# Supplemental Online Appendices *for* Organized Labor, Labor Market Imperfections, and Employer Wage Premia

Sabien Dobbelaere, Boris Hirsch, Steffen Mueller, and Georg Neuschaeffer

## A Derivations for the production function approach

Plant $i$'s short-run profits at time $t$ are given by

$$\Pi_{it} = R_{it} - W_{it}N_{it} - J_{it}M_{it} \tag{A.1}$$

where $R_{it} = P_{it}Q_{it}$ denotes the plant's revenues, $P_{it}$ the price of the good, and $W_{it}$ and $J_{it}$ the input prices of labor and intermediate inputs, respectively. Then, the plant's optimization problem involves maximizing short-run profits (equation (A.1)) with respect to output $Q_{it}$, labor $N_{it}$, and intermediate inputs $M_{it}$.

### A.1 Price-cost markups on the product market

Turning to the plant's product market first, the first-order condition with respect to $Q_{it}$ yields the plant's price-cost markup:

$$\mu_{it} = \frac{P_{it}}{(C_Q)_{it}} = \left(1 + \frac{s_{it}\kappa_{it}}{e_t}\right)^{-1} \tag{A.2}$$

where $(C_Q)_{it} = \partial C_{it}/\partial Q_{it}$ denotes the marginal cost of production, $C_{it}$ the cost function, $s_{it} = Q_{it}/Q_t$ the market share of plant $i$ in sector demand $Q_t$, $e_t = (\partial Q_t/\partial P_t)(P_t/Q_t)$

the own-price elasticity of sector demand, and $\kappa_{it} = \partial Q_t / \partial Q_{it}$ a conjectural variations parameter that captures competitors' quantity response to plant $i$'s output choice.[1]

Turning to plant $i$'s choice of intermediate inputs next, the first-order condition with respect to $M_{it}$ yields $(Q_M)_{it} = \mu_{it} J_{it} / P_{it}$ where $(Q_M)_{it} = \partial Q_{it} / \partial M_{it}$ denotes the marginal product of intermediate inputs. Multiplying this expression by $M_{it}/Q_{it}$ yields

$$(\varepsilon_M^Q)_{it} = \mu_{it} \alpha_{Mit} \tag{A.3}$$

with the output elasticity of intermediate inputs $(\varepsilon_M^Q)_{it} = (\partial Q_{it} / \partial M_{it})(M_{it}/Q_{it})$ and their revenue share $\alpha_{Mit} = J_{it} M_{it} / R_{it}$. Hence, in the optimum the output elasticity of intermediate inputs equals the share of their expenditures in output evaluated at the marginal cost of production. Using equation (A.3), the price-cost markup is given as:

$$\mu_{it} = \frac{(\varepsilon_M^Q)_{it}}{\alpha_{Mit}} \tag{A.4}$$

### A.2 Wage markdowns and wage markups on the labor market

Unlike the price of intermediate inputs that the plant takes as given, wage formation depends on possible labor market imperfections. If there is perfect competition on the labor market, the first-order condition with respect to $N_{it}$ is analogous to intermediate inputs $(Q_N)_{it} = \mu_{it} W_{it} / P_{it}$ where $(Q_N)_{it} = \partial Q_{it} / \partial N_{it}$ denotes the marginal product of labor. Multiplying this expression by $N_{it}/Q_{it}$ yields

$$(\varepsilon_N^Q)_{it} = \mu_{it} \alpha_{Nit} \tag{A.5}$$

with the output elasticity of labor $(\varepsilon_N^Q)_{it} = (\partial Q_{it} / \partial N_{it})(N_{it}/Q_{it})$ and its revenue share $\alpha_{Nit} = W_{it} N_{it} / R_{it}$. As with intermediate inputs, this condition means that in the optimum

[1] Specifically, under Cournot competition with plants producing a homogenous good and competing in quantities, $\kappa_{it} = \partial Q_t / \partial Q_{it} = 1$ with a single sector-wide output price in equilibrium $P_{it} = P_t$. Hence, in this case the price-cost markup is $\mu_{it} = P_t / (C_Q)_{it} = (1 + s_{it}/e_t)^{-1}$. Under Bertrand competition with plants producing a horizontally differentiated good and competing in prices instead of quantities, $\partial P_t / \partial P_{it} = 1$ and thus $\kappa_{it} = \partial Q_t / \partial Q_{it} = e_t / (s_{it} e_{it})$ with $e_{it} = (\partial Q_{it} / \partial P_{it})(P_{it}/Q_{it})$ denoting plant $i$'s own-price elasticity of residual demand. Hence, in this case the price-cost markup is $\mu_{it} = P_{it} / (C_Q)_{it} = (1 + 1/e_{it})^{-1}$.

the output elasticity of labor equals the share of the plant's wage bill in its output evaluated at the marginal cost of production.

Absent labor market imperfections, comparing equations (A.3) and (A.5) shows that there exists no gap between the output elasticities of intermediate inputs and labor and their respective revenue shares:

$$\psi_{it} = \frac{(\varepsilon_M^Q)_{it}/\alpha_{Mit}}{(\varepsilon_N^Q)_{it}/\alpha_{Nit}} = 1 \tag{A.6}$$

What is more, $\psi_{it}$ gives the ratio of the employer's wage to the marginal revenue product of labor (see Caselli et al. 2021; Yeh *et al.* 2022), as is seen from rewriting equation (A.6) as:

$$\psi_{it} = \frac{(\varepsilon_M^Q)_{it}/\alpha_{Mit}}{(\varepsilon_N^Q)_{it}/\alpha_{Nit}} = \frac{\mu_{it}}{\frac{(Q_N)_{it}N_{it}}{Q_{it}}\frac{P_{it}Q_{it}}{W_{it}N_{it}}} = \frac{W_{it}}{P_{it}(Q_N)_{it}/\mu_{it}} = \frac{W_{it}}{(R_N)_{it}} \tag{A.7}$$

where the second equality makes use of equation (A.4) for the price-cost markup $\mu_{it}$ and the last equality uses that the marginal revenue product of labor is given by $(R_N)_{it} = P_{it}(Q_N)_{it}/\mu_{it}$. From equation (A.7) we thus see that $\psi_{it}$ provides a reduced-form plant-level measure of how much wages deviate from the marginal revenue product of labor. A below-unity ratio $\psi_{it}$ indicates a wage markdown and an above-unity ratio $\psi_{it}$ a wage markup.

### A.3 Implied labor supply elasticity in case of wage markdowns

That said, we can also transform a given value of $\psi_{it}$ into the implied labor supply elasticity in case of a wage markdown or $\psi_{it} < 1$ and into the implied rent-sharing elasticity in case of a wage markup or $\psi_{it} > 1$ that rationalize the observed wage outcomes in a monopsony or efficient bargaining framework. We first consider the case of a wage markdown or $\psi_{it} < 1$ under monopsony.

In this case, plants' wage-setting power stems from the fact that the labor supply curve faced by a single plant is upward-sloping rather than horizontal as it would be under perfect competition. Let the labor supply faced by the plant paying $W_{it}$ be $N_{it}(W_{it})$ and its inverse $W_{it}(N_{it})$. Plugging the latter into the plant's profits (equation (A.1)), maximizing these with respect to $N_{it}$ yields the first-order condition

$$(R_N)_{it} = (W_N)_{it}N_{it} + W_{it}(N_{it}) \tag{A.8}$$

where $(W_N)_{it} = \partial W_{it}/\partial N_{it}$ is the slope of the labor supply curve to the plant.

Using equation (A.7) for the ratio $\psi_{it}$ and substituting equation (A.8) in the ratio $\psi_{it}$ gives:

$$\psi_{it} = \frac{W_{it}}{(R_N)_{it}} = \frac{(\varepsilon_W^N)_{it}}{(\varepsilon_W^N)_{it} + 1} \tag{A.9}$$

where $(\varepsilon_W^N)_{it} = (\partial N_{it}/\partial W_{it})(W_{it}/N_{it})$ is the wage elasticity of plant-level labor supply. Solving equation (A.9) for the labor supply elasticity yields:

$$(\varepsilon_W^N)_{it} = \frac{\psi_{it}}{1 - \psi_{it}} \tag{A.10}$$

The labor supply elasticity informs us on the plant's monopsony power as implied by the observed wage outcomes. Under perfect competition, the plant-level labor supply curve is horizontal with $(\varepsilon_W^N)_{it} = \infty$ and workers obtain the marginal revenue product of labor or $\psi_{it} = 1$. Under monopsony or $\psi_{it} < 1$, the plant's wage-setting power is negatively related to the labor supply elasticity $(\varepsilon_W^N)_{it}$ which, in turn, is positively related to $\psi_{it}$.

### A.4 Implied rent-sharing elasticity in case of wage markups

We now turn to the case of a wage markup of $\psi_{it} > 1$. As an underlying structural model rationalizing a wage markup, we consider efficient bargaining (McDonald and Solow 1981) between a risk-neutral plant and its risk-neutral workforce, though other structural models are possible as well. For instance, Stole and Zwiebel (1996) consider wage bargaining between individual workers and their employer when incomplete labor contracts provide incumbent workers with hold-up power.

Under efficient bargaining, the negotiated wage-employment pair maximizes both parties' joint surplus and follows from maximizing the generalized Nash product

$$\Omega = [N_{it}(W_{it} - \overline{W}_{it})]^{\phi_{it}}[R_{it} - W_{it}N_{it} - J_{it}M_{it}]^{1-\phi_{it}} \tag{A.11}$$

with respect to $W_{it}$ and $N_{it}$ where $\overline{W}_{it}$ denotes workers' outside option and $0 < \phi_{it} < 1$ the part of the surplus accruing to workers, which captures workers' bargaining power. In the generalized Nash product, workers' net gain is the amount by which their payroll exceeds the alternative wage while the plant's net gain is its short-run profits.[2]

The first-order condition with respect to $W_{it}$ and $N_{it}$, respectively, gives:

$$W_{it} = \overline{W}_{it} + \frac{\phi_{it}}{1-\phi_{it}}\left[\frac{R_{it} - W_{it}N_{it} - J_{it}M_{it}}{N_{it}}\right] \tag{A.12}$$

$$W_{it} = (R_N)_{it} + \phi_{it}\left[\frac{R_{it} - (R_N)_{it}N_{it} - J_{it}M_{it}}{N_{it}}\right] \tag{A.13}$$

Combining the two first-order conditions yields the so-called contract curve that characterizes efficient wage-employment pairs:

$$(R_N)_{it} = \overline{W}_{it} \tag{A.14}$$

The equality of the marginal revenue product of labor and workers' outside option means that the term in brackets on the right-hand side of equation (A.13) represents the quasi-rent per worker $QR_{it}/N_{it}$.

Using equation (A.13), the elasticity of the wage with respect to the quasi-rent per worker, that is the rent-sharing elasticity, is given by:

$$(\varepsilon^W_{QR/N})_{it} = \frac{\phi_{it}QR_{it}/N_{it}}{(R_N)_{it} + \phi_{it}QR_{it}/N_{it}} = \frac{W_{it} - (R_N)_{it}}{W_{it}} = \frac{\psi_{it} - 1}{\psi_{it}} \tag{A.15}$$

where the last equality uses $\psi_{it} = W_{it}/(R_N)_{it}$. The rent-sharing elasticity informs us on what fraction of a one percent increase in plant surplus shows up in workers' wages

[2] This formulation of efficient bargaining assumes that all employed union members immediately return to the external labor market when negotiations fail. Yet, results do not change when considering a sequence of bargaining sessions between the plant and a union of declining size whose members gradually lose jobs when disagreement continues (Dobbelaere and Luttens 2016).

and thus on workers' monopoly power as implied by the observed wage outcomes. Under perfect competition, there is no rent sharing with $(\varepsilon^{W}_{QR/N})_{it} = 0$ and workers obtain the marginal revenue product of labor or $\psi_{it} = 1$. Under efficient bargaining or $\psi_{it} > 1$, the rent-sharing elasticity $(\varepsilon^{W}_{QR/N})_{it}$, which captures workers' bargaining power, is positively related to $\psi_{it}$.

## B Measuring employer wage premia and surplus

To measure employer wage premia and plant surplus, we follow Card et al. (2018) and Hirsch and Mueller (2020). Our measure of wage premia builds on an AKM decomposition that splits up a worker's individual wage into a worker-specific and a plant-specific component. Specifically, the log wage of worker $m$ in period $t$ is decomposed as:

$$\ln W_{mt} = \zeta_m + \theta_{i(m,t)} + \mathbf{X}'_{mt}\boldsymbol{\beta} + \upsilon_{mt} \tag{B.1}$$

In equation (B.1), $\zeta_m$ is a permanent log wage component specific to worker $m$, $\theta_{i(m,t)}$ is a permanent component specific to plant $i$ employing worker $m$ at time $t$, $\mathbf{X}'_{mt}\boldsymbol{\beta}$ is a time-varying component stemming from time-varying worker characteristics $\mathbf{X}_{mt}$ that are rewarded equally across plants, and $\upsilon_{mt}$ is an idiosyncratic component.

In the AKM framework, $\zeta_m$ reflects the worker's permanent skills, such as education and ability, $\mathbf{X}'_{mt}\boldsymbol{\beta}$ mirrors the worker's time-varying skills, such as experience, that affect the worker's productivity no matter where the job is held, and $\theta_{i(m,t)}$ is the percentage wage premium paid to every worker of plant $i$. The crucial assumption for this interpretation of the AKM decomposition to hold is that the idiosyncratic log wage component $\upsilon_{mt}$ is unrelated to the sequence of employers $\{i(m,t)\}_t$, for which Card, Heining, and Kline (2013) provide supporting evidence in their AKM wage decomposition for Germany. For a critical assessment of the validity of the AKM framework in the US context, we refer to Lamadon, Mogstad, and Setzler (2022).

To measure the plant surplus to be split between employers and workers, we follow Abowd and Lemieux (1993) and use the quasi-rent per worker, with the plant's quasi-rent

$QR_{it}$ being defined as:

$$QR_{it} = P_{it}Q_{it} - J_{it}M_{it} - \overline{R}_{it}K_{it} - \overline{W}_{it}N_{it} \tag{B.2}$$

That is, the quasi-rent $QR_{it}$ is revenues $P_{it}Q_{it}$ net of the value of intermediate inputs $J_{it}M_{it}$ and capital inputs $\overline{R}_{it}K_{it}$, where $\overline{R}_{it}$ denotes the competitive rental rate of capital, and net of the value of labour inputs $\overline{W}_{it}N_{it}$ priced at workers' outside option $\overline{W}_{it}$.[3]

When constructing workers' outside option $\overline{W}_{it}$, we follow the idea in Abowd and Allain (1996) and calculate workers' outside option as:

$$\ln \overline{W}_{it} = \overline{\ln W}_{st} + (\bar{\zeta}_{it} - \bar{\zeta}_{st}) - (\bar{\theta}_{st} - \theta_{st}^{p25}) \tag{B.3}$$

In (B.3), $\overline{\ln W}_{st}$ is the average log wage (i.e. plant-level wage bill per worker) in the respective two-digit sector $s$, $\bar{\zeta}_{it}$ is the average AKM worker wage effect in plant $i$, $\bar{\zeta}_{st}$ is the average AKM worker wage effect, $\bar{\theta}_{st}$ is the average AKM plant wage effect, and $\theta_{st}^{p25}$ its 25th percentile in the two-digit sector. The term $\bar{\zeta}_{it} - \bar{\zeta}_{st}$ captures the deviation in worker quality between plant $i$ and the sector average and thus accounts for unobserved quality differences between plants' workforces. Moreover, subtracting the spread between the average AKM plant effect and its 25th percentile $\bar{\theta}_{st} - \theta_{st}^{p25}$ in the respective two-digit sector accounts for the influence of wage premia paid by future employers on workers' current outside option. Specifically, we assume that risk-averse workers expect to receive just a modest pay premium at the 25th percentile when switching employers.

As detailed in Hirsch and Mueller (2020), this way of constructing workers' outside option involves quite some decisions, and some of these may seem somewhat arbitrary. Yet, as also discussed there, in general different choices, such as using the 10th percentile of wage premia rather than the 25th percentile, make only little difference.

[3] Note that we compute the competitive rental rate of capital $\overline{R}_{it}$ from the plant's capital stock and in doing so distinguish between prices for debt and equity at the two-digit sector level because the IAB data do not contain such information at the plant level. Specifically, we use the information on the "cost of equity and capital" for Europe issued by Aswath Damodaran on 5th January 2019 at `http://pages.stern.nyu.edu/~adamodaran` and the 10-year long-term treasury bond rate for Germany to calculate the average rental rate of capital at the two-digit sector. Our average rental rate of capital is 9.9% for the years 1998–2004, 9.0% for 2005–2010, and 6.9% for 2011–2016.

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