Non-Compete Agreements, Tacit Knowledge and Market Imperfections

Eric Bartelsman[1], Sabien Dobbelaere[2] and Alessandro Zona Mattioli[3]

[1,2]Vrije Universiteit Amsterdam, Tinbergen Institute
[3]Vrije Universiteit Amsterdam

EEA 2024

Aug 28, 2024

Our Research Question

Study the role of **tacit knowledge** embedded in specific technologies in driving the **co-movement of product and labor market imperfections**

This Paper: Setting, Approach & Findings

1. We estimate jointly product and labor market imperfections across firms in manufacturing and services industries in the Netherlands

This Paper: Setting, Approach & Findings

1. We estimate jointly product and labor market imperfections across firms in manufacturing and services industries in the Netherlands
   - Most firm set prices above marginal costs ($\frac{P_{it}}{(C_Q)_{it}} > 1$) and pay workers above their marginal revenue product ($\frac{W}{(R_N)} > 1$)
   - This behavior is most prevalent among firms that adopt technologies relying more heavily on tacit knowledge

This Paper: Setting, Approach & Findings

1. We estimate jointly product and labor market imperfections across firms in manufacturing and services industries in the Netherlands
   - Most firm set prices above marginal costs ($\frac{P_{it}}{(C_Q)_{it}} > 1$) and pay workers above their marginal revenue product ($\frac{W}{(R_N)} > 1$)
   - This behavior is most prevalent among firms that adopt technologies relying more heavily on tacit knowledge
2. We develop a theoretical model to show how the processes of intangible investment and wage bargaining of heterogeneous firms rationalize these observed patterns

This Paper: Setting, Approach & Findings

1. We estimate jointly product and labor market imperfections across firms in manufacturing and services industries in the Netherlands
   - Most firm set prices above marginal costs ($\frac{P_{it}}{(C_Q)_{it}} > 1$) and pay workers above their marginal revenue product ($\frac{W}{(R_N)} > 1$)
   - This behavior is most prevalent among firms that adopt technologies relying more heavily on tacit knowledge
2. We develop a theoretical model to show how the processes of intangible investment and wage bargaining of heterogeneous firms rationalize these observed patterns
3. We validate the model through a natural experiment, leveraging on a change in the enforceability of non-compete agreements in the Netherlands in 2015

This Paper: Setting, Approach & Findings

1. We estimate jointly product and labor market imperfections across firms in manufacturing and services industries in the Netherlands
   - Most firm set prices above marginal costs ($\frac{P_{it}}{(C_Q)_{it}} > 1$) and pay workers above their marginal revenue product ($\frac{W}{(R_N)} > 1$)
   - This behavior is most prevalent among firms that adopt technologies relying more heavily on tacit knowledge
2. We develop a theoretical model to show how the processes of intangible investment and wage bargaining of heterogeneous firms rationalize these observed patterns
3. We validate the model through a natural experiment, leveraging on a change in the enforceability of non-compete agreements in the Netherlands in 2015
   - Lifting NCAs increases workers' wages and mobility
   - The impact is stronger for workers employed in intangible-intensive firms

Related Literature

This paper contributes to several strands of literature:

- Joint presence of **imperfections in product and labor markets** (Calligaris, Criscuolo, and Marcolin 2018; Yeh, Macaluso, and Hershbein 2022; De Loecker, Eeckhout, and Unger 2020; Heuvelen, Bettendorf, and Meijerink 2021; Mertens 2023; Raval 2023)

Related Literature

This paper contributes to several strands of literature:

- Joint presence of **imperfections in product and labor markets** (Calligaris, Criscuolo, and Marcolin 2018; Yeh, Macaluso, and Hershbein 2022; De Loecker, Eeckhout, and Unger 2020; Heuvelen, Bettendorf, and Meijerink 2021; Mertens 2023; Raval 2023)
- Impact of **intangible capital** on production (Corrado et al. 2013; Döttling and Perotti 2017; Haskel and Westlake 2018; Aghion, Antonin, et al. 2020; Crouzet et al. 2022; Hsieh and Rossi-Hansberg 2023) and **market power** (Bessen 2019; Acemoglu 2023; Aghion, Bergeaud, et al. 2023; De Ridder 2024)

Related Literature

This paper contributes to several strands of literature:

- Joint presence of **imperfections in product and labor markets** (Calligaris, Criscuolo, and Marcolin 2018; Yeh, Macaluso, and Hershbein 2022; De Loecker, Eeckhout, and Unger 2020; Heuvelen, Bettendorf, and Meijerink 2021; Mertens 2023; Raval 2023)
- Impact of **intangible capital** on production (Corrado et al. 2013; Döttling and Perotti 2017; Haskel and Westlake 2018; Aghion, Antonin, et al. 2020; Crouzet et al. 2022; Hsieh and Rossi-Hansberg 2023) and **market power** (Bessen 2019; Acemoglu 2023; Aghion, Bergeaud, et al. 2023; De Ridder 2024)
- **Non-compete agreements**:
    - Effect on worker-level outcomes (Marx, Strumsky, and Fleming 2009; McAdams 2019; Boeri, Garnero, and Luisetto 2022; Balasubramanian et al. 2022; Shi 2023)
    - Way to appropriate firm's intangible assets (Thomä and Bizer 2013; Stoyanov and Zubanov 2012; Sampat and Williams 2019)

Outline of Presentation

1. Product and labor market imperfections in Dutch manufacturing and services industries
   - Correlation with intangible intensity
2. Theoretical framework
3. Natural experiment
   - Lifting enforcement of non-compete agreements (NCAs) for temporary contracts in 2015 as part of the Dutch Work and Security Act
4. Conclusion

Estimating Product and Labour market imperfections

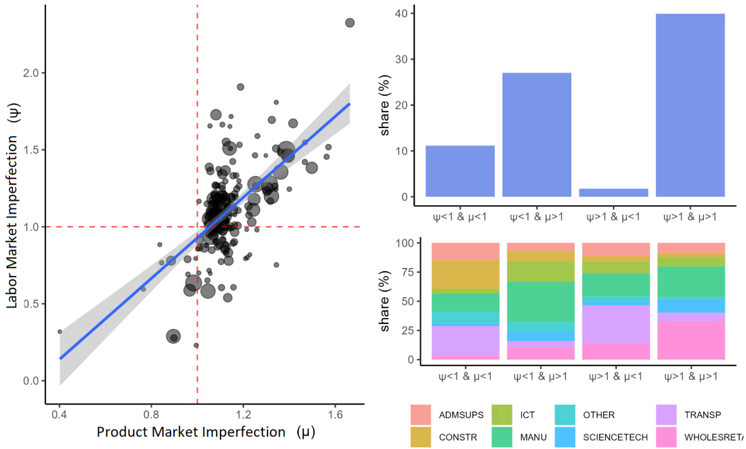
We build on the methodology first introduced by Dobbelaere and Mairesse 2013 to estimate:

- **Markups on intermediate inputs**: $\mu = \frac{P}{MC}$
  - $\mu > 1$ suggests that the firm may have some market power on final demand.
- **Wage markups/markdowns**: $\psi = \frac{W}{MRPL}$
  - $\psi > 1$ workers are paid above their MRP (rent-sharing).
  - $\psi < 1$ workers are paid below their MRP (monopsony).

The approach requires the structural estimation of a production function, where we follow the methodology of Ackerberg, Caves, and Frazer 2015 and Yeh, Macaluso, and Hershbein 2022.

Details on derivation | Details on Production Function Estimation | Data

Product and Labor Market Imperfections in Manufacturing and Services

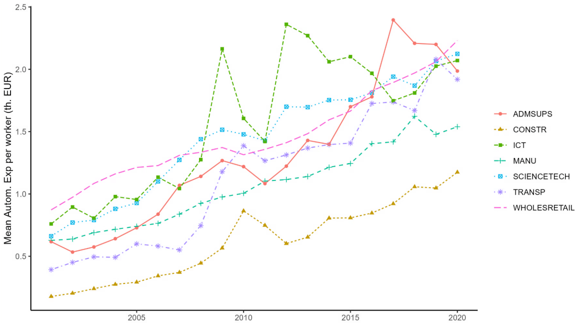


Manufacturing vs Services | Firm characteristics by quadrant

Intangible Intensity Measured by Automation Expenditure

To proxy for the importance of tacit knowledge within the firm, we use a firm's **automation expenditure**

- captures all forms of expenditure aimed at automating complex production processes and internal procedures within the firm via the use of data, software and hardware technologies, often not covered by IP protection.



Correlation between Market Imperfections and Intangible Intensity

	ψ	ψ	μ	μ	$\psi \mid \mu \geq 1$	$\psi \mid \mu \geq 1$
	(1)	(2)	(3)	(4)	(5)	(6)
Automation exp. per worker	0.018***	0.021***	0.003**	0.004***	0.014***	0.017***
Firm size	−0.135***	−0.166***	−0.021***	−0.026***	−0.126***	−0.165***
Firm age	0.009**	0.018***	−0.003	0.022***	0.007	0.009
Average wage	0.002**	0.002*	−0.000*	0.000	0.001*	0.001
Productivity	0.036***	0.014*	0.066***	0.041***	0.042***	0.034***
Foreign control		0.014*		−0.007*		0.023***
Export share of sales		−0.000*		−0.000		−0.000
HHI	0.000**	0.000***	0.000**	0.000***	0.000**	0.000***
Industry-level patenting share	0.274***	0.162	0.001	−0.186**	0.245***	0.257
Observations	172,211	82,708	174,686	84,605	148,246	72,750
R-squared	0.084	0.086	0.057	0.047	0.089	0.096
Number of Firms	29,100	18,444	29,305	18,593	27,340	17,072
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes

Automation by quadrant

Descriptive Evidence

- Dutch firms predominantly set **price-cost markups** and pay **wage markups**
- Such co-movement is **correlated to the use of technologies** within the firm
  - especially those that are knowledge-intensive, involve data manipulation and the use of software

Model Sketch

- A firm may rely for production on **intangible capital**:
  - The intangible asset lowers marginal cost of production $\implies$ higher competitiveness (Hsieh and Rossi-Hansberg 2023; De Ridder 2024)
  - The intangible asset is the product of a joint investment with some key workers and is imperfectly appropriable by the firm (Döttling and Perotti 2017; Crouzet et al. 2022)
    - workers are assumed to have tacit knowledge about the intangible asset
    - if workers leave, they walk away with part of the intangible capital $\implies$ loss of competitiveness
- Therefore, the firm is willing to **pay a wage premium to the workers**, to maintain the asset within the firm
- We lay down the processes of intangible investment and wage bargaining in an environment where:
  - firms are heterogeneous in their ability to invest in intangible capital
  - the labor market has job posting and on-the-job search (Burdett and Mortensen 1998)

Environment

Households

- Representative household maximizing U subject to a budget constraint:

$$U = \sum_{t=0}^{\infty} \beta^t \ln C_t$$

- C_t is consumption of final good made of a continuum of differentiated intermediate goods indexed by j
- Consumption is financed through labor income

Firms

- Final good is an aggregate of differentiated goods:

$$Y_t = \exp \int_0^1 \ln \left(\sum_{i \in I_j} q_{ij} y_{ij} \right) dj$$

where y_{ij} and q_{ij} denote quantity and quality of good j produced by firm i

- Each good j can be produced by the set of firms I_j that own a patent for it
- Firms in I_j compete à la Bertrand: consumers buy the good with the lowest quality-adjusted price p_{ij}/q_{ij}

Heterogeneous Firms

- Firms produce according to a general Cobb-Douglas production function:

$$y_{ij} = l_{ij}^{\alpha} \cdot (z_{ij} m_{ij})^{\beta}$$

l_{ij} denotes labor, m_{ij} intermediate inputs and $z_{ij} \geq 1$ the productivity of purchased intermediate inputs

- Hence, the marginal cost equals:

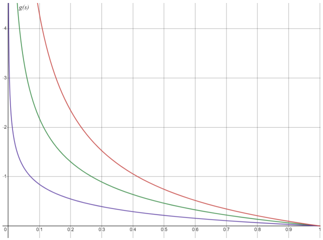
$$mc(w_i, z_{ij}) = w_i + \frac{v}{z_{ij}}$$

where w_i denote wages and v unit cost of intermediate input

Investment in Intangibles I

- Firms can reduce $s_{ij} = 1/z_{ij}$ by paying the investment cost g:

$$g(s_{ij}, \phi_i) = v\phi_i \left(s_{ij}^{-\theta} - 1\right)$$



- Firms are heterogeneous in q_{ij} and ϕ_i

- In order to invest, firms need workers to pay a cost as well:

$$r(s_{ij}) = \eta s_{ij}^{\eta}$$

- Workers are paid a wage w_i to compensate for their production work l_{ij} and investment

Investment in Intangibles II

- If workers and firms co-invest in intangible capital, firms reduce marginal cost by a share $(1 - s_{ij})$
- Workers are remunerated via wages but always **maintain ownership to a part of the intangible capital**
- If they leave their current employer, they will carry part of the asset with them
- We model this by a **loss of the competitive gain** (marginal-cost savings) by a fixed amount $\xi_{it} \in (0, \frac{1}{s_{ij}}]$ in case of separation
  - $\xi_{it} = \frac{1}{s_{ij}}$ is the limit case where the intangible asset is fully de facto ownership of the workers

Labor Market

- Jobs consist of a match between households and firms in a setting akin to the Burdett-Mortensen model
- Contact between workers and firms happens at rate λ_0 and λ_1 for unemployed and employed workers, respectively
- Workers pick a wage from the distribution $F(w)$
- Unemployed workers accept all wage offers that exceed the reservation wage w_R
- There is a fixed cost c of separation that each worker needs to pay to leave their current employer
- In each period, workers can transition to unemployed with exogenous probability δ

Workers' Value Functions Fundamental workers' equation

Timing

1. Each firm observes its own parameter ϕ_i and the quality levels of all the other firms in the economy
2. Firms decide whether to invest in intangible capital and attain s_{ij}, pay the associated fixed cost and commit to the level of wages they will pay
3. All workers (employed and unemployed) search for jobs and match with new employers
4. Firms update their marginal costs based on the labor market outcomes, observe those of their competitors and make pricing decisions, as well as produce the quantities they are demanded
5. Production factors are rewarded and employed workers end up in unemployment with probability δ

Partial Equilibrium

Solve the model by backward induction:

1. In each I_j, only the firm with **the lowest quality-adjusted price (p^c_{ij}) will produce** $\implies$ firm with the best combination of $\{q_{ij}, s_{ij}\}$ will engage in limit-pricing on its nearest competitor:

$$p^*_{ij} = mc(1) \cdot \frac{q_{ij}}{\max_{k \in I_j \setminus i} q_{kj}} = (w_i + v) \cdot \hat{q}_{ij}$$

   Only one firm ends up investing in intangibles in each I_j, as $g(\cdot)$ is sunk $\implies mc(1)$

2. Corresponding equilibrium levels of s^*_{ij} and w^*_i can be found by plugging in p^*_{ij} into the lowest quality-adjusted price p^c_i:

$$p^c_i = \min \Big\{ p_{ij} > 0 : \max_{s_{ij} \in (0,1]; w_i > 0} [p_{ij} - mc(s_{ij}, w_i)] \cdot y_{ij} - g(s_{ij}, \phi_i) - \Big(\lambda_1 [1 - F(w_i + c)] + \delta\Big)(1 - \xi) \cdot s_{ij} \cdot v \cdot y_{ij} \Big\}$$

- where the blue/red expressions indicate the investment cost/risk of losing the asset

Equilibrium s_{ij}^* and w_i^*

Solving for s_{ij} and w_i gives the equilibrium level of investment in intangibles and corresponding wages:

$$s_{ij}^* = \left[\frac{\theta\phi_i p_{ij}^*}{Y} \cdot \frac{1}{1+(\lambda_1(1-F(w_i+c)+\delta)(1-\xi_{ij})}\right]^{\frac{1}{1+\theta}}$$

$$w_i^* = f^{-1}\left(\frac{1}{\lambda_1(1-\xi_{ij})s_{ij}^* v}\right) - c$$

- Firms take into account not only ϕ_i when setting the optimal level of marginal costs they want to save but also their relative position in the overall wage distribution
- Firms have a pure strategy when opting for which wage to offer
- Conditional on the value of ξ_{ij}, the more a firm invests in intangibles (the lower s_{ij}^*), the higher the wedge between the offered wage and the competitive wage, i.e. the marginal revenue product of labor
- In equilibrium, $F(w)$ is given by the wages of firms which end up producing

Equilibrium μ_{ij}^*

- The equilibrium s_{ij}^* allows to derive equilibrium price-cost markups as follows:

$$\mu_{ij}^* = \frac{p_{ij}^*}{mc(s_{ij}^*)} = \frac{mc(1)}{mc(s_{ij}^*)} \cdot \widehat{q}_{ij} = \frac{w_i^* + v}{w_i^* + s_{ij}^* v} \cdot \widehat{q}_{ij}$$

Hence, the more a firm invests in intangibles (the lower s_{ij}^*), the higher price-markups

Main Takeaways from the Model

- The model implies that firms which invest more in intangibles that cannot be fully appropriated (i.e. where tacit knowledge may play a role) ...

  1. ... charge higher price-cost markups
  2. ... pay workers wages exceeding their marginal revenue product of labor, with the wage premium increasing in the use of intangibles

Main Takeaways from the Model

- The model implies that firms which invest more in intangibles that cannot be fully appropriated (i.e. where tacit knowledge may play a role) . . .

  1. . . . charge higher price-cost markups
  2. . . . pay workers wages exceeding their marginal revenue product of labor, with the wage premium increasing in the use of intangibles

- Any barriers to workers' mobility (c) reduces their outside option and, therefore, the wage premium firms are willing to pay to prevent workers from leaving

Validation Exercise

- An exogenous decrease in c should prompt firms to offer a higher wage premium to retain their employees
  - if this mechanism is in place, we anticipate wages to rise consequently
  - does this happens within the firm or via switching to a higher- paying job?
  - put differently: are firms successful in retaining their intangible capital or not?
- Exploit a **2015 Dutch Labor Market Reform**, where **NCAs were permanently banned** for temporary contracts.

Data

- From **Labor Force Survey** (EIB), we observe whether workers are subject to NCAs in their labor contracts from 2015 up to 2018, for up to 2 jobs per worker
  - we also observe other characteristics, such as demographics, education, occupation, contract characteristics
- We match this to **Employer-Employee data** (SPOLIS) to retrieve information on wages and tenure and to match workers to firms in the Production Survey
- Time frequency: monthly

Presence of NCAs

NCAs are not exclusive to skilled workers and are found in approximately 18% of the workforce (Streefkerk, Elshout, and Cuelenaere 2015)

ISCO major category	No	Yes	% share
Managers	10	1	1
Professionals	115	17	14
Technicians and associate professionals	71	24	20
Clerical support workers	55	10	8
Service and sales workers	186	28	24
Skilled agricultural, forestry and fishery workers	11	1	1
Craft and related trades workers	41	15	13
Plant and machine operators and assemblers	44	6	5
Elementary occupations	131	8	7
Not available	144	8	7
Total	808	118	100

Employer characteristics

Experiment I

- We focus on workers affected by the reform:
  - workers with fixed term-contracts and presence of NCAs in December 2014
- We match treated workers to a control group via propensity score matching based on individual characteristics over 2014 (demographics, contract structure, pay, gender, pay composition, number of employers) Balance Table
  - Matching is done **separately** by type of employer (intangible intens. vs non-intangible intens.)
- We are left with **a panel of 378 workers, with monthly data from 2013 until end of 2019**

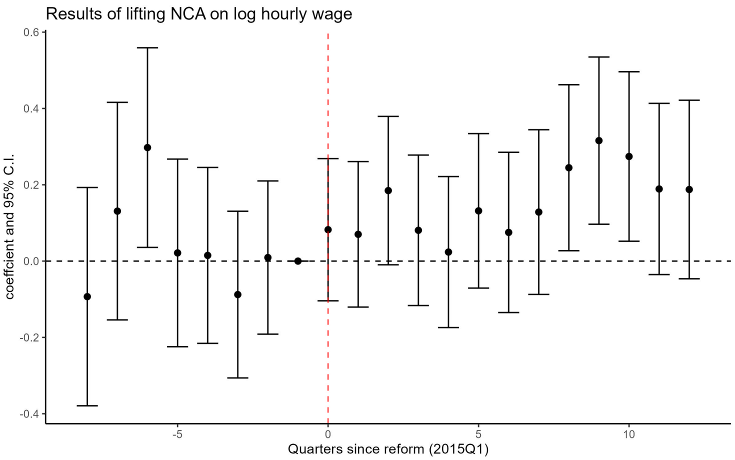
Experiment II

- We use a standard event-study framework to estimate how worker-level outcomes change around the reform:

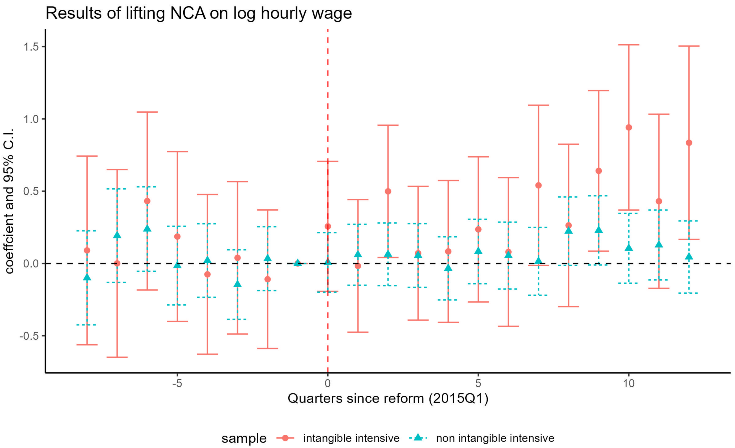
$$Y_{it} = \alpha_i + \alpha_j + \beta \cdot D_i + \sum_{\tau=T_0}^{T} \beta_\tau \cdot I_\tau + \sum_{\tau=T_0}^{T} \gamma_\tau \cdot I_\tau \cdot D_i + X'_{it}\delta + \upsilon_{jt}$$

  - Y_{it} is worker-level outcome variable (log hourly wage in main regression)
  - D_i: Binary treatment indicator
  - I_τ Time indicator
  - Additional controls in X: firm and worker FE, tenure, age, age^2, occupation, fixed term vs open ended contract, gender, **wage bargaining regime**, employer characteristics (size and productivity)

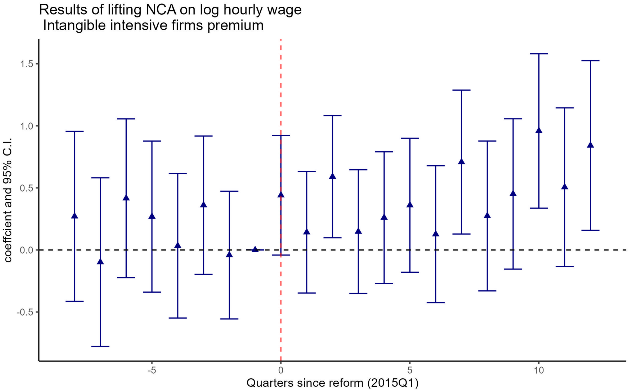
Increased Labor Income for Treated Workers



Treated Workers Employed in Intangible-Intensive Firms are Driving the Increased Labor Income Result



Treated Workers Employed in Intangible-Intensive Firms are Driving the Increased Labor Income Result - DDD Specification



Estimation Equation

Increased Mobility for Treated Workers

	Remaining time at current job (1)	Future mobility (2)
Any NCA	11.492***	1.621***
Post-reform	0.120***	-0.015***
Any NCA * Post-reform	0.047**	0.005*
Tenure	−0.020***	0.005***
Gender	4.742***	0.313***
Full-time work (0-1)	−0.016	−0.014***
Age	−0.369***	−0.051***
Age squared	0.0004***	0.0001***
Month FE	Yes	Yes
Worker FE	Yes	Yes
Observations	17,039	17,472

Additional Results

- **Education does not drive the result**: Interacting interact our event-time coefficient with skill types does not change the baseline result.
  - We also fit year FE instead of the before-after treatment dummy to control for changing sample composition.
- Estimations are robust to repeating the analysis at the monthly or yearly (instead of quarterly) frequency
- Results are robust to placebo tests where we change the year of intervention.
- The effect remains if we look separately at workers who stay at their current employer vs workers who switch employer or if we include an employer FE.

Estimation Results

Conclusion

1. We find that the majority of Dutch firms set price-cost markups and pay wage markups
   - We show suggestive evidence that **investment in intangible capital and technology at the firm level is correlated with both market imperfections**
2. We rationalize the finding with a model where higher compensation is used as a tool to retain intangible capital within the firm
3. We validate this mechanism exploiting an experiment lifting the enforceability of of NCAs
   - Lifting NCAs increases worker wages and worker mobility
   - **The effect is stronger for workers in intangible-intensive firms** and is not driven by workers' skill type

APPENDIX

Details on Derivations of μ and ψ I

Consider the conditional firm cost minimization problem:

$$\min_{\mathrm{X}\in\mathbb{R}^k_+} \sum_k P_k(X_k)X_k$$
$$\text{s.t. } Q = F(\mathrm{X}, \omega)$$

where X_k and $P_k(X_k)$ are production inputs and their associated unit cost functions, $F(\cdot)$ is the production technology and ω denotes productivity.

Details on Derivations of μ and ψ II

From the first order condition of the problem above, after multiplying both sides by X_k/Q we can derive:

$$\frac{\partial F(\cdot)}{\partial X_k}\frac{X_k}{Q} = \frac{1}{\lambda}\frac{P_k(X_k)X_k}{Q}$$
$$\theta^k = \frac{1}{\lambda}\frac{P_k(X_k)X_k}{Q}$$

As in this case λ can be precisely interpreted as the marginal cost, we can introduce the markup on input k $\mu^k \equiv P/\lambda$, where P is the price of a unit of output charged by the firm and obtain:

$$\mu = \frac{\theta^k}{\alpha^k}$$

where $\alpha^k = \frac{P_k(X_k)X_k}{PQ}$ is the expenditure share in input X_k.

Details on Derivations of μ and ψ III

Consider now the associated conditional cost minimization problem:

$$\min_{l \geq 0} w(l)l \text{ s.t. } Q = F(l, \mathrm{X}^*(l), \omega)$$

where $\mathrm{X}^*(l)$ denotes all inputs are evaluated at their optimum with the exception of the labor input l and $w(n)$ is the unit cost of such input (wage). Solving the optimization problem we get:

$$\begin{aligned} \left[\frac{w(l)'l}{w(l)} + 1\right] &= \lambda \cdot \frac{\partial F}{\partial l} / w(l) \\ &= \frac{\lambda}{P} \cdot \frac{\partial F}{\partial l} \frac{l}{Q} \cdot \frac{PQ}{w(l)l} \\ &= \frac{1}{\mu^k} \cdot \frac{\theta^l}{\alpha^l} \end{aligned} \tag{1}$$

Details on Derivations of μ and ψ IV

One can show that the term on the left hand side of equation (1) can be expressed as:

$$\left[\frac{w(l)'l}{w(l)} + 1\right]^{-1} = w(l)/R'(l)$$

where $R(l)$ is a revenue function where all inputs are chosen optimally but l (Yeh, Macaluso, and Hershbein 2022). Combine this result with that of equation (1) and retrieve labor market distortion as:

$$\psi = \frac{\theta^k}{\alpha^k} \cdot \left(\frac{\theta^l}{\alpha^l}\right)^{-1}$$

Back to main presentation

Structural Estimation

- Measuring product and labor market imperfections based on μ_{it} and ψ_{it} requires consistent estimates of $(\varepsilon_M^Q)_{it}$ and $(\varepsilon_L^Q)_{it}$ as well as α_{Mit} and α_{Lit}
- We estimate **translog production functions** for each 2-digit industry where identification of the coefficients requires imposing a functional form assumption on the productivity process and timing assumptions of the firm's input choices
  - To control for unobserved productivity, we use the control-function approach (Ackerberg, Caves, and Frazer 2015)
  - Production function coefficients are estimated through standard GMM using the moment conditions formed by the timing assumptions

Structural Estimation

- Measuring product and labor market imperfections based on μ_{it} and ψ_{it} requires consistent estimates of $(\varepsilon_M^Q)_{it}$ and $(\varepsilon_L^Q)_{it}$ as well as α_{Mit} and α_{Lit}
- We estimate **translog production functions** for each 2-digit industry where identification of the coefficients requires imposing a functional form assumption on the productivity process and timing assumptions of the firm's input choices
  - To control for unobserved productivity, we use the control-function approach (Ackerberg, Caves, and Frazer 2015)
  - Production function coefficients are estimated through standard GMM using the moment conditions formed by the timing assumptions
- To cross-validate our measure of labor market imperfections, we examine its predictive power for the wage premia paid by employers to their workers
  - To measure employer wage premia, we estimate a standard AKM model
  - We find a statistically significant positive association between ψ_{it} and employer wage premia Back to Main Presentation

Details on Production Function Estimation I

"Proxy variable method" to correctly retrieve the elasticities β (Olley and Pakes 1996; Levinsohn and Petrin 2004; Ackerberg, Caves, and Frazer 2015). We assume for firm i in year t:

1. firms operate according to a *translog* production function of inputs $x_{it} = (k_{it}, l_{it}, m_{it})$ (capital, labor and intermediate inputs).
2. in each period t each firm takes decisions based on an information set given by $\{\omega_\tau\}_{\tau \in (-\infty, t-1)}$ and after the decision it is hit by an unobserved shock ξ.
3. the state variables of the firm are given by $\{k_t, \omega_t\}$ and capital k_t evolves as a function of k_{t-1} and investment i_t.
4. The parameters of the production function β are constant across time and common within an industry group (3 digit NACE).
5. Productivity evolves according to a first-order Markov process known to the firm and is the only unobservable factor to the econometrician.
6. Intermediate input demand m_t is invertible in ω_t

Details on Production Function Estimation II

We follow the following steps to retrieve β:

1. Run a third-order-polynomial regression of log deflated output y_{it} on x_{it}, export dummy and year fixed effects so to purge our output of measurement error. We use the estimates to predict the corrected log output ϕ_{it}.
2. We derive an estimate of productivity $\hat{\omega}_{it} = \phi_{it} - f(x_{it})$, where $f()$ is the translog production function. To obtain an estimate of the productivity shock $\hat{\xi}_{it}$ hitting a firm at the beginning of each period we run a second-order-polynomial regression of $\hat{\omega}_{it}$ on $\hat{\omega}_{it-1}$.
3. In the last step, we obtain estimates of the parameters β of the production function using GMM system induced by the moment condition $E\left(\hat{\xi}_{it} \cdot z_{it}\right) = 0$, where we use as instruments the lag of the flexible inputs (so all but k) and contemporaneous value of k_t.

Back to Main Presentation

Data

- We estimate production functions using the **Production Survey (PS)**, covering 37,451 firms in manufacturing and services from 2000 until 2020
- PS includes firm accounting information (employment, capital input, intermediate input costs, labor costs, value added, automation expenditure) which we match to the **customs data** to retrieve firms' export status
- We match the firm panel with the **Use of ICT and E-commerce survey (ICTeC)**, covering a representative sample of Dutch firms each year, stratified at the industry level
    - Each year, the survey asks questions about the use of specific ICT technologies in the firm (e.g. broadband, industrial robots, telework)

Back to Main Presentation

Details on Automation Expenditure

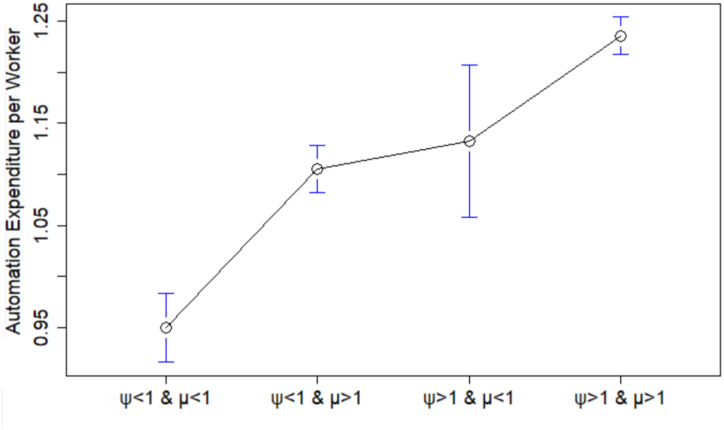
Automation expenditure has been used in existing work to assess the impact of automation (Bessen, Goos, Salomons, and Berge 2020; Bessen, Goos, Salomons, and Van den Berge 2023) but captures in reality both labor-saving and labor-augmenting technologies

Using similar data as ours, Bessen, Goos, Salomons, and Van den Berge 2023 show that automation expenditure

- is highly correlated with process innovation but less so with product and organizational innovation
- is correlated with technologies that involve using data for automated processing (e.g. CRM, ERP, use of big data, cloud computing, exchanging data through EDI networks, sales software)
- is substantially higher than imports in industrial robots, a measure widely used in the literature to identify investment in purely labor-saving technologies (Acemoglu and Restrepo 2019)

Back to Main Presentation

Firm Level Evidence



Back to main presentation

Firm characteristics by "Quadrant"

Q	Firm age	W/L	$\log(VA/L)$	Q	Q/L	L	K/L	$AUTO/L$	% Exp.	% SME
$\mu < 1$ & $\psi > 1$	24.4	58.4	4.02	33536.11	250.26	138.12	1.41	1.59	0.71	0.87
$\mu > 1$ & $\psi > 1$	28.27	63.49	4.45	31323.02	249.33	111.15	11.13	1.72	0.79	0.91
$\mu > 1$ & $\psi < 1$	26.97	49.25	4.38	48899.30	257.5	160.42	5.05	1.42	0.75	0.87
$\mu < 1$ & $\psi < 1$	24.38	48.17	4.2	49141.78	255.96	232.49	12.27	1.49	0.61	0.83

Back to main presentation

Employer characteristics by NCA

Table: Firm characteristics

	Means No NCA	Means Some NCA	Norm. Mean Diff.
Firm size	8666.43	2367.36	-1.48
Automation exp. per worker	0.84	1.08	0.15
Sales per worker	143.99	159.5	0.09
Average wage	45.41	46.45	0.06
Labor productivity	62.89	68.47	0.09
Capital intensity	6.47	8.08	0.07
% Patenters	0	4.49	0.22
% Exporters	80.95	64.79	-0.34
% FTE in Collective Barg.	25.46	31.46	0.13
Firm FE (AKM model based)	-0.01	-0.02	-0.09
Number of firms	229	115	

Back to main presentation

Workers Value Functions

the Bellman equations for unemployed and employed workers can be found below:

$$rV_U = b + \lambda_0 \int_{w_R}^{\infty} [V_E(z) - V_U] dF(z)$$

$$rV_E = w - \eta s_{ij}^{\eta} - \delta[V_E(w) - V_U] + \lambda_1 \int_{w}^{\infty} [V_E(z) - V_E(w) - c] dF(z)$$

Back to main presentation

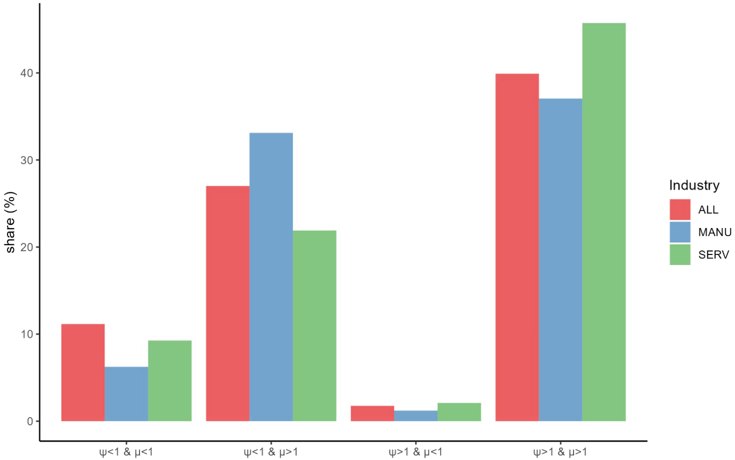
Fundamental Workers Equation

We exploit $rV_E(w_R) = rV_U$ and use integration by parts to solve for w_R.

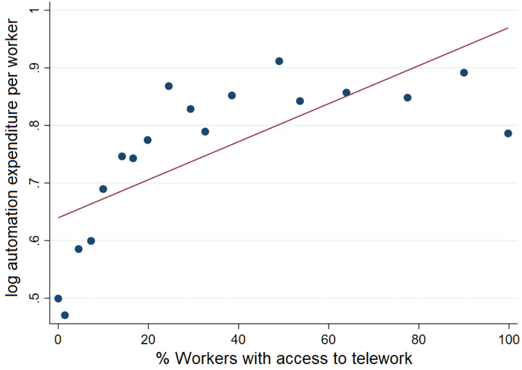
$$w_R = \eta s_{ij}^{\eta} + b + (\kappa_0 - \kappa_1) \int_{w_R}^{\infty} \frac{1 - F(z)}{1 + \kappa_1(1 - F(z))} dz + \kappa_1 \delta c$$

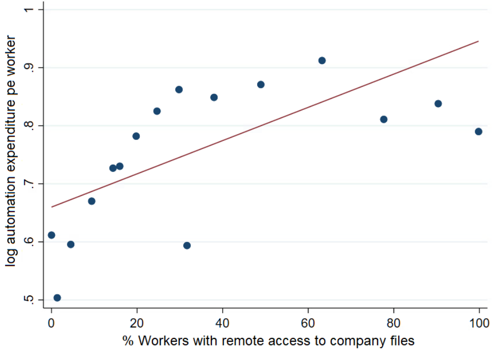
where $\kappa_i = \lambda_i / \delta$. Back to main presentation

Manufacturing vs Services



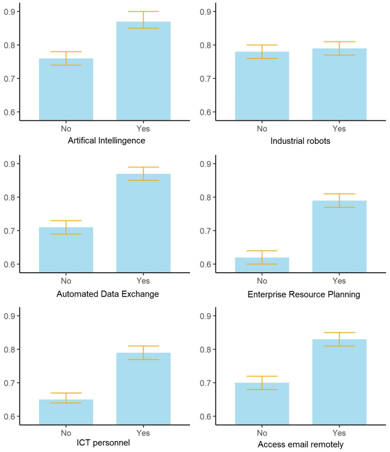
Automation and ICT variables - cont. indicators





Back

Automation and ICT variables - discrete indicators



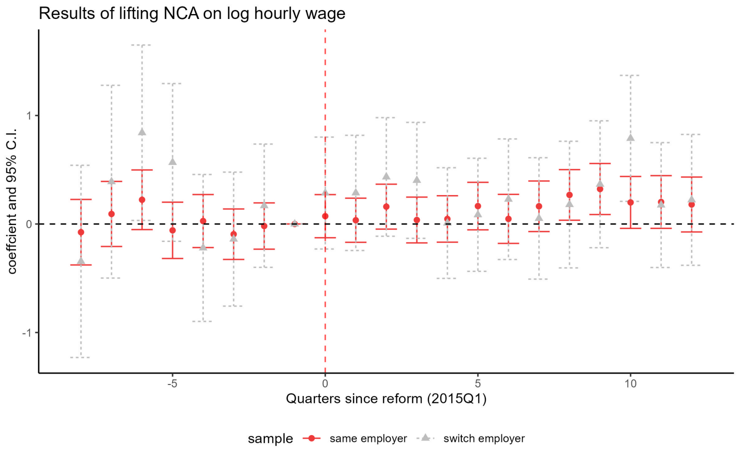
Matching Result

	Means Control	Means Treated	Norm. Mean Diff.
Intangible Intensive Firms			
Age	29.83	28.71	-0.10
Gender (1=Male, 2=Female)	1.29	1.24	-0.11
FTE	1.00	0.97	-0.22
Labour Income	9.43	8.67	-0.15
Share of extraordinary income	0.06	0.08	0.28
% Full time	0.33	0.39	0.12
Tenure (months)	21.58	20.37	-0.08
# Employers	1.09	1.11	0.07
Sh. Overtime	0.16	0.19	0.1
Skill category (1-4)	2.05	2.17	0.13
Worker FE (AKM model based)	-0.05	-0.08	-0.11
Employer's Autom. Expenditure	1.31	1.15	-0.09
Number of workers	41	21	
Non Intangible Intensive Firms			
Age	29.77	30.32	0.04
Gender (1=Male, 2=Female)	1.58	1.47	-0.21
FTE	0.99	0.99	-0.09
Labour income	8.92	8.67	-0.03
Share of extraordinary income	0.06	0.06	-0.04
% Full time	0.28	0.27	-0.03
Tenure (months)	11.62	10.43	-0.09
# Employers	1.19	1.2	0.01
Sh. Overtime	0.03	0.04	0.09
Skill category (1-4)	2.32	2.22	-0.1
Worker FE (AKM model based)	-0.03	-0.03	0.01
Number of workers	219	97	

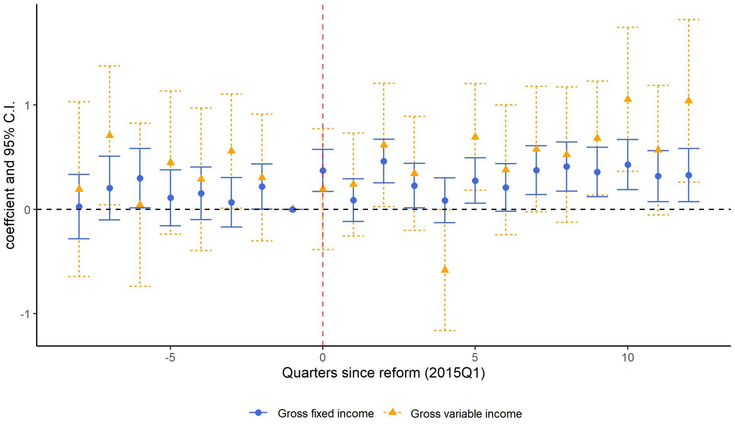
Matching is done with a ratio of 1:4 with replacement. We get on average 2.9 control units per treated unit.

Back

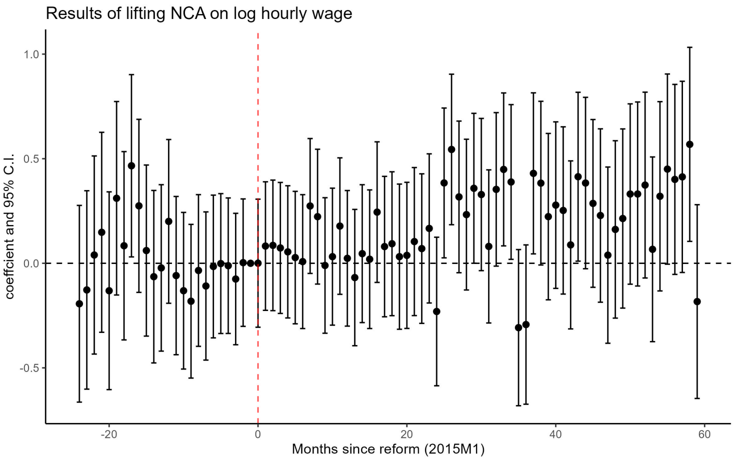
Within vs Between Employer effect



Varible vs Fixed component of Gross income



Monthly frequency coefficients



Back to Main Presentation

DDD Estimation Equation

$$Y_{mt} = \alpha_m + \alpha_t + \beta \cdot D_m + \zeta \cdot F_m + \sum_{\tau=T_0}^{T} \beta_\tau \cdot I_\tau +$$
$$\sum_{\tau=T_0}^{T} \gamma_\tau \cdot D_m \cdot I_\tau + \sum_{\tau=T_0}^{T} \iota_\tau \cdot F_m \cdot I_\tau + \kappa \cdot F_m \cdot D_m +$$
$$\sum_{\tau=T_0}^{T} \theta_\tau \cdot D_m \cdot I_\tau \cdot F_m +$$
$$X'_{mt}\boldsymbol{\delta} + \upsilon_{mt}$$

Back to Main Presentation

- Acemoglu, Daron (2023). "Distorted Innovation: Does the market get the direction of technology right?" In: *AEA Papers and Proceedings*. Vol. 113. American Economic Association, pp. 1–28.
- Acemoglu, Daron and Pascual Restrepo (2019). "Automation and new tasks: How technology displaces and reinstates labor". In: *Journal of Economic Perspectives* 33.2, pp. 3–30.
- Ackerberg, Daniel A, Kevin Caves, and Garth Frazer (2015). "Identification properties of recent production function estimators". In: *Econometrica* 83.6, pp. 2411–2451.
- Aghion, Philippe, Céline Antonin, et al. (2020). *What are the labor and product market effects of automation? New evidence from France*. Discussion Paper 14443. Centre for Economic Policy Research.
- Aghion, Philippe, Antonin Bergeaud, et al. (2023). "A theory of falling growth and rising rents". In: *Review of Economic Studies* 90.6, pp. 2675–2702.
- Balasubramanian, Natarajan et al. (2022). "Locked in? The enforceability of covenants not to compete and the careers of high-tech workers". In: *Journal of Human Resources* 57.S, S349–S396.

- Bessen, James (2019). "Automation and jobs: When technology boosts employment". In: *Economic Policy* 34.100, pp. 589–626.
- Bessen, James, Maarten Goos, Anna Salomons, and Wiljan van den Berge (2020). "Firm-level automation: Evidence from the Netherlands". In: *AEA Papers and Proceedings*. Vol. 110, pp. 389–393.
- Bessen, James, Maarten Goos, Anna Salomons, and Wiljan Van den Berge (2023). "What happens to workers at firms that automate?" In: *Review of Economics and Statistics*, pp. 1–45.
- Boeri, Tito, Andrea Garnero, and Lorenzo G Luisetto (2022). *The use of non-compete agreements in the Italian labour market*. Tech. rep. prepared for the XXIV European Conference of the Fondazione Ing. Rodolfo Debenedetti.
- Burdett, Kenneth and Dale T. Mortensen (1998). "Wage Differentials, Employer Size, and Unemployment". In: *International Economic Review* 39.2, pp. 257–273.
- Calligaris, Sara, Chiara Criscuolo, and Luca Marcolin (2018). *Mark-ups in the digital era*. Working Paper 2018/10. OECD.

Corrado, Carol et al. (2013). “Innovation and intangible investment in Europe, Japan, and the United States”. In: *Oxford Review of Economic Policy* 29.2, pp. 261–286.

Crouzet, Nicolas et al. (2022). “The economics of intangible capital”. In: *Journal of Economic Perspectives* 36.3, pp. 29–52.

De Loecker, Jan, Jan Eeckhout, and Gabriel Unger (2020). “The rise of market power and the macroeconomic implications”. In: *Quarterly Journal of Economics* 135.2, pp. 561–644.

De Ridder, Maarten (2024). “Market power and innovation in the intangible economy”. In: *American Economic Review* 114.1, pp. 199–251.

Dobbelaere, Sabien and Jacques Mairesse (2013). “Panel data estimates of the production function and product and labor market imperfections”. In: *Journal of Applied Econometrics* 28.1, pp. 1–46.

Döttling, Robin and Enrico C Perotti (2017). *Secular trends and technological progress*. Discussion Paper 12519. Centre for Economic Policy Research.

Haskel, Jonathan and Stian Westlake (2018). *Capitalism without capital: The rise of the intangible economy*. Princeton University Press.

Heuvelen, Gerrit Hugo van, Leon Bettendorf, and Gerdien Meijerink (2021). "Markups in a dual labour market: The case of the Netherlands". In: *International Journal of Industrial Organization* 77, p. 102762.

Hsieh, Chang-Tai and Esteban Rossi-Hansberg (2023). "The industrial revolution in services". In: *Journal of Political Economy Macroeconomics* 1.1, pp. 3–42.

Levinsohn, James and Amil Petrin (2004). "Production function estimation in Stata using inputs to control for unobservables". In: *The Stata Journal* 4.2, pp. 113–123.

Marx, Matt, Deborah Strumsky, and Lee Fleming (2009). "Mobility, skills, and the Michigan non-compete experiment". In: *Management Science* 55.6, pp. 875–889.

McAdams, John M (2019). "Non-compete agreements: A review of the literature". In: *Available at SSRN 3513639*.

Mertens, Matthias (2023). "Labor market power, superstar firms, and between-firm wage (in) equality". In: *International Journal of Industrial Organization* 91, p. 103005.

Olley, G. S. and A. Pakes (1996). "The Dynamics of Productivity in the Telecommunications Equipment Industry". In: *Econometrica* 64 (6), pp. 1263–1297.

Raval, Devesh (2023). “Testing the production approach to markup estimation”. In: *Review of Economic Studies* 90.5, pp. 2592–2611.

Sampat, Bhaven and Heidi L Williams (2019). “How do patents affect follow-on innovation? Evidence from the human genome”. In: *American Economic Review* 109.1, pp. 203–236.

Shi, Liyan (2023). “Optimal regulation of noncompete contracts”. In: *Econometrica* 91.2, pp. 425–463.

Stoyanov, Andrey and Nikolay Zubanov (2012). “Productivity spillovers across firms through worker mobility”. In: *American Economic Journal: Applied Economics* 4.2, pp. 168–198.

Streefkerk, M, S Elshout, and B Cuelenaere (2015). *Concurrentiebeding. Dataverzameling bij het LISS panel*.

Thomä, Jörg and Kilian Bizer (2013). “To protect or not to protect? Modes of appropriability in the small enterprise sector”. In: *Research Policy* 42.1, pp. 35–49.

Yeh, Chen, Claudia Macaluso, and Brad Hershbein (2022). “Monopsony in the US labor market”. In: *American Economic Review* 112.7, pp. 2099–2138.