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IMPERFECT COMPETITION AND RENTS IN LABOR AND PRODUCT MARKETS: THE CASE OF THE CONSTRUCTION INDUSTRY

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ABSTRACT

We quantify the importance of imperfect competition in the US construction industry by estimating the size of rents earned by American firms and workers. To obtain a comprehensive measure of the total rents and to understand its sources, we take into account that rents may arise due to markdown of wages in the labor market, or markup of prices in the product market, or both. Our analyses combine the universe of US business and worker tax records with newly collected records from US procurement auctions. We use this data to identify and estimate a model where construction firms compete with one another for projects in the product market and for workers in the labor market. The firms may participate both in the private market and in government projects procured through auctions. We find evidence of considerable wage- and price-setting power. This imperfect competition creates sizable rents, three-fourths of which is captured by the firms. The incentives of firms to mark down wages and reduce employment due to wage-setting power are attenuated by their price-setting power in the product market.

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1 Introduction

Researchers and policymakers are keenly interested in measuring the degree of imperfect competition in the US economy and in understanding how it affects the outcomes of workers and firms. In the labor market, firms may exploit their market power to mark down the wages of workers below their marginal revenue products, with important implications for earnings inequality, employment, and the labor share of gross domestic product. In the product market, firms may use their market power to mark up prices above marginal costs, thereby increasing profits while reducing output. To draw inferences about imperfect competition in these two markets, it is natural to measure the size of rents earned by employers and workers, where rents refer to the excess return over that required to change a decision, as in Robinson (1933) and Rosen (1986). Because reservation wages and productivity are not directly observed, rents are not directly observed and recovering this from data has proved elusive.

The primary contribution of our paper is to address these and other empirical challenges to accurately measure, and to understand the mechanisms behind, the size and sharing of the rents earned by firms and workers in the context of the American construction industry. To obtain a comprehensive measure of the total rents and to understand its sources, we take into account that rents may arise due to the mark down of wages in the labor market, or the mark up of prices in the product market, or both. Analyzing imperfect competition in both markets jointly could be important as the incentives of firms to mark down wages and reduce employment due to wage-setting power depend on whether, and the degree to which, they have price-setting power. In contrast to our paper, existing work on imperfect competition typically focuses on either the labor market or the product market in isolation. This may result in a limited or misleading picture of the total rents earned by firms and workers and of the consequences of market power for employment, wages, output, and prices.

In Section 2, we present the theoretical model where construction firms compete with one another for projects in the product market and for workers in the labor market. The labor market side of the model builds on work by Rosen (1986), Boal and Ransom (1997), Bhaskar et al. (2002), Manning (2003), Card et al. (2018), and Lamadon et al. (2021). Competitive labor market theory requires firms to be wagetakers so that labor supply facing a given firm is perfectly elastic. To allow the firm-specific labor supply curve to be imperfectly elastic so that the firm may have wage-setting power, we let workers have heterogeneous preferences over the non-wage job characteristics or amenities that firms offer. We assume that firms do not observe the idiosyncratic taste for amenities of any given worker. This information asymmetry implies that employers cannot price discriminate with respect to workers' reservation wages. Instead, if a firm faces higher demand for its products and wants to hire more labor, it needs to offer higher wages to all workers. As a result, the equilibrium allocation of workers to firms creates rents to inframarginal workers.

The firm side of the model consists of two types of product markets in which the construction firms may participate: private market projects and government projects, the latter of which are procured through auctions. Incorporating both types of product markets not only gives a more accurate representation of firms' production choices in the construction industry, but also facilitates identification of key model parameters. The firm's behavior is specified as a two-stage problem, which we solve backwards. In the first stage, firms bid for a government project procured through a first-price sealed-bid auction. The project specifies the amount of output that must be produced. At the end of the first stage, firms learn the outcome of the auction. If a firm wins the auction, it receives the winning bid amount as revenue and commences production. In the second stage, the firm chooses inputs to maximize profit from total production. A firm may earn rents in the private market due to price-setting power and in the government projects because of a limited number of bidders in the auction.

After presenting the theoretical model, we describe the data. As explained in Section 3, our analyses are based on a matched employer-employee panel data set, which is constructed by combining the universe of US business and worker tax records for the period 2001-2015. Firm data contain information on sales, profits, intermediate inputs, and industry. Worker data contain information on the number of workers and their earnings. We merge the employer-employee panel data set with a new data set on US procurement auctions that we constructed primarily by scraping bidding websites. The resulting data set covers billions of dollars in procurement contracts awarded to thousands of firms. Importantly, we observe the bid of each firm in an auction, not only that of the winner.

In Section 4, we demonstrate how the model parameters are identified from the data. The primary challenge to identify the firm-specific labor supply curve is changes over time in firm-specific amenities, which are unobserved correlates of both employment and wages. We consider several empirical strategies to overcome this identification challenge, including restrictions on the timing of the firm's decisions, comparisons between winners and losers (with close bids) in the (price-only) auctions, or a restriction on the firm-specific amenities to be fixed over the estimation window or only subject to transitory shocks.[1] The primary challenge to identify technology and product demand is changes over time in firm-specific productivity, which are unobserved correlates of both inputs and output. We overcome this identification challenge by inverting the bidding function of the firms in procurement auctions, which allows us to control for firm-specific productivity. We also show that the model is over-identified, and we use the additional moment condition to fit and assess the model.

In Sections 5 and 6, we present the estimates, which yield four key findings. First, firms have significant wage-setting power with an estimated firm-specific labor supply elasticity of about 4.1. This estimate indicates that, if an American construction firm aims to increase the number of employees by 10 percent, it needs to increase wages by around 2.4 percent. This implies wages are marked down 20 percent relative to the marginal revenue product. Second, firms have significant price-setting power in the private product market with an estimated product demand elasticity of 7.3. The estimate suggests that, in order for a firm to increase output by 10 percent in the private market, it must reduce the price of its product by about 1.4 percent. This implies prices are marked up 16 percent relative to the marginal cost of production.

[1] Similar timing assumptions are used in the large literature on production function estimation (see the discussions by Ackerberg et al. 2015 and Gandhi et al. 2020). Lamadon et al. (2021) assume that firm-specific amenities are constant within the estimation window or only subject to transitory shocks in their identification of firm-specific labor supply curves. A small number of papers have used research designs comparing winners and losers of procurement auctions. They estimate how government purchases affect employment during an economic crisis (Gugler et al., 2020) and firm dynamics and growth (Ferraz et al., 2015, Hvide and Meling, 2020). None of these studies use these comparisons to draw inference about imperfect competition or rents, nor do they use these comparisons to identify and estimate an economic model of firm and worker behavior.

Third, we find that worker rents are about \$11,600 per worker (20 percent of the average wage), while firm rents (i.e. profits) amount to about \$43,100 per worker. Comparing worker rents to firm rents, we see that more than three-fourths of total rents are captured by firms. Fourth, although winning a procurement contract crowds out some private market production, it increases total output, employment, and rents. We find that 40 percent of these additional rents are captured by workers.

In Section 7, we use our model to perform counterfactuals which show how labor market power interacts with product market power to shape the outcomes and behavior of workers and firms in the American construction industry. We first show theoretically, in Section 7.1, that the consequences of increased market power in one market are attenuated by the existence of market power in the other market. Next, in Section 7.2, we use the estimated model to quantify the importance of interactions between market power in the two markets. When the labor supply elasticity of a given firm is reduced by half, we find that the firm employs 12 percent fewer workers and decreases wages by 6 percent. By comparison, if the firm did not have price-setting power in the product market, we find that it would employ 22 percent fewer workers and decreases wages by 11 percent. These counterfactuals illustrate how analyses of imperfect competition that focuses on either the labor market or the product market in isolation may result in a limited or misleading picture of the total rents earned by firms and workers and of the consequences of market power for employment, wages, output, and prices.

Our paper is primarily related to a large literature on imperfect competition, rents, and inequality in the labor market, reviewed by Manning (2011), Card et al. (2018), and Lamadon et al. (2021). Much of this existing work is trying to measure imperfect competition in the entire labor market, paying little attention to the large heterogeneity in technology and market structure across industries.[2] In contrast, we focus on the construction industry, paying closer attention to the structure and the functioning of the relevant markets. For example, many construction firms participate simultaneously in the private market, where output and prices are endogenously

[2]Notable exceptions include Azar et al. (2021) and Lamadon et al. (2021). They study imperfect competition in the entire US labor market, but account for imperfect substitutability across markets using a nested-logit structure on preferences.

chosen by firms, and in government projects, which are procured through auctions where firms choose how much to bid but not how much to produce. This institutional feature is essential for our identification arguments, for understanding and modeling the behavior of firms in the construction industry, and for accurately predicting the profits the firms make if they win a procurement auction.

Our paper also differs from much of the existing empirical work on imperfect competition in that we fully specify the equilibrium model and identify and estimate the model parameters. This allows us to not only measure the current size and share of the rents earned by firms and workers, but also to understand the underlying mechanisms and to quantify how the rents and rent sharing would change if market power changed. The closest study to ours in this regard is Lamadon et al. (2021), who also identify and estimate the model parameters to draw inference about imperfect competition and rents. Our paper complements this analysis in several important ways, including that we focus on a specific industry and explicitly incorporate how rents may also arise from price-setting power in the product market.

Our paper also relates and contributes to the empirical literature on auctions, reviewed by Athey and Haile (2007). Our modeling of auctions differs in that we consider incomplete information in unobserved productivity rather than costs, which allows for a flexible relationship between the probability of winning the auction and other firm outcomes that depend on productivity, such as employment and output. Our paper also contributes by quantifying how winning a procurement auction affects the firm's total production and whether it crowds-in or crowds-out activity in the private market. In addition, our work complements existing papers on auctions by taking into account how bidding behavior depends on market power, both in the labor market and in the private product market.

Lastly, our paper relates to a growing body of work that estimates the pass-through and incidence of firm-specific shocks, reviewed by Card et al. (2018). An early example is Van Reenen (1996), who studies how innovation affects firms' profits and workers' wages. He also investigates patents as a source of variation, but finds them to be weakly correlated with profits. Building on this insight, Kline et al. (2019) study the incidence of patents that are predicted to be valuable and Howell and Brown (2020) study the incidence of R&D grants. A related literature on skill-biased technical change has examined the wage and productivity effects of the adoption of new technology in firms (see Akerman et al., 2015, and the references therein).

2 A Model of the Construction Industry

In this section, we develop a model where construction firms compete with one another for projects in the product market and for workers in the labor market. The model incorporates two types of product markets in which the construction firms may participate: the private market and the government market, where government projects are procured through auctions. It is important to account for the government market for two reasons. First, more than 10 percent of all revenues in the construction industry are due to government procurement projects. By accounting for the government market, we provide a more accurate representation of firms' production choices and can draw policy implications regarding the incidence of government expenditure on construction projects. Second, as shown in Section 4, variation in government demand for procurement projects can be leveraged to identify key model parameters governing the labor market, private product market, and firm technology.

2.1 Worker Preferences and Labor Supply

Worker i in year t has the following preferences over being employed at a firm j:

$$u_{it}(j, W_{jt}) = \log W_{jt} + g_{jt} + \eta_{ijt}, \tag{1}$$

where W_{jt} represents earnings, g_{jt} represents the average value of firm-specific amenities, and η_{ijt} captures worker i's idiosyncratic tastes for the amenities of firm j. Since we allow amenities to be unobserved to the analyst, they can include a wide range of characteristics, such as distance of the firm from the worker's home, flexibility in the work schedules, effort required, and so on.

Our specification of preferences allows for the possibility that workers view firms as imperfect substitutes. The term g_{jt} gives rise to *vertical* employer differentiation: some employers offer good amenities while other employers offer bad amenities. The term η_{ijt} gives rise to *horizontal* employer differentiation: workers are heterogeneous in their preferences over the same firm. The importance of horizontal differentiation is governed by the variability across workers in their idiosyncratic taste for a given firm. We parameterize the distribution of η_{ijt} as i.i.d. Type-1 Extreme Value (T1EV) with dispersion θ.[3] When θ is larger, horizontal employer differentiation becomes relatively more important, as η_{ijt} has greater variability.

We consider an environment where labor is hired in a spot market. We make two additional assumptions on the supply of labor. First, firms do not observe the idiosyncratic taste for amenities of any given worker η_{ijt}. This information asymmetry implies that employers cannot price discriminate with respect to workers' reservation wages. Instead, if a firm wants to hire more labor, it needs to offer higher wages to both marginal and inframarginal workers. Second, since we find no evidence of changes in worker quality in response to winning a procurement auction, we assume all workers are homogenous in skill. It is possible to extend the model and the empirical analysis to allow for differences in worker quality (see Lamadon et al., 2021).

Given these assumptions, the number of workers who accept a job at firm j at time t for a posted wage offer W_{jt} is $L_{jt} = (W_{jt}/(A_{jt}\Xi_t))^{1/\theta}$, where $A_{jt} \equiv g_{jt}^{-\theta}$ captures the vertical differentiation due to firm-specific amenities and Ξ_t captures aggregate labor supply factors in the relevant market.[4] In the baseline analysis, we consider the entire construction industry to be the relevant market. We also perform several specification checks to show that our findings are robust to alternative market definitions.

Our empirical analysis focuses on the inverse labor supply curve facing firm j at time t, which is given by

$$W_{jt} = L_{jt}^{\theta} U_{jt}, \tag{2}$$

where $U_{jt} \equiv A_{jt}\Xi_t$. The labor supply elasticity facing the firm is $1/\theta$, so labor supply becomes more inelastic when idiosyncratic tastes are more dispersed. We assume firms are "strategically small" in the sense that $\frac{\partial \Xi_t}{\partial W_{jt}} \approx 0$, so marginal wage changes at one firm do not impact aggregate labor supply factors.[5]

[3] We only require that η_{ijt} is independently distributed across firms and workers within each cross-section t; η_{ijt} may be arbitrarily persistent within a worker-firm pair over time.

[4] Formally, $\Xi_t \equiv \left(\overline{W}_t/\overline{L}_t\right)^{\theta}$, where $\overline{L}_t$ is the total number of workers in the market and $\overline{W}_t \equiv \sum_{j'} W_{j't}^{1/\theta} g_{j't}$ is the price index of labor.

[5] See Berger et al. (2021), Chan et al. (2019), and Jarosch et al. (2019) for models of the labor market in which this assumption is relaxed. Identification of such models is challenging, especially

For the empirical analysis, it is useful to decompose the firm-specific amenity term into a fixed component and a time-varying component. Denoting $a_{jt} \equiv \log A_{jt}$, we can write firm-specific amenities available to workers at firm j at time t as $a_{jt} \equiv \psi_j + \nu_{jt}$, which is without loss of generality since we can simply define $\psi_j \equiv \mathbb{E}[a_{jt}|j]$ and $\nu_{jt} \equiv a_{jt} - \psi_j$. Then, denoting $w_{jt} \equiv \log W_{jt}$, $\ell_{jt} \equiv \log L_{jt}$, $\xi_t \equiv \log \Xi_t$, and $u_{jt} \equiv \log U_{jt}$, log wages are given by

$$w_{jt} = \theta \ell_{jt} + u_{jt} = \theta \ell_{jt} + \psi_j + \nu_{jt} + \xi_t. \tag{3}$$

Letting Δ indicate differences over time, changes in log wages are thus

$$\Delta w_{jt} = \theta \Delta \ell_{jt} + \Delta \nu_{jt} + \Delta \xi_t, \tag{4}$$

where the time-invariant firm-specific amenity term ψ_j does not appear in differences over time. Equation (4) shows that wages change over time for three reasons. All else equal, the firm needs to pay higher wages to hire more workers, as captured by $\theta \Delta \ell_{jt}$; the firm must pay higher wages to keep the same number of workers if its amenities get worse, as captured by $\Delta \nu_{jt}$; and the firm needs to pay more to keep the same number of workers if aggregate labor supply declines or the price index of labor rises, as captured by $\Delta \xi_t$.

2.2 Firm Technology and Product Demand

Following Ackerberg et al. (2015), the production function (in physical units) is

$$Q_{jt} = \min\{\Omega_{jt} L_{jt}^{\beta_L} K_{jt}^{\beta_K}, \beta_M M_{jt}\} \exp(e_{jt}), \tag{5}$$

where Ω_{jt} denotes total factor productivity (TFP), K_{jt} denotes capital, M_{jt} denotes intermediate inputs, and e_{jt} represents measurement error. We assume that capital markets are perfect, so firms can rent capital at constant rate p_K. While the assumption of a rental market for capital is standard in the literature, it may be a fairly good description of the construction industry, which heavily utilizes rental equipment and

if one allows for two-sided heterogeneity.

machinery. We also assume the market for intermediate inputs is competitive with constant price p_M.

Our Leontief functional form in equation (5) imposes strong complementarity between labor and intermediate inputs, while allowing for substitutability between labor and capital. This assumption may be relatively reasonable for the construction industry, where greater capital expenditure (i.e., renting more efficient equipment and machinery) may substitute for labor, but labor cannot take the place of concrete, asphalt, wood, and other materials required to construct a bridge or road.[6] The Leontief functional form implies a zero marginal rate of technical substitution between labor and intermediate inputs. In Online Appendix C, we solve, identify, and estimate the model with a Cobb-Douglas production function, which has a marginal rate of technical substitution of unity and thus allows for substitutability between labor and intermediate inputs. As shown in Section 5.2, the key results are broadly similar when using the Cobb-Douglas production function, implying that the Leontief functional form is not crucial to our findings.

Given the technology in equation (5), the construction firms may choose to produce in two product markets. The first is the market for private projects, which we denote H. Specifically, firm j at time t posts a price P_{jt}^H at which it is willing to produce in the market for private projects. Consumers have idiosyncratic preferences over producers. Consumer i's utility from purchasing from firm j at time t is $u_{ijt}^H = -\log P_{jt}^H + \omega_{ijt}$. We parameterize the distribution of ω_{ijt} as i.i.d. T1EV with dispersion ϵ. When ϵ is larger, horizontal producer differentiation becomes relatively more important, as ω_{ijt} has greater variability.

Given these assumptions, the quantity purchased from firm j at t for a posted price P_{jt}^H can be expressed as $Q_{jt}^H = \left(P_{jt}^H\right)^{-1/\epsilon} / \aleph$, where $\aleph \equiv \sum_{j'} \left(P_{j't}^H\right)^{-1/\epsilon}$ is the aggregate price index. Rearranging, $P_{jt}^H = p_H \left(Q_{jt}^H\right)^{-\epsilon}$, where $p_H \equiv \aleph^{-\epsilon}$.[7] This implies private

[6]Indeed, the assumed functional form appears broadly consistent with the standard construction cost estimation handbook (RSMeans, 2008). This handbook provides task-specific construction cost estimates for the typical crew (labor and equipment needed) per unit of material. While crew choices may vary depending on the contractor, material input requirements are fixed for each task.

[7]In the private product market, we assume firms are "strategically small" in the sense that $\frac{\partial \aleph}{\partial P_{jt}^H} \approx 0$; that is, no firm can change the aggregate price index through its own marginal price changes. Thus, $\frac{\partial \log Q_{jt}^H}{\partial \log P_{jt}^H} = -1/\epsilon$, so $1/\epsilon$ is the price elasticity of demand.

market revenues are

$$R_{jt}^{H} = P_{jt}^{H} Q_{jt}^{H} = p_H \left(Q_{jt}^{H}\right)^{1-\epsilon}. \tag{6}$$

Denoting $r_{jt}^{H} \equiv \log R_{jt}^{H}$ and $q_{jt}^{H} \equiv \log Q_{jt}^{H}$, it follows that

$$r_{jt}^{H} = \log p_H + (1-\epsilon)\, q_{jt}^{H}, \tag{7}$$

so $1-\epsilon$ can be interpreted as the revenue elasticity of output in the private market.[8]

In addition to the private product market, firms may participate in the market for government projects, denoted by G. Output for the government market is denoted Q_{jt}^{G}. Firm j produces total output $Q_{jt} = Q_{jt}^{H} + Q_{jt}^{G}$ simultaneously across both markets using the production function in equation (5). We denote $D_{jt} = 1$ if firm j holds a procurement contract at t and $D_{jt} = 0$ otherwise. If firm j does not hold a procurement contract ($D_{jt} = 0$), it does not produce in the government market ($Q_{jt}^{G} = 0$). If firm j receives a procurement contract ($D_{jt} = 1$), it must produce exactly $\overline{Q}^{G}$ in the government market ($Q_{jt}^{G} = \overline{Q}^{G}$), where $\overline{Q}^{G}$ is set by the government. The quantity produced by firm j in the government market can then be expressed as $Q_{jt}^{G} = \overline{Q}^{G} D_{jt}$. The allocation of procurement contracts to firms as well as the revenues received from procurement projects are determined through first-price sealed-bid auctions, which we describe below.

2.3 Firm's Problem and Behavior

We model firm behavior as a two-stage problem which we solve backwards. In the first stage, a firm submits a bid for a government project that is procured through a first-price sealed-bid auction. The project specifies the amount of output that must be produced within a given time frame. At the end of the first stage, the firm learns the auction outcome. If the firm wins the auction, it receives as revenue the winning bid amount. In the second stage, the firm chooses inputs to maximize profit from total production, taking as given the outcome of the procurement auction. Production in both private and government projects occurs simultaneously at the end of the second

[8] Our derivations in the text focus on $\epsilon > 0$. Online Appendix B provides derivations with perfect competition, $\epsilon = 0$. As discussed below, $\epsilon = 0$ is at odds with our findings.

stage.

Second stage: Private market

We now solve for the optimal private market behavior of firm j if it receives a procurement contract in the government market as well as if it does not.

Denote profit excluding procurement revenue by π^H_{1jt} if $D_{jt} = 1$ and π^H_{0jt} if $D_{jt} = 0$. In order to obtain a procurement contract, firms place bids in auctions. Denote firm j's bid in year t by Z_{jt}. Total profit is then $\pi_{1jt} = Z_{jt} + \pi^H_{1jt}$ if the firm receives a procurement contract, and $\pi_{0jt} = \pi^H_{0jt}$ otherwise. Observed profit is $\pi_{jt} = \pi_{1jt} D_{jt} + \pi_{0jt}(1 - D_{jt})$. Given $\overline{Q}^G$ and $D_{jt} = d$, the firm's second stage problem is to hire labor L_{djt}, purchase intermediate inputs M_{djt}, and rent capital K_{djt} to maximize private market profits,

$$\pi^H_{djt} = R^H_{djt} - W_{djt} L_{djt} - p_M M_{djt} - p_K K_{djt}, \tag{8}$$

for $d = 0, 1$, subject to the labor supply curve (equation 2), the production function (equation 5), the private market revenue curve (equation 6), the price of intermediate inputs (p_M), the price of capital (p_K), and that the government project is fulfilled by the procured firm ($Q_{1jt} \geq \overline{Q}^G$).

We now use the profit-maximizing first-order conditions to characterize the firm's private market behavior. The first-order condition for capital implies a composite production function,

$$Q_{jt} = \min\{\Phi_{jt} L^\rho_{jt}, \beta_M M_{jt}\} \exp(e_{jt}), \tag{9}$$

where $\Phi_{jt} \equiv \Omega_{jt} [\frac{\beta_K}{\beta_L} \frac{(1+\theta)U_{jt}}{p_K}]^{\beta_K}$ is composite TFP and $\rho \equiv (1 + \theta)\beta_K + \beta_L$ is the composite returns to labor. We refer to Online Appendix A.1 for the derivation of the composite production function in equation (9).

Given the composite production function, the first-order condition for intermediate inputs implies

$$X_{jt} = \frac{p_M}{\beta_M} Q_{jt} = \frac{p_M}{\beta_M} L^\rho_{jt} \Phi_{jt}, \tag{10}$$

where $X_{jt} \equiv p_M M_{jt}$ denotes expenditure on intermediate inputs. Letting $x_{jt} \equiv \log X_{jt}$ and $\phi_{jt} \equiv \log \Phi_{jt}$, and defining $\kappa_X \equiv \log(p_M/\beta_M)$, it follows that

$$x_{jt} = \kappa_X + \rho \ell_{jt} + \phi_{jt}. \tag{11}$$

Thus, our model implies a log-linear relationship between expenditure on intermediate inputs and labor, which will prove useful for identifying ρ.

Combining the product demand curve in equation (7) with the first-order condition for intermediate inputs yields

$$r_{jt} = \kappa_R + (1-\epsilon)\, x_{jt} + (1-\epsilon)\, e_{jt} \quad \text{if} \quad D_{jt} = 0, \tag{12}$$

where $\kappa_R \equiv \log p_H + (1-\epsilon) \log (\beta_M / p_M)$. There are two aspects of this equation that will be useful to identify ϵ. First, it shows that revenues are log-linear in intermediate input expenditures with coefficient $1-\epsilon$ among firms that are only producing for the private market ($D_{jt} = 0$). Second, the only unobserved source of variation in log revenues is measurement error e_{jt} and not TFP ϕ_{jt}. Intuitively, both revenues and intermediate input expenditures are log-linear in TFP, so controlling for log intermediate inputs absorbs all of the variation in TFP. The same reasoning allows a related literature on production function estimation to control for TFP by controlling for intermediate inputs (see the discussions by Ackerberg et al. 2015 and Gandhi et al. 2020).

The first-order condition with respect to labor implies the following relationship between private market revenues and expenditures on labor and intermediate inputs:

$$R^H_{djt}(1-\epsilon)\frac{Q_{djt}}{Q^H_{djt}} = \frac{1+\theta}{\beta_L} B_{djt} + X_{djt}, \tag{13}$$

where $B_{jt} \equiv L_{jt} W_{jt}$ denotes the firm's wage bill. This equation will prove useful for identifying β_L. The derivation of this equation and several important implications of the first-order conditions for labor are reported in Online Appendix A.2; we briefly summarize implications here.

One implication of the first-order condition for labor is that both winners and losers of procurement contracts always produce strictly positive output for the private market ($Q^H_{djt} > 0$, $d = 0, 1$). This follows from the fact that firms have market power ($\epsilon > 0$), which implies that the marginal revenue in the private market is strictly greater than marginal cost as private market output approaches zero. For the same reason, total production is strictly greater if the firm receives a procurement contract versus if it does not ($Q_{1jt} > Q_{0jt}$). Another implication is that the government project crowds-out private projects for firm j ($Q^H_{1jt} < Q^H_{0jt}$) if $1+\theta > \rho$, and conversely, crowds-in private projects ($Q^H_{1jt} > Q^H_{0jt}$) if $1+\theta < \rho$. To see why this is the case, note that winning a government project increases the total output level. This requires more employment to achieve a greater level of production. Due to the upward-sloping labor supply curve, greater employment leads to higher costs of labor, determined by $1+\theta$. On the other hand, greater scale induces greater private production under increasing return to scale (in labor and capital), $\rho > 1$. Thus, the magnitude of $1+\theta$ relative to ρ determines if receiving a procurement contract leads to crowd-out or crowd-in of private market output for firm j.

First stage: Government market

We now specify how procurement contracts are allocated to firms and the determination of procurement revenues.

Firms choose bids in consideration of their opportunity costs. The opportunity cost of receiving a procurement contract from the government is the difference in private market profits between holding no government contract and holding a government contract. Formally, denote the opportunity cost by $\sigma_{u_{jt}}(\phi_{jt}) \equiv \pi^H_{0jt} - \pi^H_{1jt}$, where the notation emphasizes that firm productivity ϕ_{jt} is the only source of heterogeneity in the opportunity cost, conditional on amenities u_{jt}.[9] The opportunity cost of winning a procurement contract is strictly positive, $\sigma_{u_{jt}}(\phi_{jt}) > 0$, as the firm would have received positive revenues if it sold the output quantity $\overline{Q}^G$ to the private market instead of the government market.

In the procurement auction, bidders observe common information about the size of the project, $\overline{Q}^G$, the number of bidders, I, and the amenities of each bidding firm, u_{jt}. The distribution of TFP conditional on amenities, $(\phi_{jt}|u_{jt} = u) \sim \tilde{F}_u(\cdot)$, is assumed to be i.i.d. and known by all firms, and induces an i.i.d. distribution of opportunity costs $\sigma_u(\phi_{jt}) \sim F_u(\cdot)$.[10] Revenue from winning the auction is the winning bid, Z_{jt}.

[9] The profit function for auction winners depends also on the size of the government project $\overline{Q}^G$, so the opportunity cost also depends on $\overline{Q}^G$. For notational convenience, we suppress this dependence.

[10] We require that TFP is i.i.d. across firms within each cross-section t, though TFP may be

The difference between the benefit and the opportunity cost of winning an auction with bid Z_{jt} is thus $Z_{jt} - \sigma_u(\phi_{jt})$. Conditional on amenities $u_{jt} = u$, a firm with TFP ϕ_{jt} chooses the optimal bid Z_{jt} to solve

$$\max_{Z_{jt}} \underbrace{\left(Z_{jt} - \sigma_u(\phi_{jt})\right)}_{\text{payoff}} \underbrace{\Pr\left(D_{jt} = 1 | Z_{jt}\right)}_{\text{probability of winning}}.$$

The first term is the payoff to winning an auction, which is increasing in Z_{jt}, while the second term is the probability of winning an auction, which is decreasing in Z_{jt}. Thus, the firm faces the usual trade-off in an auction between profits if one wins and the probability of winning.

The firm's optimal bidding strategy in the procurement auction is

$$s_u(\phi_{jt}) = \sigma_u(\phi_{jt})\,\delta_u(\phi_{jt}), \text{ where } \delta_u(\phi_{jt}) \equiv 1 + \frac{\int_{\sigma_u(\phi_{jt})}^{\bar{\sigma}} [1 - F_u(\tilde{\sigma})]^{I-1} d\tilde{\sigma}}{\sigma_u(\phi_{jt})\left[1 - F_u(\sigma_u(\phi_{jt}))\right]^{I-1}}. \quad (14)$$

We can interpret $\delta_u \geq 1$ as the bid markup relative to the opportunity cost. When $\delta_u = 1$, each firm's optimal bid equals its opportunity cost, so each firm makes zero economic profit from receiving a procurement contract. As the number of auction participants I declines, δ_u rises, so firms that receive procurement contracts extract greater profits in the government market when there is less competition. Since Z_{jt} exceeds $\sigma_u(\phi_{jt})$ due to finite I and the bidding strategy $s_u(\phi_{jt})$ is strictly increasing in the opportunity cost $\sigma_u(\phi_{jt})$, equation (14) defines the unique symmetric equilibrium (Milgrom and Weber, 1982; Maskin and Riley, 1984).[11] Finally, the winner of the auction is determined as

$$D_{jt} = 1\left\{s_u(\phi_{jt}) < s_u(\phi_{j't}),\ \forall j' \neq j \text{ such that } j, j' \in \mathcal{J}_\iota\right\}, \quad (15)$$

where $\mathcal{J}_\iota$ is the set of firms participating in auction ι. This expression makes clear that the winner of a procurement contract is selected on TFP.

arbitrarily persistent within a firm over time.

[11] One potential concern with our model of bids is that firms may collude to achieve bid revenues greater than those predicted by our first-price sealed-bid auction model. In Online Appendix Figure A.1, we apply the collusion test of Chassang et al. (2019) to each of the 28 states in our data separately, finding no evidence of collusion.

Before proceeding, it is useful to note that we have assumed auctions are symmetric. Though this assumption will not be crucial for our identification strategy discussed below, it is convenient for expositional and computational purposes, as symmetric auctions are easier to solve. Furthermore, symmetry is a standard assumption in the empirical auction literature (Athey and Haile, 2007). Nevertheless, in our empirical application, we provide a robustness check which relaxes this symmetry assumption.

2.4 Worker and Firm Rents

Given the specification of the labor and product markets above, we can now define the surplus or rents that firms and their workers accrue. We focus both on the total rents from production for the private market (in the absence of procurement projects) and the additional rents generated from receiving a procurement contract or, equivalently, the incidence of government procurement.

Rents for workers

Our concept of worker rents is defined as the excess return over that required to change the worker's choice of employer, as in Robinson (1933) and Rosen (1986). Denote worker i's preferred firm at time t excluding j as j_t^*. The equivalent variation (EV) of worker i for an exogenous wage increase at firm j, denoted V_{ijt}, is the solution to:

$$\underbrace{\max\left\{\begin{array}{c}\log \widetilde{W}_{jt} + g_{jt} + \eta_{ijt},\\ \log W_{j_t^* t} + g_{j_t^* t} + \eta_{ij_t^* t}\end{array}\right\}}_{\text{utility with wage increase at firm } j} = \underbrace{\max\left\{\begin{array}{c}\log\left(W_{jt} + V_{ijt}\right) + g_{jt} + \eta_{ijt},\\ \log\left(W_{j_t^* t} + V_{ijt}\right) + g_{j_t^* t} + \eta_{ij_t^* t}\end{array}\right\}}_{\text{equivalent utility at the initial choice of firm}}.$$

The EV is the amount of compensation the worker would require at the initial choice of firm (right-hand side) to attain the same utility that the worker receives after the wage increase at firm j (left-hand side). There are two cases. If j is the worker's initial choice of firm, then $V_{ijt} = \widetilde{W}_{jt} - W_{jt}$. This is because the worker is an incumbent at firm j, so the wage gain at j is the equivalent amount of compensation required. If $j_t^* \neq j$ is the worker's initial choice of firm, V_{ijt} is more complicated, as it must account for the differences in both wages and amenities between firms j and j_t^* at t.

Letting $V_{jt} \equiv \sum_i V_{ijt}$ denote the total EV at firm j in year t, it follows from Theorem 2 of Bhattacharya (2015) that

$$V_{jt} = \int_{W_{jt}}^{\widetilde{W}_{jt}} L_{jt}^*(W)dW, \tag{16}$$

where $L_{jt}^*(\cdot)$ is firm j's labor supply curve, which depends only on the wage at firm j under the assumption that each firm is strategically small. From our labor supply curve (equation 2),

$$V_{jt} = \frac{\widetilde{W}_{jt}\widetilde{L}_{jt} - W_{jt}L_{jt}}{1 + 1/\theta} = \frac{\widetilde{B}_{jt} - B_{jt}}{1 + 1/\theta}, \tag{17}$$

where $L_{jt} = L_{jt}^*(W_{jt})$ is the initial labor, $\widetilde{L}_{jt} = L_{jt}^*(\widetilde{W}_{jt})$ is labor after the wage increase, $B_{jt} = W_{jt}L_{jt}$ is the initial wage bill, and $\widetilde{B}_{jt} = \widetilde{W}_{jt}\widetilde{L}_{jt}$ is the wage bill after the wage increase. See Online Appendix A.3 for the derivation. Intuitively, V_{jt} can be interpreted as the willingness-to-pay to stay at the current firm, which is greater when horizontal employer differentiation is more important (i.e., when θ is greater).[12]

There are two distinct sources of V_{jt}. The first is the baseline worker rents if the firm does not receive a procurement contract, given by $V_{0jt} \equiv \frac{B_{0jt}}{1+1/\theta}$. It can be obtained from equation (17) by setting $W_{jt} = 0$ (the wage at which firm j shuts down production) and $\widetilde{W}_{jt} = W_{0jt}$ (the wage at firm j if it does not hold a procurement contract). The second is the additional rents captured by workers due to working at a firm that wins a procurement contract, given by $V_{\Delta jt} \equiv \frac{B_{1jt} - B_{0jt}}{1+1/\theta}$, where subscripts 1 and 0 denote holding and not holding procurement contracts, as above. This can be obtained from equation (17) by setting $W_{jt} = W_{0jt}$ (the wage at firm j if it does not hold a procurement contract) and $\widetilde{W}_{jt} = W_{1jt}$ (the wage at firm j if it holds a procurement contract). For completeness, we also define the total rents to workers if

[12]Note that B_{jt} is a function of $1/\theta$, so these expressions do not imply that rents increase for workers as labor supply becomes more inelastic. In our counterfactual exercises below, we will show that worker rents decrease when labor supply becomes more inelastic due to the wage bill decrease.

the firm holds a procurement contract V_{1jt}, so that

$$\underbrace{V_{1jt}}_{\text{Total rents}} = \underbrace{V_{0jt}}_{\text{Baseline rents}} + \underbrace{V_{\Delta jt}}_{\text{Incidence}} = \underbrace{\frac{B_{0jt}}{1+1/\theta}}_{\text{Baseline rents}} + \underbrace{\frac{B_{1jt}-B_{0jt}}{1+1/\theta}}_{\text{Incidence}}. \tag{18}$$

We can further decompose $V_{\Delta jt}$ into the additional rents captured by incumbent workers and additional rents captured by new hires drawn into firm j by the wage increase:[13]

$$\underbrace{V_{\Delta jt}}_{\text{Incidence}} = \underbrace{L_{0jt}\left(W_{1jt}-W_{0jt}\right)}_{\text{Incidence for incumbents}} + \underbrace{W_{1jt}\left(L_{1jt}-L_{0jt}\right) - \frac{B_{1jt}-B_{0jt}}{1+\theta}}_{\text{Incidence for new hires}}. \tag{19}$$

The incidence for incumbents is the wage change multiplied by the number of incumbent workers. The incidence for new hires is the wage bill of new hires minus the wage bill required to make them indifferent between the new and initial firm choices.

Rents for firms

As our measure of firm rents, we use profits. There are three relevant measures of profits. First, π_{0jt} is the profit that the firm captures from production for the private market if it does not receive a procurement contract. Second, π_{1jt} is the profit the firm captures from joint production for the government and private markets if it receives the procurement contract. Third, $\pi_{\Delta jt} \equiv \pi_{1jt} - \pi_{0jt}$ is the additional rents earned by the firm from receiving the procurement contract. They are related by

$$\underbrace{\pi_{1jt}}_{\text{Total firm rents}} = \underbrace{\pi_{0jt}}_{\text{Baseline firm rents}} + \underbrace{\pi_{\Delta jt}}_{\text{Incidence on firms}}. \tag{20}$$

It is important to observe that profits do not necessarily represent ex-ante rents for the employer. Suppose, for example, that each employer initially invests in amenities

[13] To clarify, an "incumbent" is a worker whose preferred firm is j even if j does not hold a procurement contract (i.e., a worker who accepts offered wage W_{0jt} by firm j). A "new hire" is a worker whose preferred firm is $j_t^* \neq j$ if j does not hold a procurement contract and whose preferred firm is j if j holds a procurement contract (i.e., a worker who accepts offered wage W_{1jt} but rejects offered wage W_{0jt} by firm j).

offered to the workers by deciding on the firm's location or working conditions. Workers' heterogeneous preferences over those amenities give rise to wage-setting power, which employers can use to extract additional profits or rents. Thus, the existence of such ex-post rents could simply be returns to costly ex-ante choices of amenities. Additionally, profits from procurement projects may in part reflect a fixed cost of entry to the auction, e.g., the cost of obtaining a license. While the presence of a fixed entry cost will affect the interpretation of profits, it will not affect identification of model parameters.

3 Data

Our empirical analyses are based on a matched employer-employee panel data set for the period 2001-2015. The data set is constructed by first linking business tax returns to worker-level tax returns, and then merging this linked data set with procurement auction records. In this section, we briefly describe data sources, sample selection, and key variables. Additional details are provided in Online Data Supplement S.

Our business tax return data include balance sheet and other information from Forms 1120 (C-corporations), 1120S (S-corporations), and 1065 (partnerships). We link the business tax returns to Form W-2 (direct employee) and 1099 (independent contractor) worker-level tax returns, defining the highest-paying firm in a given year as the worker's primary employer. Our baseline set of workers consists of prime-aged W-2 employees who are full-time equivalent (FTE), by which we mean that their annual earnings from the primary employer are greater than the annualized full-time minimum wage in the year. Because firms sometimes use independent contractors, we also consider a broader measure of the workforce that includes any FTE independent contractors from Form 1099.

The key variables that we draw from the business tax returns are revenues, intermediate input expenditures, profits, and NAICS industry codes. Revenues include those from business operations, excluding non-business-operation revenues such as dividends and capital gains. We follow De Loecker et al. (2020) in measuring intermediate input expenditures by the cost of goods sold, which includes variable costs associated with intermediate goods, transportation, and storage while excluding costs associated with overhead, durables, and labor.[14] Our measure of profits is earnings before interest, taxes, and depreciation (EBITD), which we construct following Kline et al. (2019).

The key variables we draw from worker-level tax returns are the number of employees and their earnings for the primary sample of workers. We also consider the number of employees and earnings when including independent contractors in the sample. Using the panel structure of the employer-employee data, we define three measures of mean earnings: mean earnings among all workers; mean earnings among stayers, which we define as workers employed at the same firm consistently from n years prior to the procurement auction until n years after; and past earnings of new hires at their previous firm, which we define as mean earnings at $t-1$ for workers who become employed by a new firm at t.

We obtain the new data set on procurement auctions by scraping the website of Bid Express (BidX.com), a service that facilitates online bidding for a number of states; scraping state-specific Department of Transportation (DOT) websites; and submitting FOIA requests to state governments. The procurement projects broadly involve the construction and landscaping of local roads, bridges, and highways. Observations in this data set are at the auction-firm level, with variables on firm's name and address as well as the firm's bid and the auction date. In total, we recover the auction records from the DOTs of 28 states.[15] Construction firms often bid in auctions in other states, so our auction sample includes construction firms from nearly every state.[16] Our data show that these 28 DOTs allocated \$383 billion through 155,768 distinct auctions involving 16,697 bidders in 2010. There are more auctions than firms, and the same firms may face one another in multiple auctions.[17] One potential concern is

[14] A potential concern is that firms in some industries (manufacturing and mining) include labor costs in the cost of goods sold. However, we consider firms in the construction industry, which do not (IRS Pub. 334).

[15] Online Data Supplement S.1 provides step-by-step instructions on obtaining and preparing the auction records.

[16] In our data from BidX, we observe the firm's business address as well as the address of the procurement project. In the BidX data, we find that 80 percent of bids are placed in auctions in the firm's home state and 21 percent of bids are placed in auctions in the firm's home commuting zone. In the empirical analyses, we provide robustness checks in which we control for auction-specific effects or commuting zone-specific effects, finding little sensitivity of the estimates.

[17] We find that, conditional on facing one another at least once, there is about a 50 percent chance

that, because firms face one another multiple times, they may collude to achieve bid revenues greater than those predicted by our first-price sealed-bid auction model. In Online Appendix Figure A.1, we apply the collusion test of Chassang et al. (2019) to each of the 28 states in our data separately, finding no evidence of collusion in any state.

The DOTs are responsible for determining the nature of the project, including the blueprints, a detailed list of tasks to be performed or items to be constructed, quality guidelines and standards, and expected or required time to completion. This information is publicly available in the solicitation for bidders posted by each DOT. The awarding of a contract has two steps. The first step is qualification. In order to submit a bid, a firm must be pre-qualified by the DOT to ensure sufficient experience, equipment, and competence to carry out the tasks involved. Once approved, the firm is awarded a license to bid. The second step is the auction. In the first-price sealed-bid auction, a qualified firm submits a bid without observing the bidding behavior of other firms, and the contract is awarded to the lowest bidder.

We observe the bid of each firm for a given auction, not only the winner.[18] In the empirical applications discussed below, we will focus on recipients of procurement contracts ($D_{jt} = 1$) who win a procurement auction for the first time at t. The mean procurement revenues for these first-time auction winners is $2.7 million. We compare them to non-recipients ($D_{jt} = 0$) that had never won an auction before t and placed a bid at t but lost. These sample restrictions are useful as they ensure that neither type of firm experiences a procurement demand shock in the pre-period. As a robustness check, we consider a number of alternative sample restrictions.[19]

To merge the auction data to the tax records, we use a fuzzy matching approach

that two firms face one another again in the future.

[18]In the event that the firm that wins the procurement contract hires a contractor to complete the work, this will be captured in our measure of labor that includes contractors from Form 1099. In the event that the firm that wins the procurement contract passes the contract to a subcontractor, the completed work is sold to the primary contractor as intermediate inputs and thus captured in our intermediate inputs measure.

[19]Some possibilities are to restrict the $D_{jt} = 0$ sample to firms that had never bid in an auction prior to t ("first-timers") or firms that would not go on to win an auction in the future ("never-winners"). In Figure 1, we will show that the labor supply elasticity estimates are nearly the same when using these comparison samples. Several other comparison sample choices are discussed in the text.

based on the firm's name and location. For six states, we were able to not only obtain the name and address but also the federal Employer Identification Number (EIN) of the firm, allowing us to perform an exact match to tax records. We trained the algorithm on these six states before applying it to the other 22 states.[20] We also provide an out-of-sample validation analysis in which we test the performance of the matching algorithm on publicly available pension data tax filings, finding that it performs well. Furthermore, we verify that our labor supply elasticity estimate does not change materially if we restrict the sample to the six states matched on EIN.

Online Appendix Table A.2 displays the sample sizes of firms and workers that participate in auctions in the year 2010. In 2010, our sample includes almost 8,000 unique firms that generate over $150 billion in annual revenues and employ about 360,000 full-time workers. Nearly all the firms are recorded as being in the construction industry (i.e., the firms have NAICS codes beginning with 23). As a share of the national construction industry (as recorded in the 2010 tax records), our sample of 8,000 firms accounts for 12 percent of sales, 12 percent of employment, 10 percent of EBITD, 12 percent of intermediate input expenditures, and 13 percent of wage payments. The state-specific sample size and share of the local economy represented by auction participants linked to tax records are displayed in Online Appendix Table A.1. California, Michigan, and Texas are the states with the most bidding firms, while Iowa, Kansas, and Montana are the states in which bidders employ the greatest share of workers in the construction industry.

4 Identification of Model Parameters

4.1 Labor Supply Elasticity

Recall from equation (3) that the inverse labor supply curve is given by $w_{jt} = \theta\ell_{jt} + u_{jt}$. Our goal is to identify the labor supply elasticity, $1/\theta$. To see why this is challenging, consider a cross-sectional regression of w_{jt} on ℓ_{jt}. This regression may result in a biased estimate of θ because both w_{jt} on ℓ_{jt} depend on time-invariant firm-specific

[20]Online Data Supplement S.2 explains how we trained and validated the linking algorithm used to merge the auction records to the tax returns.

amenities (ψ_j). Instead, one might consider taking differences over time, denoted by Δ, in order to eliminate ψ_j. As evident from equation (4), a regression of Δw_{jt} on $\Delta \ell_{jt}$ may be biased due to each variable depending on the change in firm-specific amenities ($\Delta \nu_{jt}$) and aggregate labor supply shocks ($\Delta \xi_t$).

To address these sources of bias, we will control for time fixed effects and use the assignment of procurement contracts, D_{jt}, as an observable shifter of product demand. We now consider two ways to use such an approach to trace out the labor supply curve.

Identification based on timing of information

The first estimator of θ that we will use is based on a restriction on the timing of information:

Assumption 1. *Suppose the firm-specific amenity shock $\Delta \nu_{jt}$ is not in the information set of the firm when bidding in the first stage of time period t, and $\Delta \nu_{jt}$ is independent of the other determinants of bidding at t, $(\phi_{jt}, \psi_j, \xi_t)$.*

This assumption implies that firms place their bids Z_{jt} in the first stage of period t, then learn the auction outcome D_{jt} and the firm-specific amenity shock $\Delta \nu_{jt}$ in the second stage and choose labor. It also ensures that the current labor supply shock is not predictable from other information considered when selecting bids, $(\phi_{jt}, \psi_j, \xi_t)$. Assumption 1 follows the large literature on production function estimation that achieves identification through restrictions on the timing of information (see the discussions by Ackerberg et al. 2015 and Gandhi et al. 2020).

Assumption 1 implies independence between the bids Z_{jt} and the firm-specific amenity shocks $\Delta \nu_{jt}$, allowing us to derive the following proposition:

Proposition 1. *Consider an instrumental variables estimator of the form*

$$\theta_{IV} \equiv \frac{Cov\left[\Delta w_{jt}, D_{jt}\right]}{Cov\left[\Delta \ell_{jt}, D_{jt}\right]}.$$

Under Assumption 1 and the rank condition $Cov\left[\Delta \ell_{jt}, D_{jt}\right] \neq 0$, θ_{IV} recovers θ.

Proof. By equation (4),

$$\theta_{\text{IV}} = \underbrace{\frac{\text{Cov}\left[\theta\Delta\ell_{jt}, D_{jt}\right]}{\text{Cov}\left[\Delta\ell_{jt}, D_{jt}\right]}}_{=\theta} + \underbrace{\frac{\text{Cov}\left[\Delta\nu_{jt}, D_{jt}\right]}{\text{Cov}\left[\Delta\ell_{jt}, D_{jt}\right]}}_{=0} + \underbrace{\frac{\text{Cov}\left[\Delta\xi_{t}, D_{jt}\right]}{\text{Cov}\left[\Delta\ell_{jt}, D_{jt}\right]}}_{=0} = \theta,$$

where the second term is zero by Assumption 1 and the third term is zero because $\Delta\xi_t$ is the same for all firms in the market in each period t. To see why the rank condition is expected to hold in our context (and, indeed, we find that it holds in the data), note that if $\epsilon > 0$, then ℓ_{jt} depends directly on D_{jt} in the firm's problem, all else equal. □

It is important to observe what is and is not restricted under Assumption 1. First, Assumption 1 does not impose any additional restrictions on the relationships among the variables $(Z_{jt}, D_{jt}, \phi_{jt}, \psi_j, \xi_t)$. In other words, Assumption 1 does not restrict how bids, TFP, time-invariant firm-specific amenities, and market-wide labor supply shocks covary. Second, Assumption 1 permits $\text{Var}\left[\Delta\nu_{jt}\right] > 0$, so it allows for firm-specific amenities to vary over time. This is less restrictive than much of the existing literature on identifying the labor supply curve, which requires that firm-specific amenities are constant within the estimation window (see the discussion by Lamadon et al. 2021). Third, Assumption 1 does not impose that there is a time delay in the responses of $\Delta\ell_{jt}$ and Δw_{jt} to $\Delta\nu_{jt}$. Thus, labor supply and wages are allowed to respond contemporaneously to firm-specific amenity shocks. However, Assumption 1 does restrict the dependence of Z_{jt} and thereby D_{jt} on $\Delta\nu_{jt}$, which may be reasonable since there is typically a time delay between the procurement solicitation for bids and the commencement of production on the government project.

Identification based on close bid comparisons

To relax Assumption 1, we take advantage of the data on bids.[21] For a firm j that bids in auction ι at time t, define the loss margin as $\tau_{jt} \equiv \frac{Z_{jt} - Z_\iota^*}{Z_\iota^*}$, where Z_ι^* is the winning bid in auction ι. We have the following proposition:

[21] See Online Appendix Figure A.2 for a visual representation of the difference between Propositions 1 and 2 in the assumed timing of information.

Proposition 2. *Consider an IV estimator of the form*

$$\theta_{\overline{\tau}} \equiv \frac{\mathbb{E}\left[\Delta w_{jt}|\tau_{jt}=0\right]-\mathbb{E}\left[\Delta w_{jt}|0<\tau_{jt}\leq\overline{\tau}\right]}{\mathbb{E}\left[\Delta \ell_{jt}|\tau_{jt}=0\right]-\mathbb{E}\left[\Delta \ell_{jt}|0<\tau_{jt}\leq\overline{\tau}\right]}, \tag{21}$$

where $\overline{\tau}$ is a proximity parameter and the conditioning on ι is implicit. Under the rank condition $\mathbb{E}\left[\Delta\ell_{jt}|\tau_{jt}=0\right] \neq \lim_{\overline{\tau}\to 0^+}\mathbb{E}\left[\Delta\ell_{jt}|0<\tau_{jt}\leq\overline{\tau}\right]$, $\lim_{\overline{\tau}\to 0^+}\theta_{\overline{\tau}}$ recovers θ.

Proof. Since these are price-only auctions, winning the auction is fully determined by the observed bids Z_{jt}. Thus, D_{jt} must be independent of $\Delta\nu_{jt}$ conditional on Z_{jt}, i.e., the amenity shocks cannot affect which firm wins an auction conditional on the bids. Since bids of winners and losers converge as $\overline{\tau}\to 0^+$,

$$\lim_{\overline{\tau}\to 0^+}\theta_{\overline{\tau}} = \theta + \lim_{\overline{\tau}\to 0^+}\frac{\mathbb{E}\left[\Delta \nu_{jt}|\tau_{jt}=0\right]-\mathbb{E}\left[\Delta \nu_{jt}|0<\tau_{jt}\leq\overline{\tau}\right]}{\mathbb{E}\left[\Delta \ell_{jt}|\tau_{jt}=0\right]-\mathbb{E}\left[\Delta \ell_{jt}|0<\tau_{jt}\leq\overline{\tau}\right]} = \theta,$$

where the second term is zero because, by independence of D_{jt} and $\Delta\nu_{jt}$ conditional on Z_{jt}, $\mathbb{E}\left[\Delta\nu_{jt}|D_{jt}=1,Z_{jt}\right]=\mathbb{E}\left[\Delta\nu_{jt}|D_{jt}=0,Z_{jt}\right]$, which implies $\mathbb{E}\left[\Delta\nu_{jt}|\tau_{jt}=0\right]=\lim_{\overline{\tau}\to 0^+}\mathbb{E}\left[\Delta\nu_{jt}|0<\tau_{jt}\leq\overline{\tau}\right]$. To see why the rank condition is expected to hold in our context (and, indeed, we find that it holds in the data), note that if $\epsilon>0$, then ℓ_{jt} depends directly on D_{jt} in the firm's problem, all else equal. □

The key assumption behind Proposition 2 is that the amenity shocks cannot affect which firm wins an auction conditional on the bids. This assumption should arguably hold in the price-only auctions we consider. However, an estimation challenge is that winners and losers of auctions do not have infinitesimally close bids, so we cannot find the perfect match using the limit as $\overline{\tau}$ approaches zero. We consider two alternative estimation approaches. The first is a nearest neighbors estimator in which we choose a small (but not infinitesimal) value of $\overline{\tau}$ while controlling for time-invariant auction and firm characteristics as well as time fixed effects. The choice of neighbor proximity $\overline{\tau}$ faces the usual bias-variance trade-off, as smaller $\overline{\tau}$ has less bias but more variance due to the loss in sample size. The second estimation approach uses a linear regression where we control flexibly for bids, while also controlling for time-invariant auction and firm characteristics as well as time fixed effects. In this approach, we consider a third-order polynomial to control for τ_{jt}. However, results are robust to choosing a lower or higher order of the polynomial.

4.2 Product demand curve

Our goal in this subsection is to identify the private product market demand elasticity, $1/\epsilon$. We will rely on equation (12), which expresses private market log revenues r_{jt}^H in terms of log intermediate input expenditures x_{jt} and the output quantity shock e_{jt} among firms that do not hold procurement contracts ($D_{jt} = 0$). Consider the following assumption:

Assumption 2. *The output quantity shock is orthogonal to log intermediate input expenditures among firms without procurement contracts,* $Cov\left[e_{jt}, x_{jt}|D_{jt} = 0\right] = 0$.

Assumption 2 is true under a standard timing assumption from the literature (Ackerberg et al., 2015): firms choose intermediate inputs in the second stage of period t before they observe the idiosyncratic shock to output at the end of period t (see the more general discussion of timing assumptions by Gandhi et al. 2020).[22] It can also be justified by the assumption that e_{jt} is measurement error: from the perspective of the firm, $r_{jt}^H = \kappa_R + (1-\epsilon)\, x_{jt}$ does not have an error, but the error appears to the econometrician in equation (12) due to issues with measuring and reporting revenues in tax data, giving rise to e_{jt}. This leads to the following proposition:

Proposition 3. *Consider a regression of log revenues on log intermediate input expenditures among firms not holding procurement contracts, i.e.,*

$$\widehat{1-\epsilon} \equiv \frac{Cov\left[r_{jt}, x_{jt}|D_{jt} = 0\right]}{Var\left[x_{jt}|D_{jt} = 0\right]}. \tag{22}$$

Given Assumption 2 and the rank condition $Var\left[x_{jt}|D_{jt} = 0\right] > 0$, $\widehat{1-\epsilon}$ *recovers* $1-\epsilon$.

Proof. By equation (12),

$$\widehat{1-\epsilon} = \underbrace{\frac{\text{Cov}\left[(1-\epsilon)\, x_{jt}, x_{jt}|D_{jt} = 0\right]}{\text{Var}\left[x_{jt}|D_{jt} = 0\right]}}_{=1-\epsilon} + \underbrace{\frac{\text{Cov}\left[(1-\epsilon)\, e_{jt}, x_{jt}|D_{jt} = 0\right]}{\text{Var}\left[x_{jt}|D_{jt} = 0\right]}}_{=0} = 1-\epsilon,$$

where the second term is zero by Assumption 2. To see why the rank condition is expected to hold in our context (and, indeed, we find that it holds in the data), note

[22] See Online Appendix Figure A.2 for a visual representation of the assumed timing of information.

that x_{jt} varies across $D_{jt} = 0$ firms due to, e.g., variation in ϕ_{jt}. □

To complete the identification of the product demand curve, we now show how to recover p_H. Rearranging equation (12), we have

$$\log p_H = \mathbb{E}[r_{jt} - (1-\epsilon)x_{jt}|D_{jt} = 0] - (1-\epsilon)\log\left(\beta_M/p_M\right), \tag{23}$$

where we normalize $\mathbb{E}\left[e_{jt}|D_{jt} = 0\right] = 0$ without loss of generality. Thus, we recover p_H given ϵ and β_M/p_M, the latter of which is recovered in the next subsection.

4.3 Firm Technology

In this subsection, our goal is to identify the composite returns to labor ρ, as well as the production parameters β_L, β_K, and β_M/p_M. The identification challenge is that log TFP, ϕ_{jt}, is an unobserved determinant of intermediate input expenditures in equation (11), and ℓ_{jt} depends directly on TFP, as shown in Online Appendix A.2. Thus, a regression of x_{jt} on ℓ_{jt} will fail to recover ρ due to the correlated unobservable ϕ_{jt}.

Instead, we propose to invert the bidding strategy to control for TFP. Given the equilibrium bidding strategy $Z_{jt} = s_{u_{jt}}(\phi_{jt})$ from equation (14), where s is monotonic in ϕ_{jt} given u_{jt}, we can write the inverse equilibrium bidding strategy as $\phi_{jt} = s^{-1}_{u_{jt}}(Z_{jt})$. Monotonicity ensures that $s^{-1}_{u_{jt}}$ is unique and ϕ_{jt} is pinned down by the bids Z_{jt}, conditional on the amenities u_{jt}. Given any consistent estimator $\widehat{\theta}$ of θ, an estimator for u_{jt} is

$$\widehat{u}_{jt} = w_{jt} - \widehat{\theta}l_{jt}. \tag{24}$$

We have the following result:

Proposition 4. *Consider a regression of x_{jt} on ℓ_{jt} controlling for $(\widehat{u}_{jt}, Z_{jt})$, i.e.,*

$$\widehat{\rho} \equiv \frac{Cov\left[x_{jt}, \ell_{jt}|\widehat{u}_{jt}, Z_{jt}\right]}{Var\left[\ell_{jt}|\widehat{u}_{jt}, Z_{jt}\right]}. \tag{25}$$

Given that $\widehat{\theta}$ recovers θ and the rank condition $Var\left[\ell_{jt}|\widehat{u}_{jt}, Z_{jt}\right] > 0$, $\widehat{\rho}$ recovers ρ.

Proof. By equation (11),

$$\widehat{\rho} = \underbrace{\frac{\text{Cov}\left[\rho\ell_{jt}, \ell_{jt}|\widehat{u}_{jt}, Z_{jt}\right]}{\text{Var}\left[\ell_{jt}|\widehat{u}_{jt}, Z_{jt}\right]}}_{=\rho} + \underbrace{\frac{\text{Cov}\left[\phi_{jt}, \ell_{jt}|\widehat{u}_{jt}, Z_{jt}\right]}{\text{Var}\left[\ell_{jt}|\widehat{u}_{jt}, Z_{jt}\right]}}_{=0} = \rho,$$

where the second term is zero because $\text{Cov}\left[\phi_{jt}, \ell_{jt}|\widehat{u}_{jt}, Z_{jt}\right] = \text{Cov}\left[\phi_{jt}, \ell_{jt}|u_{jt}, \phi_{jt}\right]$ by the uniqueness of $\phi_{jt} = s_{u_{jt}}^{-1}\left(Z_{jt}\right)$ and that u_{jt} recovers $\widehat{u}_{jt}$ since $\widehat{\theta}$ recovers θ. To see why the rank condition is expected to hold in our context (and, indeed, we find that it holds in the data), note that if $\epsilon > 0$, then ℓ_{jt} depends directly on D_{jt} in the firm's problem, all else equal. As can be seen in equation (15), D_{jt} depends not only on u_{jt}, ϕ_{jt}, but also on the realized competitors' bids in the auction. Competitors' bids are unknown to the firm at the time it bids and thus not captured by the optimal bidding function. □

In practice, we implement this control function approach by controlling for auction fixed effects as well as third-order polynomials in $\log Z_{jt}$ and $\widehat{u}_{jt}$. The results do not change materially if we increase the polynomial order.

We now show how to recover β_L, β_K, and β_M/p_M given θ, ρ, and ϵ. Rearranging equation (13) and using that $Q_{0jt} = Q_{0jt}^H$, we recover β_L as[23]

$$\beta_L = \mathbb{E}\left[\frac{(1+\theta)\, B_{jt}}{(1-\epsilon)\, R_{jt} - X_{jt}}\bigg| D_{jt} = 0\right]. \tag{26}$$

From the definition of ρ, we recover β_K as $\beta_K = (\rho - \beta_L)\,/\,(1+\theta)$. From equation (11), we recover β_M/p_M as

$$\log(\beta_M/p_M) = \mathbb{E}[\rho\ell_{jt} - x_{jt}], \tag{27}$$

where we normalize $\mathbb{E}\left[\phi_{jt}\right] = 0$ without loss of generality.

[23]The right-hand side of equation (26) can be interpreted as the labor share of value added adjusted for imperfect competition in the labor and product markets. As $\theta \to 0$ and $\epsilon \to 0$, the right-hand side of equation (26) simplifies to the labor share of value added.

4.4 Over-identifying Restriction

We have demonstrated that $1/\epsilon$, ρ, and β_L are identified under Assumptions 1-2. An additional moment will allow us to over-identify $(1/\epsilon, \rho, \beta_L)$ and thus directly examine the validity of the model.

Among firms that hold procurement contracts, the profit-maximizing first-order condition corresponding to equation (13) implies

$$\Lambda_{jt} = \kappa_\Lambda + \rho \ell_{jt} + \phi_{jt} + e_{jt} \quad \text{if} \quad D_{jt} = 1. \tag{28}$$

where $\Lambda_{jt} \equiv \frac{\epsilon}{1-\epsilon} r^H_{jt} + \log\left(\frac{1+\theta}{\beta_L} B_{jt} + X_{jt}\right)$ and $\kappa_\Lambda \equiv \log(1-\epsilon) + \frac{\log p_H}{1-\epsilon}$. The derivation is provided in Online Appendix A.4. Given θ, for any candidate values of (ϵ, β_L), we can construct the left-hand side variable. Furthermore, note that for any candidate value of ρ, we can rearrange equation (11) to recover log TFP as

$$\widetilde{\phi}_{jt}(\rho) \equiv x_{jt} - \kappa_X - \rho \ell_{jt}. \tag{29}$$

We can then construct the covariance between ℓ_{jt} and the left-hand side of equation (28), which is a moment equation that depends only on the unknown parameters $(\epsilon, \rho, \beta_L)$, the TFP estimates $\widetilde{\phi}_{jt}(\rho)$, and the data. Thus, in addition to equations (22), (25), and (26), equation (28) gives us a fourth equation that must be satisfied by the true values of $(\epsilon, \rho, \beta_L)$. In practice, we estimate $(\epsilon, \rho, \beta_L)$ simultaneously in equations (22), (25), (26), and (28) using the general method of moments (GMM).

4.5 Rents and Incidence

We now show how to recover the total rents, baseline rents, and the incidence of procurement on firms and workers, focusing on the sample of firms with procurement contracts ($D_{jt} = 1$). From equation (18) and given that we identified θ above, we can characterize rents and incidence for workers if we recover B_{0jt} and B_{1jt} for each (j, t). From equation (20), we can characterize rents and incidence for firms if we recover π_{0jt} and π_{1jt} for each (j, t). For firms with $D_{jt} = 1$, we observe B_{1jt} and π_{1jt}, so the only remaining challenge is to recover B_{0jt} and π_{0jt}.

To recover B_{0jt} and π_{0jt}, we use the profit-maximizing first-order condition with respect to labor for the counterfactual in which the firm loses the procurement contract ($d = 0$), which is

$$\rho p_H (1-\epsilon) \Phi_{jt}^{1-\epsilon} L_{0jt}^{\rho(1-\epsilon)-1} = (1+\theta) \kappa_U U_{jt} L_{0jt}^{\theta} + \rho \frac{p_M}{\beta_M} \Phi_{jt} L_{0jt}^{\rho-1}, \tag{30}$$

where $\kappa_U \equiv \frac{\beta_K}{\beta_L}(1+\theta) + 1$. The derivation of equation (30) is provided in Online Appendix A.2. We identify $(\theta, \rho, \epsilon, p_H, \beta_M/p_M)$ above, and recover U_{jt} from equation (24) and Φ_{jt} from equation (29). Thus, we can numerically solve equation (30) to obtain L_{0jt} for each (j,t). Given L_{0jt}, it is then straightforward to recover B_{0jt} and π_{0jt} using the firm's constraints (equations 2, 8, 9, and 10).

5 Estimates of Model Parameters and Rents

We now combine the identification strategies in Section 4 with the data described in Section 3 to estimate the parameters that govern labor supply, product demand, and firm technology.

5.1 Labor Supply Elasticity

Empirical implementation. We now implement the baseline instrumental variables estimator θ_{IV} described in Section 4.1 using the data described in Section 3. The numerator of θ_{IV} is $\mathbb{E}[\Delta w_{jt}|D_{jt}=1] - \mathbb{E}[\Delta w_{jt}|D_{jt}=0]$ and the denominator is $\mathbb{E}[\Delta \ell_{jt}|D_{jt}=1] - \mathbb{E}[\Delta \ell_{jt}|D_{jt}=0]$. Each of these is a difference-in-differences (DiD) estimand, so we draw on the literature on DiD estimation to implement and interpret the IV estimator.

Consider the cohort of firms that receive a procurement contract in year t ($D_{jt} = 1$) and the set of comparison firms that bid for a procurement in year t but lose ($D_{jt} = 0$). Let e denote an event time relative to t. For each event time $e = -4, ..., 4$, our DiD estimation is implemented as

$$w_{jt+e} = \underbrace{\sum_{e' \neq \bar{e}} 1\{e' = e\}\, \mu_{te'}}_{\textit{event time fixed effect}} + \underbrace{\sum_{j'} 1\{j' = j\}\, \psi_{j't}}_{\textit{firm fixed effect}} + \underbrace{\sum_{e' \neq \bar{e}} 1\{e' = e\}\, D_{jt}\lambda_{te'}}_{\textit{treatment status by event time}} + \underbrace{\epsilon_{jte}}_{\textit{residual}}, \tag{31}$$

where λ_{te} recovers the numerator of θ_{IV} for a particular pair (e, t) and $\bar{e} = -2$ is the omitted event time.[24] The analogous regression in which ℓ_{jt+e} is the outcome recovers the denominator of θ_{IV}. We average across event times e to form the main estimate. Based on the patterns observed at annual frequency across e (see Online Appendix Figure A.8), we choose event times $e \in \{0, 1, 2\}$ as the post-treatment period. The pre-period event times can be used in falsification tests. The model predicts that both DiD estimands are zero in the pre-period. We fail to reject this null hypothesis in Online Appendix Figure A.3, consistent with the identifying assumption.

The baseline specification includes firm fixed effects. This removes any time-invariant characteristics of firms, such as the time-invariant firm-specific amenities (ψ_j) emphasized in Section 4.1, but also any other time-invariant characteristics of the firms, such as the identities of the auctions in which they participate.[25] However, this only controls for time-invariant characteristics in an additive fashion. In a robustness check discussed further below, we re-estimate the DiD estimator separately for each auction using a fully-interacted specification, finding similar estimates.

Estimates based on Proposition 1. The main estimate of the labor supply elasticity $1/\theta$ is displayed in the bar labeled "Baseline" in Figure 1. This estimate is based on Proposition 1 and is valid under the timing of firm-specific amenity shocks restriction in Assumption 1. The point estimate of the firm-specific labor supply elasticity is 4.08, which is statistically significant at the 0.01 level.[26] This indicates that, if

[24]We estimate λ_{te} for all t and e and then average across t, using the delta method to compute standard errors (which are clustered at the firm level j to account for serial correlation). By doing so, we avoid the problem pointed out by Callaway and Sant'Anna (2020) that cohorts can be negatively weighted in pooled cohort DiD estimators.

[25]The inclusion of event time fixed effects (μ_{te}) for each cohort ensures that the aggregate labor supply shocks ($\Delta\xi_t$) are controlled for (see Proposition 1).

[26]Statistical inference is based on 200 block bootstrap random draws with replacement from our sample, where a block is taken to be a firm.

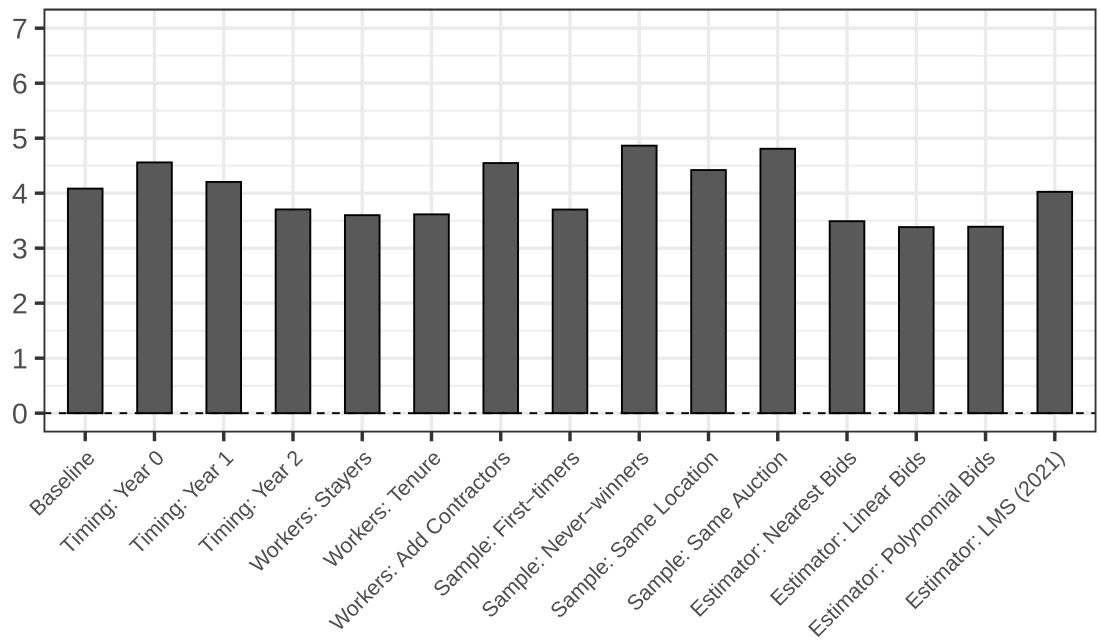


Figure 1: Labor Supply Elasticity: Baseline Estimate and Alternative Specifications

Notes: This figure presents the baseline estimate and sensitivity checks for the labor supply elasticity $1/\theta$. Specification details and sample definitions are provided in the text. Corresponding estimates of the wage markdown $(1/\theta)\,/\,(1+1/\theta)$ are provided in Online Appendix Figure A.4.

an American construction firm aims to increase the number of its employees by 10 percent, it needs to increase wages by around 2.4 percent. Our estimates are broadly comparable to existing work. Lamadon et al. (2021) estimate a labor supply elasticity of 4.6 using firm-level variation and Suárez Serrato and Zidar (2016) estimate a labor supply elasticity of 4.2 using state-level variation, while Card et al. (2018) pick 4.0 as the preferred value in their calibration exercise. A related literature using experimentally manipulated piece-rates for small tasks typically finds labor supply elasticities ranging from 3.0 to 5.0 (Caldwell and Oehlsen, 2018; Dube et al., 2020; Sokolova and Sorensen, 2018).

Estimates based on Proposition 2. The baseline IV estimates are based on the assumption that firms do not observe the firm-specific amenity shock ($\Delta\nu_{jt}$) when bidding. To relax this assumption, we can instead leverage the fact that whether or not a firm wins the procurement auction is determined solely by its bid. We proved in Proposition 2 that the nearest neighbors IV estimator $\theta_{\overline{\tau}}$ recovers θ without imposing restrictions on the timing of amenity shocks. This estimator compares procurement auction winners to losers that had small loss margins (by taking the parameter $\overline{\tau}$ to be small) while controlling for time-invariant auction and firm characteristics. In the bar labeled "Estimator: Nearest Bids" in Figure 1, we find for $\theta_{\overline{\tau}}$ a labor supply elasticity estimate of 3.5, which is very similar to the baseline estimate. Online Appendix Figure A.9 shows that the labor supply elasticity is relatively robust to the choice of $\overline{\tau}$. Note, however, that there are alternative approaches to implementing the IV estimator that conditions on bids. In the bars labeled "Estimator: Linear Bids" and "Estimator: Polynomial Bids" in Figure 1, we also consider linear regressions where we control for bids linearly or using a third-order polynomial, respectively, finding nearly identical estimates to the nearest bids estimator.

External sample validity using the LMS estimator. The approaches we considered so far have relied on procurement auctions to identify the labor supply elasticity. One potential concern is that firms that bid in auctions differ from the rest of the construction industry. In order to investigate this possibility, we consider the estimator of Lamadon et al. (2021, LMS), which uses lagged revenue changes as instruments. The LMS estimator can be justified either if firm-specific amenities are fixed over the estimation window or if TFP shocks are more persistent than firm-specific amenity shocks.[27] Importantly, revenue shocks are defined for all firms in the construction industry, not only for firms that participate in auctions, so they can be used to assess the representativeness of the subsample of firms that participate in auctions. The bar labeled "Estimator: LMS" in Figure 1 shows that, when applying the LMS estimator to the entire construction industry, we find a labor supply elasticity of 4.0, which is nearly the same as the baseline estimate.

[27] Proposition 5 of Online Appendix D provides the formal conditions for identification using the LMS estimator.

Sensitivity to adjustment costs. A possible threat to identification is adjustment costs: If labor enters the firm slowly over time rather than immediately when the new wage is posted, the short-run relation between wages and quantity of labor may understate the labor supply elasticity, resulting in downward-bias of $1/\theta$. While our "Baseline" specification averages estimates across three event years, the bars labeled "Timing: Year 0", "Timing: Year 1", and "Timing: Year 2" in Figure 1 provide estimates separately for the announcement event year ($e = 0$) as well as the subsequent two event years ($e = 1, 2$). We find approximately the same labor supply elasticity estimates, suggesting adjustment costs are relatively unimportant in our setting.

Sensitivity to worker composition changes. Our identification of $1/\theta$ relies on the argument that receiving a procurement contract shifts the firm's demand for labor along the labor supply curve. One potential reason this argument may fail is skill-upgrading: If earnings per worker increase for the winning firm in part because new hires are more productive, the estimator will include a bias related to the change in worker composition. To investigate this, we consider restricting worker mobility in two ways. First, the bar labeled "Workers: Stayers" in Figure 1 only considers earnings changes among workers who stay in the same firm before and after the auction announcement. Second, the bar labeled "Workers: Tenure" in Figure 1 only considers earnings changes among workers who had at least two years of tenure in the firm before the auction announcement.[28] The estimates are nearly the same when imposing these worker restrictions, indicating that there is no skill-upgrading bias in our context.[29] Another possibility is that firms disproportionately hire independent contractors in order to complete procurement contracts, and independent contractors may have a different labor supply elasticity from formal employees. We find in the bar labeled "Workers: Add Contractors" that the labor supply elasticity is quite similar when including independent contractors in the sample of workers.

[28]In Online Appendix Figure A.5, we show that these results are insensitive to the number of years used in defining stayer or tenured worker samples.

[29]As an alternative way of investigating this issue, we consider earnings at previous firms as a proxy for worker quality of new hires. We find that the average previous earnings of new hires does not experience a statistically significant change in response to winning a procurement auction (p-value about 0.5), which is again consistent with no skill-upgrading in our context.

Sensitivity to local market shocks. Our identification strategy controls for the aggregate labor supply shocks ($\Delta\xi_t$) by controlling for time-specific fixed effects under the assumption that winners and the losers of the procurement auction experience the same aggregate shock. However, if more procurement contracts are awarded in local labor markets with worse labor supply shocks, this could induce correlation between local aggregate labor supply shocks and procurement contracts. We can address this issue by comparing procurement contract winners and losers in the same market, as firms in the same local market are by definition subject to the same local aggregate shocks. In the bars labeled "Sample: Same Location" and "Sample: Same Auction" in Figure 1, we control for local labor supply shocks by only comparing firms in the same commuting zone or the same auction, respectively. We find nearly the same labor supply elasticity estimates under these restrictions on the comparison group, indicating local aggregate shocks do not confound our baseline estimates.

Sensitivity to unionization and prevailing wage laws. Another potential concern is that unions or prevailing wage laws confound the estimates of the labor supply elasticity. However, a prevailing wage law would only be expected to impact wage changes under an unusual set of circumstances. First, the firm must have initial wages below the prevailing wage, while our model predicts that procurement contracts are disproportionately won by high-productivity and high-wage firms. Second, even if the firm's initial wage were below the prevailing wage, it could still be that the new wage after winning the procurement contract meets or exceeds the prevailing wage due to the upward-sloping labor supply curve (i.e., the prevailing wage may not bind for the wage increase). Third, the procurement contract must be funded by the federal government (to be covered by the federal Davis-Bacon Act) or by a state with its own prevailing wage laws. Even if a prevailing wage law applies, Duncan and Ormiston (2019) survey the empirical literature and find that prevailing wage laws have no impact on construction firms that win procurement contracts. To investigate this issue in our context, we examine the sensitivity of our estimates to heterogeneity across states in coverage by prevailing wage and right-to-work laws. The results are displayed in Online Appendix Figure A.6. Wage bill and employment responses are nearly identical across these types of states, implying similar labor supply elasticities across state-level prevailing wage or right-to-work coverage.

Sensitivity to labor hours and full-time status. A potential concern is that we measure earnings changes rather than hourly wage changes. If part of the earnings change is due to an increase in hours, then we overstate the wage increase relative to the labor increase, leading to a downward-biased estimate of the labor supply elasticity, $1/\theta$. We now investigate this possibility.

One natural way to increase hours is to promote part-time workers to full-time status. However, part-time employment is rare in the construction industry: in 2015, 13.9 percent of all US private sector workers were part-time but only 4.6 percent of construction industry workers were part-time (BLS, 2021). To better understand the relationship between full-time employment status and annual earnings, we analyze CPS ASEC cross-sectional random samples of the US labor force, which include measures of hours worked and annual earnings. In the 2001-2015 ASEC samples, 6.4 percent of construction workers are part-time employed, compared to 11.9 percent across all industries. When imposing in the ASEC samples our FTE restriction that annual earnings from the primary employer are greater than the annualized full-time minimum wage, only 4.4 percent of the remaining construction sample is part-time employed, compared to 7.1 percent across all industries. Thus, the FTE restriction removes a substantial share of part-time employees from the ASEC samples.

Nevertheless, one may worry that promotions from part-time to full-time employment in response to winning a procurement contract explain our estimated increase in earnings per worker. To investigate this, we consider again the stayers sample described above. Since stayers are defined as workers who were already FTE before the procurement contract was received and remained FTE after, stayers could not have been promoted from non-FTE to FTE status in response to winning the procurement contract. We find almost the same estimates for the stayers sample as we do for the full sample of workers, suggesting that promotion from part-time to full-time status does not drive our results. However, it could be that our baseline FTE sample includes some part-time workers with relatively high hourly wages. In Online Appendix Figure A.7, we strengthen the FTE restriction up to 150 percent of the baseline definition. Transitions from part-time to full-time status should become less likely as the FTE restriction rises. We find that the estimate is insensitive to raising the FTE restriction, suggesting we have successfully ruled out part-time to full-time promotions with the baseline FTE restriction. It is not surprising that part-time employment does not confound our estimates, given how rare part-time employment is in the construction industry.

The other natural way to increase hours is over-time pay for incumbent full-time workers. When thinking about the plausibility that our estimates are driven by over-time pay, it is useful to observe that the effects of receiving a procurement contract persist over several years. In Online Appendix Figure A.8, we find that the change in earnings due to receiving a procurement contract (which is the numerator of θ_{IV}) is positive, statistically significant, and relatively stable over the four years after the firm wins the auction, whereas the typical procurement project lasts for less than one year. Thus, it is unlikely that over-time pay to meet a short-lived increase in product demand explains our estimated increase in earnings.

While the evidence from the US data indicate that the increase in earnings is not due to increased hours worked, the most compelling evidence would come from directly estimating annual earnings versus hourly wage responses in data with administrative measures of each worker's labor hours. Labor hours data is not available from the IRS, nor is it available in other nationally representative employer-employee panel data from the US (e.g., LEHD).[30] To overcome this challenge, we consider data from Norway. Norway provides a rare opportunity, as it is one of the few countries where the hours worked by each employee are reported to the government. We restrict the Norwegian sample to the construction industry and workers who satisfy the same FTE restriction as we impose in the US data. See Online Data Supplement S.4 for details on the Norwegian data sources and sample construction.

To determine whether or not labor hours responses confound wage responses to firm shocks in Norway, we apply the LMS estimator (discussed above) to recover the pass-through from revenue shocks to annual earnings and hourly wages. We find that the elasticity of annual earnings and hourly wages to revenue shocks are 0.092 and

[30]Only Minnesota, Oregon, Rhode Island, and Washington State collect labor hours data as part of their unemployment insurance records, representing a small fraction of the US workforce and a small fraction of states covered by our procurement auction records. This hourly wage data is not available through the IRS.

0.091, respectively, while the elasticity of hours to revenue shocks is 0.001. Thus, the labor supply elasticity is nearly identical when estimated using annual earnings versus hourly wages.

5.2 Firm Technology and Product Demand Parameters

We use the general method of moments (GMM) to jointly estimate $(1/\epsilon, \rho, \beta_L)$ based on equations (22), (25), (26), and (28). The estimates and standard errors are reported in Panel A of Table 1.

We estimate β_L to be 0.50 and ρ to be 1.09. The value of β_L implies that a 100 percent increase in a firm's employment results in 50 percent more output, all else equal. The value of ρ implies that, if a firm has 100 percent more labor than another firm, we expect it to produce 109 percent more output, *not* holding all else equal. The larger firm will optimally have greater utilization of capital and intermediate inputs. Since $\rho \equiv (1+\theta)\beta_K + \beta_L$, these estimates imply that β_K is about 0.47 (see Panel B in Table 1). The returns to scale over labor and capital, $\beta_L + \beta_K$, is about 1.0, which is comparable to the range of estimates from 1.0 to 1.2 by Levinsohn and Petrin (2003).

As discussed in Section 2.3, the government project crowds-out private projects ($Q^H_{1jt} < Q^H_{0jt}$) since we estimate that $1 + \theta > \rho$. To see why this is the case, note that winning a government project increases the total output level. In turn, more employment is required to achieve a greater level of production. Due to the upward-sloping labor supply curve, greater employment leads to higher costs of labor, determined by $1 + \theta$. On the other hand, greater scale induces greater private production under composite economies of scale, $\rho > 1$. Since we estimate $1 + \theta > \rho$, it is optimal for a firm to cut its production for the private market if it receives a procurement contract. We quantify the crowd-out effect when discussing incidence in the next section.

In the private product market, we estimate that the elasticity of revenue with respect to output $1-\epsilon$ is 0.86, so the product demand elasticity $1/\epsilon$ is about 7.3. This implies that, in order for a firm to increase output by 10 percent, it must reduce its price by about 1.4 percent. Online Appendix Figure A.11 estimates heterogeneity in $1-\epsilon$ across Census regions, finding little variation. Though we do not find directly comparable estimates of the price elasticity of demand from the construction industry,

Panel A. Technology and Product Demand Parameters			
	Baseline Estimates using Over-identified GMM		
	Parameters	**Data**	
Private demand parameter	$1-\epsilon$	0.863	(0.015)
Composite returns to labor	ρ	1.089	(0.017)
Marginal returns to labor	β_L	0.499	(0.192)
	Alternative Estimates using Exactly-identified OLS		
	Parameters	**Data**	
Diminishing returns to output (eq 22)	$1-\epsilon$	0.863	(0.008)
Optimal intermediate inputs to employees (eq 25)	ρ	1.057	(0.015)
Labor to value added ratio (eq 26)	β_L	0.514	(0.209)
Panel B. Remaining Parameters for Price, Scale, and TFP			
	Parameter and Identifying Moments	**Data**	
Scale of log output price	$\log p_H = \mathbb{E}[r_{jt} - (1-\epsilon)(\log \frac{\beta_M}{p_M} + x_{jt})\vert D=0]$	12.801	(0.053)
Scale of log amenities	$\mathbb{E}[u_{jt}] = \mathbb{E}[b_{jt}] - (1+\theta)\mathbb{E}[\ell_{jt}]$	10.075	(0.000)
Scale term for intermediates	$\log \frac{\beta_M}{p_M} = \rho\mathbb{E}[\ell_{jt}] - \mathbb{E}[x_{jt}]$	-11.722	(0.047)
Marginal returns to capital	$\beta_K = (\rho - \beta_L)/(1+\theta)$	0.474	(0.161)
Interquartile range of log TFP	$\text{IQR}(\phi_{jt}) = \text{IQR}(x_{jt} - \rho\ell_{jt})$	0.918	(0.001)

Table 1: Firm Technology and Product Demand Parameters

Notes: This table summarizes identifying equations and provides estimates of several model parameters. GMM and OLS estimates of $(1-\epsilon, \rho, \beta_L)$ are provided in Panel A, while estimates of the remaining parameters are provided in Panel B.

some estimates from the literature suggest our estimate is within a reasonable range. Goldberg and Knetter (1999) estimate demand elasticities for German beer to be 2.3-15.4. Goldberg and Verboven (2001) estimate demand elasticities for foreign cars to be 4.5-6.5.

Sensitivity analyses. We now apply several sensitivity checks to our GMM estimates of $(1/\epsilon, \rho, \beta_L)$ to verify that our results are not driven by model assumptions. In Panel A of Table 1, we provided baseline estimates from over-identified GMM. In order to directly examine the validity of the model, we can instead estimate the parameters using simple OLS estimation of the exactly-identified equations, dropping the over-identifying restriction discussed in Section 4.4.[31] Using this approach, we estimate that $1-\epsilon$ is 0.86, ρ is 1.06, and β_L is 0.51, which are nearly the same as the

[31] In particular, equation (22) provides an OLS estimate of $1-\epsilon$, equation (25) provides an OLS estimate of ρ, and equation (26) provides a plug-in estimate of β_L given the OLS estimates of $1-\epsilon$ and ρ.

baseline estimates.

Our baseline analyses have assumed that the price parameters (p_H, p_K, p_M) do not vary over time. While time-varying price parameters would lead to the same model equations in Section 2, the regression intercepts in equations (22), (25), and (28) would have year subscripts, which suggests controlling for year fixed effects in these regressions. When doing so, we find that the GMM estimates of $(1/\epsilon, \rho, \beta_L)$ remain identical, so accounting for time-variation in the price parameters does not affect our results.

The Leontief production function is motivated by institutional features of the construction industry and allows us to derive a linear relationship between x_{jt} and ℓ_{jt} (equation 11), but one may worry that it is misspecified. Although misspecification in the production function would not affect the estimated labor supply elasticity or total rents, it could affect the estimates of ρ and $1/\epsilon$ as well as counterfactual analyses like the incidence of procurement. In Online Appendix C, we solve, identify, and estimate the model with a Cobb-Douglas production function. In this case, we estimate that ρ is 1.08 and $1/\epsilon$ is 5.04, which are similar to the estimates based on the Leontief production function. We also find similar estimates of the incidence of procurement on firms and workers. Thus, the functional form of the production function does not drive our results.

In Section 2.3, we discussed the assumption that auctions are symmetric, which leads to a closed-form expression for the optimal bidding strategy. While the identification strategies for $1/\theta$, $1/\epsilon$, and β_L do not rely on auction symmetry, we used symmetry to recover ρ in Proposition 4. If auctions were not symmetric, inverting the bidding function to control for TFP would require not only controlling for a firm's own amenity term and bid but also the amenities of all other bidders in the auction. As a sensitivity check, we re-estimate ρ when controlling for a polynomial in the average amenities of all other firms in the same auction, finding a nearly identical estimate of ρ. Thus, the assumption that auctions are symmetric does not drive estimates of key model parameters.

Remaining model parameters. For the few remaining model parameters, the identifying equations and estimates are provided in Panel B of Table 1. These include the private market price index parameter p_H (using equation 23), the scale of amenities (using equation 24), the returns to intermediate inputs relative to marginal cost β_M/p_M (using equation 27), the returns to capital (using the definition of ρ), and the interquartile range of TFP (using equation 29). Although the magnitudes of these parameters are perhaps not of interest on their own, they are needed to perform counterfactual simulations.[32]

6 Market Power, Rents, and the Incidence of Government Procurement

In this section, we use the model of Section 2 and the parameter estimates from Section 5 to understand how market power influences wages, to recover the rents captured by firms and workers, and to quantify the incidence of government procurement.

6.1 Market Power and the Combined Markdown of Wages

We now use the estimated model to understand how market power influences wage-setting in the construction industry. For simplicity, we focus on firms that are not producing for the government market ($D_{jt} = 0$), although the expressions are similar for firms that produce for the government market.

As shown in Appendix A.2, the equilibrium wage equates marginal revenues with marginal costs, so that

$$\underbrace{\overbrace{(1+\theta)}^{\text{inverse markdown}} \times W_{jt}}_{\text{marginal cost of labor (MCL}_{jt})} = \underbrace{\overbrace{(1-\epsilon)}^{\text{inverse markup}} \times P_{jt}\text{MP}_{jt}}_{\text{marginal revenue product (MRP}_{jt})} - \underbrace{s_M \times P_{jt}\text{MP}_{jt}}_{\text{marginal intermed. costs}}, \tag{32}$$

where $s_M \equiv X_{jt}/R_{jt}$ is the expenditure on intermediates relative to revenues. The marginal product MP_{jt} reflects the change in output resulting from a one unit change

[32]For example, the simulation exercises below use the TFP interquartile range when simulating optimal bids as a function of TFP dispersion from equation (14). One potential concern is that the distribution of TFP varies over time, so our interquartile range estimate may be overstated due to pooling across years. Online Appendix Figure A.10 estimates the TFP interquartile range separately by calendar year, finding little evidence of changes over time.

in labor, while optimally adjusting other input usages (capital and intermediates). This definition of the marginal product reflects the composite Leontief production function (see De Loecker et al. 2020). The marginal revenue product MRP_{jt} reflects the markup of prices (if any) due to product market power and the extra revenue that would have been created at the fixed price P_{jt}.

Equation (32) makes clear how market power in the labor and product markets enters the wage-setting. On the one hand, if labor and product markets are perfectly competitive (i.e. $\theta = 0$ and $\epsilon = 0$), the wage is equal to the marginal revenue product at fixed prices, $P_{jt}\text{MP}_{jt}$, times the share of revenue that is paid to labor, $1-s_M$. On the other hand, both labor market power ($\theta > 0$) and product market power ($\epsilon > 0$) incentivize the firm to lower its wage relative to $P_{jt}\text{MP}_{jt}$. Using the estimates from Section 5, we see that the markdown $\frac{1/\theta}{1+1/\theta}$ is 0.80 and the markup $\frac{1/\epsilon}{1/\epsilon-1}$ is 1.16. As a result, wages are marked down 31 percent (i.e., $0.80 \times (1.16)^{-1} = 0.69$) relative to $P_{jt}\text{MP}_{jt}$ due to imperfect competition in both the labor market and the product market.

While equation (32) is useful to describe how θ and ϵ enter equilibrium wages, this equation is not suitable for drawing conclusions about the wage impacts of changes in market power. To see this, consider the equilibrium response to a change in θ. The optimal wage and labor of the firm are characterized by two conditions: labor supply ($W_{jt} = L_{jt}^{\theta} U_{jt}$) and labor demand (equation 32). Each of these equations depends directly on θ. When counterfactually changing θ, there is a "labor supply effect" which operates by changing the labor supply elasticity, $1/\theta$, and a "labor demand effect" which operates by changing the markdown term in labor demand, $\frac{1/\theta}{1+1/\theta}$. To isolate the second effect, i.e., the effect that operates through the markdown, we will, in Section 7, compensate the location parameter in labor supply (U_{jt}) until the labor supply effect is exactly zero. This corresponds to the standard "compensated rotation" approach to characterize market power in industrial organization (Bresnahan, 1982). Another possible counterfactual would be to change θ without adjusting U_{jt}, in which case, we would mix together the impacts of worker preference changes (labor supply effect) and the exploitation of labor (labor demand effect).

			Actual outcomes	Counterfactual no procurements	Change due to procurements Level	Relative
Labor market						
L_{jt}	Employment	(workers)	24.7	12.8	11.9	92.7%
W_{jt}	Wage	($1,000)	59.1	50.4	8.8	17.4%
B_{jt}	Wage bill	($1,000)	1,459.6	645.2	814.4	126.2%
Intermediate markets						
X_{jt}	Intermediate inputs	($1,000)	4,715.1	2,308.6	2,406.5	104.2%
$p_K K_{jt}$	Capital rentals	($1,000)	1,724.7	762.4	962.3	126.2%
Total production						
Q_{jt}	Output	(quantity)	38.3	18.7	19.5	104.2%
R_{jt}	Revenue	($1,000)	8,962.1	4,541.6	4,420.5	97.3%
Private production						
Q^H_{jt}	Output	(quantity)	13.7	18.7	-5.1	-27.0%
R^H_{jt}	Revenue	($1,000)	3,460.7	4,541.6	-1,080.9	-23.8%
Rents						
V_{jt}	Worker rents	($1,000/worker)	11.6	5.1	6.5	126.2%
π_{jt}	Firm rents or Profits	($1,000/worker)	43.1	33.4	9.6	28.7%

Table 2: Outcomes of Firms and Workers and the Incidence of Procurement

Notes: For the median-TFP firm in the sample of firms that received procurement contracts ($D_{jt} = 1$), this table presents the observed values of various outcomes (column 1) as well as counterfactual outcomes that would have been experienced if the firm had not received a procurement contract (column 2) using the approach of Section 4.5. It presents the differences between columns 1 and 2 in levels (column 3) and in percent changes (column 4).

6.2 Rents and Rent Sharing

The first column of Table 2 provides our main estimates of firm and worker outcomes. We focus on firms that receive a procurement contract ($D_{jt} = 1$) and provide estimates for the typical firm, by which we mean the median-TFP firm. The typical firm employs about 25 workers and pays them an annual wage of $59,100. This amounts to an annual wage bill of about $1.5 million. From equation (18), this implies that worker rents are about $11,600 per worker, which amounts to 20 percent of their average earnings. Comparing revenues to expenditures on all inputs, firm rents (i.e. profits) amount to about $43,100 per worker. Comparing worker rents to firm rents, 79 percent of total rents are captured by firms.

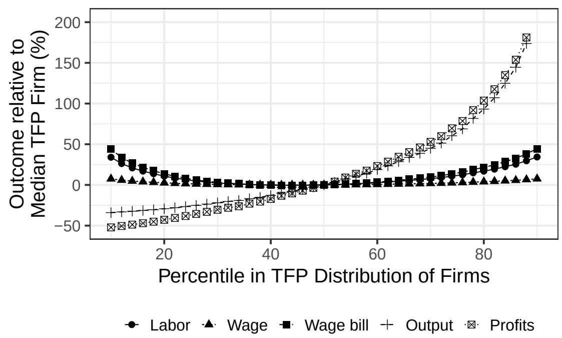
Figure 2 examines heterogeneity in outcomes across the TFP distribution. The x-axis displays the firm's percentile in the TFP distribution. In Figure 2(a), the y-axis presents the firm's labor, wage, wage bill, output, and profits, where each is normalized relative to the median-TFP firm. When a firm is more productive, it chooses to produce more output, which requires hiring more workers. Since the labor supply curve is upward-sloping, it must bid up wages to increase employment, which also increases the wage bill. Empirically, relative to the median-TFP firm, a firm at the 75th percentile of the TFP distribution employs 12 percent more labor, pays 3 percent higher wages, and spends 15 percent more on labor. It produces 65 percent more output and earns 74 percent more profits. By contrast, a firm at the 25th percentile of the TFP distribution produces 26 percent less output and earns 37 percent lower profits. Firms with low TFP employ more workers and pay greater wages than the median-TFP firm. This is because they need to produce the minimum output specified by the government, $\overline{Q}^G$, and must compensate for low productivity by hiring more labor than the median-TFP firm.[33]

In Figure 2(b), we compare the rents earned by firms and workers across the TFP distribution. Since firm rents increase much more than worker rents as TFP increases, the share of rents captured by workers is decreasing in TFP. This result complements the recent literature on product market competition which has found that more productive firms have higher markups and lower labor shares (Autor et al., 2020; De Loecker et al., 2020). We account for both labor and product market power and find a lower rent share to workers at more productive firms.

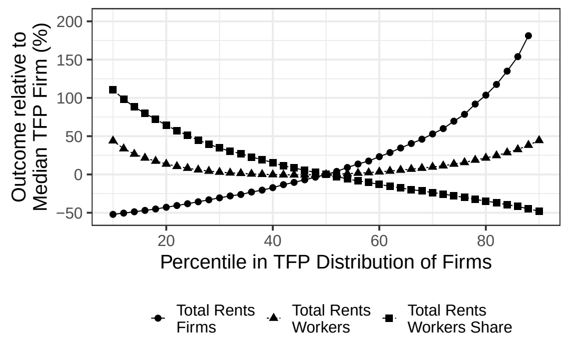
6.3 Incidence of Government Procurement

The second column of Table 2 provides our estimates of the counterfactual outcomes that would have been experienced if the firm had not received a procurement contract using the approach of Section 4.5. The difference between columns 1 and 2 is the incidence of procurement on the outcomes of firms and workers, which are both presented in absolute level changes (column 3) and changes relative to the case in which the firm does not receive a procurement contract (column 4). In the typical

[33]Online Appendix Figure A.12 provides the same figure but counterfactually shutting down the government market for procurements, as described in Online Appendix G. We find that wages, employment, the wage bill, and rents are monotonically increasing in TFP when shutting down the government market, confirming that the non-monotonicity in these outcomes in Figure 2 is due to the constraint that $Q_{1jt} \geq \overline{Q}^G$.



(a) Outcomes of Workers and Firms



(b) Total Rents of Workers and Firms

Figure 2: Firm Heterogeneity across the TFP Distribution

Notes: This figure presents the values of labor, wages, the wage bill, output, and profits (subfigure a) as well as total rents (subfigure b) across the TFP distribution. It expresses these values as percentage differences from the typical firm, defined as the median-TFP firm.

firm, we find that receiving a procurement contract induces it to hire 12 more workers (nearly doubling the firm's workforce) and pay each of its workers about $8,800 more in wages (a 17 percent increase), increasing its wage bill by about $0.8 million. Worker rents increase by about $6,500 per worker (more than double the baseline rents). Using the decomposition in equation (19), 70 percent of worker rents generated by the procurement contract accrue to incumbent workers rather than new hires.

In response to receiving the procurement contract, the median firm increases expenditure on intermediate inputs by $2.4 million (about double the baseline) and capital rental by nearly $1.0 million (more than double the baseline). Total output approximately doubles. Government demand crowds out private market production, with private market output decreasing by about 27 percent. Total revenues increase by $4.4 million, while private market revenues decrease by about $1.0 million. Comparing revenues to expenditures on all inputs, firm rents (i.e. profits) increase by $9,600 per worker. Comparing incidence on worker rents to incidence on firm rents, we see that 40 percent of the incidence of government procurement is captured by workers. Thus, workers get a larger share of the rents for the marginal procurement contract than for the average output.

7 How Labor Market Power Interacts with Product Market Power

In this section, we use our model to perform counterfactuals which show how labor market power interacts with product market power to shape the outcomes and behavior of workers and firms in the American construction industry. We first show theoretically, in Section 7.1, that the consequences of increased market power in one market are attenuated by the existence of market power in the other market. Next, in Section 7.2, we use the estimated model to quantify the importance of the interactions between the market power in the two markets.

Throughout this section, we follow the standard "compensated rotation" approach to characterize market power in industrial organization (Bresnahan, 1982). This compensated rotation allows us to isolate the labor demand effect, which operates through the change in the markdown term ($\frac{1/\theta}{1/\theta+1}$), while removing the labor supply effect, which operates through the labor supply elasticity ($1/\theta$). To achieve this, we induce a greater markdown by increasing θ, then compensate the location parameter in labor supply (U_{jt}) until the labor supply effect is exactly zero (i.e. labor supply at the initial wage is the same after changing θ as it was at the initial value of θ). Similarly, a change in ϵ has both a product supply effect, which operates through the change in the markup term in prices ($\frac{1/\epsilon}{1/\epsilon-1}$), and a product demand effect, which operates through the product demand elasticity ($1/\epsilon$). To isolate the product supply effect, we induce a greater markup by increasing ϵ, then compensate the location parameter in product demand (p_H) until the product demand effect is exactly zero (i.e. product demand at the initial price is the same after changing ϵ as it was at the initial value of ϵ).

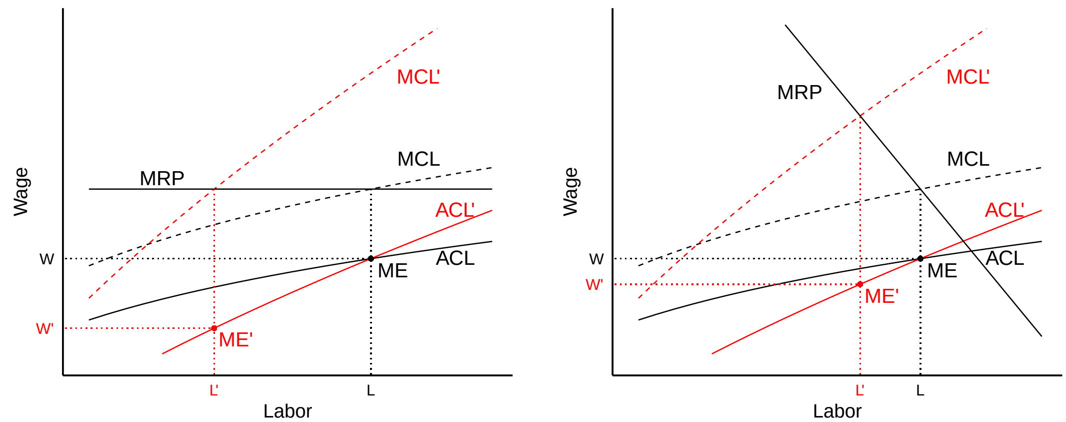
7.1 Theoretical Predictions

We begin by providing a theoretical analysis of how the impacts of labor market power depend on the degree of product market power, and vice versa. For simplicity, we consider a production function in which labor is the only input, returns to scale are constant ($\rho = 1$), and firms can only sell output to the private market when deriving theoretical predictions. We relax these restrictions when quantifying effects using the estimated model in the next subsection. We present the results graphically here and report the formal comparative static results in Online Appendix F.

How the impacts of labor market power depend on product market power. We start by reviewing the impacts of labor market power if firms have no product market power ($\epsilon = 0$). Figure 3(a) visualizes how labor market equilibrium is determined. It considers a fictional firm, with labor on the x-axis and wage on the y-axis. Since $\epsilon = 0$, output is priced at the constant rate p_H (i.e., the firm is a price-taker in the product market), so the marginal revenue product (MRP) curve is constant. The initial average cost of labor curve (ACL, solid line) and its associated marginal cost of labor curve (MCL, dashed line) are in black. Note that MCL is upward-sloping due to $\theta > 0$. To determine the initial monopsonistic equilibrium (ME), the firm chooses labor to equate MCL and MRP, then marks down the wage below the MRP by choosing the lowest feasible wage at this quantity of labor, which is on the ACL directly below the intersection of MCL and MRP.

The red lines in Figure 3(a) present the "compensated rotation" exercise in which the labor supply curve is made less elastic by lowering $1/\theta$ to $1/\theta$'. The new marginal cost of labor curve (MCL') is higher than MRP at the initial choice of labor (L). This induces the firm to reduce labor along the MCL' curve until it reaches the quantity of labor L' at which MCL' equals MRP. It follows that the equilibrium wage is lower at the new equilibrium (ME') than the initial equilibrium. Thus, we have the classical result that, if the firm gains labor market power, it reduces wages and employment, and, as a result, output is lower as well.

In Figure 3(b), we shift attention to how labor market power interacts with product market power to determine employment and wages. We repeat the exercise of Figure 3(a) except that we now allow firms to have product market power ($\epsilon > 0$). The initial equilibrium and labor supply curve are the same in Figures 3(a-b). The key difference between these figures is that $\epsilon > 0$ in Figure 3(b) so the MRP is downward-sloping. Thus, when $1/\theta$ shifts to $1/\theta'$ and employment (and therefore also output) falls, the MRP rises, which counterbalances the incentive to reduce employment. It follows that L' and thereby W' and output are greater at the new equilibrium in



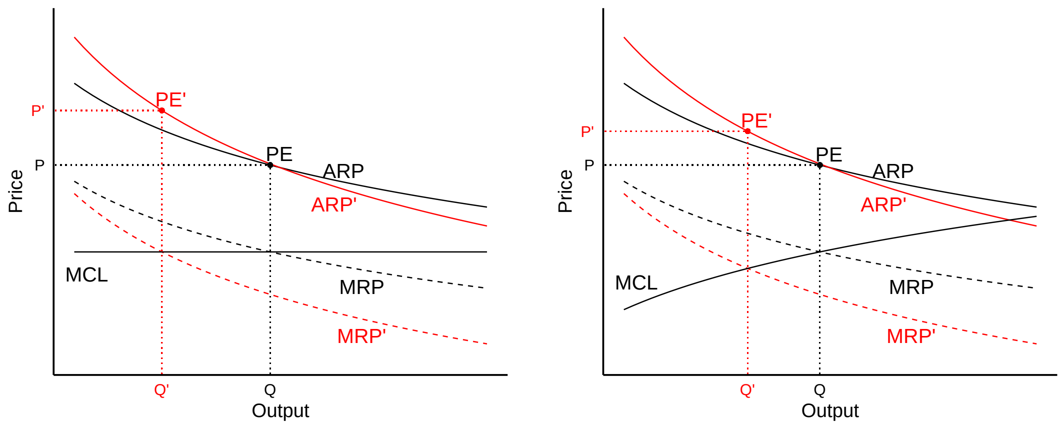
(a) No Product Market Power ($\epsilon = 0$) (b) With Product Market Power ($\epsilon > 0$)

Figure 3: Impacts of Labor Market Power on Wages and Employment

Notes: This diagram visualizes how giving firms more labor market power would impact wages and employment. ACL denotes the average cost of labor, MCL denotes the marginal cost of labor, ME denotes the monopsonistic equilibrium, and MRP denotes the marginal revenue product. Black colors denote the initial economy, and red colors denote the new economy after the firm gains labor market power, which is achieved by making labor supply less elastic through a "compensated rotation" (Bresnahan, 1982). Subfigures (a) and (b) consider the cases in which the firm does not and does have product market power, respectively. The subfigures differ only by the rotation of the MRP curve.

Figure 3(b) than in Figure 3(a).

How the impacts of product market power depend on labor market power. As a point of departure, consider the impacts of product market power if firms have no labor market power ($\theta = 0$). Figure 4(a) visualizes how product market equilibrium is determined. It considers a fictional firm, with output on the x-axis and price on the y-axis. Since $\theta = 0$, labor is priced at the constant wage (i.e., the firm is a price-taker in the labor market), so the marginal cost of labor (MCL) curve is constant. The initial average revenue product (ARP, solid line) and its associated marginal revenue product (MRP, dashed line) are in black. Note that MRP is downward-sloping due to $\epsilon > 0$. To determine the initial monopolistic equilibrium (PE), the firm chooses output to equate MCL and MRP, and then marks up the price by choosing the highest feasible price at this quantity of output, which is on ARP directly above the



(a) No Labor Market Power ($\theta = 0$) (b) With Labor Market Power ($\theta > 0$)

Figure 4: Impacts of Product Market Power on Prices and Output

Notes: This diagram visualizes how giving firms more private product market power would impact prices and output. MCL denotes the marginal cost of labor, MRP denotes marginal revenue product, ARP denotes average revenue product, and PE denotes the monopolistic product market equilibrium. Black colors denote the initial economy, and red colors denote the new economy after the firm gains product market power, which is achieved by making product demand less elastic through a "compensated rotation" (Bresnahan, 1982). Subfigures (a) and (b) consider the cases in which the firm does not and does have labor market power, respectively. The subfigures differ only by the rotation of the MCL curve.

intersection of MCL and MRP.

The red lines in Figure 4(a) present the "compensated rotation" exercise in which the product demand curve is made less elastic by lowering $1/\epsilon$ to $1/\epsilon$'. The new marginal revenue product curve (MRP') is lower, so the marginal revenue is lower than the marginal cost of labor at the initial choice of output (Q). This induces the firm to reduce output along the MRP' curve until it reaches the quantity of output Q' at which MRP' equals MCL. It follows that the equilibrium price is higher at the new equilibrium (PE') than the initial equilibrium. Thus, we have the classical result that, if the firm gains product market power, it reduces output and increases prices, and, as a result, employment is lower as well.

In Figure 4(b), we shift attention to how product market power interacts with labor market power to determine output and price. We repeat the exercise of Figure 4(a) except that we allow firms to have labor market power ($\theta > 0$). The initial equilibrium and product demand curve are the same in Figures 4(a-b). The key difference between these figures is that $\theta > 0$ in Figure 4(b) so the MCL is upward-sloping. Thus, when $1/\epsilon$ decreases to $1/\epsilon'$ and output (and therefore also employment) falls, the MCL falls, which counterbalances the incentive to reduce output. It follows that Q' is greater and P' is lower at the new equilibrium in Figure 4(b) than in Figure 4(a).

The impacts of simultaneously increasing labor and product market power. Above, we showed that the consequences of increased market power in one market are attenuated by the existence of market power in the other market. It is important to observe that this attenuation is a second-order effect and does not imply that increasing market power in both markets has a smaller impact than increasing market power in one market only. To see this, consider Figure 5. In this figure, we first increase labor market power (blue lines) by rotating ACL to be steeper, and then increase product market power (red lines) by rotating ARP to be steeper.

As evident from Figure 5, increasing labor market power reduces labor (from L to L') and the wage (from W to W'). Because labor is reduced, output is also reduced (from Q to Q'), which allows the firm to set a higher price (from P to P'). This first set of effects were the result of shifting MCL to MCL' along the MRP curve. Then, we see that increasing product market power induces the firm to further reduce output (from Q' to Q") and raise prices (from P' to P"). Because output is now lower, labor is also further reduced (from L' to L"), which allows the firm to set a lower wage (from W' to W"). This second set of effects were the result of shifting MRP to MRP' along the MCL' curve. Combined, we see that increasing labor and product market power simultaneously leads to greater reductions in wages, labor, and output as well as a greater increase in prices than only increasing labor market power. However, as shown in Online Appendix F, the combined impact is smaller than the sum of the impacts of each type of market power in isolation due to the interactions between the two markets.

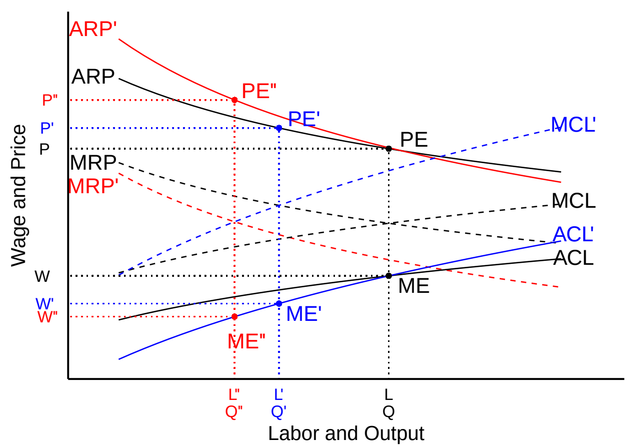


Figure 5: Impacts of Simultaneously Increasing Labor and Product Market Power

Notes: This diagram visualizes how giving firms more labor and product market power would impact wages and employment, as well as prices and output. ACL denotes the average cost of labor, MCL denotes the marginal cost of labor, ARP denotes the average revenue, MRP denotes the marginal revenue, ME denotes the monopsonistic equilibrium (in the labor market), and PE denotes the monopolistic equilibrium (in the product market). Black colors denote the initial economy, blue colors denote the intermediate economy in after the firm gains labor market power, and red colors denote the final economy after the firm gains labor and product market power. Increasing market power is achieved in the labor market by making labor supply less elastic and in the product market by making product demand less elastic, respectively, through a "compensated rotation" (Bresnahan, 1982).

7.2 Quantifying the Impacts of Market Power

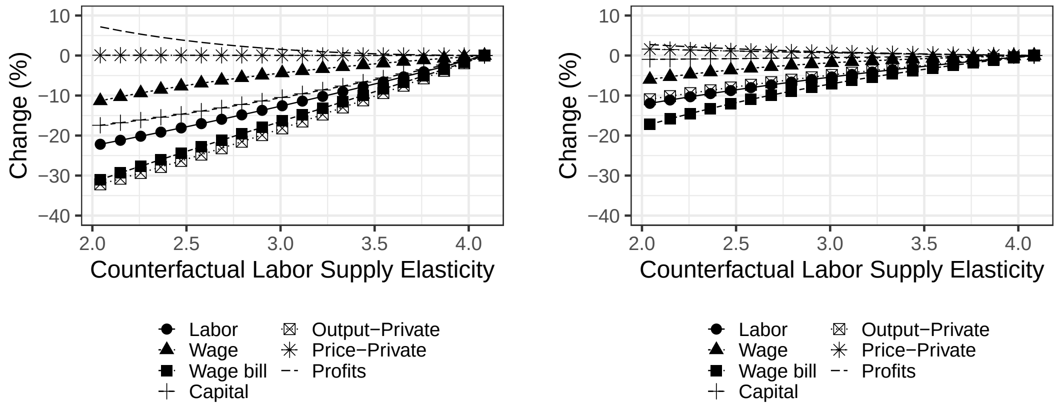
As shown above, product market power counterbalances the incentives to exploit labor market power, and vice versa. We now quantify the strength and impact of these incentives, using the model from Section 2 evaluated at the parameter estimates from Section 5. In contrast to the simplified environment considered in the theoretical predictions in Section 7.1, we solve the imperfectly competitive auctions for government procurements and evaluate the composite returns to labor at the estimated value.[34] See Online Appendix H for details on how we computationally solve the model, including simulating equilibrium auction bidding.[35]

How the impacts of labor market power depend on product market power. We start by quantifying the impacts of labor market power if firms have no product market power. In Figure 6(a), we increase the degree of labor market power through a compensated decrease in the labor supply elasticity $1/\theta$ (see the discussion above) while counterfactually shutting down product market power ($\epsilon = 0$). We find that, as the firm gains labor market power, it employs fewer workers and pays a lower wage to each employee. By taking advantage of its market power to increasingly mark down wages, the firm earns higher profits. For each outcome, there is a monotonic relationship across values of the labor supply elasticity. Consider a comparison between the actual value of the labor supply elasticity and half of this amount. When the labor supply elasticity of a given firm is reduced by half, the firm employs 22 percent fewer workers, decreases wages by 11 percent, and decreases the wage bill by 31 percent. Output for the private market is reduced by 32 percent, private market prices are constant (since $\epsilon = 0$), and capital rental falls by 17 percent. Despite these reductions in the firm's activities, its profit rises 7 percent due to the increased exploitation of labor.

We now quantify the impacts of labor market power if firms have product market power. In Figure 6(b), we increase the degree of labor market power through a compensated decrease in the labor supply elasticity $1/\theta$ while setting product market

[34]Online Appendix G presents a simplified model and analyses that shut down the government market for procurement projects, finding qualitatively similar results.

[35]In particular, we simulate the bidding using the quantile representation method of Luo (2020).



(a) No Product Market Power ($\epsilon = 0$) (b) With Product Market Power ($\epsilon > 0$)

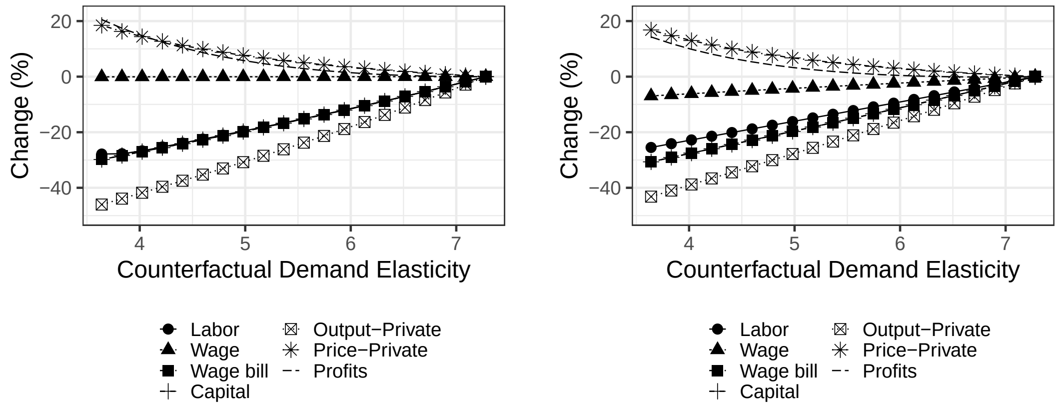
Figure 6: Quantifying the Impacts of Labor Market Power

Notes: This figure presents our estimates of the degree to which various outcomes change when the firm gains labor market power, which is achieved by making labor supply less elastic through a "compensated rotation". Subfigure (a) considers the counterfactual case in which the firm has no product market power, while subfigure (b) sets product market power to the estimated value. It expresses these values as percentage changes relative to the actual economy for the median-TFP firm.

power to the estimated value ($1/\epsilon = 7.28$). As before, outcomes are monotonic across values of the labor supply elasticity. When the labor supply elasticity of a given firm is reduced by half, the firm employs 12 percent fewer workers, decreases wages by 6 percent, and decreases the wage bill by 17 percent. Output for the private market decreases by 11 percent, private market prices rise by 2 percent, capital rental decreases by 1 percent, and profits rise by 3 percent. Thus, we see that the incentives to reduce wages per worker by lowering employment are attenuated by product market power. The reason is that a firm with product market power can charge a higher price as employment, and thus output, declines. At the level of employment that it would choose if it were fully exploiting its labor market power, the output price would be so high that marginal revenue product would exceed the marginal cost of labor. Thus, a firm chooses to exploit labor market power to a lesser extent if it also is exploiting product market power.

How the impacts of product market power depend on labor market power. We start by quantifying the impacts of product market power if firms have no labor market power. In Figure 7(a), we increase the degree of product market power through a compensated decrease in the product demand elasticity $1/\epsilon$ (see the discussion above) while counterfactually shutting down labor market power ($\theta = 0$). We find that, as the firm gains product market power, it produces less output and receives a greater price. By taking advantage of its market power to increasingly mark up prices, the firm earns higher profits. For each outcome, there is a monotonic relationship across values of the product demand elasticity. Consider a comparison between the actual value of the product demand elasticity and half of this amount. When the product demand elasticity of a given firm is reduced by half, the firm produces 46 percent less output for the private market and increases private market prices by 19 percent. Employment is reduced by 28 percent, wages are constant (since $\theta = 0$), and wage bill and capital rental fall by 30 percent. Despite these reductions in the firm's activities, its profit rises 21 percent due to the increased exploitation of product market power.

We now quantify the impacts of product market power if firms have labor market power. In Figure 7(b), we increase the degree of product market power through a compensated decrease in the product demand elasticity $1/\epsilon$ while setting labor market power to the estimated value ($1/\theta = 4.08$). As before, outcomes are monotonic across values of the product demand elasticity. When the product demand elasticity of a given firm is reduced by half, the firm produces 43 percent less output for the private market and increases private market prices by 17 percent. Employment is reduced by 26 percent, wages are reduced by 7 percent, and wage bill and capital rental fall by 30 percent. Profits increase by 14 percent. Thus, we see that the incentives to reduce prices for the private market by lowering output are somewhat attenuated by labor market power. The reason is that a firm with labor market power can pay a lower wage as output, and thus employment, declines. At the level of employment that it would choose if it were only exploiting its product market power, the wage would be so low that the marginal cost of labor would be less than the marginal revenue product. Therefore, firms that are also exploiting labor market power would choose to exploit product market power to a lesser extent.



(a) No Labor Market Power ($\theta = 0$)

(b) With Labor Market Power ($\theta > 0$)

Figure 7: Quantifying the Impacts of Product Market Power

Notes: This figure presents our estimates of the degree to which various outcomes change when the firm gains product market power, which is achieved by making product demand less elastic through a "compensated rotation". Subfigure (a) considers the counterfactual case in which the firm has no labor market power, while subfigure (b) sets labor market power to the estimated value. It expresses these values as percentage changes relative to the actual economy for the median-TFP firm.

The impacts of simultaneously increasing labor and product market power. We conclude our counterfactual analyses by quantifying the impacts of simultaneously increasing market power in both markets. In particular, we perform a simultaneous "compensated rotation" of the labor supply and product demand curves so that the new labor supply and product demand elasticities are $1/\theta' = \gamma \times 1/\theta$ and $1/\epsilon' = \gamma \times 1/\epsilon$, respectively. The results are presented in Figure 8, where γ is displayed on the x-axis and changes in the firm's outcomes relative to the baseline economy are displayed on the y-axis. The baseline economy corresponds to $\gamma = 1$.

We find that the combined impact of both types of market power on each outcome is substantially larger than the impact of either type of market power in isolation. However, the combined impact is considerably smaller than the sum of the impacts of each type of market power in isolation. This is due to the second-order effect discussed above, namely, that the impacts of labor and product market power attenuate one another. Cutting the labor supply elasticity in half reduces the wage bill and private market output by 17 and 11 percent (see Figure 6), whereas cutting the product

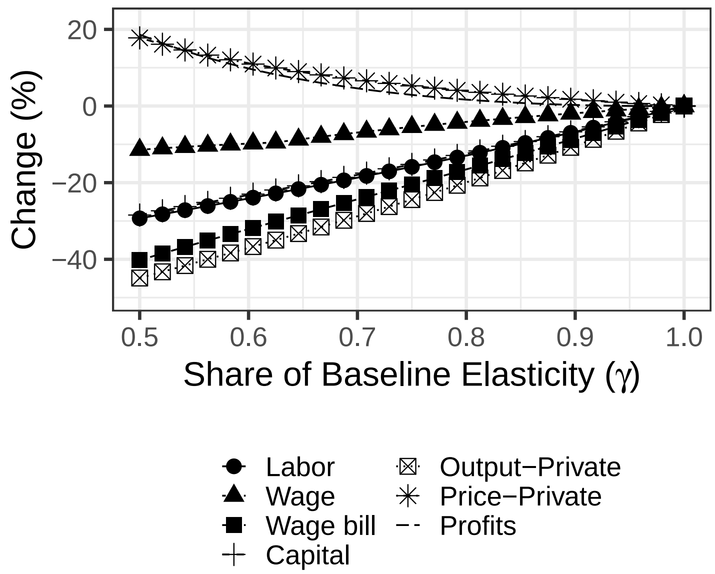


Figure 8: Quantifying the Combined Impacts of Labor and Product Market Power

Notes: This figure presents our estimates of the degree to which various outcomes change when the firm simultaneously gains labor and product market power, which is achieved by making labor supply and product demand less elastic at the same time. In particular, we perform a "compensated rotation" of the labor supply and product demand curves so that the new labor and product demand elasticities are $1/\theta' = \gamma \times 1/\theta$ and $1/\epsilon' = \gamma \times 1/\epsilon$, respectively, where that the baseline economy corresponds to $\gamma = 1$.

demand elasticity in half reduces the wage bill and private market output by 30 and 40 percent (see Figure 7). By comparison, simultaneously cutting the labor and product demand elasticities in half leads to a 40 percent decline in the wage bill and a 45 percent decline in private market output (see Figure 8).

8 Conclusion

The primary goal of our paper was to quantify the importance of imperfect competition in the US construction industry by estimating the size of rents earned by American firms and workers. To obtain a comprehensive measure of the total rents and to understand its sources, we took into account that rents arise due to both wage markdowns and price markups. We found that American construction firms have significant wage-setting and price-setting power. Wages are marked down 20 percent relative to the marginal revenue product while prices are marked up 16 percent relative to the marginal cost of production. This imperfect competition generates a considerable amount of rents, more than three-fourths of which is captured by the firms. The incentives of firms to mark down wages and reduce employment due to wage-setting power are attenuated by their price-setting power in the product market.

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Online Appendix to "Imperfect Competition and Rents in Labor and Product Markets: The Case of the Construction Industry"

A Model Derivations

A.1 The Composite Production Function

In this appendix, we derive equation (9). To do so, we express revenues and costs as functions of Q_{jt} so as to separate the joint maximization into two steps: In the first step, we find the optimal combination (K_{jt}, L_{jt}) for each Q_{jt}. In the second step, we solve for the optimal Q_{jt}.

Recall that firms can rent capital at price p_K and hire labor at price $W_{jt} = U_{jt}L_{jt}^{\theta}$. The production function (in physical units) satisfies

$$Q_{jt} = \Omega_{jt} K_{jt}^{\beta_K} L_{jt}^{\beta_L}. \tag{33}$$

Intermediate inputs have constant price p_M and, due to the Leontief functional form, must satisfy $M_{jt} = Q_{jt}/\beta_M$. Given any production level Q_{jt}, the firm can find the most cost efficient combination (K_{jt}, L_{jt}) by solving the Hicksian cost-minimization problem,

$$\min_{(K_{jt}, L_{jt}): Q_{jt} = \Omega_{jt} K_{jt}^{\beta_K} L_{jt}^{\beta_L}} p_K K_{jt} + U_{jt} L_{jt}^{1+\theta}, \tag{34}$$

where $p_K K_{jt} + U_{jt} L_{jt}^{1+\theta}$ is the total cost of capital and labor. We now solve for the Hicksian demand for capital and labor using the Lagrangian,

$$\mathcal{L}_{jt} \equiv p_K K_{jt} + U_{jt} L_{jt}^{1+\theta} + \lambda_{jt}(Q_{jt} - \Omega_{jt} K_{jt}^{\beta_K} L_{jt}^{\beta_L}), \tag{35}$$

where λ_{jt} is the Lagrange multiplier. The first-order conditions for capital and labor, respectively, are as follows:

$$p_K = \lambda_{jt}\Omega_{jt}\beta_K K_{jt}^{\beta_K-1}L_{jt}^{\beta_L}, \tag{36}$$

$$(1+\theta)U_{jt}L_{jt}^{\theta} = \lambda_{jt}\Omega_{jt}\beta_L K_{jt}^{\beta_K}L_{jt}^{\beta_L-1}. \tag{37}$$

These equations lead to the optimal choice of capital as a function of labor:

$$K_{jt} = \frac{\beta_K}{\beta_L}\frac{(1+\theta)}{p_K}U_{jt}L_{jt}^{1+\theta}. \tag{38}$$

Substituting equation (38) into equation (33), the inverse Hicksian demand is

$$Q_{jt} = \Omega_{jt}\left(\frac{\beta_K}{\beta_L}\frac{(1+\theta)}{p_K}U_{jt}L_{jt}^{1+\theta}\right)^{\beta_K}L_{jt}^{\beta_L} = \Phi_{jt}L_{jt}^{\rho}, \tag{39}$$

where we define $\rho \equiv (1+\theta)\beta_K + \beta_L$ and $\Phi_{jt} \equiv \Omega_{jt}\left(\frac{\beta_K}{\beta_L}\frac{(1+\theta)}{p_K}U_{jt}\right)^{\beta_K}$. Thus, $L_{jt} = (Q_{jt}/\Phi_{jt})^{1/\rho}$. Substituting into the first-order condition for intermediate inputs, the Hicksian expenditure on intermediate inputs is

$$X_{jt} \equiv p_M M_{jt} = p_M Q_{jt}/\beta_M = \frac{p_M}{\beta_M}\Phi_{jt}L_{jt}^{\rho}. \tag{40}$$

Lastly, total costs can be expressed in terms of labor as

$$W_{jt}L_{jt} + p_K K_{jt} + p_M M_{jt} = \kappa_U U_{jt}L_{jt}^{1+\theta} + \frac{p_M}{\beta_M}\Phi_{jt}L_{jt}^{\rho}, \tag{41}$$

where $\kappa_U \equiv \frac{\beta_K}{\beta_L}(1+\theta)+1$.

A.2 Firm's Behavior in the Private Product Market

In this appendix, we derive equation (13) and several related results on firm behavior in the private market. Throughout, we assume a downward-sloping private product demand curve ($\epsilon > 0$) and increasing composite returns to labor ($\rho > 1$), consistent with the empirical evidence.

If $d = 0$, the firm's profit maximization problem is,

$$\max_{L_{0jt}} p_H \left(\Phi_{jt} L_{0jt}^{\rho}\right)^{1-\epsilon} - \kappa_U U_{jt} L_{0jt}^{1+\theta} - \frac{p_M}{\beta_M} \Phi_{jt} L_{0jt}^{\rho}, \tag{42}$$

where we substituted equations (9) and (41) into equation (8) for the case with $d = 0$. The profit-maximizing first-order condition is,

$$\frac{\partial \pi_{0jt}}{\partial L_{0jt}} \equiv \underbrace{p_H \Phi_{jt}^{1-\epsilon}(1-\epsilon)\rho L_{0jt}^{(1-\rho)\epsilon-(1-\rho)-\epsilon}}_{\text{MRP}} - \underbrace{\left(\kappa_U U_{jt}(1+\theta) L_{0jt}^{\theta} + \frac{p_M}{\beta_M} \Phi_{jt} \rho L_{0jt}^{-(1-\rho)}\right)}_{\text{MCL}} = 0. \tag{43}$$

This expression shows that L_{0jt} only varies across firms due to Φ_{jt} and U_{jt}. Equation (43) can be arranged as equation (32):

$$\underbrace{\overbrace{(1-\epsilon)}^{\text{markup}^{-1}} \overbrace{p_H \Phi_{jt}^{-\epsilon} L_{0jt}^{-\rho\epsilon}}^{P_{jt}} \overbrace{\Phi_{jt} \rho L_{0jt}^{\rho-1} / \kappa_U}^{\text{MP}_{jt}}}_{\text{MRP}_{jt}} = \underbrace{\overbrace{(1+\theta)}^{\text{markdown}^{-1}} \overbrace{U_{jt} L_{0jt}^{\theta}}^{W_{jt}}}_{\text{MCL}_{jt}} + \underbrace{\overbrace{\frac{p_M}{\beta_M}}^{s_M P_{jt}} \overbrace{\Phi_{jt} \rho L_{0jt}^{\rho-1} / \kappa_U}^{\text{MP}_{jt}}}_{\text{marginal intermed. costs}}, \tag{44}$$

which is the same as equation (32), where we use that $\beta_M = Q_{jt}/M_{jt}$ implies $\frac{p_M}{\beta_M} = \frac{p_M M_{jt}}{Q_{jt}} = \frac{p_M M_{jt}}{Q_{jt} P_{jt}} P_{jt} = \frac{X_{jt}}{R_{jt}} P_{jt}$.

We will now show that MRP is greater than MCL as L_{0jt} approaches zero. Multiplying marginal profits in (43) by $L_{0jt}^{\rho\epsilon+(1-\rho)}$, which is strictly positive, we have

$$\frac{\partial \pi_{0jt}}{\partial L_{0jt}} L_{0jt}^{\rho\epsilon+(1-\rho)} = \underbrace{p_H \Phi_{jt}^{1-\epsilon}(1-\epsilon)\rho}_{\text{MRP}\times L_{0jt}^{\rho\epsilon+(1-\rho)}} - \underbrace{\left(\kappa_U U_{jt}(1+\theta) L_{0jt}^{\theta+\rho\epsilon+(1-\rho)} + \frac{p_M}{\beta_M} \Phi_{jt} \rho L_{0jt}^{\rho\epsilon}\right)}_{\text{MCL}\times L_{0jt}^{\rho\epsilon+(1-\rho)}}. \tag{45}$$

Note that $\text{MRP} \times L_{0jt}^{\rho\epsilon+(1-\rho)}$ is constant with respect to L_{0jt} and positive. By contrast, given $\theta + \rho\epsilon + (1-\rho) > 0$, then $\text{MCL} \times L_{0jt}^{\rho\epsilon+(1-\rho)}$ converges to zero as L_{0jt} approaches zero. Thus, we have shown that $\lim_{L_{0jt}\to 0^+} \frac{\partial \pi_{0jt}}{\partial L_{0jt}} > 0$. As a result, it is always optimal to choose $L_{0jt} > 0$ if $\theta + \rho\epsilon + (1-\rho) > 0$.

Furthermore, multiplying both sides of equation (43) by L_{0jt}, we have

$$\frac{\partial \pi_{0jt}}{\partial L_{0jt}} \equiv p_H \Phi_{jt}^{1-\epsilon}(1-\epsilon)\rho L_{0jt}^{\rho(1-\epsilon)} - \kappa_U U_{jt}(1+\theta)L_{0jt}^{1+\theta} - \frac{p_M}{\beta_M}\Phi_{jt}\rho L_{0jt}^{\rho} = 0. \tag{46}$$

Recall that $\kappa_U U_{jt} L_{0jt}^{1+\theta} = \frac{\rho}{\beta_L} B_{0jt}$, $R_{0jt}^H = p_H \Phi_{jt}^{1-\epsilon} L_{0jt}^{\rho(1-\epsilon)}$, and $X_{0jt} = \frac{p_M}{\beta_M}\Phi_{jt} L_{0jt}^{\rho}$. Substituting, we have

$$(1-\epsilon)R_{0jt}^H = \frac{1+\theta}{\beta_L} B_{0jt} + X_{0jt}. \tag{47}$$

Similarly, if $d = 1$, the firm's profit maximization problem is,

$$\max_{L_{1jt}:\ \Phi_{jt}L_{1jt}^{\rho} \geq \overline{Q}^G} p_H \left(\Phi_{jt} L_{1jt}^{\rho} - \overline{Q}^G\right)^{1-\epsilon} - \kappa_U U_{jt} L_{1jt}^{1+\theta} - \frac{p_M}{\beta_M}\Phi_{jt} L_{1jt}^{\rho}. \tag{48}$$

The first-order condition is,

$$\frac{\partial \pi_{1jt}}{\partial L_{1jt}} \equiv p_H \Phi_{jt}(1-\epsilon)\rho \left(\Phi_{jt} L_{1jt}^{\rho} - \overline{Q}^G\right)^{-\epsilon} L_{1jt}^{-(1-\rho)} - \kappa_U U_{jt}(1+\theta) L_{1jt}^{\theta} - \frac{p_M}{\beta_M}\Phi_{jt}\rho L_{1jt}^{-(1-\rho)} = 0. \tag{49}$$

As $\Phi_{jt} L_{1jt}^{\rho}$ approaches $\overline{Q}^G$, $\left(\Phi_{jt} L_{1jt}^{\rho} - \overline{Q}^G\right)^{-\epsilon}$ approaches infinity while all other terms involving L_{1jt} approach constants. Thus, $\Phi_{jt} L_{1jt}^{\rho} > \overline{Q}^G$ is necessary to satisfy the equation. Since $Q_{1jt} = \Phi_{jt} L_{1jt}^{\rho}$, it follows that $Q_{1jt}^H = Q_{1jt} - \overline{Q}^G > 0$, so the winning firm always produces for the private market. Furthermore, it is always true that $\frac{\partial \pi_{1jt}}{\partial L_{1jt}}|_{L_{1jt}=L_{0jt}} > 0$. Thus, Q_{djt} is larger if $d = 1$ than $d = 0$.

Multiplying both sides of equation (49) by L_{1jt} and replacing $p_H \left(\Phi_{jt} L_{1jt}^{\rho} - \overline{Q}^G\right)^{1-\epsilon}$ by R_{1jt}^H, we have

$$R_{1jt}^H \Phi_{jt}(1-\epsilon)\left(\Phi_{jt} L_{1jt}^{\rho} - \overline{Q}^G\right)^{-1} L_{1jt}^{\rho} - \frac{1+\theta}{\beta_L} B_{1jt} - X_{1jt} = 0. \tag{50}$$

Since $Q_{1jt}^H = \Phi_{jt} L_{1jt}^{\rho} - \overline{Q}^G$ and $Q_{1jt} = \Phi_{jt} L_{1jt}^{\rho}$, it follows that

$$R_{1jt}^H (1-\epsilon)\frac{Q_{1jt}}{Q_{1jt}^H} - \frac{1+\theta}{\beta_L} B_{1jt} - X_{1jt} = 0. \tag{51}$$

Thus, combining equations (47) and (51), we have equation (13).

Lastly, it is interesting to consider if winning a procurement project will lead a firm to produce more for the private market (crowd-in) or less (crowd-out). To determine this, we evaluate the marginal profits of the winner when the total output is $\hat{Q}_{1jt} \equiv \overline{Q}^G + Q^H_{0jt}$; that is, $\hat{Q}_{1jt}$ is the hypothetical output of the firm in the $d = 1$ case such that there is neither crowd-in nor crowd-out. The winner would prefer to produce more (less) than $\hat{Q}_{1jt}$ if the marginal profit is positive (negative, respectively). Let the corresponding labor choice be $\hat{L}_{1jt}$ such that $\Phi_{jt}\hat{L}^{\rho}_{1jt} - \overline{Q}^G = Q^H_{0jt} = \Phi_{jt}L^{\rho}_{0jt}$. Note that, since $\rho > 1$ and $\hat{L}^{\rho}_{1jt} = L^{\rho}_{0jt} + \overline{Q}^G/\Phi_{jt}$, then $\hat{L}^{\rho}_{1jt} > L_{0jt}$. Evaluating equation (49) at $\hat{L}_{1jt}$, marginal profits for the firm if it wins and produces hypothetical output $\hat{Q}_{1jt}$ are,

$$\frac{\partial \pi_{1jt}}{\partial L_{1jt}}|_{L_{1jt}=\hat{L}_{1jt}} = p_H \Phi_{jt}(1-\epsilon)\rho(Q^H_{0jt})^{-\epsilon}\hat{L}^{\rho-1}_{1jt} - \kappa_U U_{jt}(1+\theta)\hat{L}^{\theta}_{1jt} - \frac{p_M}{\beta_M}\Phi_{jt}\rho\hat{L}^{\rho-1}_{1jt}. \quad (52)$$

Multiplying by $L^{1-\rho}_{1jt}$ and substituting $Q^H_{0jt} = \Phi_{jt}L^{\rho}_{0jt}$, we have,

$$L^{1-\rho}_{1jt}\frac{\partial \pi_{1jt}}{\partial L_{1jt}}|_{L_{1jt}=\hat{L}_{1jt}} = p_H \Phi^{1-\epsilon}_{jt}(1-\epsilon)\rho L^{-\rho\epsilon}_{0jt} - \kappa_U U_{jt}(1+\theta)\hat{L}^{\theta+1-\rho}_{1jt} - \frac{p_M}{\beta_M}\Phi_{jt}\rho. \quad (53)$$

Finally, substituting equation (46), this simplifies to,

$$L^{1-\rho}_{1jt}\frac{\partial \pi_{1jt}}{\partial L_{1jt}}|_{L_{1jt}=\hat{L}_{1jt}} = \kappa_U U_{jt}(1+\theta)(L^{\theta+1-\rho}_{0jt} - \hat{L}^{\theta+1-\rho}_{1jt}). \quad (54)$$

Since $\hat{L}_{1jt} > L_{0jt}$, we have that $\frac{\partial \pi_{1jt}}{\partial L_{1jt}}|_{L_{1jt}=\hat{L}_{1jt}} < 0$ if $\theta+1-\rho > 0$, and $\frac{\partial \pi_{1jt}}{\partial L_{1jt}}|_{L_{1jt}=\hat{L}_{1jt}} > 0$ otherwise. Therefore, winning a government project crowds-out private projects when $1 + \theta > \rho$ and crowds-in if $1 + \theta < \rho$.

A.3 Worker Rents Expressions

We prove that equation (16) implies the results in equations (17) and (19). Defining $u = l, dv = dW$, we calculate V_j for a wage change from $W_j = W^0_j$ using integration by parts:

$$\begin{aligned} V_{jt} &= \int_{W_{jt}^0}^{W_{jt}^1} L(W)dW = [L(W)W]_{W_{jt}^0}^{W_{jt}^1} - \int_{W_{jt}^0}^{W_{jt}^1} \frac{dL}{dW} W dW \\ &= \underbrace{L(W_{jt}^0)\left(W_{jt}^1 - W_{jt}^0\right)}_{\text{incumbents}} + \underbrace{\int_{W_{jt}^0}^{W_{jt}^1} \left(W_{jt}^1 - W\right) \frac{dL}{dW} dW}_{\text{new hires}} \end{aligned}$$

Following Lamadon et al. (2021), define $\omega \equiv \frac{W}{W_{jt}^1}$ so that $\frac{d\omega}{dW} = \frac{1}{W_{jt}^1}$. Next, $L(\omega_{jt}W_{jt}^1) = \frac{\left(\omega_{jt}W_{jt}^1\right)^{1/\theta} g_{jt}}{\sum_{j'}\left(\omega_{j't}W_{j't}\right)^{1/\theta} g_{j't}} = \omega_{jt}^{1/\theta} L(W_{jt}^1)$. Thus, $\frac{dL}{dW}dW = \frac{dL}{d\omega}d\omega$. Moreover, $\frac{dL}{d\omega} = \frac{\partial \omega^{1/\theta}}{\partial \omega} L(W_{jt}^1)$. Then,

$$V_{jt} = L(W_{jt}^0)\left(W_{jt}^1 - W_{jt}^0\right) + W_{jt}^1 \int_{\frac{W_{jt}^0}{W_{jt}^1}}^{1} (1-\omega) \frac{dL}{d\omega} d\omega = \frac{W_{jt}^1 L(W_{jt}^1)}{1+1/\theta} - \frac{W_{jt}^0 L(W_{jt}^0)}{1+1/\theta} = \frac{B_{jt}^1 - B_{jt}^0}{1+1/\theta}.$$

Furthermore, to solve the expression for rents captured by new hires, note that $\int_{W_{jt}^0}^{W_{jt}^1} W \frac{dL}{dW} dW = \frac{B_{jt}^1 - B_{jt}^0}{1+\theta}$ and $\int_{W_{jt}^0}^{W_{jt}^1} \frac{dL}{dW} dW = L_{jt}^1 - L_{jt}^0$. Thus,

$$\int_{W_{jt}^0}^{W_{jt}^1} \left(W_{jt}^1 - W\right) \frac{dL}{dW} dW = W_{jt}^1 \int_{W_{jt}^0}^{W_{jt}^1} \frac{dL}{dW} dW - \int_{W_{jt}^0}^{W_{jt}^1} W \frac{dL}{dW} dW = W_{jt}^1 \left(L_{jt}^1 - L_{jt}^0\right) - \frac{B_{jt}^1 - B_{jt}^0}{1+\theta}.$$

A.4 Over-identifying Restriction

In this appendix, we derive equation (28). Taking the log of both sides of equation (13) for the $d = 1$ case, we have,

$$\log(1-\epsilon) + r_{1jt}^H + q_{1jt} - q_{1jt}^H = \log\left(\frac{1+\theta}{\beta_L} B_{1jt} + X_{1jt}\right).$$

From equation (7), $r_{1jt}^H = \log p_H + (1-\epsilon) q_{1jt}^H$, so $q_{1jt}^H = \frac{1}{1-\epsilon} r_{1jt}^H - \frac{1}{1-\epsilon} \log p_H$. From equation (10), $q_{1jt} = \rho \ell_{1jt} + \phi_{jt} + e_{jt}$. Substituting, we have

$$\log(1-\epsilon) + r_{1jt}^H + (\rho \ell_{1jt} + \phi_{jt} + e_{jt}) - \left(\frac{1}{1-\epsilon} r_{1jt}^H - \frac{1}{1-\epsilon} \log p_H\right) = \log\left(\frac{1+\theta}{\beta_L} B_{1jt} + X_{1jt}\right),$$

which can be rearranged as equation (28).

B Product Market with Perfect Competition

This section solves the firm's problem in the private product market assuming the firm is a price-taker ($\epsilon = 0$). Denote the competitive price as p_H. In terms of the composite production function $Q_{jt} = \Phi_{jt} L_{jt}^{\rho}$, the firm's problem is

$$\max_{L_{jt}:\ \Phi_{jt} L_{jt}^{\rho} \geq d\overline{Q}^{G}} \quad p_H \left(\Phi_{jt} L_{jt}^{\rho} - d\overline{Q}^{G} \right) - \kappa_U U_{jt} L_{jt}^{1+\theta} - \frac{p_M}{\beta_M} \Phi_{jt} L_{jt}^{\rho}$$

where the government's output must be produced if the firm receives a procurement contract ($\Phi_{jt} L_{jt}^{\rho} \geq d\overline{Q}^{G}$). We consider three cases:

Suppose $d = 0$. The government constraint is always satisfied, so we can ignore this constraint. The profit-maximizing solution is simply

$$L_{0jt} = \left(\left(p_H - \frac{p_M}{\beta_M} \right) \frac{\Phi_{jt} \rho}{\kappa_U U_{jt} (1+\theta)} \right)^{\frac{1}{\theta+1-\rho}}$$

and $Q_{0jt} = \Phi_{jt} L_{0jt}^{\rho}$.

Suppose $d = 1$ and $Q_{0jt} > \overline{Q}^{G}$. Then, the solution $L_{1jt}^{interior} = L_{0jt}$ and $Q_{1jt}^{interior} = Q_{0jt}$ satisfies the government constraint and otherwise solves the profit-maximization problem, so this is the optimal solution. An implication is that $Q_{1jt}^{interior}$ is invariant to marginal changes in the size of the government contract, i.e., government projects crowd-out the firm's private market production one-for-one. Since input costs are not affected by receiving a procurement contract, the opportunity cost of receiving a procurement contract is simply the loss in revenues in the private product market, $\sigma_{jt}^{interior} = p_H \left(Q_{0jt} - \left(Q_{1jt}^{interior} - \overline{Q}^{G} \right) \right) = p_H \overline{Q}^{G}$.

Suppose $d = 1$ and $Q_{0jt} \leq \overline{Q}^{G}$. Then, the firm is at the corner solution in which it only produces for the government market, i.e., $Q_{1jt}^{corner} = \overline{Q}^{G}$ and $L_{1jt}^{corner} = \left(\overline{Q}^{G} / \Phi_{jt} \right)^{1/\rho}$. The opportunity cost is $\sigma_{jt}^{corner} = p_H Q_{0jt} - \left\{ T_{jt} \left(L_{0jt} \right) - T_{jt} \left(L_{1jt}^{corner} \right) \right\}$, where $T_{jt}(L) \equiv \kappa_U U_{jt} L^{1+\theta} + \frac{p_M}{\beta_M} \Phi_{jt} L^{\rho}$ is the total cost of production using labor L.

C Cobb-Douglas Production Function

C.1 Cobb-Douglas Model: Composite Production Function

Consider a Cobb-Douglas production function (in physical units)

$$Q_{jt} = \Omega_{jt} L_{jt}^{\beta_L} K_{jt}^{\beta_K} M_{jt}^{\beta_M}. \tag{55}$$

Given any production level Q_{jt}, the firm can find the most cost efficient combination (L_{jt}, K_{jt}, M_{jt}) by solving the cost-minimization problem,

$$\min_{L_{jt}, K_{jt}, M_{jt}} \quad C_{jt} \quad \text{s.t.} \quad Q_{jt} = \Omega_{jt} L_{jt}^{\beta_L} K_{jt}^{\beta_K} M_{jt}^{\beta_M}. \tag{56}$$

where $C_{jt} \equiv U_{jt} L_{jt}^{1+\theta} + p_K K_{jt} + p_M M_{jt}$ denotes the total cost. This leads to the Lagrangian,

$$\mathcal{L}_{jt} \equiv U_{jt} L_{jt}^{1+\theta} + p_K K_{jt} + p_M M_{jt} + \lambda_{jt}(Q_{jt} - \Omega_{jt} K_{jt}^{\beta_K} L_{jt}^{\beta_L} M_{jt}^{\beta_M}) \tag{57}$$

where λ_{jt} is the Lagrange multiplier. The first-order conditions are:

$$\begin{aligned} p_K &= \lambda_{jt} \Omega_{jt} \beta_K K_{jt}^{\beta_K - 1} L_{jt}^{\beta_L} M_{jt}^{\beta_M}, \\ (1+\theta) U_{jt} L_{jt}^{\theta} &= \lambda_{jt} \Omega_{jt} \beta_L K_{jt}^{\beta_K} L_{jt}^{\beta_L - 1} M_{jt}^{\beta_M}, \\ p_M &= \lambda_{jt} \Omega_{jt} \beta_M K_{jt}^{\beta_K} L_{jt}^{\beta_L} M_{jt}^{\beta_M - 1}. \end{aligned} \tag{58}$$

We can use these first-order conditions to write the optimal choices of capital and intermediate inputs as a function of labor

$$K_{jt} = \frac{\beta_K}{\beta_L} \frac{(1+\theta) U_{jt}}{p_K} L_{jt}^{1+\theta} = \chi^{(K)} U_{jt} L_{jt}^{1+\theta} \text{ and } M_{jt} = \frac{\beta_M}{\beta_L} \frac{(1+\theta) U_{jt}}{p_M} L_{jt}^{1+\theta} = \chi^{(M)} U_{jt} L_{jt}^{1+\theta} \tag{59}$$

where $\chi^{(K)} \equiv \frac{\beta_K}{\beta_L} \frac{(1+\theta)}{p_K}$ and $\chi^{(M)} \equiv \frac{\beta_M}{\beta_L} \frac{(1+\theta)}{p_M}$. We can substitute these expressions into $Q_{jt} = \Omega_{jt} L_{jt}^{\beta_L} K_{jt}^{\beta_K} M_{jt}^{\beta_M}$ and obtain

$$Q_{jt} = \Omega_{jt} \left[\chi_j^{(K)} U_{jt} L_{jt}^{1+\theta} \right]^{\beta_K} L_j^{\beta_L} \left[\chi_j^{(M)} U_{jt} L_{jt}^{1+\theta} \right]^{\beta_M} = \Phi_{jt} L_{jt}^{\rho} \tag{60}$$

where $\Phi_{jt} \equiv \Omega_{jt} \left[\chi^{(K)} U_{jt}\right]^{\beta_K} \left[\chi^{(M)} U_{jt}\right]^{\beta_M}$ and $\rho \equiv \beta_L + (1+\theta)(\beta_K + \beta_M)$. We can also use equations (60) and equation (59) to rewrite the firm's problem in the private product market as

$$
\begin{aligned}
&\max_{L_{djt}, K_{djt}, M_{djt}} \pi_{djt} = p_H(\Omega_{jt} L_{djt}^{\beta_L} K_{djt}^{\beta_K} M_{djt}^{\beta_M} - \bar{Q}^G d)^{1-\varepsilon} - C_{djt}, \\
\iff &\max_{L_{djt}} \pi_{djt} = p_H(\Phi_{jt} L_{djt}^{\rho} - \bar{Q}^G d)^{1-\varepsilon} - \chi^{(W)} U_{jt} L_{djt}^{1+\theta},
\end{aligned} \tag{61}
$$

where cost-minimization implies $C_{djt} = \chi^{(W)} U_{jt} L_{djt}^{\theta+1}$, $\chi^{(W)} \equiv \frac{\rho}{\beta_L} \equiv \left(1 + \frac{(\beta_M + \beta_K)(1+\theta)}{\beta_L}\right)$.

C.2 Cobb-Douglas Model: First-order Conditions

We now derive the profit-maximizing first-order conditions in the model with Cobb-Douglas production. These derivations assume $\rho \equiv \beta_L + (1+\theta)(\beta_K + \beta_M) > 1$ and $\varepsilon > 0$.

If the firm loses the auction, its profit maximization problem is

$$
\max_{L_{0jt}} p_H(\Phi_{jt} L_{0jt}^{\rho})^{1-\varepsilon} - \chi^{(W)} U_{jt} L_{0jt}^{1+\theta}. \tag{62}
$$

The first-order condition is,

$$
\rho(1-\varepsilon) p_H \Phi_{jt}^{1-\varepsilon} L_{0jt}^{\rho(1-\varepsilon)-1} = \chi^{(W)} U_{jt} L_{0jt}^{\theta} (1+\theta), \tag{63}
$$

which implies,

$$
L_{0jt} = \left[\frac{\rho(1-\varepsilon) p_H \Phi_{jt}^{1-\varepsilon}}{\chi^{(W)} U_{jt}(1+\theta)}\right]^{\frac{1}{\theta+1-\rho(1-\varepsilon)}}. \tag{64}
$$

Thus $0 < L_{0jt} < \infty$.

Similarly, if the firm wins the auction, the profit maximization problem is:

$$
\max_{L_{1jt}:\, \Phi_{jt} L_{1jt}^{\rho} \geq \bar{Q}^G} p_H(\Phi_{jt} L_{1jt}^{\rho} - \bar{Q}^G)^{1-\varepsilon} - \chi^{(W)} U_{jt} L_{1jt}^{1+\theta}. \tag{65}
$$

The first-order condition is

$$\frac{\partial \pi_{1jt}}{\partial L_{1jt}} \equiv \rho(1-\varepsilon)\Phi_{jt}p_H(\Phi_{jt}L_{1jt}^{\rho} - \bar{Q}^G)^{-\varepsilon}L_{1jt}^{\rho-1} - \chi^{(W)}U_{jt}L_{1jt}^{\theta}(1+\theta) = 0, \tag{66}$$

which implies,

$$\rho(1-\varepsilon)\Phi_{jt}p_H(\Phi_{jt}L_{1jt}^{\rho} - \bar{Q}^G)^{-\varepsilon} = \chi^{(W)}U_{jt}L_{1jt}^{1+\theta-\rho}(1+\theta). \tag{67}$$

As $\Phi_{jt}L_{1jt}^{\rho}$ approaches $\bar{Q}^G$, the left-hand side of equation (67) approaches infinity while the RHS approaches a constant. Thus, $\Phi_{jt}L_{1jt}^{\rho} > \bar{Q}^G$ is necessary to satisfy the equation. Since $Q_{1jt} = \Phi_{jt}L_{1jt}^{\rho}$, it follows that $Q_{1jt}^H = Q_{1jt} - \bar{Q}^G > 0$, so the winning firm always produces for the private market.

Furthermore, since the solution is interior (i.e., $L_{0jt} \geq \overline{Q}^G$) due to $\epsilon > 0$, equation (63) implies $\rho(1-\varepsilon)\Phi_{jt}p_H(\Phi_{jt}L_{0jt}^{\rho})^{-\varepsilon}L_{0jt}^{\rho-1} - \chi^{(W)}U_{jt}L_{0jt}^{\theta}(1+\theta) = 0$ and therefore $\rho(1-\varepsilon)\Phi_{jt}p_H(\Phi_{jt}L_{0jt}^{\rho} - \bar{Q}^G)^{-\varepsilon}L_{0jt}^{\rho-1} - \chi^{(W)}U_{jt}L_{0jt}^{\theta}(1+\theta) \equiv \frac{\partial \pi_{1jt}}{\partial L_{1jt}}|_{L_{1jt}=L_{0jt}} > 0$. Thus, $\frac{\partial \pi_{1jt}}{\partial L_{1jt}}|_{L_{1jt}=L_{0jt}} > 0$, so total production will be larger if the firm receives a procurement contract than if it does not.

C.3 Cobb-Douglas Model: Identification

We now show identification of $(1-\epsilon, \rho, \beta_L)$ in the model with a Cobb-Douglas production function.

In the $d = 0$ case, revenues are related to labor by

$$r_{jt} = \log p_H + (1-\epsilon)\,\phi_{jt} + \rho\,(1-\epsilon)\,\ell_{jt} \tag{68}$$

From this, we can identify $\rho\,(1-\epsilon)$ by regressing r_{jt} on ℓ_{jt} controlling for ϕ_{jt} among $D_{jt} = 0$ firms. In practice, we can control for $(\widehat{u}_{jt}, Z_{jt})$ in place of ϕ_{jt} as in Proposition 4 due to the invertibility of bids with respect to TFP, conditional on amenities. Thus, $\rho\,(1-\epsilon)$ is recovered by the estimator

$$\widehat{\rho\,(1-\epsilon)} \equiv \frac{\mathrm{Cov}\,[r_{jt}, \ell_{jt}|\widehat{u}_{jt}, Z_{jt}, D_{jt} = 0]}{\mathrm{Var}\,[\ell_{jt}|\widehat{u}_{jt}, Z_{jt}, D_{jt} = 0]}. \tag{69}$$

In the $d = 0$ case, equation (63) implies

$$\rho\,(1{-}\epsilon)\,\frac{R^H_{0jt}}{L_{0jt}} = \chi^{(W)} U_{jt} L^{\theta}_{0jt}(1+\theta).$$

Since we showed above that cost-minimization requires $C_{djt} = \chi^{(W)} U_{jt} L^{\theta+1}_{djt}$, it follows that

$$\rho\,(1{-}\epsilon) = (1+\theta)\,\frac{C_{0jt}}{R^H_{0jt}}. \tag{70}$$

Taking expectations in logs and rearranging, this yields another estimator that over-identifies $\rho\,(1{-}\epsilon)$:

$$\widetilde{\rho\,(1{-}\epsilon)} \equiv \exp\left(\log(1+\theta) + \mathbb{E}\left[c_{jt} - r^H_{jt} | D_{jt} = 0\right]\right). \tag{71}$$

In the $d = 1$ case, multiplying both sides of equation (66) by L_{1jt} implies

$$\rho(1-\varepsilon)\Phi_{jt} p_H (\Phi_{jt} L^{\rho}_{1jt} - \bar{Q}^G)^{-\varepsilon} L^{\rho}_{1jt} = \chi^{(W)} U_{jt} L^{\theta+1}_{1jt}(1+\theta) = (1+\theta) C_{jt}$$

Furthermore, since $(\Phi_{jt} L^{\rho}_{1jt} - \bar{Q}^G)^{-\varepsilon} = (Q^H_{1jt})^{-\epsilon} = (R^H_{1jt}/p_H)^{\frac{-\epsilon}{1-\epsilon}}$, we can rewrite this expression as

$$\rho(1-\varepsilon) p_H (R^H_{1jt}/p_H)^{\frac{-\epsilon}{1-\epsilon}} \Phi_{jt} L^{\rho}_{1jt} = (1+\theta) C_{jt}$$

Taking logs,

$$\log\rho + \log(1-\varepsilon) + \log p_H + \frac{-\epsilon}{1-\epsilon} r^H_{1jt} - \frac{-\epsilon}{1-\epsilon}\log p_H + \phi_{jt} + \rho\ell_{1jt} = \log(1+\theta) + c_{jt}$$

Rearranging, this gives,

$$\underbrace{c_{jt} + \frac{\epsilon}{1{-}\epsilon} r^H_{jt}}_{\Lambda^{\mathrm{CD}}_{jt}(\epsilon)} = \text{constant} + \phi_{jt} + \rho\ell_{jt} \tag{72}$$

where constant $\equiv \log\rho + \log(1-\varepsilon) + \frac{1}{1-\epsilon}\log p_H - \log(1+\theta)$. Thus, for any candidate value of ϵ, a regression of $\Lambda^{\mathrm{CD}}_{jt}(\epsilon)$ on ℓ_{jt} controlling for ϕ_{jt} for the winners identifies ρ. Since $\rho\,(1{-}\epsilon)$ is identified above, this implies $(1{-}\epsilon)$ is uniquely determined by this implicit system of equations.

Furthermore, since we showed above that cost-minimization requires $C_{jt} = \frac{\rho}{\beta_L} B_{jt}$, the expected labor share of costs is

$$\frac{\beta_L}{\rho} = \mathbb{E}\left[\frac{B_{jt}}{C_{jt}}\right], \tag{73}$$

so we identify β_L given ρ.

In practice, we simultaneously estimate $(1-\epsilon, \rho, \beta_L)$ by applying equally-weighted GMM to equations (69), (71), (72), and (73).

For the remaining parameters, note that $X_{jt} = \frac{(1+\theta)\beta_M}{\beta_L} B_{jt}$ and $p_K K_{jt} = \frac{(1+\theta)\beta_K}{\beta_L} B_{jt}$, which implies the following expressions:

$$\beta_M = \exp\left(\mathbb{E}\left[x_{jt} - b_{jt}\right] - \log\frac{(1+\theta)}{\beta_L}\right), \tag{74}$$

$$\beta_K = \exp\left(\mathbb{E}\left[\log\left(p_K K_{jt}\right) - b_{jt}\right] - \log\frac{(1+\theta)}{\beta_L}\right), \tag{75}$$

$$\mathbb{E}\left[u_{jt}\right] = \mathbb{E}\left[b_{jt}\right] - (1+\theta)\,\mathbb{E}\left[\ell_{jt}\right], \tag{76}$$

$$\log p_H = \mathbb{E}\left[r_{jt}\right] - \rho\,(1-\epsilon)\,\mathbb{E}\left[\ell_{jt}\right]. \tag{77}$$

D Identification of the Labor Supply Elasticity using the LMS Estimator

Following Lamadon et al. (2021, LMS), we consider instrumenting for long-differences in log labor using short-differences in log revenues. Denoting the short-difference in log revenues by $\Delta r_{jt} \equiv \log R_{jt} - \log R_{jt-1}$, the estimator of LMS is,

$$\widehat{\theta}_{\Delta r} \equiv \frac{\mathrm{Cov}\left[w_{jt+e} - w_{jt-e'}, \Delta r_{jt}\right]}{\mathrm{Cov}\left[\ell_{jt+e} - \ell_{jt-e'}, \Delta r_{jt}\right]}$$

Unlike the estimators of Propositions 1-2, this estimator does not make use of information on procurement auctions and thus can be applied to the entire construction industry rather than only construction firms that bid for procurement projects.

Consider the following assumption, which compares short-run changes in revenues to longer-run changes in TFP and firm-specific amenity shocks:

Assumption 3. *Suppose* $\exists e, e' > 0$ *sufficiently large such that (i)* $\phi_{jt+e} - \phi_{jt-e'}$ *is correlated with* Δr_{jt}*, and (ii)* Δr_{jt} *is orthogonal to* $\nu_{jt+e} - \nu_{jt-e'}$*.*

We then have the following result:

Proposition 5. *Under Assumption 3 and the rank condition* $Cov\left[\left(\ell_{jt+e} - \ell_{jt-e'}\right), \Delta r_{jt}\right] \neq 0$*,* $\widehat{\theta}_{\Delta r}$ *recovers* θ*.*

Proof. By equation (4),

$$\widehat{\theta}_{\Delta r} = \underbrace{\frac{\text{Cov}\left[\theta\left(\ell_{jt+e} - \ell_{jt-e'}\right), \Delta r_{jt}\right]}{\text{Cov}\left[\left(\ell_{jt+e} - \ell_{jt-e'}\right), \Delta r_{jt}\right]}}_{=\theta} + \underbrace{\frac{\text{Cov}\left[\left(\nu_{jt+e} - \nu_{jt-e'}\right), \Delta r_{jt}\right]}{\text{Cov}\left[\left(\ell_{jt+e} - \ell_{jt-e'}\right), \Delta r_{jt}\right]}}_{=0} = \theta,$$

where the denominator of each term is non-zero (i.e., the rank condition is satisfied) by Assumption 3(i) and the second term is zero by Assumption 3(ii). □

The key result, the exclusion condition $\text{Cov}\left[\left(\nu_{jt+e} - \nu_{jt-e'}\right), \Delta r_{jt}\right] = 0$, relies on the assumption that firm-specific amenity shocks are transitory while TFP shocks are persistent. Thus, short-run revenue growth is correlated with long-run employment growth (satisfying the rank condition due to persistence in TFP shocks), but orthogonal to long-run firm-specific amenity shocks.

In practice, we must take a stand on the persistence of the transitory shocks. LMS argue that these transitory shocks are well-approximated as a moving average of order one, in which case, Assumption 3 holds as long as $e \geq 2, e' \geq 3$ and TFP shocks persist for at least e periods. We use the same choices of e and e' as LMS in our empirical implementation.

E Additional Tables and Figures

State	DOT Auction Records		Final Sample: Matched Auction-Tax Data		
	Data Source	Includes EIN	Bidders in 2010 (Num. Firms)	Share of 2010 Construction Sector: Value Added	FTE Workers
AL	State Website	✗	196	15.7%	17.4%
AR	State Website	✗	149	7.9%	12.8%
AZ	No	✗	*	*	*
CA	State Website	✗	1,041	8.3%	11.2%
CO	FOIA Request	✓	241	12.6%	14.7%
CT	FOIA Request	✗	126	9.4%	15.5%
FL	State Website	✓	344	30.7%	10.6%
GA	BidX Website	✗	137	4.3%	7.0%
IA	BidX Website	✗	256	15.4%	20.7%
ID	BidX Website	✗	112	17.2%	13.6%
IL	No	✗	*	*	*
IN	State Website	✓	213	10.6%	16.6%
KS	BidX Website	✓	130	13.7%	21.6%
KY	No	✗	*	*	*
LA	BidX Website	✗	167	11.5%	10.8%
MA	No	✗	*	*	*
MD	No	✗	*	*	*
ME	BidX Website	✗	141	13.7%	16.9%
MI	BidX Website	✗	391	9.5%	16.3%
MN	BidX Website	✗	262	13.5%	19.8%
MO	BidX Website	✗	179	14.9%	13.3%
MS	No	✗	*	*	*
MT	FOIA Request	✗	122	15.0%	23.6%
NC	BidX Website	✗	135	5.2%	9.8%
ND	FOIA Request	✗	*	*	*
NE	No	✗	*	*	*
NH	No	✗	*	*	*
NJ	No	✗	*	*	*
NM	BidX Website	✗	*	*	*
NV	No	✗	*	*	*
NY	No	✗	*	*	*
OH	BidX Website	✗	320	43.7%	17.5%
OK	No	✗	*	*	*
OR	No	✗	*	*	*
PA	No	✗	*	*	*
SC	No	✗	*	*	*
SD	No	✗	*	*	*
TN	BidX Website	✗	140	5.3%	11.5%
TX	FOIA Request	✓	551	4.9%	9.6%
UT	No	✗	*	*	*
VA	BidX Website	✗	241	14.2%	12.0%
VT	BidX Website	✗	*	*	*
WA	BidX Website	✗	200	7.5%	14.0%
WI	BidX Website	✗	194	12.1%	14.6%
WV	BidX and State Websites	✓	103	13.7%	19.0%
National			6,792	10.7%	9.9%

Table A.1: Summary of Auction Data by State

Notes: The first two columns provide information on in-state DOT data sources by state, where "state" refers to the state in which the auction occurred. The first column indicates the source from which we obtained data on that state's DOT auctions, and the second column indicates whether or not EINs were included in the auction records. The final three columns provide information on the final sample of firms in the matched auction-tax data, where "state" refers to the state in which the firm filed taxes. Among firms in the construction industry in 2010, the last two columns consider the share of value added and FTE workers due to the firms that participated in auctions in our sample. We drop from these calculations firms that have missing values on the variables displayed, so the total sample size must be smaller than in Online Appendix Table A.2. An asterisk (*) denotes that number of bidders is non-zero but below the disclosure threshold.

	Sample Size		Share of the Construction Sector
Number of Firms	7,876		0.9%
Workers per Firm	46		11.7%
	Value Per Firm ($ millions)	**Mean of the Log**	**Share of the Construction Sector (%)**
Sales	19.927	15.061	12.1%
EBITD	9.159	14.075	9.6%
Intermediate Costs	14.661	14.719	12.4%
Wage bill	2.737	13.549	13.4%

Table A.2: Sample Characteristics

Notes: This table displays descriptive statistics for the sample of firms that place bids in 2010. The third column compares aggregates for this sample to all firms in the construction industry in the 2010 tax records.

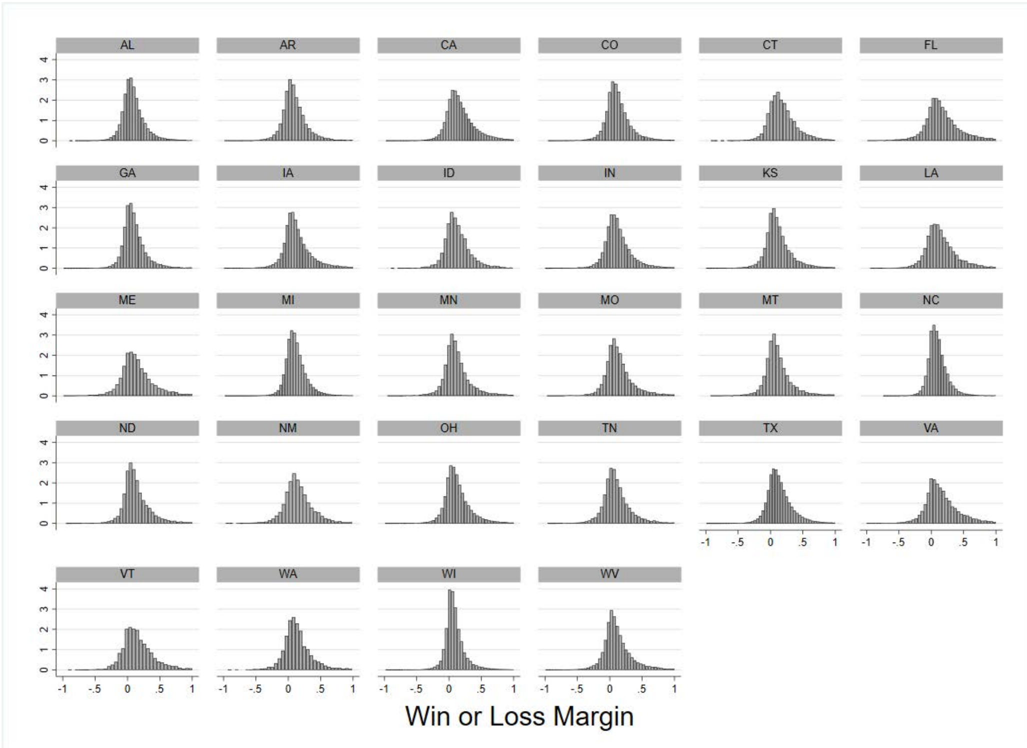


Figure A.1: Chassang et al. (2019) Visual Test for Collusion

Notes: This figure displays the histogram of bid competition for each of the 28 states in our sample. Negative values indicate the difference between the winner's bid and the bid of the runner-up. Positive values indicate the difference between each loser's bid and the winner's bid. Differences are scaled by the winner's bid in each case. Chassang et al. (2019) demonstrate that, under some assumptions on the auction environment, these differences should display discontinuities in the histogram near zero if there is collusion.

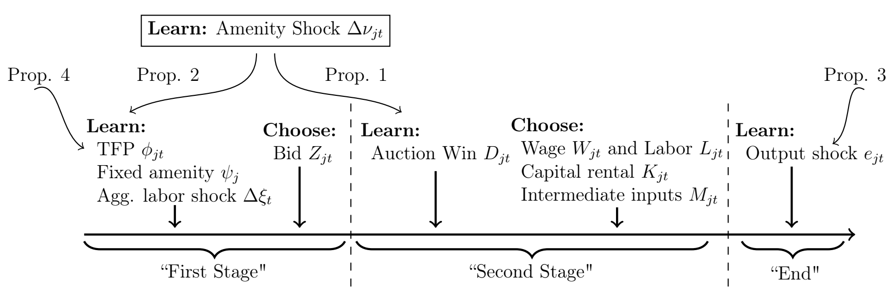
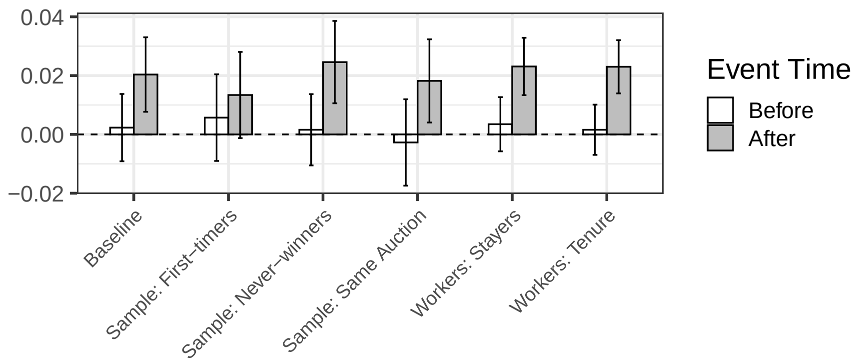
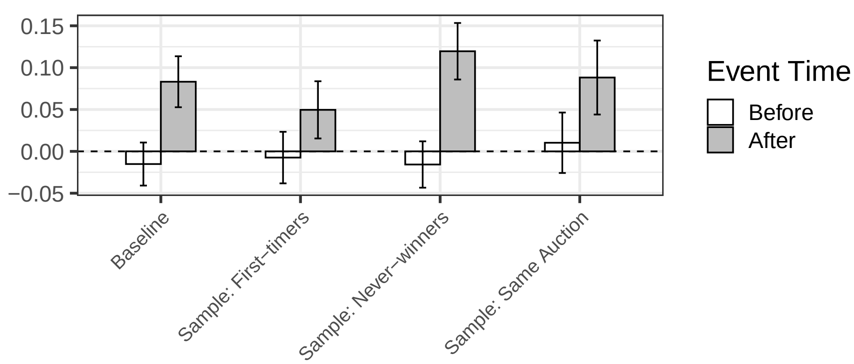


Figure A.2: Visual Representation of the Timing of Information



(a) Log earnings per worker (numerator of θ_{IV})



(b) Log number of employees (denominator of θ_{IV})

Figure A.3: Falsification Test: DiD Estimands in the Pre-period

Notes: This figure presents the baseline estimate and sensitivity checks for the DiD estimands corresponding to the numerator and denominator of θ_{IV}, respectively. "Before" refers to event times $\{-4, -3\}$ while "After" refers to event times $\{0, 1, 2\}$.

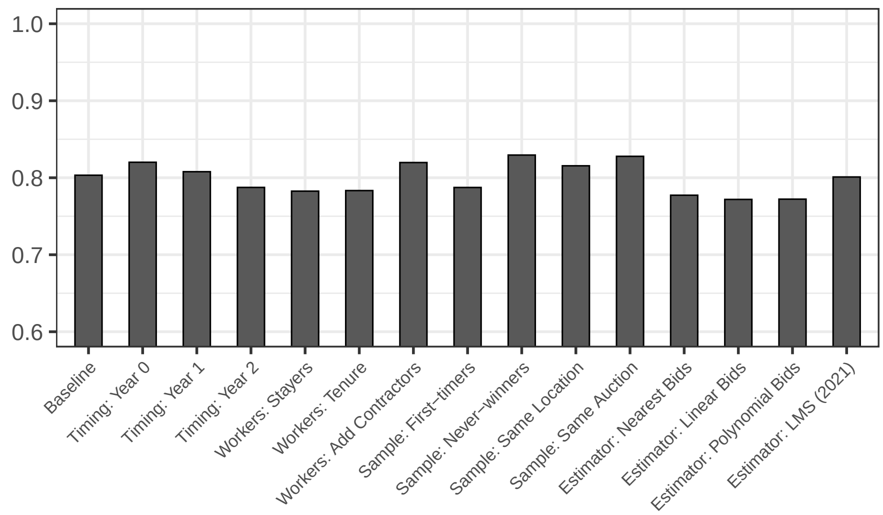
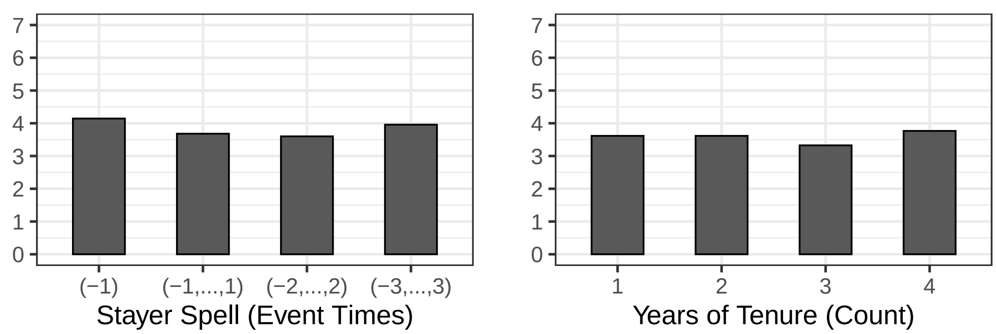


Figure A.4: Markdown: Baseline Estimate and Alternative Specifications

Notes: This figure presents the baseline estimate and sensitivity checks for the markdown, $\frac{1/\theta}{1+1/\theta}$. Specification details and sample definitions are provided in the text in Section 5.1.

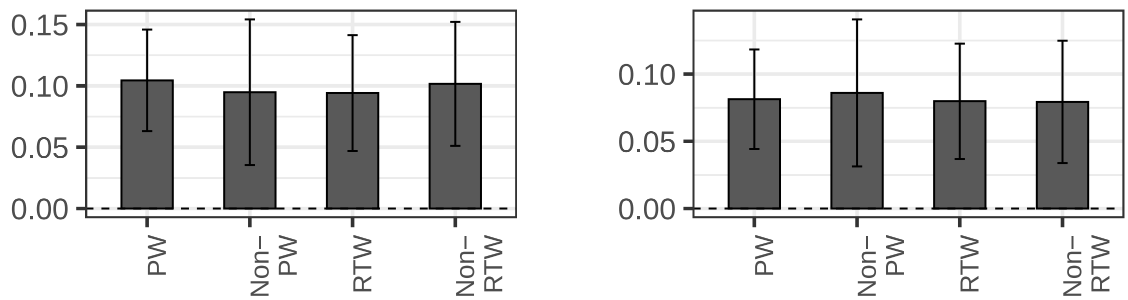


(a) Stayer Definitions

(b) Tenure Definitions

Figure A.5: Labor Supply Elasticity: Robustness to Stayer and Tenure Sample Definitions

Notes: This figure presents estimates of the IV estimator defined in Proposition 1 of Section 4.1. It provides these estimates for alternative sample definitions for stayers (subfigure a) and tenured workers (subfigure b).

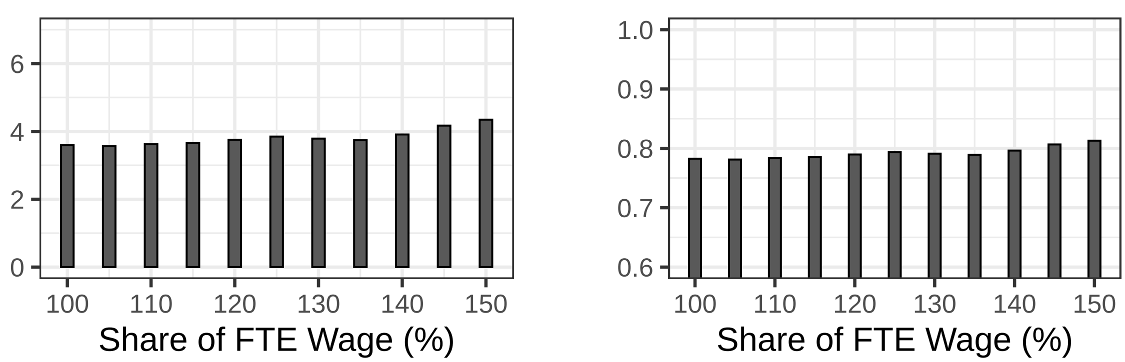


(a) Wage bill

(b) Employees

Figure A.6: Reduced Form Estimates by Right-to-Work or Prevailing Wage States

Notes: This figure presents estimates used in the numerator and denominator, respectively, of the IV estimator defined in Proposition 1 of Section 4.1. We restrict the sample to auctions located in Right-to-Work (RTW) or non-RTW states, or auctions located in Prevailing Wage (PW) or non-PW states.

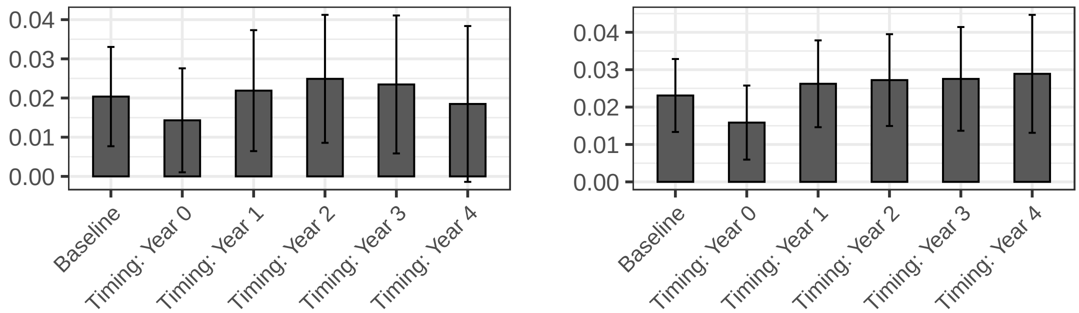


(a) Labor Supply Elasticity

(b) Markdown

Figure A.7: Estimates for Stayers: Robustness to FTE Wage Restriction

Notes: This figure presents estimates using the IV estimator defined in Proposition 1 of Section 4.1. It focuses on the sample of "stayers" who remained FTE employed by the same firm from at least 2 years prior to the auction until at least 2 years after the auction. It varies the FTE restriction from 100 percent to 150 percent of the baseline definition.

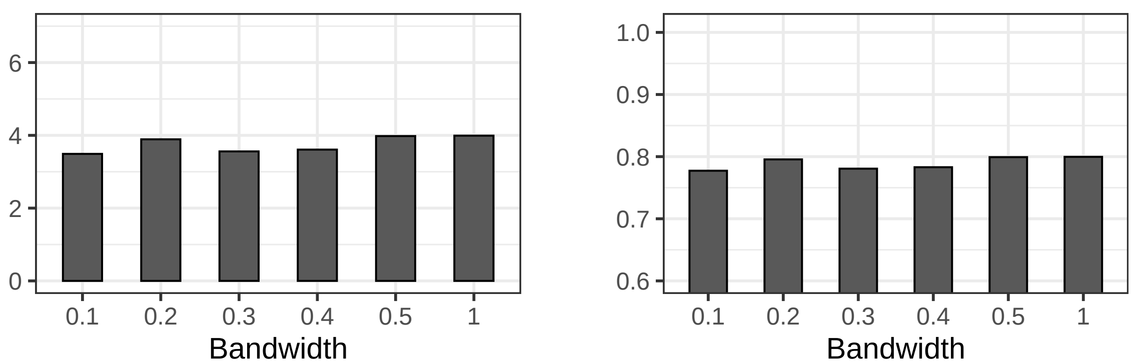


(a) Workers: All

(b) Workers: Stayers

Figure A.8: Reduced Form Estimates at Annual Frequency

Notes: This figure presents estimates of the DiD estimand corresponding to the numerator of θ_{IV}. It provides these estimates separately by year relative to the year in which the recipient of the procurement contract is announced, both for all the workers in the firm (subfigure a) and stayers (subfigure b).



(a) Labor Supply Elasticity

(b) Markdown

Figure A.9: Bandwidth Estimator: Robustness to Choice of Bandwidth

Notes: This figure presents results from the bandwidth estimator characterized by Proposition 2 in Section 4.1. On the x-axis, it specifies the bandwidth parameter $\overline{\tau}$. On the y-axis, it provides estimates of the labor supply elasticity $1/\theta$ (subfigure a) and the markdown $\frac{1/\theta}{1+1/\theta}$ (subfigure b).

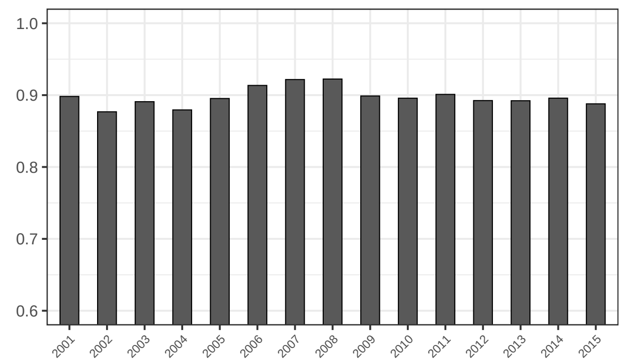
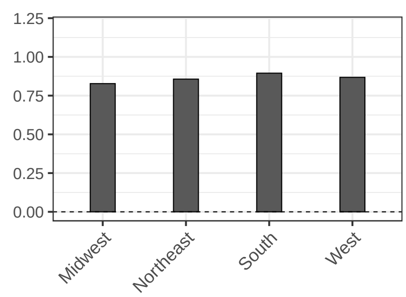
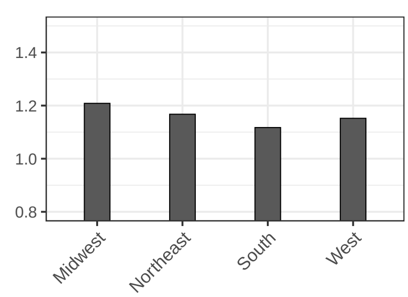


Figure A.10: Interquartile Range in TFP by Year

Notes: This figure presents the interquartile range of TFP estimated separately by calendar year.



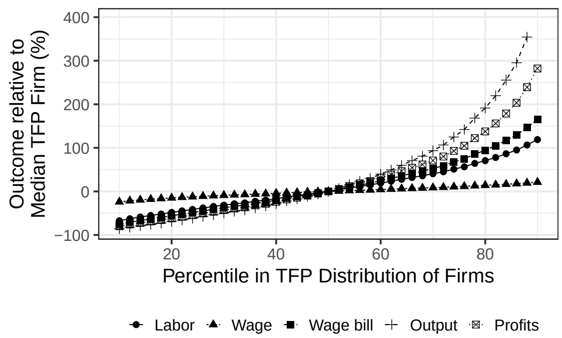
(a) Estimate of $1-\epsilon$



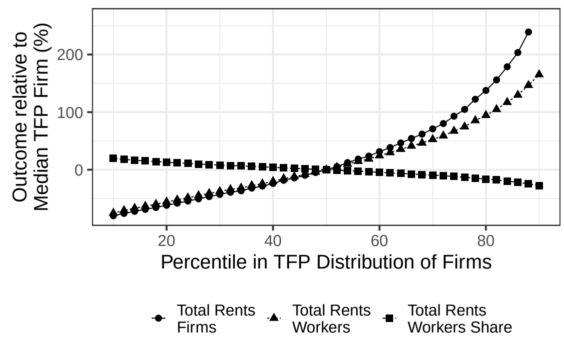
(b) Implied Price Markup

Figure A.11: Heterogeneity across Census Regions in the Estimate of $1-\epsilon$

Notes: This figure presents heterogeneity across Census regions in the estimate of $1-\epsilon$ using the estimator of Proposition 3, as well as the implied price markup $(1/\epsilon)\,/\,(1/\epsilon-1)$.



(a) Outcomes



(b) Total Rents

Figure A.12: Firm Heterogeneity, Simplified Model in which Firms Only Produce for the Private Product Market

Notes: This figure presents the counterfactual values of labor, wages, the wage bill, output, and profits (subfigure a) as well as total rents (subfigure b). It expresses these values as percentage differences from the typical firm, defined as the median-TFP firm. See Appendix G for the model equations used to estimate these outcomes while shutting down the procurement market.

F Compensated Rotation Comparative Statics

Set up: For simplicity, we consider a production function in which labor is the only input, returns to scale are constant ($\rho = 1$), and firms can only sell output to the private market when deriving theoretical predictions. We focus on firm j at time t, omitting these subscripts without loss of generality, and normalize TFP as $\Phi = 1$. The production function is then $Q = L$. This implies that revenue can be expressed in terms of labor as $R = p_H L^{1-\epsilon}$, so marginal revenue is $\text{MRP} = p_H(1-\epsilon)L^{-\epsilon}$. Since labor is the only input, the marginal cost of production is given by the marginal cost of labor, which is $\text{MCL} = U\,(1+\theta)\,L^{\theta}$. We solve for the baseline equilibrium by equating MRP and MCL. The baseline equilibrium is characterized by $\overline{L} = \overline{Q} = \left(\frac{p_H}{U}\frac{1-\epsilon}{1+\theta}\right)^{\frac{1}{\theta+\epsilon}}$, $\overline{P} = p_H\overline{L}^{-\epsilon}$, $\overline{R} = p_H\overline{L}^{1-\epsilon}$, and $\overline{W}_{jt} = U\overline{L}^{\theta}$.

Rotation of labor supply curve: We now consider a compensated rotation of the labor supply curve. In particular, consider an (inverse) labor supply curve $W\,(L|U', \theta') = U'L^{\theta'}$ for some $\theta' \neq \theta$. This labor supply curve is a "rotation" around the initial equilibrium only if $W\left(\overline{L}|U',\theta'\right)=\overline{W}$; that is, the baseline labor quantity receives the same wage after the rotation as it did in the baseline equilibrium. This rotation $W\left(\overline{L}|U',\theta'\right)=\overline{W}$ is solved by $U'=\overline{W}\ \overline{L}^{-\theta'}$; that is, there is a unique "compensation" $U'-U$ to the location parameter of the labor supply curve such that $W\left(L|U',\theta'\right)$ is a "rotation" around the initial equilibrium and $\theta'\neq\theta$.

Suppose labor supply is rotated to become more inelastic; that is, $\theta'>\theta$, which also implies $U'<U$. The new equilibrium satisfies $L'=Q'=\left(\frac{p_H}{U'}\frac{1-\epsilon}{1+\theta'}\right)^{\frac{1}{\theta'+\epsilon}}=\overline{L}\left(\frac{1+\theta}{1+\theta'}\right)^{\frac{1}{\theta'+\epsilon}}$. Since $\left(\frac{1+\theta}{1+\theta'}\right)^{\frac{1}{\theta'+\epsilon}}<1$, then $L'<\overline{L}$ and thereby $Q'<\overline{Q}$. An implication is that $p_H\left(Q'\right)^{-\epsilon}>p_H\left(Q\right)^{-\epsilon}$, so $P'>\overline{P}$. Another implication is that $W'=U'\left(L'\right)^{\theta'}=U'\left(\overline{L}\left(\frac{1+\theta}{1+\theta'}\right)^{\frac{1}{\theta'+\epsilon}}\right)^{\theta'}=\overline{W}\frac{U'}{U}\left(\frac{1+\theta}{1+\theta'}\right)^{\frac{\theta'}{\theta'+\epsilon}}$. Since $\frac{U'}{U}\left(\frac{1+\theta}{1+\theta'}\right)^{\frac{\theta'}{\theta'+\epsilon}}<1$, it follows that $W'<\overline{W}$. Therefore, a compensated rotation of the labor supply curve to become less elastic results in reductions in the firm's employment, wage, and output, as well as an increase in its price.

Rotation of product demand curve: We now consider a compensated rotation of the product demand curve. In particular, consider an (inverse) product demand curve $P\left(Q|p_H',\epsilon'\right)=p_H'Q^{-\epsilon'}$ for some $\epsilon'\neq\epsilon$. This product demand curve is a "rotation" around the initial equilibrium only if $P\left(\overline{Q}|p_H',\epsilon'\right)=\overline{P}$; that is, the baseline output quantity receives the same price after the rotation as it did in the baseline equilibrium. This rotation $P\left(\overline{Q}|p_H',\epsilon'\right)=\overline{P}$ is solved by $p_H'=\overline{PQ}^{\epsilon'}$; that is, there is a unique "compensation" $p_H'-p_H$ to the location parameter of the product demand curve such that $P\left(Q|p_H',\epsilon'\right)$ is a "rotation" around the initial equilibrium and $\epsilon'\neq\epsilon$.

Suppose product demand is rotated to become more inelastic; that is, $\epsilon'>\epsilon$, which also implies $p_H'>p_H$. The new equilibrium satisfies $L'=Q'=\left(\frac{p_H'}{U}\frac{1-\epsilon'}{1+\theta}\right)^{\frac{1}{\theta+\epsilon'}}=\overline{L}\left(\frac{1-\epsilon'}{1-\epsilon}\right)^{\frac{1}{\theta+\epsilon'}}$. Since $\left(\frac{1-\epsilon'}{1-\epsilon}\right)^{\frac{1}{\theta+\epsilon'}}<1$, then $L'<\overline{L}$ and thereby $Q'<\overline{Q}$. An implication is that $U\left(L'\right)^{\theta}<U\left(\overline{L}\right)^{\theta}$, so $W'<\overline{W}$. Another implication is that $P'=p_H'\left(Q'\right)^{-\epsilon'}=p_H'\left(\overline{Q}\left(\frac{1-\epsilon'}{1-\epsilon}\right)^{\frac{1}{\theta+\epsilon'}}\right)^{-\epsilon'}=\overline{P}\frac{p_H'}{p_H}\left(\frac{1-\epsilon'}{1-\epsilon}\right)^{\frac{-\epsilon'}{\theta+\epsilon'}}$. Since $\frac{p_H'}{p_H}\left(\frac{1-\epsilon'}{1-\epsilon}\right)^{\frac{-\epsilon'}{\theta+\epsilon'}}>1$, it follows that $P'>\overline{P}$. Therefore, a compensated rotation of the product demand curve to become less elastic results in reductions in the firm's employment, wage, and output, as well as an increase in its price.

Rotation of both labor supply and product demand curves: Lastly, we consider rotating both the labor supply and product demand curves to become more inelastic; that is, $\epsilon' > \epsilon$ and $\theta' > \theta$. Following the same logic as above, $L' = \overline{L}\left(\frac{1+\theta}{1+\theta'}\frac{1-\epsilon'}{1-\epsilon}\right)^{\frac{1}{\theta'+\epsilon'}}$. Since $\left(\frac{1+\theta}{1+\theta'}\frac{1-\epsilon'}{1-\epsilon}\right)^{\frac{1}{\theta'+\epsilon'}} < 1$, then $L' < \overline{L}$ and thereby $Q' < \overline{Q}$. Since $W' = \overline{W}\frac{U'}{U}\left(\frac{1+\theta}{1+\theta'}\frac{1-\epsilon'}{1-\epsilon}\right)^{\frac{\theta'}{\theta'+\epsilon'}}$ and $\frac{U'}{U}\left(\frac{1+\theta}{1+\theta'}\frac{1-\epsilon'}{1-\epsilon}\right)^{\frac{\theta'}{\theta'+\epsilon'}} < 1$, it follows that $W' < \overline{W}$. Since $P' = \overline{P}\frac{p'_H}{p_H}\left(\frac{1+\theta}{1+\theta'}\frac{1-\epsilon'}{1-\epsilon}\right)^{\frac{-\epsilon'}{\theta'+\epsilon'}}$ and $\frac{p'_H}{p_H}\left(\frac{1+\theta}{1+\theta'}\frac{1-\epsilon'}{1-\epsilon}\right)^{\frac{-\epsilon'}{\theta'+\epsilon'}} > 1$, it follows that $P' > \overline{P}$. Therefore, a simultaneous compensated rotation of both the labor supply and product demand curves to become less elastic results in reductions in the firm's employment, wage, and output, as well as an increase in its price.

Lastly, we show that the impacts of increased market power in one market are attenuated by the existence of market power in the other market. In particular, we show that

$$\left.\frac{\partial^2 L}{\partial\theta'\partial\epsilon'}\right|_{\left\{P\left(\overline{Q}|p'_H,\epsilon'\right)=\overline{P},\ W\left(\overline{L}|U',\theta'\right)=\overline{W}\right\}} = \overline{L}\frac{1}{(\theta+\epsilon)^2}\left[\frac{1}{1+\theta}+\frac{1}{1-\epsilon}+\frac{1}{(1+\theta)(1-\epsilon)}\right] > 0.$$

Proof. We start with $L = \overline{L}\left[\frac{(1+\theta)(1-\epsilon')}{(1-\epsilon)(1+\theta')}\right]^{\frac{1}{\theta'+\epsilon'}}$, which implies

$$\log L - \log\overline{L} = \frac{1}{\theta'+\epsilon'}\left[\log\frac{(1+\theta)(1-\epsilon')}{(1-\epsilon)(1+\theta')}\right]$$

Setting $\theta = \theta'$ and $\epsilon = \epsilon'$ delivers $\log L - \log\overline{L} = 0$. We can calculate the following derivatives:

$$\frac{d\log L}{d\theta'} = \frac{1}{L}\frac{dL}{d\theta'} = -\frac{1}{(\theta'+\epsilon')^2}\left[\log\frac{(1+\theta)(1-\epsilon')}{(1-\epsilon)(1+\theta')}\right] - \frac{1}{\theta'+\epsilon'}\frac{1}{1+\theta'}$$

$$\frac{d\log L}{d\epsilon'} = \frac{1}{L}\frac{dL}{d\epsilon'} = -\frac{1}{(\theta'+\epsilon')^2}\left[\log\frac{(1+\theta)(1-\epsilon')}{(1-\epsilon)(1+\theta')}\right] - \frac{1}{\theta'+\epsilon'}\frac{1}{1-\epsilon'}$$

Substituting,

$$\frac{dL}{d\theta'} = -\left[\frac{1}{(\theta'+\epsilon')^2}\left[\log\frac{(1+\theta)(1-\epsilon')}{(1-\epsilon)(1+\theta')}\right] + \frac{1}{\theta'+\epsilon'}\frac{1}{1+\theta'}\right]L$$

$$\frac{dL}{d\theta'} = -\frac{1}{\theta' + \epsilon'} \left[\log L - \log \overline{L} + \frac{1}{1+\theta'} \right] L$$

$$\frac{dL}{d\epsilon'} = -\frac{1}{\theta' + \epsilon'} \left[\log L - \log \overline{L} + \frac{1}{1-\epsilon'} \right] L$$

Thus,

$$\begin{aligned}
\frac{d^2 L}{d\theta' d\epsilon'} &= \frac{1}{(\theta' + \epsilon')^2} \left[\log L - \log \overline{L} + \frac{1}{1+\theta'} \right] L - \frac{1}{\theta' + \epsilon'} L \frac{d \log L}{d\epsilon'} - \frac{dL}{d\epsilon'} \frac{1}{\theta' + \epsilon'} \left[\log L - \log \overline{L} + \frac{1}{1+\theta'} \right] \\
&= \frac{1}{(\theta' + \epsilon')^2} \left[\log L - \log \overline{L} + \frac{1}{1+\theta'} \right] L + \frac{1}{\theta' + \epsilon'} \left[\frac{1}{\theta' + \epsilon'} \left[\log L - \log \overline{L} + \frac{1}{1-\epsilon'} \right] \right] L \\
&= \frac{1}{(\theta' + \epsilon')^2} \Bigg(\left[\log L - \log \overline{L} + \frac{1}{1+\theta'} \right] L + \left[\log L - \log \overline{L} + \frac{1}{1-\epsilon'} \right] L \\
&+ \left[\log L - \log \overline{L} + \frac{1}{1-\epsilon'} \right] \left[\log L - \log \overline{L} + \frac{1}{1+\theta'} \right] L \Bigg)
\end{aligned}$$

Finally, evaluating at $L = \overline{L}$, $\theta = \theta'$, and $\epsilon = \epsilon'$ delivers:

$$\frac{d^2 L}{d\theta' d\epsilon'} = \overline{L} \frac{1}{(\theta' + \epsilon')^2} \left[\frac{1}{1+\theta'} + \frac{1}{1-\epsilon'} + \frac{1}{1-\epsilon'} \frac{1}{1+\theta'} \right] > 0.$$

□

G A Simplified Model in which Firms Only Produce for the Private Product Market

Our main analyses account for imperfect competition in both the private product market for construction projects and the government market for procurement projects. The government market for procurement projects is primarily relevant for the construction industry and is only a fraction of the size of the private market for construction projects. As a result, one may be interested in examining the importance of imperfect competition in labor and product markets when firms only have the option to produce for the private product market. To this end, this appendix presents the simplified model in which construction firms only produce for the private product market. Then, it uses this simplified model to repeat the counterfactual analyses from Section 7.2 when shutting down the government market for procurement projects.

We find in this appendix that counterfactual responses in output, wage bill, employment, and other outcomes are qualitatively similar to the results in the main model if we do not account for the government market. Counterfactual responses are somewhat more sensitive in the simplified model, as the government market serves as an outside option that makes firms less dependent on, and thus less sensitive to, demand from the private product market. We note that, while accounting for the government market does not alter the qualitative findings from these counterfactual exercises, including the government market for procurement projects in the model of the main text is key to deriving the identification results of Propositions 1, 2, and 4. Without these identification results, we could not have recovered the key model parameters like θ and ρ, which are in turn required to perform all counterfactual analyses.

G.1 Model

We parameterize worker preferences over employers the same way as we did in the main model, leading to the inverse labor supply curve for firm j at time t,

$$W_{jt} = L_{jt}^{\theta} U_{jt}, \tag{78}$$

where W_{jt} is the posted wage offer, L_{jt} is the number of employees, and U_{jt} represents amenities. As in our main model, the production function (in physical units) is

$$Q_{jt}^{H} = \min\{\Omega_{jt} L_{jt}^{\beta_L} K_{jt}^{\beta_K}, \beta_M M_{jt}\} \exp(e_{jt}), \tag{79}$$

where Ω_{jt} denotes total factor productivity (TFP), K_{jt} denotes capital, M_{jt} denotes intermediate inputs, and e_{jt} represents measurement error. We assume that capital and intermediate input markets are perfect, so firms can rent capital at constant rate

p_K and purchase intermediate inputs at constant price p_M. The first-order condition for capital implies a composite production function,

$$Q_{jt}^H = \min\{\Phi_{jt} L_{jt}^{\rho}, \beta_M M_{jt}\} \exp(e_{jt}), \tag{80}$$

where $\Phi_{jt} \equiv \Omega_{jt}[\frac{\beta_K}{\beta_L}\frac{(1+\theta)U_{jt}}{p_K}]^{\beta_K}$ is composite TFP and $\rho \equiv (1+\theta)\beta_K + \beta_L$ is the composite returns to labor. Defining $X_{jt} \equiv p_M M_{jt}$ as expenditure on intermediate inputs, the Leontief functional form implies that

$$X_{jt} = \frac{p_M}{\beta_M} L_{jt}^{\rho} \Phi_{jt}. \tag{81}$$

In the private product market, firm j at time t posts a price P_{jt}^H at which it is willing to produce. Consumers have idiosyncratic preferences over producers. We follow the parameterization of consumer preferences from the main model, which implies private market revenues are related to output in physical units by

$$R_{jt}^H = p_H \left(Q_{jt}^H\right)^{1-\epsilon}. \tag{82}$$

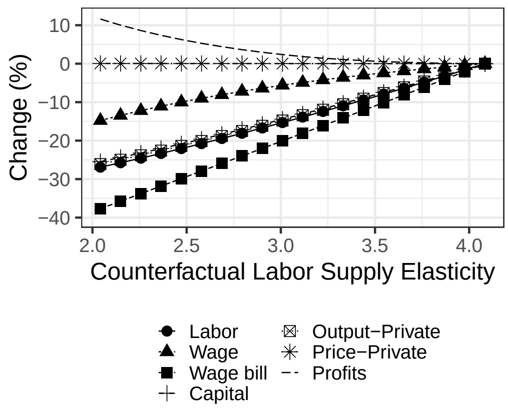
The firm's problem is to hire labor L_{jt}, purchase intermediate inputs M_{jt}, and rent capital K_{jt} to maximize private market profits,

$$\pi_{jt}^H = R_{jt}^H - W_{jt} L_{jt} - p_M M_{jt} - p_K K_{jt}, \tag{83}$$

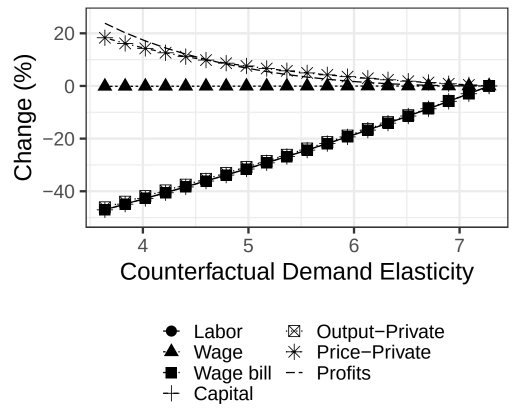
subject to the labor supply curve (equation 78), the production function (equation 80), the choice of intermediate inputs (equation 81), the private market revenue curve (equation 82), the price of intermediate inputs (p_M), and the price of capital (p_K). The profit-maximizing first-order condition is

$$\rho p_H (1-\epsilon) \Phi_{jt}^{1-\epsilon} L_{jt}^{\rho(1-\epsilon)-1} = (1+\theta) \kappa_U U_{jt} L_{jt}^{\theta} + \rho \frac{p_M}{\beta_M} \Phi_{jt} L_{jt}^{\rho-1}, \tag{84}$$

which uniquely determines L_{jt} as a function of Φ_{jt}, U_{jt}, and the model parameters. Given L_{jt}, Φ_{jt}, U_{jt}, and estimates of the model parameters, the other firm choices



(a) Impacts of Labor Market Power (assuming $\epsilon = 0$)



(b) Impacts of Product Market Power (assuming $\theta = 0$)

Figure A.13: Simplied Model with Only the Private Product Market: Quantifying the Impacts of Labor and Product Market Power

Notes: This figure presents counterfactual median outcomes when the labor market becomes less competitive and the product market is perfectly competitive (subfigure a) or the private product market becomes less competitive and the labor market is perfectly competitive (subfigure b). It expresses these values as percentage changes relative to the actual economy for the median-TFP firm.

W_{jt}, M_{jt}, K_{jt}, Q^H_{jt}, and R^H_{jt} are also uniquely determined from equations (78, 80, 81, 82).

G.2 Counterfactual Analyses

We now perform counterfactual analyses to examine how the outcomes and behavior of firms and workers would change if firms gained labor or product market power. As noted above, we need estimates of the model parameters such as θ, ϵ, and ρ in order to perform counterfactual analyses. Bids and outcomes from the procurement auctions are key to identifying these parameters, so we calibrate the model parameters to the estimates from the main model. We caution that these parameter estimates may or may not be reasonable in a counterfactual economy with no government market for procurement projects.

The results for labor market power are displayed in Figure A.13(a). In this figure, we increase the degree of labor market power through a compensated decrease in the labor supply elasticity $1/\theta$ while counterfactually shutting down product market power ($\epsilon = 0$). We find that, as the firm gains labor market power, the extent to which it employs fewer workers and pays a lower wage to each employee is greater when it does not produce for the government market. When the labor supply elasticity of a given firm is reduced by half, the firm employs 27 percent fewer workers (versus 22 percent in the main model), decreases wages by 15 percent (versus 11 in the main model), and decreases the wage bill by 38 percent (versus 31 in the main model). Output is reduced by 26 percent (the same as the reduction in total output in the main model) and the profit of the firm is 12 percent higher (versus 7 in the main model). Thus, we see that the requirement to produce the amount of output specified in the procurement contract limits the extent to which firms producing in the government market can exploit labor by reducing output.

The results for product market power are displayed in Figure A.13(b). In this figure, we increase the degree of product market power through a compensated decrease in the product demand elasticity $1/\epsilon$ while counterfactually shutting down labor market power ($\theta = 0$). We find that, as the firm gains product market power, the extent to which it produces less output and receives a higher price is greater when it does not produce for the government market. When the product demand elasticity of a given firm is reduced by half, the firm produces 46.1 percent less output for the private market (versus 46.0 percent in the main model) and increases private market prices by 18.3 percent (versus 18.5 percent in the main model). Employment is reduced by 47 percent (versus 28 percent in the main model) and the profit of the firm is 24 percent higher (versus 21 percent in the main model). Thus, we see that the requirement to produce the amount of output specified in the procurement contract limits the extent to which firms producing in the government market can exploit product market power by reducing output.

H Computational Details

Overview: Simulating model counterfactuals is computationally challenging. Since $1/\theta$ and $1/\epsilon$ both appear in the firm's opportunity cost $\sigma(\phi_{jt}, u_{jt})$ (recall the definition associated with equation 8), it follows that changing these parameters also changes the optimal bid Z^*_{jt} (equation 14). In turn, the bid affects the additional rents captured by firms from winning a procurement contract. To perform the counterfactuals, we first solve the second stage problem for each ϕ_{jt} to find the counterfactual distribution of opportunity costs. Next, we solve the first stage problem to obtain the distribution of optimal bids given the counterfactual opportunity costs. Finally, we combine the optimal bid distribution from the first stage with the optimal private market profits from the second stage. From this, we recover all counterfactual outcomes. To ease the computational burden in solving for these distributions we implement the quantile representation method of Luo (2020). Our main results focus on counterfactual outcomes for the typical firm (the firm with the median value of ϕ_{jt}), which further reduces the computational burden.

Second stage: Denote the TFP quantile function as $\phi(\alpha)$ where, for example, $\alpha = 0.10$ indicates the 10th quantile of the TFP distribution. We use a log Normal distribution to approximate the distribution of TFP, which allows for a simple mapping between ϕ and α, choosing the standard deviation that matches the interquartile range of TFP (reported in Table 1). For each combination of winner status, TFP quantile, and auction size $\left(d, \alpha, \bar{Q}^G\right)$, we solve the second-stage problem for firm and worker outcomes. This is done by numerical optimization of the profit function (equation 8) subject to the labor supply curve (equation 2), the production function (equation 9), and the optimal intermediate inputs condition (equation 10).

First stage: The challenge is to compute expectations of the second-stage across the distribution of outcomes from the first-stage. To solve the first-stage, note that the opportunity cost of winning an auction of size $\overline{Q}^G$ is $\sigma\left(\alpha|\overline{Q}^G\right) = \pi^H_0(\alpha) - \pi^H_1\left(\alpha|\overline{Q}^G\right)$. Since π^H_{1jt} is the winning firm's revenue in the private market net of the total cost, it follows that $\pi^H_{0jt} > \pi^H_{1jt}$ and thus $\sigma > 0$. π^H_1 is decreasing in $\overline{Q}^G$, and π^H_0 does not depend on $\overline{Q}^G$. Moreover, σ is decreasing in α. In other words, a higher TFP firm has a lower opportunity cost of producing in the government procurement market. Since α represents quantiles of TFP, it has the standard uniform distribution. The probability that the winning quantile is less than α is the probability that it is the lowest among all I bidders' draws from the standard uniform distribution, yielding the probability α^I and associated density function $f_1(\alpha, I) = I\alpha^{I-1}$. By similar reasoning, the density function of a losing firm's TFP quantile is $f_0(\alpha, I) = \frac{I}{I-1}(1 - \alpha^{I-1})$.

Solution: Let $Y_d\left(\alpha|\overline{Q}^G\right)$ denote a second-stage outcome for a firm characterized by TFP quantile α bidding in an auction of size $\overline{Q}^G$. Using the distribution functions from the first stage, we compute the expected outcome as $\mathbb{E}\left[Y_d|\overline{Q}^G, I\right] = \int_0^1 Y_d\left(\alpha|\overline{Q}^G\right) f_d(\alpha, I)\, d\alpha$. For example, the probability that a bidder with TFP ϕ_{jt} wins the project is the probability that its TFP is the highest among all participating bidders, i.e, $H(\phi_{jt})^I$,where H denotes the distribution of TFP. This implies that the density function of the winner's TFP is $IH(\phi_{jt})^{I-1}h(\phi_{jt})$. The profit function depends on who wins the auction, in particular, the TFP of the winner. The expected profit of the winner is then

$$\bar{\pi}_{1jt} = \int \pi_{1jt}(\phi_{jt}|\overline{Q}^G)[IH(\phi_{jt})^{I-1}h(\phi_{jt})]d\phi_{jt} = \int \pi_{1jt}(\phi_{jt}(\alpha)|\overline{Q}^G)I\alpha^{I-1}d\alpha.$$

Note that this expectation depends on the combinations $\left(\overline{Q}^G, I\right)$. One possibility is to solve the model for each possible combination of $\left(\overline{Q}^G, I\right)$, and then average across them. In our setting, this is computationally infeasible. An alternative is to evaluate $\left(\overline{Q}^G, I\right)$ at representative values. In practice, we choose the values of $\left(\overline{Q}^G, I\right)$ that provide the best fit to the additional rents from procurement projects, $(V_{jt\Delta}, \pi_{jt\Delta})$, for the typical firm. The best fit yields a model-simulated incidence on workers of about \$6,500, which is the same as the main estimate in Table 2, and incidence on firms of \$9,200, which is very close to the main estimate of about \$9,600 in Table 2. The implied incidence share on workers is about 41 percent, which is about the same as our main estimate. The best fit is achieved at $I = 5$ bidders per auction, which is in the right ballpark to the mean observed value in the data of around 8 bidders per auction.

Additional details: We now provide the derivation of the quantile representation of the optimal bidding strategy. Consider a standard first-price auction model. Following Guerre et al. (2000), we can rewrite the first-order condition and obtain a representation of the cost as a function of observables:

$$c = b - \frac{1}{I-1}\frac{1-G(b)}{g(b)},$$

where $G(\cdot)$ and $g(\cdot)$ are the bid distribution and density, respectively. Since the bidding strategy is strictly increasing, we can further rewrite this expression in terms of quantiles:

$$c(\alpha) = b(\alpha) - \frac{1}{I-1}[1-\alpha]b'(\alpha),$$

where $c(\cdot)$ and $b(\cdot)$ are the cost quantile function and the bid quantile function, respectively. The boundary condition is that the least efficient firm bids the highest, i.e., $c(1) = b(1)$. Following Luo (2020), we solve this ODE and obtain the mapping from the cost quantile function to the bid quantile function:

$$b(\alpha) = (I-1)(1-\alpha)^{1-I}\int_{\alpha}^{1} c(x)(1-x)^{I-2}dx.$$

This representation is convenient for numerically solving the first-price procurement auction model.

S Online Data Supplement

S.1 Acquisition and Preparation of Auction Data

This appendix describes our data sources for auction bids and how we build the data set for our main application. Appendix Table A.1 provides a summary of the sources of DOT records by state.

Bid Express Auction Records

The Bid Express website collects information on bids and bidders for procurement auctions held by Departments of Transportation of many US states. It can be freely accessed at `www.bidx.com`, although the access to information on the bidders requires a paid account registration. We scraped 17 states' DOT auction records from Bid Express. We performed the scraping using the Python library *Selenium* to automate browser actions. We registered a BidX.com account, which is required to access bidder information.

We collect the auction information for a given state using the following procedure:

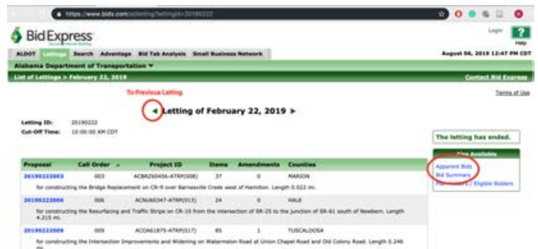
1. We go to the web page of that state on BidX.com and select the latest letting.

   Browser actions: visit `www.bidx.com`, select the desired agency from "Select a U.S. Agency" drop down menu and click the button "go". An illustration is provided in Appendix Figure S.1a. Then click the "Letting" tab on the top left corner of the new refreshed web page and click the first letting date hyperlink in "List of Letting" table. An illustration is provided in Appendix Figure S.1b.

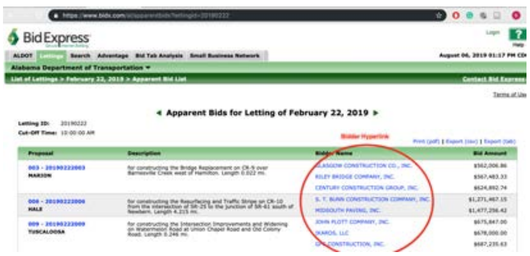
2. There are two different sources of information - "Apparent Bids" and "Bid Summary" - on a letting page. More specifically, "Apparent Bids" and "Bid Summary" contain auction information but in different formats, and both of them have links to additional bidder information, which requires a paid account to access. Starting from the latest letting page, our scraper clicks the hyperlink "Apparent Bids" (Appendix Figure S.1c) then downloads a csv file for every

bidder by clicking on the bidder hyperlink (Appendix Figure S.1d) and "Export(csv)" on the refreshed page.

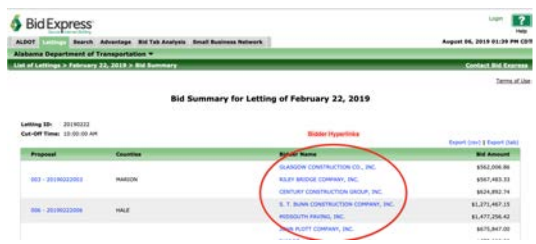
(a) Front Page



(b) Letting Page



(c) Apparent Bids Page



(d) Bid Summary Page

Figure S.1: Web Pages from BidX.com

If there is no information on the refreshed page, it moves to a new letting by clicking the arrow with html class "prev_arrow". The procedure is iterated until the arrow is not clickable. We repeat the same procedure for the "Bid Summary" hyperlink.

Through this procedure, we obtain three tables for each letting:

a. auction information from "Apparent Bids", which contains: bidder names, bidder ID, bidder ranks, bid amounts, bidder call orders, project description, counties, letting ID and letting date. We do note that a few states record two extra variables: DBE Percentage and DBE Manual.

b. auction information from "Bid Summary", which contains: bidder names, bidder ID, bidder ranks, bid amounts, bidder call orders, counties, proposal ID and letting date.

c. additional bidder information from bidder links, which contains: company name, company address, company phone number, company fax number.

We then merge the table c into a and b. Therefore, two files are created for every letting, one for "Apparent Bids" and one for "Bid Summary" with both auction and firm level information.

The information at the letting level is then further aggregated for each state as follow:

1. For a state X, we merge its "Apparent Bids" files into one single file *X_ apparentbid* and "Bid Summary" files into one single file *X_ bidsummary*. Then we add a new variable *State*, which is the two-letter abbreviation of states, in *X_ apparentbid* and *X_ bidsummary*.

2. Then we find lettings that are in *X_ bidsummary* but not in *X_ apparentbid*, and augment them so that they have the same variables as lettings in *X_ apparentbid*.[1] The variables added are filled with "N/A". Then we merged these lettings with *X_ apparentbid* into one file *X_ all*

3. We merge all **_ all* files into one final file.

As a result, we obtain a comprehensive file that has the following variables: Date of the auction, unique auction identifier, name of the bidding firm, address of the bidding firm, unique firm identifier, total bid amount, and state in which the auction occurred.

State-specific Auction Records

We obtained auction records on 12 other states from two types of sources: scraping state-specific bidding websites (7 states) and submitting Freedom of Information Act (FOIA) requests to state governments (5 states). Each data set included different variables and were organized in different formats. For example, the data from Texas included 121 variables while the data from West Virginia included only 11 variables.

[1]Proposal in *X_ bidsummary* is treated as Letting ID.

We harmonized these data sets focusing on the core set of variables: Date of the auction, unique auction identifier, name of the bidding firm, address of the bidding firm, unique firm identifier, total bid amount, and state in which the auction occurred. Note that one state, West Virginia, transitioned from its own website to Bid Express in 2011, so we use combined records from both sources. Once harmonized, we combined the various state-specific DOT auction records with the records obtained from Bid Express.

EIN Availability

We were able to obtain the EINs for firms that bid in DOT auctions in six states:

- Florida, Indiana, and West Virginia: These states' DOT auction records were scraped from state-specific websites. The EINs were available from these websites.
- Colorado and Kansas: These states' DOT auction records were obtained through FOIA requests. The requested data included EINs.
- Texas: This state's DOT auction records were obtained through a FOIA request. Although this request did not include EINs, we were able to look up EINs by firm name and address through a Texas state government website: https://mycpa.cpa.state.tx.us/coa/.

S.2 Matching Auction Data to Tax Records

This appendix describes the procedure adopted to match the bidders in our auction sample to the tax data. For a subset of bidders the Employer Identification Number (EIN) is available in the auction data, providing a unique identifier for the matching. For those observations an exact matching can be performed. We refer to this subset of perfect matches as the *training data*. In any other case, we rely on the fuzzy matching algorithm described below.

The procedure takes advantage of some regularities in the denomination of firms and common abbreviations to improve the quality of matching. Furthermore, in order to properly distinguish different branches of the same company, additional information on value added or state will be used.

Overview of denominations

Generally, a business name consists of three parts: a distinctive part, a descriptive part, and a legal part.[2] The distinctive part is named by the business owner and is usually required by governments to be "*substantially different*" from any other existing name. The descriptive part describes what the business does, or its sector.[3] Finally, the legal part refers to the business structure of a corporation. For example, for the name "Rogers Communications Inc.", "Rogers" is the distinctive part, "Communication" is the descriptive part, and "Inc." is the legal part. Most of the discrepancies of company names between different sources arise from the descriptive and the legal parts, since they are more subject to be abbreviations or common synonyms.

The legal part of corporation names takes a fairly small number of denominations, therefore can be identified using a properly constructed dictionary and treated separately. Conversely, disentangling the distinctive and the descriptive parts is not as straightforward. However, conventionally, the descriptive part follows the distinctive one within the string. This observation motivates a procedure that gives more weight to the first words within a company name, since they are more likely to be part of the distinctive part.

Legal-Parts Dictionary

In order to construct a uniform abbreviation in the legal part, we constructed a many-to-one dictionary using a subsample of our training data. We manually select abbreviations (including for misspelled words) by comparing mismatched names for the same firm in multiple databases. For example, "Incorporated" appears as "Inc."

[2]Although there are no specific regulations on this naming structure, it is in alignment with naming convention and government guidelines. https://www.ic.gc.ca/eic/site/cd-dgc.nsf/eng/cs01070.html

[3]An example would be California Code of Regulations for business entities. https://www.sos.ca.gov/administration/regulations/current-regulations/business/business-entity-names/#section-21000

Algorithm 1 Matching Algorithm Pseudocode

```
Input: S^a, State^a, Dict, IRS_Firmlist_normalized
Output: Match^a, Score^a
1. Name Normalization;
S^a_norm = Remove non-alphanumeric characters and double spaces from S^a and set uppercase letters;
W^a ≡ {w^a_1, w^a_2, ..., w^a_n} = Split substrings at spaces (S^a_norm);
for i = 1, ..., n do
    if w_i ∈ Dict then W = W −' {w_i};
S^a_norm = Merge words in W ;
2. Shortlisting; Shortlist = IRS_Firmlist_normalized
Candidate="Unmatched"
Out=0
i=0
repeat
    i=i+1
    C= {FirmName ∈ IRS_Firmlist_normalized  |  w^a_i ∈ FirmName}
    Shortlist= Shortlist ∩  C
    if Shortlist is singleton then
        Candidate= Shortlist
        Out=1
    if Shortlist is empty then
        Out = 1
    else
        Candidate= Shortlist
until Out=1;
3. Scoring
for c ∈ Candidate do
    Score^c= Levenshtein distance(c,S^a_norm)
Best= argmax{Score^c}
if Levenshtein distance(Best,S^a_norm)<0.6 then
    Match^a ="Unmatched"
else
    Match^a=Best;
    Score^a= Levenshtein distance(Best,S^a_norm)
```

"INC", "Incorp" and so on in our data. Therefore, these abbreviations, when found, are mapped into "Incorporated" as described below. Our dictionary and matching algorithm are available upon request for replicability.

Matching Algorithm

We now describe the database matching algorithm (written in Python). A pseudocode representation of this procedure is provided in Appendix Algorithm 1. For each company name in the auction database, the algorithm searches the best match in the tax database. Although the algorithm is meant for the comparison of corporate names, it can be augmented with additional information if available. In our main application, the auction data contains information about the name and the state of origin of the bidding firms. The latter can be used to improve the quality of the matching by using a "blocking" procedure that prioritizes firms from the same origin state, as explained below. Let a be the firm, S^a be the firm's string name and $State^a$ be the firm's state of origin. The state of origin is only used if the *state* option is enabled in the code provided. The algorithm proceeds as follow.

1. Name Normalization

   All non-alphanumeric characters with the exception of spaces are removed from S^a and all letter characters are capitalized. Consecutive white spaces are replaced with one white space. Any sub-string separated by one space is considered a "word". Every word in the legal-parts dictionary is removed. For example, "Amnio Brothers Inc." is composed by the three words "Amnio" "Brothers" and "Inc.". After the first step, it would be normalized to "AMNIO BROS", since the word "Brothers" is recognized in our dictionary as a synonym for "BROS" and "Inc." is recognized in our dictionary as a legal part and therefore removed. We refer to the normalized string as S^a_{norm}. The same normalization is applied to every company name in the tax database. If the normalized name is not unique in the tax database, we restrict to the ones that ever filed at least one of the three firm tax returns (1120,1120-S or 1065). If the same firm name filed multiple firm tax returns, we select the one with highest value added, as the firm with greater value added is participating in more economic activity and therefore more likely to be the firm that participated in the auction.

2. Shortlisting

   Let S^a_{norm} be composed by $n \geq 2$ words. Starting from the first word, we search in the list of normalized tax data company names the subset of names that contains that word. If the subset is empty, no matching occurs and the matching for A ends. If the subset is a singleton, A is paired with the unique element of the set and the shortlisting step ends for A. If the subset has more than one element, we proceed with the second word in S^a_{norm} and consider only the candidate matches that also contain the second word. If the set still contains more than one element, we proceed with the third word and so on, until all the n words are used or we obtain either a singleton or an empty set. If this iteration leads to a singleton, A is paired with the unique element of the set. If it leads to an empty set, then A is paired with the smallest non-empty subset from the previous iterations. In short, this step selects a shortlist of candidate matches that share, after normalization, the highest number of initial words with A. If the *state* option is enabled, only firms that match exactly the $State^a$ are considered for shortlisting.

3. Scoring

   This step employs the Levenshtein ratio (LR), a widespread measure of distance between strings, to select the best match from the shortlist. For each element of the set paired to A we compute its LR with respect to S^a. The company whose name has the highest score is selected as the match. If multiple companies tie for the top score, the one with the highest value added is selected. If the option *strict* is enabled, all the company names that do not reach a minimum threshold $T \in (0, 1)$ in their LR are dropped. If all candidate matches are dropped, then A is considered unmatched. Hence the higher the T, the more stringent is the matching process. In our application, we considered $T = 0.6$.

Appendix Table S.1 illustrates how the algorithm works with an example search, using "Hannaford Bros. Distribution Co." as the search query. In our example, *strict* and *state* are disabled.

In-Sample Algorithm Validation

In order to validate the algorithm, we apply it to the subset of firms for which we were provided the EIN by the state DOT, thus allowing us to link records exactly rather than using the algorithm (the "Known EIN" sample). The results are displayed in Appendix Table S.2. In Column (1), we provide results from using a simple string matching algorithm, in which a firm in the auction database is only matched to a firm in the tax database if they have identical names. In Columns (2-5), we apply our approach presented in Appendix Algorithm 1. Overall, the algorithm outperforms string matching in both accuracy and number of matches achieved. In our preferred specification in column (5), the algorithm correctly matches 84.5 percent of the bidders whose EIN are known and could be found in tax database. The use of

Steps	Output
String Normalization	Normalized Name: HANNAFORD BROS DISTRIBUTION
Shortlisting	The names(in bracket) and normalized names in the shortlist are shown below. The shared word is in bold. KELLY **HANNAFORD BROS DISTRIBUTION** (Kelly Hannaford Brothers Distribution Company) **HANNAFORD BROS DISTRIBUTION**(Hannaford Brothers Distri. C.) HASTING **HANNAFORD BROS DISTRIBUTION** (Hasting Hannaford Bros. Distribution Inc.)
Scoring	Normalized names in the shortlist are shown below. The scores are shown on the right of the names. KELLY HANNAFORD BROS DISTRIBUTION **(LR = 0.9)** HANNAFORD BROS DISTRIBUTION **(LR =1)** HASTING HANNAFORD BROS DISTRIBUTION **(LR =0.87)**
Unique match	HANNAFORD BROS DISTRIBUTION(Hannaford Brothers Distri. C.)

Table S.1: Example Search

the *State* option proves effective in increasing the number of true matches, while the *Strict* option with $T = 0.6$ improves accuracy by reducing the false matches.

Out-of-Sample Algorithm Validation

In order to assess the external validity of the algorithm outside our specific application, we constructed two test data sets using data from the Employee Benefits Security Administration (ESBA). Our test data sets, *PensionData* and *PensionTest*, are constructed using Form 5500 data sets that are published by the Employee Benefits Security Administration (ESBA)[4]. Form 5500 data sets contain information, including company names and EINs, about the operations, funding and investments of approximately 800,000 business entities. We consider both retirement and Health and Welfare data sets, drop every variable except the Company Name and EIN, then remove duplicate observations. For every unique EIN, we find all names that are associated with it, then we discard any duplicate names. Most of the EINs are associated with multiple company names, which reproduces a challenge in the tax database. For each EIN, if multiple names are associated with it, we select the first name and put

[4]https://www.dol.gov/agencies/ebsa/researchers/data

	Simple Search	Fuzzy Match			
	(1)	(2)	(3)	(4)	(5)
% Bidders Matched to Any Tax Record	80.2	99.9	97.6	99.9	95.8
% Bidders Matched to the True Tax Record	65.3	63.0	62.5	71.0	70.3
% Potential Matches Correctly Matched to Tax Records	78.6	75.8	75.1	85.4	84.5
Algorithm Parameters:					
Match must be perfect (string score = 1.0)	✓	✗	✗	✗	✗
Match must be high-quality (string score ≥ 0.6)	✗	✗	✓	✗	✓
Prefer matches in same state as auction	✓	✗	✗	✓	✓

Table S.2: In-Sample Algorithm Validation

Notes: This table provides summary statistics on the in-sample performance of the matching algorithm when applied to the six states that provided EINs. For these six states, we observe the true match between auction and tax records. Since some contractors are individuals rather than firms or are otherwise not required to file one of the three firm tax forms, not all contractors in auction data have a true match in firm tax records. First row provides share of contractors in the auction data that the algorithm matches to a firm tax record. Second row provides share of contractors in the auction data that the algorithm matches to a firm tax record and the match is true. Third row provides share of contractors in the auction data that the algorithm matches to a firm tax record and the match is true, among contractors in the auction data for which the true match exists in the firm tax data.

in into the *PensionData* data set and all the others into the *PensionTest* data set. If there is only one name associated with the EIN, we still add that name into *PensionData*. This gives us 709,850 companies in *PensionTest* and 1,270,079 companies in *PensionData*. We then proceeded to test our program using *PensionData* as a main data set and *PensionTest* as a query set.

T	0	0.2	0.4	0.6	0.8	0.9	1
Matches	99.05%	99.04%	98.46%	91.68 %	74.52%	64.44%	49.01%
Correct Matches	70.36%	70.37%	70.57%	73.39 %	80.69%	84.12%	82.58%

(a) Performance for Values of T

Quantile	1%	10%	30%	50 %	70%	90%	99%
Length	1	1	1	1	2	37	2733

(b) Quantiles of Shortlist Lengths

Table S.3: Out-of-Sample Algorithm Validation using Pension Data

We tested the program by searching in *PensionData* all the $709,850$ *PensionTest* firms. Since we have the EIN for all the names in the two data sets, we can evaluate the matching performance. The program achieved an average speed of 152 queries per second and an average accuracy of 73.39 percent among matched queries for a $T = 0.6$ using the *strict* option. Appendix Table S.3a presents the percentage of correctly matched firms and false matches for different values of T. We note that the percentage of correct matches is not monotone in T when T is close to 1. In fact, requiring extreme level of string similarity leads to a loss of correct matches that outweighs the gains in precision. Therefore, we do not recommend setting T above 0.9. In Appendix Table S.3b, instead, we provide a closer look at the effectiveness of the shortlisting step. Looking at the distribution of the shortlists' length, we see that over 50% of the sample is matched at the shortlisting step and 70 percent of the candidate matches requires the scoring of at most 2 candidates. Furthermore, the 99th percentile of the longest shortlist amounts to $2,733$ candidates. This is only 0.2 percent of the potential matches that a standard matching algorithm would have to consider for each query and, therefore, much more efficient.

S.3 Description of the Tax Data

All firm-level variables are constructed from annual business tax returns over the years 2001-2015: C-Corporations (Form 1120), S-Corporations (Form 1120-S), and Partnerships (Form 1065). Worker-level variables are constructed from annual tax returns over the years 2001-2015: Direct employees (Form W-2) and independent contractors (Form 1099).

Tax Return Variable Definitions:

- **Earnings:** Reported on W-2 box 1 for each Taxpayer Identification Number (TIN). Each TIN is de-identified in our data.
- **Employer:** The Employer Identification Number (EIN) reported on W-2 for a given TIN. Each EIN is de-identified in our data.
- **Employees:** Number of workers matched to an EIN in year t from Form W-2 with annual earnings above the annualized full-time minimum wage and where

the EIN is this worker's highest-paying employer.

- **Wage bill:** Total earnings among employees in year t.
- **Independent contractors:** Number of workers matched to an EIN in year t from Form 1099-MISC with annual compensation above the annualized full-time minimum wage.
- **NAICS Code:** The NAICS code is reported on line 21 on Schedule K of Form 1120 for C-corporations, line 2a Schedule B of Form 1120S for S-corporations, and Box A of form 1065 for partnerships.
- **Sales:** Line 1 of Form 1120 for C-Corporations, Form 1120S for S-Corporations, and Form 1065 for partnerships. Also referred to as gross revenues.
- **Intermediate Input Expenditures:** Line 2 of Form 1120 for C-Corporations, Form 1120S for S-Corporations, and Form 1065 for partnerships. Also referred to as cost of goods sold.
- **EBITD:** We follow Kline et al. (2019) in defining Earnings Before Interest, Taxes, and Depreciation (EBITD) as the difference between total income and total deductions other than interest and depreciation. Total income is reported on Line 11 on Form 1120 for C-corporations, Line 1c on Form 1120S for S-corporations, and Line 1c on Form 1065 for Partnerships. Total deductions other than interest and depreciation are computed as Line 27 minus Lines 18 and 20 on Form 1120 for C-corporations, Line 20 minus Lines 13 and 14 on Firm 1120S for S-corporations, and Line 21 minus Lines 15 and 16c on Form 1065 for partnerships.

Procurement Auction Variable Definitions:

- **Bid:** The dollar value submitted by the firm as a price at which it would be willing to complete the procurement project.
- **Auction winner:** A firm is an auction winner if it placed the lowest bid in a procurement auction.

- **Amount of winnings:** Bid placed by the winner in each auction.

- **Year of first win:** First year in which the firm is an auction winner. To account for left-censoring, we do not define a win as a "first win" unless there were at least two observed years of data during which the firm could have won and did not win an auction. For example, if a state provided auction records for 2001-2015, and a firm is first observed winning in 2001 or 2002, we do not consider this firm a first-time winner, but if the firm is first observed winning in 2003 or later, we consider it a first time winner.

Firm Sample Definitions:

- **Baseline sample:** A firm that files Form 1120, 1120-S, or 1065 is considered part of the baseline sample centered around auction cohort t if it is observed bidding in an auction in year t.

- **Sample of non-winners:** A firm in the baseline sample at t that does not win an auction before or during t is called a non-winner if it continues to not win any auctions until at least relative time $e \geq 4$. For example, if $t = 2005$, then a non-winner must not win its first auction until at least 2009.

- **Sample of first-timers:** A firm in the baseline sample at t that does not bid in an auction before t and bids in an auction at t.

- **Sample in the same location:** Firm j and j' are in the same location at t if their business address zip codes reported on the business tax filings correspond to the same commuting zone at t.

- **Known EIN sample:** Firms from the six states in which the auction records included the EIN, thus allowing us to link records exactly rather than using a fuzzy matching algorithm.

Worker Sample Definitions:

- **Main sample:** A worker is considered part of the main sample at t if the worker's highest-paying firm at t on Form W-2 is in the baseline sample of firms and the W-2 wage payments from that firm are greater than $15,000 in 2015 USD. We also restrict to workers aged 25-60.

- **Add Contractors:** Add to the main sample any independent contractor whose highest-paying firm at t on Form 1099 is in the baseline sample of firms and the 1099 wage payments from that firm are greater than $15,000 in 2015 USD. We also restrict to contractors aged 25-60.
- **Stayers:** A worker is a stayer for $2e+1$ years at firm j in the baseline sample of firms at t if the worker's highest-paying W-2 firm is the same firm during each time period in $(t-e,...,t+e)$ and the W-2 wage payments from that firm in each year are greater than $15,000 in 2015 USD.
- **Tenure:** A worker has e years of tenure at firm j in the baseline sample of firms at t if the worker's highest-paying W-2 firm is the same firm during each time period in $(t-e,...,t)$ and the W-2 wage payments from that firm in each year are greater than $15,000 in 2015 USD.
- **New Hires:** A worker is a new hire at firm j in year t if the worker's highest-paying W-2 employer in year t was firm j and highest-paying W-2 employer in year $t-1$ was firm $j' \neq j$, where the worker received W-2 wage payments greater than $15,000 in 2015 USD from j' in $t-1$ as well as from j in t.

A potential drawback of tax data is limited coverage of undocumented immigrants. As a result, we primarily interpret our paper as providing an analysis of the legal labor market. However, there is substantial coverage of undocumented immigrants in our W-2 returns. Since 1996, the IRS has assigned a tax identification number, called the ITIN, to undocumented immigrants in order to facilitate filing. By law, the IRS cannot share undocumented immigrant status with other agencies for purposes of immigration enforcement, so filing does not pose deportation risks. The IRS imposes penalties on employers for failing to file W-2 tax forms on behalf of undocumented employees, while tax refunds (e.g., child tax credits) and other benefits (e.g., evidence of consistently filing taxes can be used in support of citizenship applications) provide substantial incentives for undocumented immigrants to file. For example, the CBO (2007) estimated that up to 75 percent of all undocumented immigrants filed during the earlier part of our sample, and this rate may have risen due to DACA and other reforms instituted during the latter part of our sample.

S.4 Description of the Norwegian Data

The Norwegian data comes from the State Register of Employers and Employees, which covers the universe of workers and firms. Our sample spans 2009-2014. For each job, it includes information on start and end dates, annual earnings, and contracted hours. We construct annual earnings at the primary employer as our main outcome of interest. Because the Norwegian data also provides hours worked per day, we can construct the average hourly wage. We supplement the employer-employee data with a measure of value added, which we define as the difference in sales and non-wage operating costs as reported to the Norwegian tax authority by the firm.

To harmonize the Norwegian data with our sample from the US, we follow Bonhomme et al. (2020) by applying the following steps. First, as is common in the literature, whenever a worker is employed by multiple employers in the same year, we focus on the employer associated with the greatest annual earnings. Second, we restrict attention to workers employed in the construction industry. Third, we restrict attention to workers who are between 25 and 60 years of age. Lastly, we restrict attention to full-time equivalent (FTE) workers. Recall that, since we do not observe hours worked in US data, or a formal measure of full-time employment, we defined a worker as FTE if his or her annual earnings exceed $15,000, which is approximately the annualized minimum wage and corresponds to 32.5% of the national average. To harmonize the sample selection across countries, we similarly restrict the Norwegian sample to workers with annual earnings above 32.5% of the national average.