Vendor Pricing and Participation in Business Markets with Affirmative Action Policies

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Abstract

Vendors in business-to-business and business-to-government markets have to make two key strategic decisions when a new sales opportunity arises: whether to participate in the process by submitting a bid for a specific contract, and what price to set. We examine how these strategic decisions are affected by the marketplace rules that the buyer has established – in particular, how they are affected by an affirmative action program that favors certain preferred vendors. We focus on a data setting in which an online platform experienced an exogenous policy change that altered the affirmative action program, thereby providing a quasi-experiment for examining this question. Vendors respond to this policy change by dramatically altering their participation decisions, as the vendors who lose preferential treatment drop out of the marketplace almost completely. However, the policy change does not seem to affect prices for vendors that do participate. Both of these results are consistent with a boundedly rational model of vendor behavior in which vendors cannot optimally account for competitors' behavior, and instead rely on simpler heuristics when deciding whether to compete for a contract and what price to set.

Keywords: Pricing, Competition, Online Platforms, B2B Markets, Government Markets, Auctions, Procurement

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1 Introduction

Buyers in business-to-business markets often take non-price factors into consideration when deciding which vendor to purchase from. In recent years, increasing numbers of buyers have stated that they would like to purchase from a diverse group of vendors, and are therefore willing to spend more money to purchase from a small business, a local vendor, a minority-owned vendor; etc.[1] These types of affirmative action policies (whether formal or informal) distort the marketplace, and vendors would be expected to strategically alter their behavior in response. In fact, given the increasing prevalence of affirmative action policies in business-to-business markets, vendors with the ability to strategically account for these programs will be at a distinct advantage in the marketplace. This research examines how vendors alter two key decisions in response to the buyer's affirmative action policy: whether to compete for a specific contract, and what price to charge.

In most centralized business-to-business procurement markets, a buyer specifies what goods or services it would like to purchase, and interested vendors then bid on that contract by submitting the price they would like to charge. The vendor who wins the contract is then obligated to provide the goods or services at the price it quoted. Examining the role of affirmative action programs in this setting can be difficult because the buyer's decision making process is opaque: buyers typically do not commit to purchasing from the cheapest option, and it is difficult to ascertain what other factors they may be taking into account, much less what their specific decision rule is. For instance, the buyer may have a strong preference towards a specific class of vendor, but this preference may not be expressed to vendors at any point.

To avoid this issue, we instead use data from business-to-government markets, which provide a cleaner setting. When a government agency is the buyer, it typically implements an auction and commits to following a transparent set of rules for awarding contracts. The fact that these government markets have clearly stated affirmative action policies means that they provide an ideal setting for this research, since it allows us to more cleanly identify the effect of the affirmative action policy on vendor behavior.

In particular, we examine how vendors' participation and pricing strategies are affected by the affirmative action program established by the state of Virginia. Prior to

[1]For example, the National Minority Supplier Development Council lists thousands of "corporate members," which are companies that are actively trying to purchase from minority-owned vendors. See `http://www.nmsdc.org/corporate-membership/corporate-members/`

2004, buyers (state agencies) did not have an affirmative action program. Instead, they always awarded contracts to the cheapest vendor, as long as that vendor could meet all stated product or service requirements. Between 2004 and 2006, the Governor asked buyers to award 40% of their contract dollars to small, woman-owned, and minority-owned (SWaM) businesses. Finally, from mid-2006 onwards, buyers were asked to award 40% of their money to small businesses. In order to help them reach these goals, the state government made two changes to the laws regarding the purchasing process: (1) buyers were allowed to set aside certain contracts so that only preferred vendors were allowed to bid, and (2) buyers were able to utilize an affirmative action program, in which they could award contracts to preferred vendors even if they were not the cheapest option for a given contract.

In our data, we do not observe any data prior to 2004, so we cannot directly analyze data corresponding to the "no affirmative action" period. Our data spans fiscal years 2006 and 2007. In 2006, SWaM vendors were all classified together as a preferred class. In 2007, small businesses were in a preferred class but woman- and minority-owned businesses were not. Given this data, we examine how moving from a wider affirmative action program to a narrower affirmative action program affects vendor behavior, where "wider" and "narrower" refer to the size of the protected class of vendors. In particular, the specific vendor behaviors we examine are the decision to bid on a given contract and what price the vendor sets for that contract.

Our data has three characteristics that enable us to make a finer set of comparisons than previous research has typically been able to do. The first is that the data contains the full set of bids (both winning and losing) for each contract; by contrast, much of the extant literature has data consisting of just the final winning bid for each contract, or the sequence of winning bids over time (Bradlow and Park, 2007; Jap and Naik, 2008). The second is the inclusion of a vendor identifier, which allows us to track vendor behavior over time. The third is that we observe detailed information about the contract and that many contracts are repeatedly auctioned off, thereby allowing us to track how vendors respond to identical contracts under different auction rules.

Our approach is to focus on contracts that appear in both 2006 and 2007. In other words, we only examine the subset of contract titles which appear within one year before and one year after the policy change. We also further refine this comparison by then focusing on vendor $\times$ contract title dyads; i.e., what price did vendor A set for the same contract when bidding in 2006 vs. when bidding in 2007? By making comparisons for

vendors who bid on the same contract titles repeatedly, we are able to better isolate the effect of the affirmative action policy change on vendors' choices of whether to participate and what price to set.

A methodological contribution of this research is to show that this type of non-parametric approach can be used to evaluate vendor behavior in a business-to-business setting. Having repeated vendor-contract observations means that we are able to control for many idiosyncratic vendor-specific or contract-specific factors, thereby allowing us to examine vendor behavior without imposing additional structural or parametric assumptions. Although our approach requires the researcher to have high quality data with many repeated contracts and many repeated vendors, these requirements are becoming easier to satisfy with increased access to large business-to-business and business-to-government purchasing datasets.

We find that vendors respond to the the policy change (moving from a policy which helps all SWaM vendors to one which only helps small vendors) in two ways: (1) minority- and woman-owned vendors largely exit the bidding process, and (2) the remaining vendors maintain the same pricing strategy that they had before. Furthermore, the overall number of bidders remains relatively stable, as the exiting minority- and woman-owned vendors are replaced almost completely by new small and non-SWaM vendors. We demonstrate that these results are consistent with a boundedly rational model of vendor behavior in which vendors focus on their own capabilities and rely upon heuristics when deciding what price to set and whether to compete for a contract.

This research yields important substantive implications for both vendors and buyers. As more buyers in business-to-business markets adopt affirmative action policies (whether formal or informal), managers at vendor firms will have to adjust for these policies when making their participation and pricing decisions. Our research indicates that there is still room for improvement on both fronts. Vendors that are better able to adjust their strategies accordingly will realize higher profits as a result. Furthermore, managers at buyer firms should account for vendor behavior when crafting their affirmative action policy. By providing a description of how vendors respond to different policies, this research also provides valuable information for buyers as well.

From a theoretical perspective, this research has important implications regarding vendor behavior. Prior research has shown that individual consumers rely upon heuristics and other shortcuts when processing information about prices, and that firms use similar rules-of-thumb when setting prices across a large product line or across multi-

ple markets (Bagchi and Davis, 2012; Dobson and Kalish, 1993; Thomas and Morwitz, 2009). This research demonstrates that vendors may also use heuristics when setting prices in a business-to-business context, where both sides of the marketplace are relatively well-informed and each price quote is an isolated, one-off occurrence. Despite the fact that vendors in this marketplace are free of many of the usual difficulties that limit a firm's ability to set prices optimally, they still seem to rely upon heuristics when making their pricing decision. Our primary contribution here is to show that these pricing heuristics are sticky: vendors rely on the same set of heuristics even when the competitive environment around them changes dramatically.

From a methodological perspective, our approach is related to a handful of recent papers that analyze matched auction titles on eBay. Haruvy and Popkowski Leszczyc (2010) focus on how search costs affect buyers' decisions regarding which auctions to bid on. Elfenbein, Fisman, and McManus (2012, 2014) use matched auction titles to examine how sellers' outcomes are affected by their reputation. Einav, Farronato, et al. (2018) use matched auction titles to understand how sellers choose between setting up an auction or selling at a posted price. Finally, Einav, Kuchler, et al. (2015) use a similar approach to identify the effect of changing various auction parameters (shipping fees, reserve prices; etc.) on auction demand.

In addition to the fact that our business-to-government setting has different characteristics than their consumer setting, our approach also differs from these papers both in intent and in the type of comparison that we make. Broadly speaking, the goal of the above papers is to examine how sellers in a consumer setting can increase their auction revenue; various options include improving their reputation, receiving certification as a high quality seller, choosing the correct bundle of shipping fees and reserve prices; etc. In this research, the goal is to examine how vendors in a business setting respond to an exogenous change in marketplace rules. In other words, our research examines how vendors respond to the rules of their marketplace, while the previous research examines how buyers (or the third-party platform) construct the rules. This difference in intent affects the type of comparison that we make: our matched unit of comparison is the vendor $\times$ contract title dyad, with observations pre- and post- policy change. On the other hand, the matched unit of comparison in the papers described above is the auction title. Applying their approach in our setting would allow us to understand how the policy change affected the government agencies by providing the total number of bidders and the distribution of bids, but it would not directly tell us anything about how each vendor responded to the policy change.

In marketing, online procurement auctions have typically been examined in the context of business-to-business markets and relationship marketing (Jap, 2007; Jap and Haruvy, 2008). Haruvy and Jap (2013) is broadly similar to this research in that they also examine vendor pricing. However, they focus on how vendors' pricing decisions are affected by perceived quality differences across vendors, whereas this research focuses on how vendors' pricing decisions are affected by affirmative action programs.

Government procurement is a major part of the economy in most developed countries, and the United States government is the single largest buyer of goods and services in the world (EPA, 2019). However, despite the size and importance of business-to-government markets, examinations of these markets have been rare in the marketing literature. In fact, a recent handbook chapter summarizing the state of B2B marketing specifically argues that government markets are "dreadfully understudied" (Grewal and Lilien, 2012). Two recent exceptions to this pattern are Josephson et al. (2019) and Mummalaneni (2019). The former focuses on the differences in profitability between vendors that are highly dependent on federal government contracts vs. those for whom the government is merely one of many buyers. The latter has data from the same Virginia government purchasing context that we use in this research, but the two papers focus on different sides of the marketplace. His research examines how buyers can set the rules of the marketplace optimally to reduce their purchasing costs, while we examine how vendors behave under two specific sets of marketplace rules. In addition to the differences in research focus, there are also notable differences in empirical approaches between this paper and the two others cited above: Josephson et al. (2019) uses qualitative interviews and longitudinal analysis of firm profitability, Mummalaneni (2019) uses a structural auction model, and we use a set of reduced-form analyses coupled with a quasi-experiment.

2 Industry Background

Online procurement platforms have become a popular tool for large businesses and state governments in recent years, as they reduce search frictions and allow buyers to receive bids for contracts without having to actively solicit individual vendors. They also provide transparency to the entire transaction process, which makes it easier for managers to notice issues such as overspending, favoritism, or corruption.

Virginia's online procurement system, eVA, was introduced in March 2001. Soon

thereafter, an independent consulting firm calculated that just 1.27% of state spending was going towards minority- and woman-owned businesses (MGT of America Inc., 2004). In an attempt to improve this figure, Governor Mark Warner instructed all state agencies to spend 40% of their money with small, women-owned, and minority-owned (SWaM) vendors (Leighty, 2004).[2] The primary tool that agencies had at their disposal was that they could chose to deviate from the usual lowest-price-wins rule if they awarded the contract to a small, woman- or minority-owned vendor.[3] In other words, the governor's office created an affirmative action program aimed at helping small, woman-, and minority-owned vendors, in which these preferred vendors could still win contracts even if they were not the cheapest option.

On August 10, 2006, in response to legal challenges from both within and outside the government, Governor Tim Kaine issued an executive order which established a gender- and race-neutral small business program by removing woman- and minority-owned businesses from the preferred bidding category (Kaine, 2006). Therefore, only small businesses could receive preferential treatment upon bidding and were eligible for set-aside auctions; woman- and minority-owned businesses no longer qualified. See Mummalaneni (2019) for a more detailed timeline regarding Virginia's affirmative action program.

Vendors must apply to the state Department of Small Business and Supplier Diversity to receive SWaM certification. Certification as a small business can be based on either the number of employees or the overall revenue: a small business either must have 250 or fewer employees or have taken in average revenue of $10 million or less over the past three years. To qualify as a woman-owned business, a vendor must be at least 51% owned by one or more women and be managed by one or more women. Similarly, to qualify as a minority-owned business, a vendor must be at least 51% owned by one or more racial minorities and be managed by one or more racial minorities. A vendor can qualify in multiple of these categories if it fulfills the requirements for each.

The changing affirmative action rules in Virginia offer a convenient and rich data source to examine questions about how affirmative action policies can affect procurement markets. Perhaps the most important benefit is that there is a clean allocation rule: buyers can either award the contract to the cheapest overall bidder or the cheapest

[2]Note that this 40% goal is neither binding or required. Agencies are not forced to meet it, but they are strongly encouraged by the governor's office to do so.

[3]Agencies were also required to solicit at least one bid from a woman- or minority-owned vendor for contracts under $5000. In addition, agencies were able to "set aside" some contracts so that only SWaM vendors could bid on them. We remove these contracts from our dataset.

SWaM bidder. This stands in sharp contrast to usual business-to-business markets, where the buyer's choice is not constrained in any way. Similarly, our setting also has a clearly stated affirmative action policy, where we know what benefits are being received and exactly which vendors are receiving them. In traditional business markets, the buyer may have affirmative action goals in mind, but typically does not make these policies public. Finally, the contracts in our data are one-off contracts, and buyers are prohibited from awarding contracts to vendors on the basis of incumbency or from a pre-existing relationship with them. These characteristics allow us to disregard a number of factors that can complicate vendor behavior in non-government business markets.

3 Data

Virginia state agencies, public institutions, public universities, and local governments are required to make their purchases through eVA. We focus on the subset of purchases that are made through eVA's Quick Quote system. Quick Quote is an interface that is used for all contracts between $5,000 and $50,000 that allows buyers to specify which goods they are interested in purchasing. Buyers can also choose to use Quick Quote for contracts above $50,000, but they typically only do so for standardized or homogeneous goods that can be evaluated solely on price.

This dataset contains Quick Quote purchases made in fiscal years 2006 - 2007, which ran from July 2005 through June 2007. We have information about which agency was making each request, what items they were requesting, when the bidding period began and ended, whether or not the contract was a small business set-aside, how much each participating vendor bid for the contract, and which vendor won the auction. Furthermore, we also have data on the vendor's SWaM status; i.e., whether they were a small business, a woman-owned business, a minority-owned business, or none of the above. Since our data contains only Quick Quote purchases, it is not representative of government purchasing as a whole. Larger projects such as highway procurement and major construction services are not present. However, the fact that the vendors are competing solely on price provides us with a cleaner setting than many other procurement markets.

In this research, we examine how vendors' participation and bidding strategies are affected by the change in Virginia's affirmative action policy. In fiscal year 2006, small, woman-owned, and minority-owned businesses were all classified together as a preferred category. In fiscal year 2007, that policy was altered so that small businesses were in a

preferred class, but woman- and minority-owned businesses were not. Given this setup, we can compare auctions which occurred in 2006 to those which occurred in 2007 in order to evaluate how the change in policy affected bidding behavior. Since the data spans just one year pre- and post-policy change, vendor costs and overall market conditions should be relatively stable, thereby allowing us to attribute any changes in vendor strategies to the policy change itself.

Since the primary goal is to evaluate the policy change which occurred between fiscal years 2006 and 2007, we need to narrow down the set of contracts to those which appear first in 2006 and then are repeated in 2007. In order to find contracts which are repeated from year to year, we focus on contracts which meet two requirements: they must have the same NIGP commodity code[4], and they must have the same contract title. An example of such an auction is "38548 Strawberries, Sliced, 6/6.5 LB.USDA Grade A", which appears multiple times in our data. The five digit NIGP code is 38548, which refers to frozen fruit. The rest of the title specifies exactly what type of product is required. We denote two contracts as being "matched" only if they have the same NIGP code and the same title; i.e., if the entire string in quotation marks above is matched.

In this analysis, we restrict the analysis to auctions which meet the following requirements:

- The contract title is auctioned off at least twice
- The first occurrence of the contract title must be in 2006
- The last occurrence of the contract title must be in 2007
- The contract must be open to all vendors; i.e., not set aside just for SWaM vendors

Each contract can contain one or multiple items. If there are multiple items, as is usually the case, vendors bid on each item separately and are not required to bid on all items. Furthermore, the agency can choose to award different items to different vendors. Therefore, it is more useful to denote a contract-item dyad as a "contract," since that is the true unit of interest.

Table 1 provides summary statistics for auction- and bid-level variables, broken down by year. Over a third of vendors bid in both years. Many of the variables are quite similar across years: the number of auctions per year, the number of bids per

[4]The National Institute of Governmental Purchasing (NIGP) is a non-profit organization that publishes a standardized list of commodity codes, along with other outreach activities.

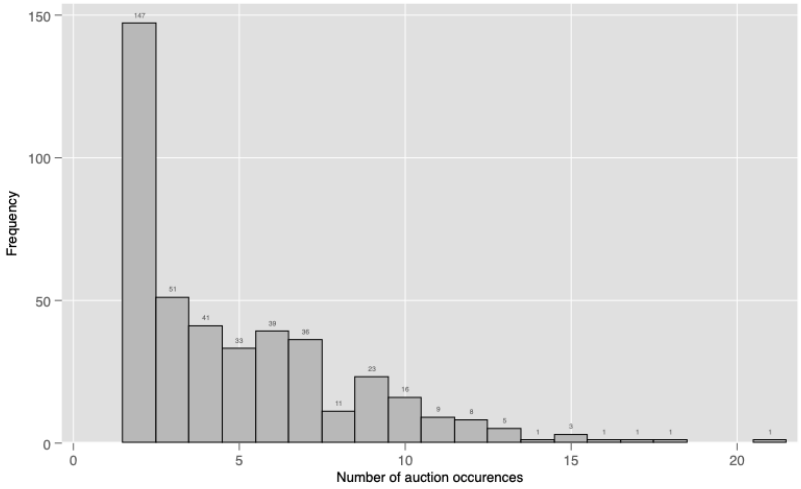
auction, and the number of buyers all remain nearly flat.

Table 1: Yearly summary statistics for matched-auction data

	2006	2007
Num. vendors	550	651
Num. vendors who bid in both years	297	
Num. auctions	1001	1107
Num. bids	4435	4664
Avg. bids per auction	4.54	4.52
Avg. price ($)	237.23	257.45
Avg. winning price ($)	122.62	161.89
Num. buyers	68	66

By construction, the dataset only includes contract titles that were auctioned off at least twice in the two-year window. However, many of these auctions occur much more often than that: the maximum number of auction occurrences in the data is 21. Figure 1 shows how this varies across contract titles.

Figure 1: Histogram of the number of times each contract title appears in the data



NOTE: Each contract title is auctioned off at least twice during the sample.

Using the data described above, we can examine the effect of the policy change on vendor participation by comparing the demographic makeup of bidders in 2006 and 2007. If the proportions of small, women, and minority-owned vendors varies significantly, then we can plausibly attribute this difference to vendors strategically responding to the policy change. Similarly, we can compare bids for identical contracts across years to see how the

affirmative action policy change in 2006 affected the pricing behavior of vendors in three different classes: (1) non-SWaM vendors, which were never beneficiaries of the policy, (2) woman- and minority-owned vendors, which benefited in 2006 but not thereafter, and (3) small vendors, which benefited in all years.

4 A Model of Participation and Bidding

We choose to model our marketplace as an auction market, albeit one that has some nonstandard features. The auction literature provides us with a coherent framework for analyzing vendor behavior in this context. As with traditional auction markets, each auction has a single item being auctioned off – in this case, a government contract. Vendors then compete with each other for the right to win this contract. Typically, vendors compete solely on the basis of price, but in our setting, we know that the buyer can also award the contract to a preferred vendor who is not the cheapest overall bidder.

A key institutional detail is that there are two sources of asymmetry in this situation. The first is that vendors from different groups (i.e., small vs. non-SWaM) likely have different costs on average; otherwise, the state would not have needed to aid SWaM vendors. The second is that the affirmative action program causes an asymmetry in the probability that a vendor will win a given auction at a certain bid level, and this asymmetry is based on the vendor's SWaM status. For instance, if a small vendor and a non-SWaM vendor bid $100 for the same contract, the small vendor has a better chance of winning than the non-SWaM vendor does.

The stages of the auction are as follows:

1. An agency initiates the auction process by submitting a "request for quote" through the eVA Quick Quote portal and describing which goods or services it would like to purchase. It also establishes a deadline by which all bids must be submitted.

2. Vendors view the description and decide how much they would be willing to bid on this auction. If the vendor believes that its expected profits upon bidding would be positive, it submits a price of b_i. Otherwise, it exits the process and does not participate.

3. Once the deadline passes, the auction is closed and the agency views the set of submitted bids $\{b_1, \ldots, b_N\}$. Any bids that do not meet the minimum requirements

are eliminated. The agency then chooses between two bids: the cheapest overall bid and the cheapest preferred bid.

4. The vendor whose bid was chosen receives revenue of b_i and must provide the good or service that was denoted in the auction description, thereby incurring cost c_i. All other vendors receive zero revenue.

In order to model the vendor's behavior, it is required to first make some basic assumptions about how the buyer treats bids from various types of vendors. We simplify the buyer's decision making process by assuming that for the purposes of evaluating bids, the buyer discounts bids from preferred vendors by dividing the bid by $(1+\delta)$, where δ is the bid discounting rate. For instance, if a preferred vendor submits a price of \$100 and the preference rate is $\delta = 0.10$, then this would be equivalent (from the perspective of the agency) to a non-preferred vendor submitting a price of $b = \frac{100}{1.10} = 90.91$. The key assumption here is that a preferred firm i will win a specific auction if two conditions are met: its price b_i must be lower than all other preferred bids, and its discounted value must be lower than all non-preferred bids. Formally, b_i wins an auction if and only if:

$$b_i < b_p \text{ for all preferred } p \neq i$$
$$\frac{b_i}{1+\delta} < b_n \text{ for all non-preferred } n$$

This section first provides a fully rational model for vendor behavior, under the assumption that vendors have full information about their competitors and can also optimally incorporate this information into their own participation and bidding behavior. Next, we show that altering this assumption yields a boundedly rational model in which vendors optimize over their own behavior but do not fully incorporate their competitors' behavior. The implications of the latter model will serve as a theoretical backbone for the empirical results that follow later.

4.1 Fully rational model

The fully rational model assumes that vendors have full information (about their own costs, the distribution of their competitors' costs, and the overall rules of the marketplace), and can fully incorporate this information into their own competitive decisions. In this context, vendors must decide whether to participate in a given auction, and if so, what price to set.

4.1.1 Participation strategies

By construction, the eVA auction system is relatively frictionless: vendors are not charged any money to register for the site, they are not charged any money to submit a bid, and they are alerted automatically whenever a new bidding opportunity arises, based on criteria that each vendor chooses. Furthermore, the items are relatively standardized, in the sense that vendors do not need to expend many resources into learning about their own costs. Given these factors, vendors' entry/participation costs should be near zero, as is common in many internet auction settings (Athey and Haile, 2007; Yoganarasimhan, 2016).[5]

If entry costs are negligble, then a vendor i who bids b_i and has cost c_i, will have expected profits

$$\pi_i(b_i) = (b_i - c_i) \Pr(\text{win} \mid b_i)$$

This implies that all vendors who participate in an auction will have positive expected profits, since they should always price above cost (i.e., $b_i - c_i > 0$) and they each have some positive probability of winning ex ante (i.e., $\Pr(\text{win} \mid b_i) > 0$). Therefore, a vendor's decision to participate in any given auction should depend only on whether it is able to provide the good or service in question, and not on the affirmative action policies in place. In our context, this means that vendors' participation decisions should be unchanged across years.

4.1.2 Pricing strategies

Krasnokutskaya and Seim (2011) analyze group-symmetric equilibria in which all firms in the same group (preferred or non-preferred) follow the same bidding strategy, and our rational model largely follows theirs. Group n (non-preferred) does not receive any preferential treatment, while group p (preferred) does. We allow for the possibility that cost asymmetries may exist; i.e., that the costs c for the two groups are drawn from different distributions F.

$$c_n \sim F_n[c]$$
$$c_p \sim F_p[c]$$

[5]This is in contrast to other common models where bidders have to incur an "acquisition cost" to discover their own project cost, either before or after deciding to bid (Levin and Smith, 1994; Samuelson, 1985).

We define β_n, β_p as the equilibrium bid functions that map costs to bids and φ_n, φ_p as the inverse-bid functions that map bids to costs. The number of bidders in each group are denoted as n_n and n_p. The profit functions are asymmetric as a result of the affirmative action policy and the natural cost asymmetries across groups:

$$\begin{aligned}
\pi_p(b_p) &= (b_p - c_i)\ \Pr(\text{win} \mid b_p) \\
&= (b_p - c_i)\ \Pr(b_p < \text{ all preferred } b_j)\ \Pr\left(\frac{b_p}{1+\delta} < \text{ all non-pref } b_n\right) \\
&= (b_p - c_i)\left(1 - F_p\left[\varphi_p(b_p)\right]\right)^{n_p - 1}\left(1 - F_n\left[\varphi_n\left(\frac{b_p}{1+\delta}\right)\right]\right)^{n_n} \qquad (1) \\
\pi_n(b_n) &= (b_n - c_i)\ \Pr(\text{win} \mid b_n) \\
&= (b_n - c_i)\ \Pr((1+\delta)b_n < \text{ all preferred } b_p)\ \Pr\left(b_n < \text{ all non-pref } b_k\right) \\
&= (b_n - c_i)\left[1 - F_p\left(\varphi_p\left[(1+\delta)b_n\right]\right)\right]^{n_p}\left(1 - F_n\left[\varphi_n\left(b_n\right)\right]\right)^{n_n - 1} \qquad (2)
\end{aligned}$$

The derivative $\frac{\partial \pi_p(b_p)}{\partial b_p}$ yields the first order condition for the preferred group, where f_p and f_n are the cost densities for preferred and non-preferred vendors, respectively:

$$1 = \left[b_p - \varphi_p(b_p)\right]\left[\frac{(n_p - 1) f_p\left[\varphi_p(b_p)\right]\varphi_p'(b_p)}{\left(1 - F_p\left[\varphi_p(b_p)\right]\right)} + \frac{n_n f_n\left[\varphi_n\left(\frac{b_p}{1+\delta}\right)\right]\frac{1}{1+\delta}\varphi_n'\left(\frac{b_p}{1+\delta}\right)}{\left(1 - F_n\left[\varphi_n\left(\frac{b_p}{1+\delta}\right)\right]\right)}\right] \qquad (3)$$

Similarly, the derivative $\frac{\partial \pi_n(b_n)}{\partial b_n}$ yields the first order condition for the non-preferred group:

$$1 = \left[b_n - \varphi_n(b_n)\right]\left[\frac{n_p f_p\left(\varphi_p\left[(1+\delta)b_n\right]\right)(1+\delta)\,\varphi_p'\left[(1+\delta)b_n\right]}{1 - F_p\left(\varphi_p\left[(1+\delta)b_n\right]\right)} + \frac{(n_n - 1) f_n\left[\varphi_n(b_n)\right]\varphi_n'(b_n)}{\left(1 - F_n\left[\varphi_n(b_n)\right]\right)}\right] \qquad (4)$$

Finding the equilibrium (and optimal) bid values of this auction will require solving the system of differential equations (equations 3 and 4), which is a notably difficult problem for any vendor to solve. These first order conditions do not have a closed form analytic solution and cannot be solved using ordinary differential equation techniques. With symmetric first-price auctions, the optimal bid value is a simple expression consisting of the cost and a markup value; in our context, this is no longer feasible. The fact that the the optimal bidding strategies cannot be cleanly determined is a major reason in support of using a simpler boundedly rational model instead.

4.2 A boundedly rational model of participation and bidding

In the fully rational model, the profit functions (equations 1 and 2) depend not only on the vendor's characteristics but also on its competitors' characteristics. In particular, the vendor needs to know the cost distribution for both groups, the number of vendors from each group, and how that vendor will be bidding. We now relax these assumptions by assuming instead that vendors form their participation and bidding decisions based solely upon their own characteristics and the rules of the marketplace. In this boundedly rational model, vendors would alter their decisions if their own private circumstances change or if the rules of the marketplace change, but they do not account for the fact that their competitors are simultaneously optimizing their own behavior.

Our preferred interpretation of the model is that vendors see full information about their competitors but are boundedly rational in the sense that they are not able to fully respond to it. However, there is also an alternate interpretation: vendors might have limited information, but are behaving rationally conditional upon their information set. Ultimately, this is an issue of model interpretation that does not affect the predictions derived from the model. Our decision to model vendors as boundedly rational is supported by Bruno, Che, and Dutta (2012), who demonstrate that firms in business-to-business markets rely upon heuristics such as reference prices when deciding what price to set.

We analyze the effect of the policy change in two stages. The first step is to see whether the policy change increased or decreased expected profits for a specific SWaM group, keeping their price b_i and their cost c_i constant. If the profits go up, then we expect that more vendors of the same SWaM group will participate in 2007; conversely, if profits go down, fewer vendors will participate in 2007. The second step is to see how prices from each SWaM group should change. In the following sections, we use this basic model to explain how each group is affected by the SWaM policy change.

4.2.1 Effect on auction participation

The first step of our theoretical analysis is to examine how the SWaM policy change affects auction participation behavior. We expect that this effect should vary directionally across groups, since some groups are helped by the policy change whereas others are hurt by it. Within each particular group, all vendors will be affected in the same way. Therefore, we can use a representative firm from each group – if profits for this representative firm rise due to the policy change, then we can expect participation from this

group to increase, and if profits decline, then we can expect participation to decrease.

Small businesses Small businesses are in the preferred group of bidders in both 2006 and 2007. Denoting $\pi_i^{\mathrm{X},\,\mathrm{t}}(b_i)$ as the expected profit for a firm belonging to group X under the rules in year t, we can write profits as the vendor's margin multiplied by the probability that their bid is chosen over all others:

$$\pi_i^{\mathrm{S},\,2006}(b_i) = (b_i - c_i)\Pr(b_i < b_j, \forall \text{ S } j)\Pr(b_i < b_k, \forall \text{ W/M } k)\Pr\left(\frac{b_i}{1+\delta} < b_n, \forall \text{ non-SWaM } n\right)$$

$$\pi_i^{\mathrm{S},\,2007}(b_i) = (b_i - c_i)\Pr(b_i < b_j, \forall \text{ S } j)\Pr\left(\frac{b_i}{1+\delta} < b_k, \forall \text{ W/M } k\right)\Pr\left(\frac{b_i}{1+\delta} < b_n, \forall \text{ non-SWaM } n\right)$$

A directional effect can be found by simply taking the ratio of expected profit under 2007 rules vs. expected profit under 2006 rules, for a given bid and cost level. In other words, if a vendor were to set the same price in both years, in which year would it receive a higher profit? This metric will be directly linked to the overall pattern of entry for small firms: if expected profits are higher in 2007 than in 2006, then we should expect more bidders of the same type to enter in 2007 than in 2006.

$$\begin{aligned}
\frac{\pi_i^{\mathrm{S},\,2007}(b_i)}{\pi_i^{\mathrm{S},\,2006}(b_i)} &= \frac{(b_i - c_i)\Pr(b_i < b_j, \forall \text{ S } j)\Pr\left(\frac{b_i}{1+\delta} < b_k, \forall \text{ W/M } k\right)\Pr\left(\frac{b_i}{1+\delta} < b_n, \forall \text{ non-SWaM } n\right)}{(b_i - c_i)\Pr(b_i < b_j, \forall \text{ S } j)\Pr(b_i < b_k, \forall \text{ W/M } k)\Pr\left(\frac{b_i}{1+\delta} < b_n, \forall \text{ non-SWaM } n\right)} \\
&= \frac{\Pr\left(\frac{b_i}{1+\delta} < b_k, \forall \text{ W/M } k\right)}{\Pr(b_i < b_k, \forall \text{ W/M } k)} \\
&> 1
\end{aligned}$$

This algebraic simplification relies upon the assumption that vendors do not account for their competitor's optimization; otherwise, the various probabilities would need to be subscripted by their year. However, in this boundedly rational model, vendors assume that their competitors are not changing their strategies, thereby allowing us to simplify the problem considerably.

Since women and minority-owned vendors lose their preferred status in 2007, small businesses can compete against them more easily and are therefore in a more advantageous position in 2007 than they were in 2006. This in turns yields higher profits for small vendors in 2007 than in 2006. Consequently, this implies that more small vendors will submit bids in 2007 than in 2006.

Women- and minority-owned businesses Women- and minority-owned vendors are in the preferred group of bidders in 2006 but not in 2007. Their profits are:

$$\pi_i^{\text{W/M, 2006}}(b_i) = (b_i - c_i)\Pr(b_i < b_j, \forall \text{ S } j)\Pr(b_i < b_k, \forall \text{ W/M } k)\Pr\left(\frac{b_i}{1+\delta} < b_n, \forall \text{ non-SWaM } n\right)$$
$$\pi_i^{\text{W/M, 2007}}(b_i) = (b_i - c_i)\Pr((1+\delta)b_i < b_j, \forall \text{ S } j)\Pr(b_i < b_k, \forall \text{ W/M } k)\Pr(b_i < b_n, \forall \text{ non-SWaM } n)$$

We can simplify the ratio of yearly profits:

$$\begin{aligned}\frac{\pi_i^{\text{W/M, 2007}}(b_i)}{\pi_i^{\text{W/M, 2006}}(b_i)} &= \frac{\Pr((1+\delta)b_i < b_j, \forall \text{ S } j)}{\Pr(b_i < b_j, \forall \text{ S } j)} \times \frac{\Pr(b_i < b_n, \forall \text{ non-SWaM } n)}{\Pr\left(\frac{b_i}{1+\delta} < b_n, \forall \text{ non-SWaM } n\right)} \\ &< 1\end{aligned}$$

In this case, the difference in profits is stark: expected profits for women-and minority-owned vendors should be much lower in 2007 than in 2006, since their ability to win despite not being the lowest bidder was removed. Furthermore, they would always win the contract if they were the cheapest bidder in 2006, but in 2007, they might lose to a small business even if they offer the cheapest price. Given these effects, we expect auction participation for women-and minority-owned vendors to decline from 2006 to 2007.

Non-SWaM businesses Non-SWaM businesses do not receive preferential treatment in either year. As a result, any effect on their auction participation rates will be indirect in nature; i.e., as a competitive response to the "direct" effects borne by SWaM vendors. Their profits are:

$$\pi_i^{\text{N, 2006}}(b_i) = (b_i - c_i)\Pr((1+\delta)b_i < b_j, \forall \text{ S } j)\Pr((1+\delta)b_i < b_k, \forall \text{ W/M } k)\Pr(b_i < b_n, \forall \text{ non-SWaM } n)$$
$$\pi_i^{\text{N, 2007}}(b_i) = (b_i - c_i)\Pr((1+\delta)b_i < b_j, \forall \text{ S } j)\Pr(b_i < b_k, \forall \text{ W/M } k)\Pr(b_i < b_n, \forall \text{ non-SWaM } n)$$

The ratio of expected profits is:

$$\begin{aligned}\frac{\pi_i^{\text{N, 2007}}(c_i)}{\pi_i^{\text{N, 2006}}(c_i)} &= \frac{\Pr(b_i < b_k, \forall \text{ W/M } k)}{\Pr((1+\delta)b_i < b_k, \forall \text{ W/M } k)} \\ &> 1\end{aligned}$$

The effect of the policy change on non-SWaM participation is similar to its effect on small vendor participation. In both cases, vendors are benefiting from the fact that women- and minority-owned vendors are losing their preferred status. The improvement in competitive conditions means that we expect non-SWaM vendors to increase their participation from 2006 to 2007.

4.2.2 Effect on pricing

If vendors were able to set prices optimally, non-SWaM vendors would respond to the policy change by increasing their prices, while women- and minority-owned vendors would respond by cutting their prices. These predicted price changes are caused by the fact that the level of competition has decreased: non-SWaM vendors were previously competing against a wider group of artificially strengthened SWaM vendors, but now that the affirmative action program has been weakened, they are now in a position of relative strength (Maskin and Riley, 2000; McAfee and McMillan, 1989). Meanwhile, women- and minority-owned vendors could previously inflate their prices when they were benefiting from the affirmative action policy, but they can no longer do so now that they are competing solely on price.

In the boundedly rational model we use here, vendors are unable to set prices optimally. Instead, the price is a function of the vendor's private cost of providing the good or service c, the auction rules r, and a set of potentially vendor-specific heuristics or rules-of-thumb θ. We remain agnostic about what specific heuristics are being used, as long as they are not linked to the affirmative action policy or to the set of competitors. Therefore, the pricing formula is

$$\text{price} = f(c, r, \theta)$$

Note that we do not impose a functional form on the pricing formula, nor do we specify what factors are included in θ: vendors might be setting prices by using a cost-plus rule, they may be applying a percentage markup rule, they may be using previous prices as an anchor; etc. Instead, the key here is that the function $f(\cdot|\theta)$ is an unchanged policy function: a given vendor will submit the same bid if its cost remains the same and if the rules of the marketplace remain the same. However, an individual firm's bid can change if its cost changes or if the auction rules change, as happens between 2006 and 2007.

Although we do not impose a particular functional form for the pricing function $f(\cdot)$, our approach is consistent with previous research indicating that B2B vendors typically use a cost-based markup rule when setting prices (Anderson, Jain, and Chintagunta, 1992; Noble and Gruca, 1999; Zhang, Netzer, and Ansari, 2014). Furthermore, this framework still allows us to make predictions about how bids in 2007 will compare to bids in 2006. Assuming that the vendor uses the same heuristics across both years, the vendor's bid will change only if its cost changes, perhaps due to market conditions or changes in commodity prices. These effects should be consistent for all groups; therefore, this model predicts that any changes in prices should also be relatively consistent for all groups. This stands in contrast to the vendors' optimal pricing behavior as described above.

5 Empirical Results

Now that we have provided a simple model to explore the various data patterns we might expect to arise from the policy change, we now move to analyzing the empirical data to see whether how vendors actually responded in terms of auction participation and pricing. We analyze each of these separately in the following sections.

5.1 Effect of affirmative action on auction participation

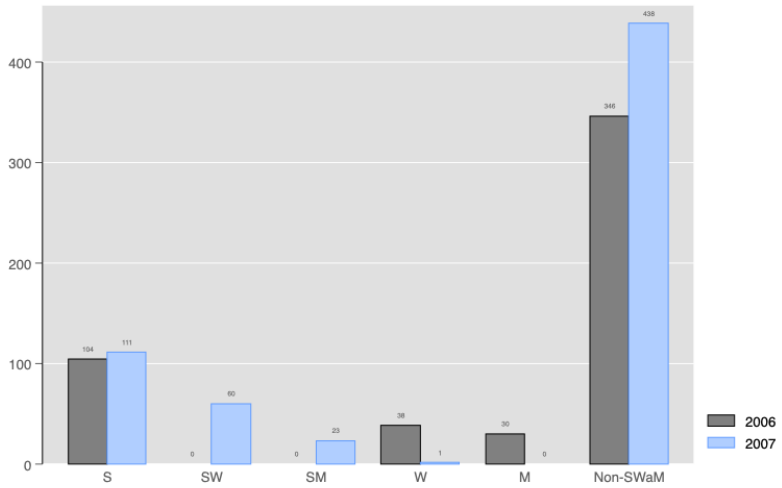
State agencies in our context have discretion to award auctions to vendors other than the cheapest bidder as long as they awarded the contract to a preferred bidder. In 2006, state agencies had discretion to award contracts to SWaM vendors even if they were not the cheapest bidder, and in 2007 they could do the same for small vendors. By introducing demographic concerns into the auction allocation decision, the affirmative action policy affects the probability that any given bid will win. In particular, the affirmative action policies make bids from preferred vendors more likely to win than bids from those who are not preferred. In our data, minority- and woman-owned vendors receive preferential treatment in 2006 but not in 2007, small vendors receive preferential treatment in both years, and non-SWaM vendors never receive preferential treatment. Since the change in SWaM rules affects each demographic group's probability of winning in a different way and since participating in an auction is affected by one's expected probability of winning, we expect that the policy change will affect each group's participation level in

different ways.

Vendors must apply for SWaM certification, and they must do so separately for each qualification. In 2006, vendors that qualified as both small and woman-owned could enjoy the benefits of the SWaM policy simply by receiving accreditation as a woman-owned business, as there was no benefit to receiving additional accreditation as a small business. In 2007, however, those same vendors would now have a strong incentive to receive accreditation as a small or small-woman business, since being a woman-owned business is no longer beneficial. As a result, there will be some vendors that switch their classification status even if their underlying characteristics have not changed.

Figure 2 displays the number of vendors in 2006 and 2007, aggregated to the their specific SWaM category at the time of bidding. The number of small-only (S) vendors is roughly the same in both years, but there is a dramatic decrease in women-only (W) and minority-only (M) vendors and commensurate increase in small-woman (SW) and small-minority (SM) vendors. This may simply be due to vendors selectively changing their classification status in response to the policy change, a possibility we examine further in table 3.

Figure 2: Number of vendors by SWaM status and year

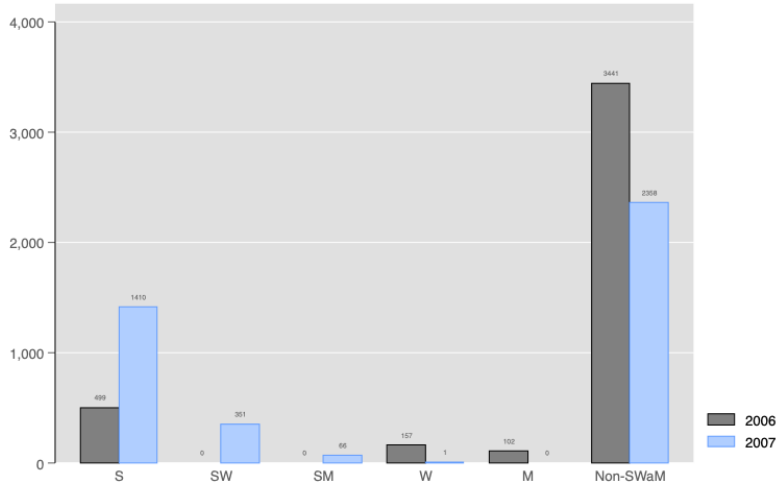


NOTE: S = Small, W = Women-owned, M = Minority-owned.

Although the number of vendors by type seems relatively stable across both years, there are clearer differences in the number of bids (see figure 3). One notable result is the significant increase in bids from small businesses, from 499 to 1,410. There is a stark decline in bidding for minority- and woman-owned vendors, who enjoyed preferred

status in 2006 but not in 2007. As the figure shows, there is only one bid from a woman- or minority-owned vendor in 2007; the other bids all come from small vendors, small-hybrid vendors (i.e., small-woman or small-minority), or non-SWaM vendors. This is a marked change from 2006, when minority-only and woman-only vendors accounted for over 250 bids.

Figure 3: Number of bids by SWaM status and year



NOTE: S = Small, W = Women-owned, M = Minority-owned.

However, despite the fact that there is only one minority-only or woman-only bidder in 2007, this does not mean that the other vendors from 2006 dropped out entirely. Figures 2 and 3 do not directly measure the fact that vendors can change their SWaM status from year to year, and in some cases are actually incentivized to do so.

Because our data includes an identifier for each specific vendor, we can track vendors over time and see how they strategically respond to the policy change. We address this issue in table 2, which shows that 24% of minority bidders and 41% of woman bidders bid on the same contract title in 2006 and 2007. In other words, a sizable percentage of the minority-only and woman-only bidders from 2006 continued to bid on the same contracts in 2006 – they simply changed their SWaM status before doing so. Nonetheless, both of these figures are significantly lower than the 53% of small bidders and 54% of non-SWaM bidders who choose to bid on the same contract title in 2007. Therefore, even when we account for vendors which switch their SWaM status, we still find that minority- and woman-owned vendors are much more likely than small and non-SWaM vendors to leave the auction market as a result of the SWaM policy change.

Table 2: Probability that a firm which bids in 2006 also bids on the same contact title in 2007, by 2006 SWaM status

		Bid in 2007? No	Bid in 2007? Yes	Total	Percent Yes
2006 status	M	57	18	75	24.00%
	S	182	209	391	53.45%
	W	66	45	111	40.54%
	Non-SWaM	904	1,057	1961	53.90%
	Total	1,209	1,329	2538	52.36%

NOTE: S = Small, W = Women-owned, M = Minority-owned.

The final column of table 2 yields an important pattern: minority-owned and woman-owned vendors are significantly less likely to bid on the same contract in 2007, relative to small and non-SWaM vendors. This finding is an intuitive one, since minority-owned and woman-owned vendors are no longer receiving preferential treatment in 2007. Coupled with the overall bid frequencies in figure 3, it becomes evident that we cannot estimate the effect of the policy change on bid values for minority-only or woman-only vendors, as there simply are not enough bids in 2007 from these groups.

Given that we have now established that many vendors change their SWaM status in response to the policy change, we now turn to describing the types of changes and the frequency with which they occur. Tables 3 and 4 show the SWaM status transition frequencies for bidders which were active in 2006. Table 3 includes all vendors that submitted bids in 2006, while table 4 only includes vendors that submitted bids for the same contract title in 2006 and 2007. Both tables provide similar results: minority-owned vendors tend to change their status to small-minority, while woman-owned vendors tend to change their status to small-woman. There is also a significant amount of movement from small to non-SWaM and vice versa; this can likely be attributed to fluctuations in vendors' revenues, since vendors can qualify as a small business if they take in less than $10 million over the past three years.

The nonparametric and model-free analysis thus far demonstrates the overall participation responses for each vendor group. We can further quantify these effects by using a simple logit model to measure the probability that a vendor will participate in a particular auction. For each auction, the set of potential bidders consists of all vendors who bid on that contract title at any point in the data. We include dummy variables for vendor's SWaM status, and these variables correspond to the "underlying" status

Table 3: Transition frequency matrix: 2006 SWaM status vs 2007 SWaM status, for vendors which bid in 2006

		2007 status					
		S	SM	SW	Non-SWaM	no bid	Total
2006 status	M	0	25	0	34	16	75
	S	148	0	28	168	47	391
	W	3	0	72	14	22	111
	Non-SWaM	384	1	149	1,074	353	1,961
	Total	535	26	249	1,290	438	2,538

NOTE: S = Small, W = Women-owned, M = Minority-owned.

Table 4: Transition frequency matrix: 2006 SWaM status vs 2007 SWaM status, for vendors which bid on the same contract title in 2006 and 2007

		2007 status				
		S	SM	SW	Non-SWaM	Total
2006 status	M	0	13	0	5	18
	S	97	0	13	99	209
	W	2	0	37	6	45
	Non-SWaM	307	0	83	667	1,057
	Total	406	13	133	777	1,329

NOTE: S = Small, W = Women-owned, M = Minority-owned.

of the vendor as opposed to the status that they report at the time of bidding. This approach allows us to carefully model participation decisions even for vendors that have changed their status in response to the policy change. Specifically: in this analysis, a vendor is denoted as small if it bid as a small business at any point in 2006 or 2007, as woman-owned if it bid as a woman-owned business at any point in 2006 or 2007, and as minority-owned if it bid as a minority-owned business at any point in 2006 or 2007. Table 5 displays coefficient estimates from this model.

The interaction term estimates from the logit model support our general findings: small vendors participate more often after the policy change, while women- and minority-owned vendors participate less. These coefficients also allow us to calculate group- and year-specific participation probabilities, which are displayed in table 6. This allows us to more clearly see how the policy change affected participation strategies for each type of vendor.

Table 5: Logit estimates for participation

	Coef.	Std. Err.
year 2007	-0.31	(0.04)
small	0.17	(0.05)
woman	-0.36	(0.07)
minority	0.11	(0.13)
year 2007 × small	0.57	(0.06)
year 2007 × woman	-0.34	(0.10)
year 2007 × minority	-0.19	(0.19)
constant	-0.11	(0.03)
# Obs.	19,506	

Table 6: Estimated participation probabilities

	2006	2007
small	51.62%	58.09%
woman	38.49%	24.67%
minority	50.18%	37.80%
non-SWaM	47.35%	39.73%

Overall, we find that the affirmative action policy change has a negative effect on minority- and woman-owned vendors. Large minority- and women-owned vendors dramatically exit the bidding process, while small minority- and women-owned vendors change their SWaM status in response to the new incentive structure. Conversely, there is a large increase in the number of bids from small businesses. Many new small businesses enter the bidding process after 2007, thereby taking advantage of the fact that they are now in a more exclusive preferred category.

These aggregate results can be explained by our model of entry. Small businesses can expect higher profits in 2007 than in 2006 (for a given bid level b_i), so more of them enter the marketplace. Conversely, women- and minority-owned vendors have much lower expected profits in 2007 than in 2006, so they exit the market in significant numbers. Furthermore, these effects stand in start contrast to the fully rational model, which predicted that participation should be stable across years despite the policy change.

5.2 Effect of affirmative action on pricing

In the previous section, we demonstrated that the change in SWaM policy had an effect on bidding probabilities for vendors from different SWaM statuses. In this section, we analyze the effect of the policy change on vendor's pricing decisions. In other words, how did those vendors which stayed in the auction market alter their bidding strategies in response to the policy change?

To facilitate this comparison, we restrict ourselves to vendor $\times$ contract title dyads which appear in both 2006 and 2007. In other words, we only consider bids which have (at least) one other corresponding bid from the same vendor and for the same contract title.

Our approach is to compare prices in pre-change auctions to prices in post-change auctions, keeping the vendor ID and the contract title the same. The assumption behind this approach is that since the vendors's individual costs should not change much over the course of the data, any variation in bid values across policy regimes can be attributed to the policy itself. We simply take the ratio of these two sets of bids to find how each vendor's pricing strategy was affected by the policy change. Averaging across vendors will yield an average treatment effect, thereby allowing us to quantify the effect of the policy change on pricing strategies in a fundamentally nonparametric way.

Restricting the data to just one pre-change year and one post-change year minimizes the possibility that vendors might be learning about the buyers' level of SWaM preference. In addition, it also minimizes the chance that vendors learn about the cost distributions of the other vendors.

In 2006, the SWaM policy was such that all small, woman-owned, and minority-owned businesses were treated as "preferred" bidders. In 2007 and afterwards, only small businesses were treated as "preferred" bidders. For each vendor v and contract title a, we calculate the ratio of bid values pre- and post- policy change:

$$\text{bid ratio}_{va} = \frac{\text{average bid in 2007}_{va}}{\text{average bid in 2006}_{va}}$$

Thus, the bid ratio$_{va}$ value represents how much the vendor's prices change after the policy change, for a specific contract title. Since we are only looking at changes for the same vendor and the same contract title, changes in the bid value are likely to be a response to the policy change. This argument is further supported by the fact that

there are unlikely to be major changes in the vendors' costs of providing the goods, since we are looking at low price, fairly homogeneous contracts as opposed to construction services or other, similarly unstandardized categories.

For ease of interpretation, we agglomerate the "status" variable into three categories: small and small-hybrid businesses of any type (S/SW/SM), large women- or minority-owned businesses (W/M/WM), and non-SWaM businesses. This taxonomy corresponds to the different effects felt by each group: S/SW/SM vendors are always in the preferred group, W/M/WM vendors were in the preferred group in 2006 but not in 2007, and non-SWaM vendors are never preferred. The other key point is that these status classifications correspond to the "underlying" status of each vendor, not necessarily to the status that the vendor reported at the time of bidding. We construct this measure by denoting a vendor as S/SW/SM if it bid as a small business at any point in 2006 or 2007, and denoting a vendor as W/M/WM if it was never a small business but bid as a women- or minority-owned business at any point in 2006 or 2007. This procedure helps us avoid misclassifying bids from the same vendor into different SWaM groups, as would otherwise arise when vendors change their SWaM status (see tables 3 and 4).

Figure 4 displays overlaid density plots of the bid ratios by SWaM status. The three groups are observationally quite similar: they each have a tight distribution with a median just above 1.

Table 7 shows summary statistics for the bid ratios by SWaM status. The average bid ratio is 1.076, which means that the SWaM policy change is associated with a 7.6% increase in bid values.

Table 7: Average 2007/2006 bid ratios, by SWaM status

	# Obs	Mean	Std. Error	Std. Dev.
S/SW/SM	672	1.076	0.014	0.369
W/M/WM	21	1.169	0.065	0.297
Non-SWaM	713	1.074	0.016	0.419
Total	1,406	1.076	0.011	0.394

As the table demonstrates, the coefficients are very close to each other, except for the W/M/WM category which suffers from a very small sample size (and a correspondingly large standard error). Three pairwise t-tests indicate that none of the differences across groups are statistically significant (see table 8).

As we mentioned when describing the boundedly rational model of bidding, the key

Figure 4: Comparison of bid ratios, by SWaM status

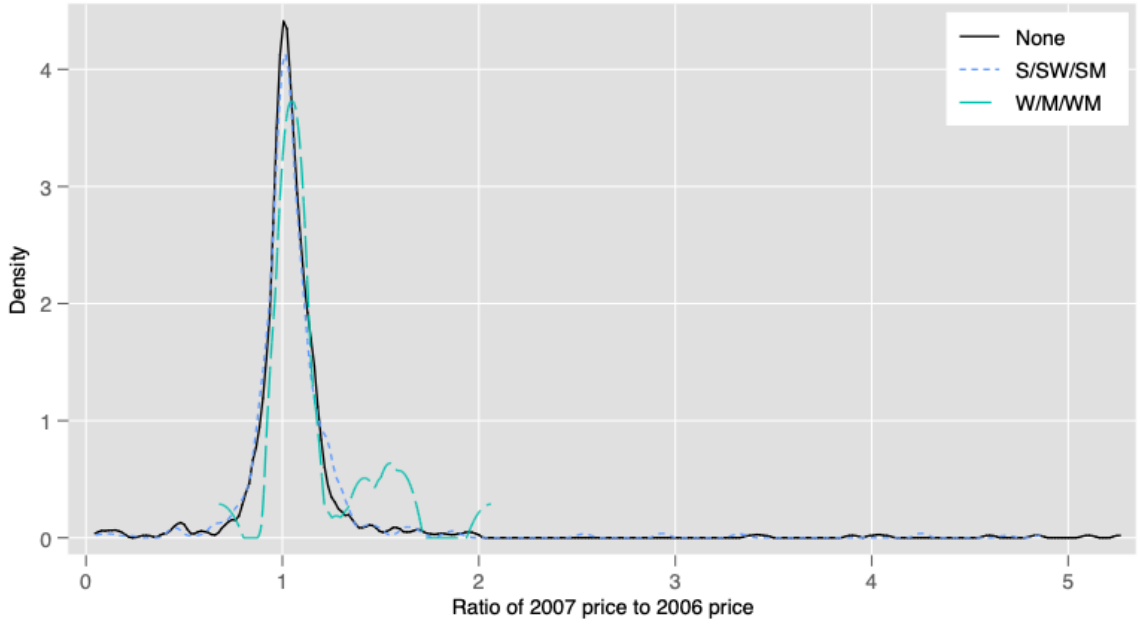


Table 8: t-test of p-values for bid ratios

Null hypothesis	p-value
$\mu_{\text{S/SW/SM}} = \mu_{\text{W/M/WM}}$	0.253
$\mu_{\text{Non-SWaM}} = \mu_{\text{W/M/WM}}$	0.303
$\mu_{\text{Non-SWaM}} = \mu_{\text{S/SW/SM}}$	0.933

metric of interest here is not whether each group raises its bid relative to 2006, because that can be explained by overall market conditions. Instead, they key question is whether there are differences in bid ratios across groups. We find that vendors raise their bids by about 7.6%, but since there are no differences across groups, this inflationary effect can be attributed to market conditions or secular changes in commodity prices. This argument is further supported by the fact that the W/M/WM group had the highest bid ratio (albeit with a small sample size), despite the fact that this group had the strongest incentive to lower its bid. In other words: if the W/M/WM vendors increased their prices, then this must have been due to market forces and not a change in individual bidding strategy.

This line of argument can be further tested via regression. In order to see whether different SWaM groups raise/lower their prices by different amounts in response to the policy change, we estimate the following model by vendor i, auction t, contract title a, product category c, and year y:

$$\begin{aligned}\ln(\text{price})_{it} = \alpha_{1ia} + \alpha_{2cy} + \beta_0 \\ + \beta_1 \left(\text{year } 2007 \times \text{S/SW/SM}\right)_{it} \\ + \beta_2 \left(\text{year } 2007 \times \text{W/M/WM}\right)_{it} + \varepsilon_{it}\end{aligned}$$

Note that this model includes two sets of two-dimensional fixed effects. The α_{1ia} term represents fixed effects at the vendor $\times$ contract title level, thereby accounting for the costs that a specific vendor may incur when trying to provide a specific product. Conversely, the α_{2cy} term represents fixed effects at the category $\times$ year level, thereby accounting for changes in input prices, commodity prices, the competitive environment; etc. Including these two fixed effects allows us to better isolate the effect of the policy change that occurred in 2007. Estimates from this model are in table 9.

Table 9: Price regression estimates

	Coef.	Std. Error
year 2007 $\times$ S/SW/SM	-0.043	(0.026)
year 2007 $\times$ W/M/WM	0.038	(0.125)
constant	2.704	(0.009)
# Obs.	6,949	
R^2	0.951	

The regression model in table 9 corroborates the findings from the nonparametric analysis: while prices generally go up in 2007, there are no significant differences across groups in terms of how much the prices change. This lack of cross-group heterogeneity in terms of pricing response is consistent with the predictions from the boundedly rational model of vendor behavior that was presented earlier.

More notably, the signs of the regression coefficients do not correspond with predictions from the fully rational model. From 2006 to 2007, small vendors were put in a more advantageous position when their woman- and minority-owned competitors lost their preferred status. Therefore, small vendors should increase their bids in 2007, while women- and minority-owned vendors should decrease their bids. Our estimation results find a null result when comparing across groups, but the signs of the effects are the

opposite of what the model would predict. This indicates that the null result is not due solely to a lack of sample size. In order to comport with the fully rational model, our estimation results would have to both become more precise, and have their signs flipped.

Our empirical analysis indicates that vendors are not adjusting their pricing strategies after the policy change, despite the fact that the policy change (a) affected their probabilities of winning contracts and (b) has dramatically affected the composition of vendors who participate in the marketplace. The fact that vendors' pricing strategies remain stable is likely a detriment, because it indicates that they are not optimizing their behavior in accordance with their new circumstances. In fact, prior research has demonstrated how vendors in a related B2B context could dramatically improve their profitability if they were able to flexibly adjust their pricing when the competitive environment changed (Zhang, Netzer, and Ansari, 2014).

6 Conclusion

The empirical effects of the affirmative action policy change can be summarized in three parts. The most notable finding is that woman- and minority-owned vendors drop out of the bidding process at a high rate; the removal of their affirmative action benefits proves to be a major deterrent for them. However, these woman- and minority-owned vendors are replaced in the marketplace by small vendors, who are taking advantage of their continued benefits. Finally, vendors do not seem to alter their bidding strategies, despite the fact that market conditions have changed significantly. Of the vendors which do bid in both years, there are no systematic differences in their bidding strategies.

At a methodological level, our contribution is to demonstrate that with sufficient data, a researcher can use a simple and nonparametric methodology to evaluate strategic behavior in the context of business-to-business markets. The empirical approach itself is not novel, but our contribution is to demonstrate that it can be applied toward auction data to test theoretical insights. The fact that our nonparametric techniques yield estimates that are in concordance with more standard parametric approaches is a further encouraging sign for these methods.

Prior research has documented the use of heuristics in a number of consumer settings, but this research shows that vendors may also be relying upon them to set prices in a business-to-business context, even when the competitive environment has changed dra-

matically. This theoretical contribution is notable because vendors in this setting have relatively good information about their market context, and relatively few constraints placed on their ability to set prices. Our model of pricing behavior encompasses many possible pricing heuristics that vendors might be using, including common approaches like cost-plus pricing or percentage markup rules.

Finally, the primary contributions from this research are substantive in nature and of practical importance for managers. Our overall finding is that the change from a wider SWaM policy (in which small, women-owned, and minority-owned businesses received preferential treatment) to a narrower SWaM policy (in which only small businesses received preferential treatment) has strong effects on the composition of bidders but does not cause any changes to each vendor's individual pricing strategy. This is consistent with a model of vendor behavior in which vendors cannot properly optimize over their competitors' behavior, but rely upon heuristics or rules-of-thumb when setting prices and deciding whether to participate. As more buyers in business-to-business markets adopt affirmative action policies, vendors that are better able to adjust their pricing and participation strategies accordingly will realize higher profits as a result.

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