

**Experiments: The Use of Market Experiments
to Evaluate the Performance of Econometric Estimators**

**James C. Cox and Ronald L. Oaxaca
University of Arizona**

Experiments with human subjects have been widely used to test hypotheses derived from economic theory and to provide stylized facts about empirical regularities in economics. One of the clear implications of experimental economics is that the efficiency and distributional properties of market allocations are dependent on the market institutions through which exchange takes place (Plott, 1982; Smith, 1982). This makes clear the limitations of economic theories of markets that are institution-free.

Econometric theory, as conventionally taught in graduate schools and applied by many economists, is largely institution-free. Properties of econometric estimators are derived from assumptions about the data generating process (DGP) and the error distribution. A clear example is provided by the most central simultaneous equations in economics, supply and demand equations. The basic results in econometric textbooks, that ordinary least squares is an inconsistent estimator and two stage least squares is a consistent estimator, are derived from the assumption that the DGP is competitive equilibrium with zero-mean random error. Can it be demonstrated that these results provide reliable guidance to applied econometricians wanting to estimate the parameters of supply and demand equations using *market* price and quantity data? Or may there be a demonstrable need to condition the choice of an estimator on the market institution that generated the data?

Experiments with human subjects are just beginning to be used to generate data for evaluation of econometric methods. Cox and Oaxaca (1999) presents results from estimating the known (to the experimenter) parameters of supply and demand equations with data from paired double auction and posted offer experiments. Double auctions are the form of market typically used on organized (stock, bond, and commodity) exchanges. Most retail trade in highly-developed economies is conducted with the posted offer market institution.

Cox and Oaxaca's analysis of the experimental data indicates that the standard simultaneous equations estimators perform quite well with closing price data from the double auction institution but that they perform very poorly, and are dominated by ordinary least squares estimation, when applied to data from the posted offer market. Thus, at least for their experimental market data, the market institution that generated the data is a critical factor in determining the performance of the estimators.

The design of experiments that are appropriate for examining the properties of econometric estimators involves some considerations that do not arise in experiments intended to address other questions.

1. Designing Experiments to Study the Properties of Estimators

In designing the first experiments to evaluate the performance of econometric estimators, Cox and Oaxaca used control parameters that produce competitive equilibrium data with the properties assumed by econometric theory. The design principles are as follows.

(a) Use of demand and supply shift variables that identify the supply and demand equations and are independently distributed.

In order *not* to design into the experiments an inconsistency with econometric theory, the controlled market demand and supply equations should each include a variable that is not in the other equation and these variables should be independently distributed. This can be accomplished by including a demand shift variable (X_d) and a supply shift variable (X_s), respectively, in the market inverse demand and supply equations and drawing their values independently.

(b) Use of controlled error variables, one for demand and one for supply, that are independently distributed.

Including induced error terms, u_d and u_s , in the market inverse demand and supply equations permits analysis of the data such that the estimators are either over-identified or exactly identified, depending on whether u_d and u_s are or are not included as right hand variables in the

estimating equations. Again, in order *not* to design into the experiments an inconsistency with econometric theory, the values of u_d and u_s should be independently drawn.

(c) Use of sets of values for the demand and supply shift and random error variables such that any possible combination of values yields a horizontal overlap of the controlled market supply and demand step functions and payment of a commission to both the buyer and seller for each trade of a unit of the abstract commodity.

This design feature implies that, in each market period, there is a unique competitive equilibrium price and quantity that lie at the intersection of the demand and supply step functions for the discrete units traded in the experiment. This unique price and quantity will also lie at the intersection of the continuous linear demand and supply curves that pass through the “outside of the steps” of the step functions. Standard econometric estimators are designed to recover the parameters of the equations of such continuous demand and supply curves. Any other design would have competitive equilibrium prices and quantities that would *not* lie at the intersection of the continuous demand and supply curves; this would artifactually “throw off” the estimators in a way that had little relation to the inherent properties of the double auction and posted offer market institutions, with human buyers and sellers, as data generating processes.

(d) Random re-initialization of the market demand and supply curves each market period so that the competitive equilibrium price and quantity vary over a wide range.

Market experiments often repeat the parameter values for several periods. This can cause experimental market prices and quantities to “lock on” to their competitive equilibrium values, especially in double auction markets. This type of design can produce data with a scatter diagram that is a “tight clump.” Such data cannot be used to estimate demand and supply parameters with any precision. In order to generate data that is more appropriate to estimation, the demand and supply parameters should be randomly varied over values that yield a wide range of prices and

quantities. Since competitive equilibrium prices and quantities can be observed during experimental design, it is natural to use their variability as the design guideline.

The principles of design of experiments for evaluating the performance of econometric estimators is more fully explained in Cox and Oaxaca (1999).

2. Performance of the Estimators

Figures 1- 4 present results from Cox and Oaxaca (1999) on the performance of four estimators, two single equation estimators (ordinary least squares and minimum absolute deviation) and two simultaneous equations estimators (two stage least squares and double two stage minimum absolute deviation). The results presented here are for the exactly identified model; results for over-identified models are similar. Performance of the estimators is measured by their mean absolute percent errors (MAPES) in recovering the true parameters. The estimators are applied to competitive equilibrium prices and quantities, double auction market data, and posted offer market data. The price measure that is used for each market institution is the one used in field versions of these institutions, closing price for the double auction and average price for the posted offer market. Closing prices are the ones usually reported for organized exchanges. The national income and product accounts report price data for retail trade that are average price indexes.

First consider Figure 1, which reports the MAPES for estimates of the demand equation's intercept and slope parameters. The four left-side bars present results from applying the estimators to competitive equilibrium prices and quantities from the experiments. This analysis is a Monte Carlo study of the small sample properties of the estimators using the same induced random errors used in the market experiments. Consistent with asymptotic econometric theory, the simultaneous equations estimators, two stage least squares (2SLS) and double two stage minimum absolute deviation (D2SMAD), are more accurate than ordinary least squares (OLS) in recovering the true demand intercept and slope parameters from the competitive equilibrium

prices and quantities for this experimental design. The single equation minimum absolute deviation estimator (MAD) does as well as D2SMAD, with both estimators having a 0.0 MAPE. The middle bars show the performance of the estimators with double auction quantity and closing price data. 2SLS and D2SMAD dominate OLS and MAD with double auction data, with D2SMAD having a 0.0 MAPE. The right-most four bars report the results from estimation with posted offer quantity and average price data. The single equation estimators dominate the simultaneous equations estimators when estimation is done with posted offer data.

Figure 2 reports results for estimates of the supply equation's intercept and slope parameters. 2SLS and D2SMAD dominate OLS and MAD with both competitive equilibrium and double auction data, with D2SMAD having a 0.0 MAPE with both data sets. The results are vastly different with posted offer data: OLS and MAD have large MAPES of 340 and 221, but 2SLS and D2SMAD have astronomical MAPES of 2,100 and 1,663.

Figure 3 shows the MAPES for only the demand slope parameters. Consistent with asymptotic theory, 2SLS and D2SMAD once again dominate OLS and MAD with both competitive equilibrium and double auction data, with D2SMAD having a 0.0 MAPE with both data sets. In contrast 2SLS and D2SMAD are only slightly better than OLS and MAD with posted offer data, and all four estimators perform poorly.

Figure 4 reports the results for estimates of the supply slope parameters. The simultaneous equations estimators dominate the single equation estimators with competitive equilibrium and double auction data, with D2SMAD once again turning in a perfect performance. In stark contrast, OLS and MAD dominate 2SLS and D2SMAD with posted offer data, with the simultaneous equations estimators having MAPES of 271 and 214.

3. Explanation of the Posted Offer Results

The inaccuracy of simultaneous equations estimators in recovering demand and, more especially, supply parameters from posted offer market data can be explained by the inherent

properties of this market institution. In contrast with the double auction, the pricing decision lies exclusively with the sellers in posted offer markets. The buyers cannot make price bids; they can only choose quantities after the sellers post their prices. This does not mean that the buyers have to be textbook “price-takers”; they can withhold demand to attempt to get lower prices. But prices are “posted” in a market period; hence buyers wanting to counterspeculate against sellers must forgo gains from exchange in an earlier market period in the hope of obtaining lower prices in later periods. The strategic disadvantage of buyers is exacerbated by a “public goods” problem: if one buyer withholds demand in a market period, in the hope of getting lower prices later, she will incur all of the cost of forgone gains from exchange but any benefit of lower prices will be shared by all of the buyers. Presumably as a consequence of this strategic disadvantage, almost all buyers in posted offer experiments do fully reveal their demands at the prices posted by the sellers. But the sellers do not know the market demand; instead, they just learn what they can sell at the prices that they post. These features of the posted offer market institution with human buyers and sellers mean that it is a DGP with properties that cause 2SLS and D2SMAD to perform very badly. The problem is that this DGP produces error terms in estimating equations that are not independent of the supply and demand shift variables. The evidence for this is as follows.

Cox and Oaxaca (1999) reports results from a series of OLS regressions in which the actual reduced form errors were regressed on the demand and supply shift variables. Figure 5 shows some of the results from the reduced form error regressions. The quantity error regressions produce generally insignificant results with both double auction and posted offer data: the R^2 's are tiny (0.003 and 0.005) and all of the absolute values of the t-ratios are less than 1.5 except the one for the constant with posted offer data, which is -4.61. This significantly negative constant reflects the fact that posted offer quantities are more often less than, instead of greater than, competitive equilibrium quantities. The regression for the price error with double auction data

yields constant and demand shift t-ratios of -2.96 and 2.80 but the R^2 is only 0.03. Results for the price error with posted offer data are very different: the R^2 is 0.62 and the constant, demand shift, and supply shift t-ratios are 16.97, -19.74, and 8.95. Here is the explanation of the huge MAPES that result from applying the simultaneous equations estimators to posted offer data: the reduced form price errors are highly dependent on the demand and supply shift variables whereas the estimators require the errors to be independent of the shift variables in order to perform well.

The dependence of the reduced form price errors on the demand and supply shift variables with posted offer data is a predictable consequence of the operation of this institution with human buyers and sellers. An increase in the supply shift variable is experienced by the sellers as marginal cost increases before they post their prices. The sellers are not able to observe demand before posting their prices and tend to react to their cost increases by posting prices that are above market-clearing prices, resulting in a significantly positive coefficient on the supply shift variable in the reduced form price error regression. In contrast, when there is an increase in demand that is unobserved by sellers before prices are posted, the sellers often post prices that are below market-clearing prices, resulting in a significantly negative coefficient on the demand shift variable in the reduced form price error regression.

In order for an estimator to have acceptable performance with the posted offer experiment data, it would have to be designed to accommodate the inherent properties of this DGP, not designed for the properties of the competitive equilibrium DGP. These results do not “prove” that 2SLS and D2SMAD would perform unacceptably with non-experimental posted offer market data such as retail trade data. It may be that there are differences between laboratory and non-laboratory posted offer markets, as DGP’s, that would affect estimator performance. But the poor performance of the simultaneous equations estimators with the posted offer experimental data are deserving of further consideration because they can be easily explained by the inherent properties of the posted offer market institution.

Acknowledgement

Todd Swarthout provided valuable assistance by preparing the figures.

References

Cox, James C. and Ronald L. Oaxaca. "Can Supply and Demand Parameters be Recovered from Data Generated by Market Institutions,?" *Journal of Business & Economic Statistics*, Vol. 17, no.3 (July 1999) pp. 285-297.

Plott, Charles R. "Industrial Organization Theory and Experimental Economics," *Journal of Economic Literature*, Vol. XX, no. 4 (Dec. 1982), pp. 1485-1527.

Smith, Vernon L. "Microeconomic Systems as an Experimental Science," *American Economic Review*, vol. 72, no. 5 (Dec. 1982), pp. 923-955.

Figure Legends

Figure 1. The figure reports the demand intercept and slope parameter estimation error rates for four estimators with both (theoretical) competitive equilibrium data and data from experiments with market institutions. Consistent with asymptotic econometric theory, simultaneous equations estimators (2SLS and D2SMAD) dominate OLS with competitive equilibrium (CE) quantities and prices. MAD does as well or better than 2SLS and D2SMAD with CE data. 2SLS and D2SMAD dominate OLS and MAD with double auction market quantity and closing price data. In contrast, OLS and MAD dominate 2SLS and D2SMAD with posted offer quantity and average price data.

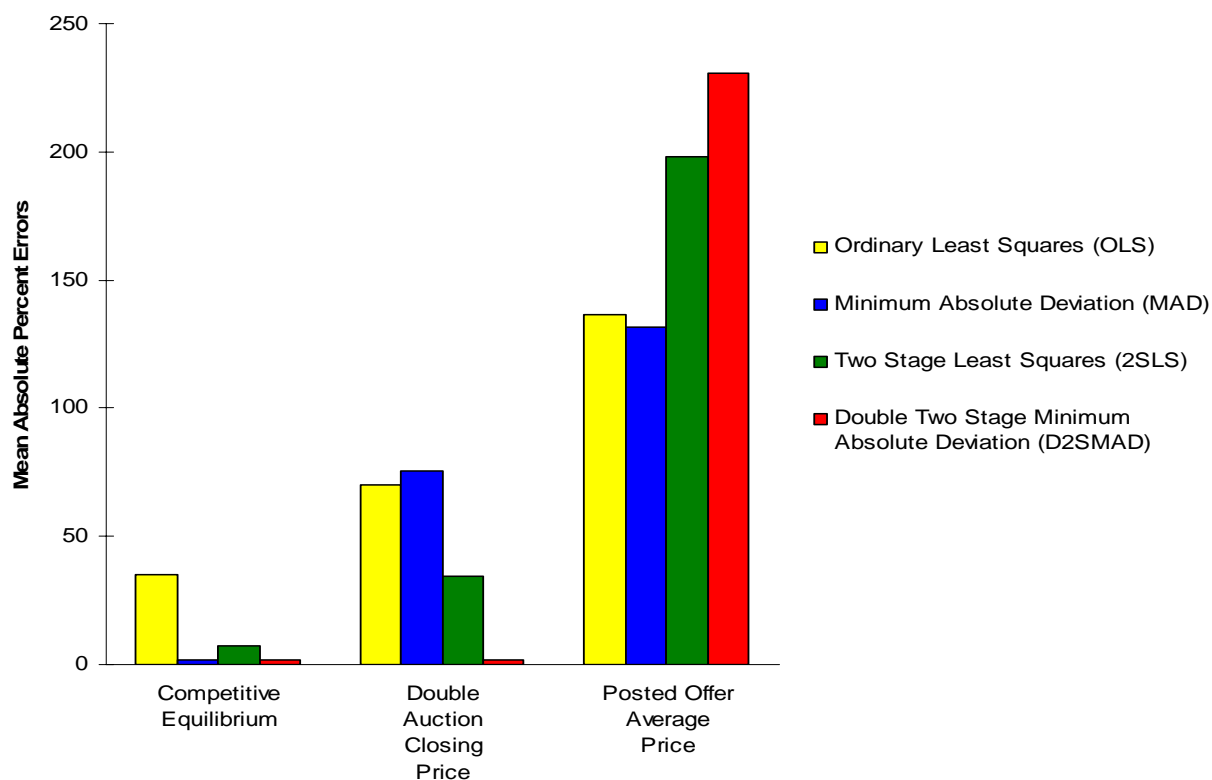


Figure 2. This figure reports supply intercept and slope parameter estimation error rates for four estimators with both (theoretical) competitive equilibrium data and data from experiments with market institutions. Consistent with asymptotic econometric theory, simultaneous equations estimators (2SLS and D2SMAD) dominate single equation estimators (OLS and MAD) with competitive equilibrium quantities and prices. Similarly, 2SLS and D2SMAD dominate OLS and MAD with double auction market quantity and closing price data. In contrast, OLS and MAD dominate 2SLS and D2SMAD with posted offer market quantity and average price data.

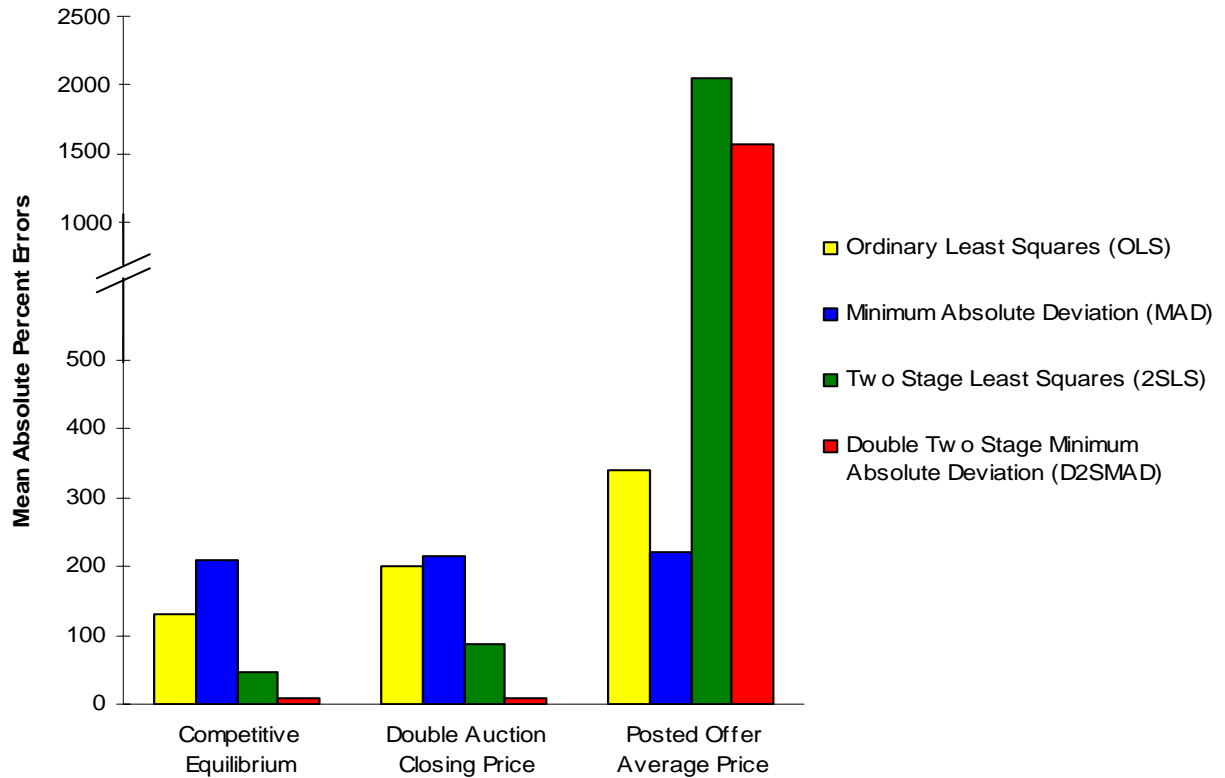


Figure 3. This figure reports demand slope parameter estimation error rates. Consistent with asymptotic econometric theory, simultaneous equations estimators (2SLS and D2SMAD) dominate OLS with competitive equilibrium (CE) quantities and prices. MAD does as well or better than 2SLS and D2SMAD with CE data. 2SLS and D2SMAD dominate OLS and MAD with double auction market quantity and closing price data. In contrast, 2SLS and D2SMAD are only slightly better than OLS and MAD, and all four estimators perform poorly with posted offer quantity and average price data.

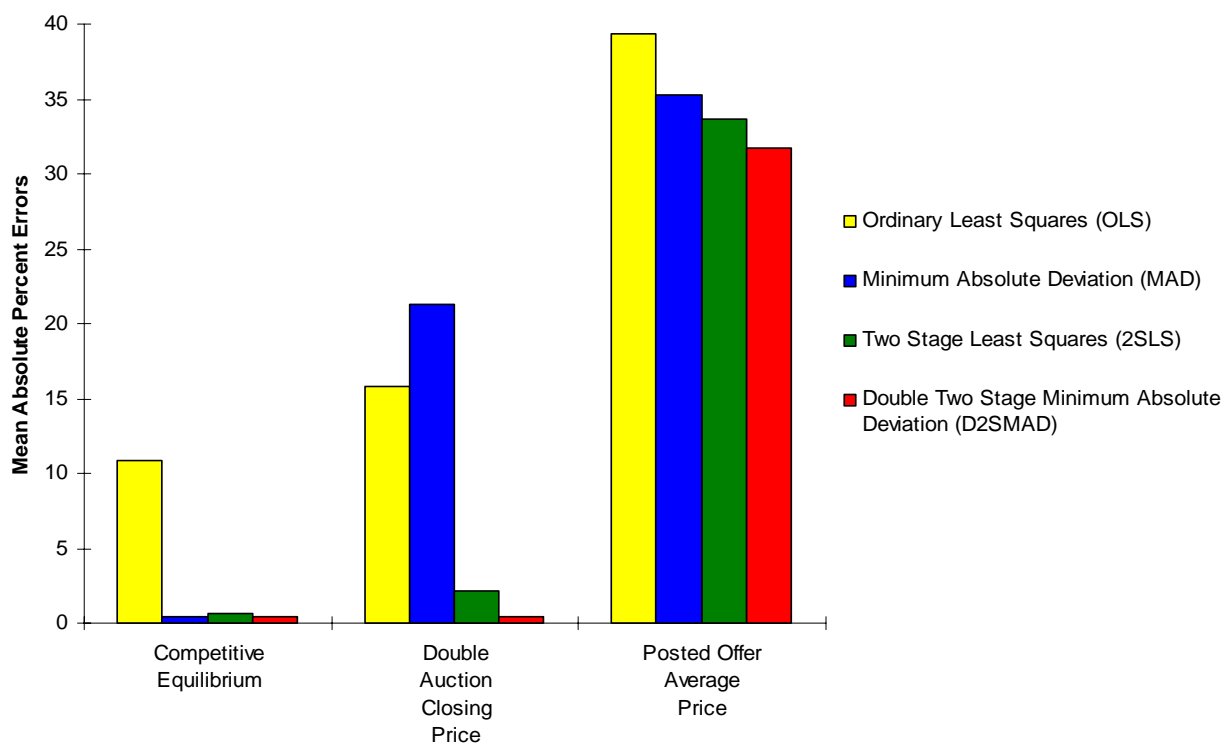


Figure 4. This figure reports supply slope parameter estimation error rates. Consistent with asymptotic econometric theory, simultaneous equations estimators (2SLS and D2SMAD) dominate single equation estimators (OLS and MAD) with competitive equilibrium quantities and prices. Similarly, 2SLS and D2SMAD dominate OLS and MAD with double auction market quantity and closing price data. In contrast, OLS and MAD dominate 2SLS and D2SMAD with posted offer market quantity and average price data.

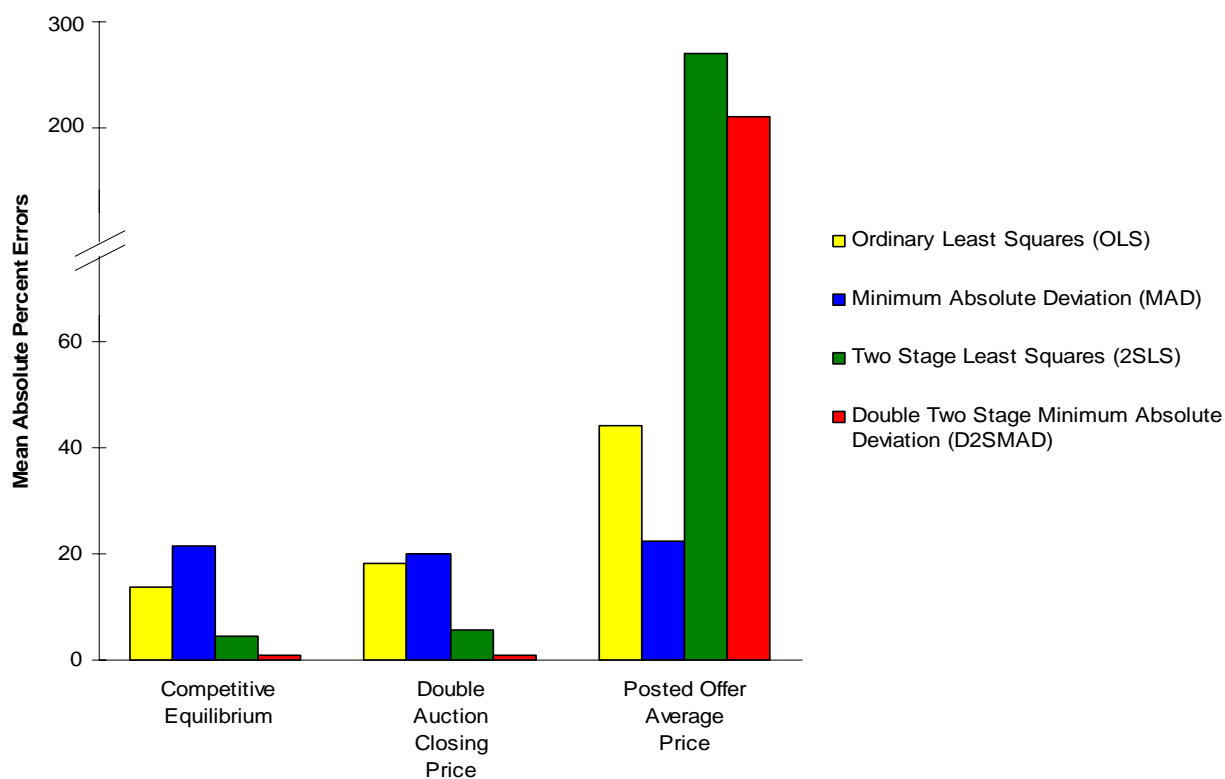


Figure 5. This figure reports results from a series of OLS regressions in which the actual reduced form errors were regressed on the demand and supply shift variables in order to learn why the simultaneous equations estimators perform as they do with market data. The quantity error regressions produce generally insignificant results with both double auction and posted offer data. The regression for the price error with double auction data yields constant and demand shift t-ratios of -2.96 and 2.80 but the R^2 is only 0.03. The price error regression with posted offer data has an R^2 of 0.62 and the constant, demand shift, and supply shift t-ratios are 16.97, -19.74, and 8.95. This explains the huge mean absolute percent errors that result from applying the simultaneous equations estimators to posted offer data.

