[18] The data omitted from the original sample was mainly caused by illegible handwriting or acts that were too deteriorated to be readable. As these were likely purely random events, there is no reason to suspect systematic under-reporting and sample selection bias.

[18]Since the owner was, by definition, alive at the time of the auction, the number and identities of heirs are unlikely to have been listed in voluntary sales, a further reason why we choose to focus on involuntary sales only.

4.3 Results

The estimation results are reported in Table 5. We start with the OLS estimates of the price equation without conditioning on the identity of the buyer in column (1). We then augment that equation with the Related binary variable in column (2). This variable is significantly positive.

As discussed in Section 4.2, observing that a buyer is related to the seller could be correlated with the unobserved characteristics of the slave. Indeed, the Durbin-Wu-Haussman test rejects the null hypothesis that the related buyer is exogenous with a value of 10.76 and a p-value of 0.001. We therefore estimate the price equation by 2SLS in columns (3) and (4), where the number of heirs is used as the instrument. Once again, a related buyer pays a significantly positive premium. However, given that relatedness between the buyer and the seller is measured by a binary variable, it may be inappropriate to use 2SLS. We therefore estimate the system of equation by full information maximum likelihood (FIML) in columns (5) and (6) without any qualitative change in the results. Both sets of estimates strongly reject the hypothesis that related buyers pay the same price as unrelated ones. The test drawn from Chiappori and Salanié (2000) also supports residual information asymmetry in the market. The correlation of the residuals between the error term of the Probit equation for whether the buyer is related or unrelated and the error term of the price equation equals 0.0548 with a p-value of 0.0203. The results obtained by using the specification (12) advocated by Dionne et al. (2001) which are reported in columns (7) and (8) again indicate that related buyers pay a statistically significant premium compared to unrelated ones.[19]

[19] Due to convergence problems for the DGV specification, the Handicapped variable was omitted from the price equation.

Table 5: Determinants of slave prices: Succession sales only. Related is a binary variable which equals 1 if the buyer and the original slave owner are related. The reference categories are: skilled workers for occupation; Creoles for ethnicity. Year and seasonal fixed effects included. Data period: 1825–1834. Robust values of T-statistics reported in parentheses.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Estimator	OLS		2SLS		FIML		FIML	
Dep. var.	Log price	Log price	Log price	Related	Log price	Related	Log price	Related
Related		0.056*	0.617*		0.373***		0.406***	
		(2.410)	(2.354)		(3.784)		(4.476)	
# Heirs				0.022***		0.072***		0.072***
				(4.329)		(5.164)		(5.248)
E(Related)							4.153**	
							(2.873)	
Age	0.048***	0.050***	0.056***	-0.012*	0.053***	-0.035*	0.089***	-0.035*
	(10.931)	(11.139)	(7.885)	(-2.196)	(9.071)	(-2.262)	(6.428)	(-2.254)
Age^2	-0.001***	-0.001***	-0.001***	0.000	-0.001***	0.000	-0.001***	0.000
	(-16.731)	(-16.836)	(-11.617)	(1.791)	(-13.340)	(1.830)	(-9.402)	(1.824)
Male	0.093***	0.094***	0.096*	0.013	0.097**	0.040	0.200***	0.041
	(3.353)	(3.378)	(2.385)	(0.383)	(2.676)	(0.414)	(3.897)	(0.426)
Handicap	-0.537***	-0.538***	-1.036**	-0.305	-1.112**	-5.808		-6.132
	(-4.421)	(-4.436)	(-2.639)	(-0.908)	(-3.180)	(-0.000)		(-0.001)
Mozamb.	-0.058	-0.067*	-0.124*	0.148***	-0.088*	0.443***	-0.561***	0.445***
	(-1.852)	(-2.126)	(-2.053)	(3.639)	(-1.975)	(3.866)	(-3.375)	(3.901)
Madag.	-0.041	-0.045	-0.076	0.053	-0.066	0.153	-0.222**	0.151
	(-1.390)	(-1.506)	(-1.667)	(1.374)	(-1.628)	(1.390)	(-3.278)	(1.381)
Indian	-0.413***	-0.421***	-0.412***	0.080	-0.396***	0.223	-0.777***	0.216
	(-7.006)	(-7.048)	(-4.781)	(1.086)	(-5.153)	(1.083)	(-5.086)	(1.047)
Child. ≤ 5 y.	0.242***	0.242***	0.269***	-0.048	0.257***	-0.136	0.317***	-0.139
	(8.217)	(8.218)	(5.483)	(-1.157)	(5.950)	(-1.136)	(6.628)	(-1.156)
Child. > 5 y.	0.389***	0.388***	0.356***	0.034	0.362***	0.086	0.274***	0.089
	(9.044)	(9.039)	(5.567)	(0.613)	(6.286)	(0.552)	(4.188)	(0.567)
Agric.	-0.188***	-0.183***	-0.121*	-0.099*	-0.143**	-0.283*	-0.065	-0.289*
	(-5.980)	(-5.820)	(-2.256)	(-2.360)	(-3.225)	(-2.417)	(-1.295)	(-2.473)
House.	-0.133***	-0.142***	-0.152*	0.108*	-0.124*	0.297*	-0.631***	0.288*
	(-3.802)	(-4.031)	(-2.493)	(2.330)	(-2.510)	(2.305)	(-3.441)	(2.238)
Const.	5.120***	5.090***	4.787***	0.390***	4.905***	-0.393	3.570***	-0.381
	(59.286)	(58.323)	(26.751)	(3.462)	(39.539)	(-1.249)	(7.573)	(-1.211)
Observ.	1812	1797	1212	1213	1212	1212	1212	1212
R^2	0.579	0.580	0.421	0.097	.	.	.	.

Hence, all the tests support Result 2 whereby the presence of a related buyer with superior information leads to higher equilibrium prices. Based on the FIML point estimates, we can compute the related buyer premium at 23% ($0.373/\mathrm{E}(Informed) - 1$), i.e. a related buyer would have ended up paying close to $1/4^{th}$ more for a slave, controlling for slave characteristics and the timing of the sale. This result is indicative of strong informational asymmetries between the two groups of participants.

Turning to the other variables, it is of interest to note that the additional determinants of the price of a slave are consistent with priors and/or with the literature. First, the number of heirs significantly increase the probability that a related bidder will end up buying the slave. Second, we identify a concave relation between age and price, a strong discount on female and on handicapped slaves, as well as on non-native slaves.[20] All these elements capture the expected correlation between determinants of physical strength, acclimation to island and work conditions and productive capacity. Third, the presence of children increases prices with lower premia on younger children indicating high mortality and lost output of child-caring mothers.[21] Fourth, human capital is valued positively with significant premia paid for skilled slaves.[22]

[20]Similar age-price profiles are found in the U.S. (Kotlikoff, 1979) and Peru (Newland and San Segundo, 1996). Our estimated male premium is the same as the one found for the Southern US by Kotlikoff (1979), very close to that for Jamaica (12% in 1817, Higman, 1976, p. 192) and close to the lower estimates for the West Indies (10% to 25%, Ward, 1988, fn. 60, p. 34).

[21]Benedict (1980); Valentine (2000); Barker (1996) (Mauritius) and Kotlikoff (1979) (New Orleans) obtain similar results.

[22]Kotlikoff (1979) for the US, Bergad et al. (1995) for Cuba and Newland and San Segundo (1996) for Peru also find positive premia on skilled slaves.

4.4 From information asymmetry to adverse selection

To test for adverse selection, we contrast prices in voluntary with those in involuntary succession sales. Assuming maintenance costs were similar for low- and high-productivity slaves, unprofitable slaves would have been put up for sale first. Anticipating this, the market would have reacted by bidding lower prices. The consequence is that only low-productivity slaves would have been effectively sold in voluntary sales. We test this conjecture using two approaches.

First, we follow the non-parametric tests of Pritchett and Chamberlain (1993) in distinguishing prime-aged field slaves aged 15 to 35 who work as laborers (*pioche*), from other slaves, in order to reduce heterogeneity. The t-tests for equality of prices between voluntary and succession slaves are reported in panel C of Table 3. We strongly reject the null hypothesis that both are equal for the whole sample and also when we consider the 1825-1830 and 1831-1835 sub-periods. Prime-aged slaves sold during succession sales earn a premium of 45% compared to those sold voluntarily which is consistent with an adverse selection interpretation. Our premium is much higher than the insignificant 10% value computed by Pritchett and Chamberlain (1993) in New Orleans between 1830 and 1860.

However, we also saw in Table 4 that related buyers were more active in involuntary sales, which could explain why prices were found to be higher. To take this sample-composition effect as well as observable slave characteristics into consideration, we augment the pricing equation in Table 5 with a succession sales binary variable and estimate it over the full sample (voluntary and succession sales). In the spirit of the empirical adverse selection literature, we can then interpret a positive premium on the succession variable as being indicative of residual adverse selection. Moreover, we can interpret a positive premium on the related buyer's variable as further evidence of informational asymmetry, once we control for the type of auctions in which related buyers were active.

Column 1 of Table 6 presents the OLS estimation results.[23] First, the related buyer dummy variable is significant and remains virtually unchanged from the OLS estimate in Table 5. This confirms that the information asymmetry evidence is robust to accounting for the type of auction as well as for observable slave characteristics. Second, the succession sale variable is significant at the 10% level and numerically larger than (but not statistically different from) the related buyer premium (0.091 vs 0.050). This indicates residual adverse selection once we control for the differences in types of bidders as well as observable characteristics. Third and finally, the other estimates remain qualitatively similar. Overall, the evidence is thus consistent with both information asymmetry and adverse selection.

5 Robustness checks

Slave prices can be affected by a number of unobserved factors which could lead to biased estimates if they are correlated with a covariate. One such unobserved factor is the number of participants in an auction. It might be argued that the presence of more participants would increase competition in the bidding process and lead to higher prices. This could imply biased estimates of the Related or the Succession premium if the number

[23]The OLS was selected over the 2SLS or FIML estimations because of data availability. By definition, our main instrument for the Related variable, the number of heirs, is absent in non-succession (i.e. voluntary) sales and we could not identify another admissible variable in our data set that could act as an instrument. As all the inference was previously found to be robust to accounting for potential endogeneity, we are confident that the OLS approach is appropriate. Finally, the Succession variable is unlikely an endogenous variable; the death of an owner shouldn't be caused by the value of his slaves.

Table 6: Determinants of slave prices: All sales (voluntary + succession). See description of Table 5. OLS estimation, with year and seasonal fixed effects included for models (1), (3)-(5).

	(1)	(2)	(3)	(4)	(5)
Model	Base	Slave lot fixed effects	Notaries fixed effects	Informed bidder participation	Informed bidder participation
Dep. var.			Log price		
Related	0.050*	0.066*	0.052*		
	(2.419)	(2.113)	(2.361)		
Succes.	0.091*	0.156	0.079		0.073
	(1.985)	(1.816)	(1.762)		(1.447)
Presence				0.071**	0.068*
				(2.616)	(2.522)
Age	0.050***	0.050***	0.050***	0.044***	0.043***
	(9.550)	(11.950)	(12.763)	(8.064)	(7.939)
Age^2	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***
	(-13.317)	(-18.218)	(-19.656)	(-12.257)	(-12.156)
Male	0.121***	0.123***	0.128***	0.151***	0.151***
	(4.179)	(4.721)	(5.199)	(4.163)	(4.166)
Handicap	-0.518***	-0.485***	-0.521***	-0.763***	-0.767***
	(-4.378)	(-4.165)	(-4.706)	(-5.298)	(-5.309)
Mozamb.	-0.074*	-0.114***	-0.070**	-0.090*	-0.088*
	(-2.417)	(-3.874)	(-2.643)	(-2.446)	(-2.407)
Madag.	-0.035	-0.023	-0.026	-0.010	-0.008
	(-1.371)	(-0.788)	(-1.012)	(-0.315)	(-0.260)
Indian	-0.355***	-0.374***	-0.343***	-0.329***	-0.328***
	(-4.668)	(-6.707)	(-6.582)	(-3.781)	(-3.743)
Child. $\leq$ 5 y.	0.226***	0.198***	0.224***	0.242***	0.241***
	(8.824)	(7.306)	(8.530)	(7.129)	(7.150)
Child. $>$ 5 y.	0.397***	0.357***	0.397***	0.401***	0.401***
	(10.493)	(9.759)	(11.361)	(8.102)	(8.094)
Agric.	-0.155***	-0.106***	-0.162***	-0.151***	-0.153***
	(-6.027)	(-3.698)	(-6.294)	(-5.065)	(-5.155)
House.	-0.097**	-0.039	-0.097**	-0.093*	-0.098**
	(-3.115)	(-1.139)	(-3.246)	(-2.481)	(-2.629)
Constant	4.918***	4.932***	4.934***	5.038***	4.993***
	(56.402)	(40.000)	(61.013)	(54.549)	(51.083)
Observations	2407	2407	2407	1740	1740
R^2	0.583	0.457	0.566	0.563	0.564
Number of groups		343	14		

of participants is correlated with the presence of an informed bidder or with the type of slave auction (see Section 3.2).

In order to account for such potential biases, the price equation is estimated over the full sample by using a slave-lot fixed-effect estimator. This estimator controls for unobserved heterogeneity which is specific to a particular slave auction, such as the unobserved number of participants. It can safely be argued that the number of participants may vary across slave lots but not within a lot. As can be seen in column 2 of Table 6, we find that all of our results are qualitatively robust to accounting for such unobserved heterogeneity.

Slave prices could also be affected by the identity of the notary conducting the auction. For instance, certain notaries may specialize in a certain type of slave sales and, as auctioneers, may be more skilled or work harder at extracting higher prices. This could pose a problem in obtaining unbiased estimates of the price equation if the identity and the effort of the notary are correlated with the identity of the deceased, the type of auction and/or the identity of related potential bidders. To control for such potential unobserved factors, we incorporate a notary fixed effect in the estimation. Column 3 of Table 6 confirms that our results are again robust.

In our data set we observe the participation of a related bidder only when he wins the auction of a particular slave. We do not observe cases where a related bidder may have participated in an auction which he didn't win. To control for the unobserved related bidder presence, we create a variable equal to 1 for the whole slave lot if at least one related buyer won a bid in this particular lot (group A) and 0 otherwise (group B). We compare the price of slaves won by non-related bidders across the two groups. It seems reasonable to assume that the related winner of an auction was present at all of the auctions of that particular slave lot and that he may have participated in those other auctions which (s)he didn't win. Thus, the prices of slaves won by unrelated bidders in group A should be higher than the prices of slaves won by unrelated bidders in group B. Our results in columns 4 and 5 of Table 6 confirm this intuition and give further support to our findings.

6 Conclusion

This paper tests for information asymmetry and adverse selection in auctions. It shows that the former can be detected in English auctions through more aggressive uninformed bidding in the presence of an informed bidder when private values are high. Consequently, equilibrium prices paid by the latter are higher. Adverse selection can be detected through the motivation for sale. Involuntary sales imply the forced liquidation of all assets and prices should be higher compared to voluntary sales under residual adverse selection.

All our estimation results based on the type of bidders confirm that information asymmetry was important in the market for slaves. Related (and better informed) bidders did pay a significant premium when they won slave auctions. Moreover, the additional tests based on the motivation for sales indicate that adverse selection was also important. Voluntary sales implied strong discounts compared to succession sales.

Applications other than slave markets could use this approach. For example, competition among bidders in the case of mergers and acquisitions can involve firms that are better informed about the target's true characteristics. Analyzing the impact of their bids on other firms and on the final acquisition cost would prove informative on the extent to which adverse selection could affect the market for M&A's. Competition among bidders for paintings, fishes, or in any other open ascending auction may also be considered, as well as competition in other types of auctions under asymmetric information such as the second price-auction.

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Appendix

A Numerical methods

A.1 Monte-Carlo experiment details

We select a number of participants ($N = 30$); distribution laws for the fixed parameters ($U(0,1)$); and a number of replications ($T = 5000$). In accordance with the model, the error terms are drawn from Gaussian distributions. Then, at each iteration $j = 1, \ldots T$ we:

1. generate the fixed parameters $\boldsymbol{\theta}_j = \{\bar{a}_i, t_i, m, r_0, s_i\}$ from $U(0,1)$;

2. generate the errors process $\boldsymbol{\epsilon}_j = \{\epsilon_{a_i}, \epsilon_v, \epsilon_{x_i}\}$ from a Gaussian distribution corresponding to the generated scedastic structure in step 1;

3. use (4) to compute the equilibrium bids for each bidder i, at each round k and for each iteration j, first without $b^0(i,k,j)$ and then with an informed bidder $b^1(i,k,j)$.

Finally, we compute the informed bidder premium (6) defined as the difference between all agents' bids with and without an informed bidder. We subsequently focus on $\hat{\pi}(i,k) \equiv \text{Median}(\pi(i,k,:))$ to obtain the desired prediction for the empirical part of our study. The number of participants is arbitrarily set at 30 (we verify robustness to that choice below). Moreover, the parameters of the model are generated at each iteration. This ensures that our results are not dependent on a specific parameter set, but are robust to very general parametric specifications. In addition, we resort to variance reduction techniques (antithetic variates) to enhance precision. Also, the identity of the informed bidder is arbitrarily chosen such that he sometimes wins the auction and sometimes doesn't. Finally, in Appendix A.2 we check for the robustness of our results by sequentially changing the number of participants and the distributional laws for the fixed distribution parameters.

A.2 Robustness check

In Figure 3, we consider comparative statics exercises where we successively change the assumptions generating the fixed parameters. For this analysis we focus exclusively on the maximum bid. Since bids are presented in descending order, this corresponds to $\pi(1,k,j) \equiv b^1(1,k,j) - b^0(1,k,j)$. First, in panel A we increase $\bar{a}_i \rightarrow 5 \times \bar{a}_i, \forall i$. This implies that the mean private value component of total value becomes more important relative to the common value and that the mean total value and signal are also higher. Conversely, the variances of both value and signal remain unaffected. The impact shifts the informed bidder premium outwards and raises it. Second, in panel B we increase $m \rightarrow 5 \times m$. This results in an increase in the mean common value, with variances again unaffected. This variable has no apparent impact on our benchmark results. An increase in $\bar{a}_i$ raises the mean levels of high-value bidders more than those of low-value bidders. In comparison, an increase in m has a uniform effect on all bidders' mean valuation. Consequently, the effect on the highest value bidder is greater than in the second case.

Third, in panel C, we increase $t_i \rightarrow 2 \times t_i, \forall i$, thereby increasing the variance of the private component of both total value and signal, while means remain unchanged. This results in lowering the premium, which nonetheless remains positive. Bidders become more uncertain regarding the informed bidder's private value; the latter could remain

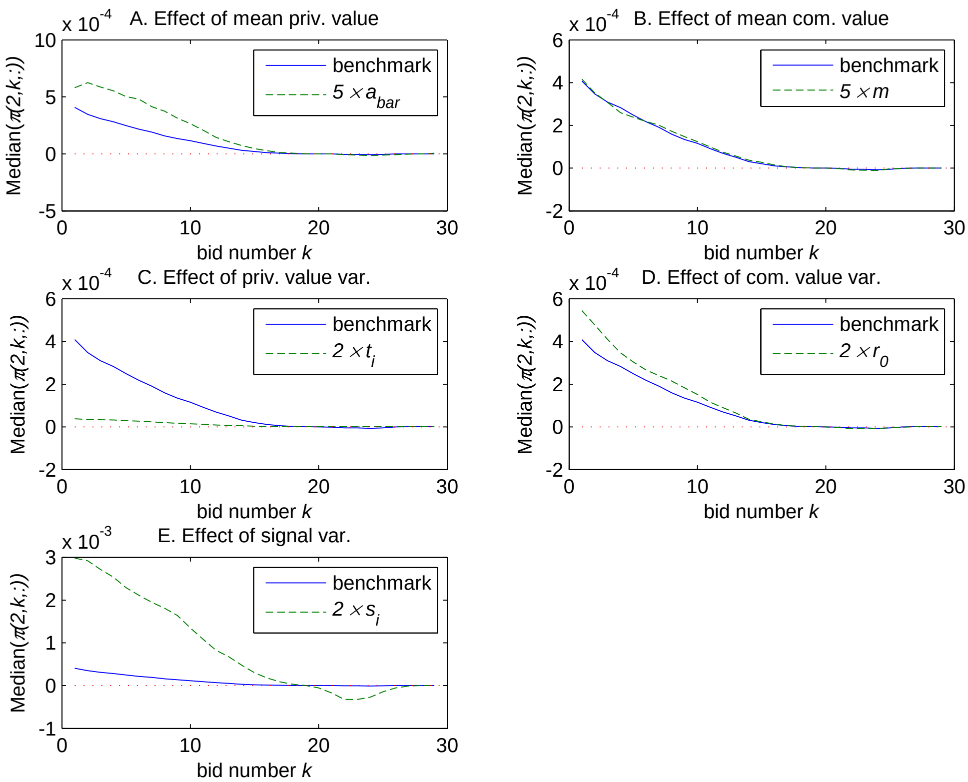

Figure 3: Second highest bidder premium: Effects of parameters. The median second highest bidder premium is Median$(\pi(i = 2, k, :))$, where $\pi(i = 2, k, j)$ is given in (6) and the premium is calculated for the second highest bid $i = 2$ and at each round k. The solid line corresponds to our benchmark specification while the dashed line varies one parameter in turn.

active because of a large private value which is irrelevant to other bidders, i.e. the winner's curse risk is greater. Fourth, in panel D we increase $r_0 \rightarrow 2 \times r_0$. This raises the standard error on the common value. This also has a positive impact on the premium, since agents are more uncertain concerning the mean common value. Any signal inferred from the informed bidder's action is therefore more valuable. Fifth, in panel E we increase $s_i \rightarrow 2 \times s_i, \forall i$ so as to increase the overall variance of the signals on common value without affecting the means. This implies that the signals received by agents become less informative. Consequently the information revealed by the informed bidder's decision becomes more significant and the premium increases strongly.[24]

B Data sources and details

The information on the sale of Mauritian slaves is obtained from the notarial acts in the General Inventory of Notaries (group NA) filed in the Mauritius Archives located in Coromandel, Mauritius. We build on the database first introduced by Chenny et al. (2003) who used the notarial acts for 1825 to 1827. They considered a sample of 152 auctions involving the sale of close to 1,300 slaves. We extend the period covered up to January 1835, for a total of 580 auctions involving 4,286 slaves in our primary data set. Even though other auctions were also held over that period, slaves were actually sold only during those auctions in our sample. These sales were recorded in the notarial acts of fifteen notaries, most of whom were operating from the capital, Port-Louis.

The notarial acts contain detailed information on each slave's characteristics. The slave's gender was recorded either explicitly or implicitly. For example, the acts written

[24] See also the discussion on the potential impact of N stochastic and endogenous in Section 3.2.

in French distinguish between *vendu* (male) and *vendue* (female). Moreover, a slave's age, known handicaps, presence of children and ethnicity were also reported. Following contemporaneous descriptions, slaves' ethnic groups were classified as being born in Mauritius (Creoles), or not (Madagascans, Mozambicans and Indians, including Malays). Finally, we use the occupational classification of Telfair (1830) to characterize a slave's work. We aggregate slave occupations into three categories: laborers,[25] household slaves,[26] and skilled slaves.[27]

To better understand how we proceed to classify sales between related and unrelated, an example might be useful. On July 2^{nd} 1826, notary Dubor (NA 63) auctioned the estate of deceased sieur Deville, a police commissioner (*Commissaire civil et de police*) in the town of Pamplemousses located in the north of Mauritius. Sylvain Chauveau, the testament executor, is recorded as the seller. The estate consisted of 12 slaves: 2 mothers with their children (1 and 3 in each case), 2 skilled males (cook and carpenter), 2 female laundresses, 1 female seamstress and 1 female domestic worker. All the slaves, except the cook Caramouche and the female domestic worker Zaize, were purchased by the wife of the deceased sieur Deville. The widow is obviously related to the original slave owner. Caramouche was purchased by Hypolite Dupery for whom we could not find any link with either sieur Deville or anyone else mentioned in the notarial act. As for Zaize, she was purchased by G. Deville. Although the latter has the same last name as the deceased, (s)he is not mentioned anywhere in the notarial archive as being related to the deceased

[25] Agriculture: chief gardener, gardener, laborer, marketman, stable-boy, watchman; and sea-related activities: caulker, fisherman, sailor.

[26] Baker, cook, innkeeper, laundress, maid, messenger, nurse, seamstress, shoe polisher, tailor.

[27] Assistant blacksmith, blacksmith, barrel maker, carpenter, carpentry trainee, carter, commander, locksmith, mason, master carpenter, master mason, mattress maker, nailer, roofer, sack-maker, sawyer, shoemaker, squarer, stone cutter, stone cutter trainee, sugar-maker.

slave owner. We code such a sale as the buyer and seller having the same names and being possibly related.[28]

[28] For robustness reasons, we also assumed that individuals with the same last name were unrelated, without any qualitative change in our results.