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ABSTRACT

Employer Market Power in Silicon Valley*

Adam Smith alleged that secret employer collusion to reduce labor earnings is common. This paper examines an important case of such behavior: no-poach agreements through which technology companies agreed not to compete for each other's workers. Exploiting the plausibly exogenous timing of a US Department of Justice investigation, I estimate the effects of these agreements using a difference-in-differences design. Data from Glassdoor permit the inclusion of rich employer- and job-level controls. Estimates indicate each agreement cost affected workers approximately 2.5 percent of annual salary. Stock bonuses and ratings of job satisfaction were also negatively affected.

JEL Classification: J42, K21, J30, L41

Keywords: monopsony, oligopsony, employer market power, labor earnings

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1 Introduction

"We rarely hear... of the combinations of masters, though frequently of those of workmen," writes Adam Smith, "But whoever imagines... that masters rarely combine [to lower wages], is as ignorant of the world as of the subject. ... These are always conducted with the utmost silence and secrecy... and when the workmen yield... they are never heard of by other people" [Smith, 1790]. Recent years have seen renewed interest in the causes and consequences of employer market power [US CEA, 2016, Krueger and Posner, 2018], including declining unionization [Blanchard and Giavazzi, 2003], mergers [Marinescu, 2018], and non-compete clauses [Lipsitz and Starr, 2021]. But this literature has not investigated the case Smith considered so common: secret coordination of managers aimed at reducing labor earnings. Today such behavior is difficult to study because it is typically illegal, giving firms powerful incentives to hide it from both government officials and researchers. The 2005-2009 "no-poach" agreements among Silicon Valley technology firms provide a rare opportunity to examine the clandestine exercise of employer market power.

The following firms were party to at least one no-poach agreement: Adobe, Apple, eBay, Google, Intel, Intuit, Lucasfilm and Pixar. Concluded at the highest levels of management, including boards and CEOs, the agreements prohibited participating firms from recruiting or hiring each other's employees. Managers informed recruiters which potential hires were off-limits and some recruiting departments maintained written lists. Implementation was straightforward. A potential new employee can hardly avoid disclosing her recent and current employers to a prospective employer. Even if she were to withhold such information, platforms like LinkedIn allow employers to obtain it easily. Enforcement was similarly straightforward. In cases where a firm violated an agreement, its counterparty often contacted a senior manager at the violating firm, who would then put a stop to the violation [US Department of Justice, 2010b, 2012]. This use of market power was remarkably simple and cheap, relying on well-defined commitments from a small number of individuals. It required no elaborate salary schedules. The ease with which these firms coordinated stands in some contrast to the difficulty of sustaining coordination in many textbook theoretical models of firm behavior.[1]

Prompted by a whistleblower, a US Department of Justice (DOJ) investigation began to unravel the no-poach agreements in early 2009. National media revealed the antitrust investigation on June 3, 2009 and the DOJ filed its civil complaint in US v. Adobe Systems on Sept. 24, 2010 [Helft, 2009, US Department of Justice, 2010b]. This was followed by a civil

[1] Adam Smith also commented on the enforcement of collusive agreements among employers: "To violate this combination is every where a most unpopular action, and a sort of reproach to a master among his neighbours and equals" [Smith, 1790].

class action in 2011, with settlements in 2015 and 2018. While the DOJ did not undertake a criminal prosecution in response to the no-poach agreements, it had the authority to do so under the Sherman Act.[2] The DOJ made this explicit in 2016 guidance for human resources departments: "Going forward, the DOJ intends to proceed criminally against naked wage-fixing or no-poaching agreements. These types of agreements eliminate competition in the same irredeemable way as agreements to fix product prices or allocate customers, which have traditionally been criminally investigated and prosecuted as hardcore cartel conduct" [U.S. DOJ and U.S. FTC, 2016].[3]

Using difference-in-differences designs, I estimate the effect of these no-poach agreements on labor outcomes. The timing of entry into the agreements is potentially a function of unobserved economic factors that also influence labor earnings. My identification relies instead on the plausibly exogenous timing of the DOJ investigation, which forced defendant firms to end the agreements and led to salary increases. I find each full-year no-poach agreement reduced salaries by approximately 2.5 percent. Consistent with theory [Oyer and Schaefer, 2005], I find negative effects on stock bonuses, but no effects on cash bonuses. Survey measures of satisfaction with compensation and benefits also declined at colluding firms. My data are a novel set of labor surveys from the website Glassdoor. They include employer names and detailed job classifications, salary and other compensation, and job ratings.

These results are important because the information technology sector is a large and growing part of the US economy. From 1997 to 2019, value added in this sector rose from $232 billion to $1.7 trillion [real 2012 dollars; US Bureau of Economic Analysis, 2019].[4] This paper's estimates may assume more general significance because recent evidence suggests growing scope for employer market power in the US. The DOJ identified reduced coordination costs from market concentration as a contributor to the technology-sector no-poach agreements [US Department of Justice, 2012]. From 1997 to 2012, the revenue share of the top 50 firms increased in the majority of US industries [US CEA, 2016]. Workers in a majority of US occupations face labor markets that are "highly concentrated" under DOJ guidelines [Azar et al., 2020]. Growing use of arbitration and non-compete clauses may also be increasing employer market power [US CEA, 2016].

This paper contributes to the empirical literature on employer market power.[5] It com-

[2] Explicit collusion to depress labor compensation is illegal under the Sherman Act, and exercising market power is illegal under the Clayton Act [US Department of Justice, 2010b, Marinescu and Hovenkamp, 2018].

[3] To date the DOJ has filed at least two indictments in accordance with this guidance [Jacobovitz and Kanters, 2021].

[4] Value-added figures are for "Information-communications-technology-producing industries."

[5] For surveys see Manning [2003] and Manning [2011].

plements the growing body of evidence on non-compete agreements [e.g. Starr, 2019, Starr et al., 2021], much of which exploits policy changes. Balasubramanian et al. [2020] evaluate a 2015 Hawaii ban on non-compete clauses in the technology sector, while Lipsitz and Starr [2021] evaluate a 2008 Oregon ban on non-compete clauses for hourly workers. Krueger and Ashenfelter [2017] study the prevalence of no-poach agreements in the franchise sector. Naidu et al. [2016] use a policy reform relaxing constraints on worker mobility in the United Arab Emirates to study the effect of monopsony on earnings. Another strand of research uses quasi-experimental wage variation to recover labor supply elasticities. Azar et al. [2019] employ instrumental variables designs and recover firm-level labor supply elasticities consistent with monopsony in US labor markets, while Dube et al. [2020] similarly find low elasticities in the labor market on Amazon's MTurk platform.[6]

Relative to the existing empirical literature, this paper differs along several dimensions. First, to the best of my knowledge, it is the first empirical work on the earnings effects of no-poach agreements. Such agreements may affect workers even in jurisdictions where non-competes are banned or unenforceable. Because workers do not agree to be constrained by no-poach agreements, the possibility of contractual compensation for the constraint is foreclosed. Because the agreements are not announced, workers receive no signal to respond, e.g. by increasing job search effort. Unlike non-compete clauses, no-poach agreements directly limit the diffusion of information to workers through recruiting calls and competing offers. Second, because my research design relies on the timing of a whistleblower tip, it avoids potential confounding from anticipatory responses to pre-announced policy changes. Third, to the best of my knowledge this is the first paper in the economics literature to examine the secret and illegal exercise of employer market power.

More broadly, my results contribute to the economic literature on white-collar crime descended from Sutherland [1940].[7] The prevalence of such crime is difficult to assess, but prominent examples occur with regularity: in 2008 the Madoff Ponzi scheme came to light; and in 2012 the US began to investigate the rigging of the LIBOR by investment banks.[8] Over the same period white-collar prosecutions have declined, falling more than 46 percent since 2011 and reaching a record low in 2019 [TRAC Reports, 2019].[9] A rational model of crime like Becker [1968] predicts increased lawbreaking in response to reduced enforcement, and this argues for the importance of research on this topic. Mark Cohen has investigated the total

[6]Staiger et al. [2010] use a policy-mandated wage change at a subset of VA hospitals and likewise estimate elasticities consistent with monopsony.

[7]Edwin Sutherland coined the phrase "white-collar crime" in a 1939 address, published as Sutherland [1940], and antitrust violations are one of the four types of such crime discussed in Sutherland [1945].

[8]LIBOR stands for "London Interbank Overnight Rate." Interest rates on many debt instruments are indexed to LIBOR.

[9]TRAC data begin in 1986.

social costs of white-collar crime using contingent valuation methods [Cohen, 2015, 2016]. Much of the economic research on white-collar crime studies tax evasion. Notable examples include Slemrod [2004] and the work of Gabriel Zucman [Zucman, 2013, Alstadsæter et al., 2019].[10] The remaining literature is rather idiosyncratic. Levitt [2006] studies non-payment for donuts and bagels in office settings where individual payments are unobserved.[11] Fisman and Miguel [2007] find that diplomats from more corrupt countries incur more unenforceable parking tickets near the UN. My study adds to the small branch of this literature on criminal violations of antitrust statutes [Gallo et al., 1994]. It also contributes by recovering a causal estimate of the impact on victims. Because victims of white-collar crime are typically many and difficult to identify, such estimates are frequently unavailable.[12]

The rest of the paper proceeds as follows. Section 2 describes my data and Section 3 presents estimating equations. Section 4 discusses empirical results and Section 5 concludes.

2 Data

2.1 Description

My primary data come from Glassdoor, an online aggregator of wage and salary self-reports. Reports cover employer, work location, job, salary, and years of experience. The chief strengths of these data, relative to public data sets like the Current Population Survey, are the inclusion of employer names and detailed job classifications. Glassdoor uses machine-learning models to classify users' jobs at three increasingly granular levels: general occupation, specific occupation, and job. The top ten categories under each classification are in Table A3. As described by the company, the machine-learning model groups jobs using job search and clicking behavior on the Glassdoor website. Importantly, salary information is not an input into the model. The Glassdoor salary variable is not censored at high values. For users that report monthly or hourly earnings (15 percent of my sample), I impute an annual salary by assuming a 40-hour work week and 50 work weeks per year.[13] Some users report non-salary compensation variables, including stock and cash bonuses. I convert all

[10] See Slemrod [2007] for a review.

[11] Contrary to the priors of many economists, Levitt finds average payment equal to 90 percent of the posted price.

[12] Sutherland [1945] writes, "The effects of a white collar crime upon the public are diffused over a long period of time and perhaps over millions of people, with no person suffering much at a particular time." In cases where white-collar crime has led to corporate bankruptcy, the effect on debt and equity holders is fairly clear and typically has not prompted econometric investigation, at least in academic publications. Examples include the Enron and Madoff bankruptcies. Impacts on victims of tax evasion, insider trading, fraud, and other common forms of white-collar crime are much more difficult to estimate.

[13] Excluding these observations does not meaningfully change my estimates; see Section 4.2.

nominal amounts to 2009 US dollars using the chained personal consumption expenditures deflator from the US Bureau of Economic Analysis. The data also include age, education, and gender for a subset of users. While some Glassdoor reports are unincentivized, others are incentivized by a "give-to-get" model: complete access to the website's aggregate salary and job satisfaction data requires a survey response that passes quality checks. Users may submit multiple reports for the same or different jobs. The resulting sample is non-random, and I discuss sample selection in Section 2.2 below. My estimation sample comprises Glassdoor reports by regular, full-time employees[14] 2007-2018 in US industries containing at least one colluding firm: "Computer Hardware & Software", "Internet", and "Motion Picture Production & Distribution." Descriptive statistics are in Table A1.

Self-reported data naturally raise the question of measurement error. Karabarbounis and Pinto [2018] investigate by comparing Glassdoor data to the QCEW and the PSID. Industry-level correlations for mean salary are .87 and .9, respectively. The authors conclude, "...the wage distribution (conditional on industry or region) in Glassdoor represents the respective distributions in other datasets, such as QCEW and PSID fairly well." More generally, previous research suggests survey respondents report annual pre-tax earnings with good accuracy. Using the Displaced Worker Supplement to the Current Population Survey (CPS), Oyer [2004] finds mean reporting error of +5.1% and median error of +1.3%. Both mean and median error are smaller for respondents reporting annual earnings, as 85 percent of respondents in my data do. Similarly, Bound and Krueger [1991] compare CPS reports to Social Security earnings records and find a signal-to-noise ratio of .82 for men, .92 for women. Abowd and Stinson [2013] relax the assumption that administrative data are accurate and survey data are measured with error. They estimate similar reliability statistics for the Survey of Income and Program Participation and Social Security earnings data. Using the same two data sets, Kim and Tamborini [2014] find reporting error is smaller for workers with undergraduate and graduate degrees, who comprise 93 percent of my sample (Table A1).

A second Glassdoor data set contains user ratings of jobs and job attributes: career opportunities, compensation and benefits, senior leadership, and work-life balance. Ratings range from one to five stars.[15] These data begin a year later, in 2008. Users are a subset of those who contribute salary reports. Table A2 provides descriptive statistics and Figure A2 is a histogram of compensation ratings. These ratings data should be approached with care. Users face no incentive to minimize misreporting, and many of the standard critiques of stated-preference measures apply. For example, three stars might have different meanings

[14] Temporary, part-time and contract workers are excluded.

[15] Half-stars were permitted for attributes (but not for overall ratings) 2008-2012.

to different users, or on different dimensions. Bearing these caveats in mind, it is interesting to study these ratings because they plausibly reveal some aspects of users' information sets. Descriptive statistics are in Table A2.

2.2 Sample selection

The plaintiffs' expert report from the civil class action [Leamer, 2012] contains some data that are useful in evaluating selection into my Glassdoor sample. Leamer [2012] Fig. 5 gives firms, jobs, years, and nominal compensation for the named plaintiffs. While these observations are not randomly selected, that does not imply that they are not representative. Indeed all but one of the observations for the named plaintiffs are close to the corresponding fitted values from Leamer's econometric model, estimated using complete administrative data from defendant firms. With one exception (described below), they are representative despite their non-random selection. One named plaintiff earned \$118,226 in salary and \$3,445 in other compensation as a Computer Scientist at Adobe in 2008. Matching on firm, job, and year, the corresponding Glassdoor means ($n = 17$) are \$127,240 and \$11,917. A second named plaintiff earned an average of \$109,363 in salary and \$30,641 in other compensation as a Software Engineer at Intel 2008-2011. The corresponding Glassdoor means ($n = 233$) are \$111,914 and \$15,565. A third named plaintiff held multiple positions at Intuit. In 2008 he earned \$91,300 in salary and \$83,877 in other compensation as a Software Engineer. (This observation is far from the corresponding fitted value of roughly \$110,000 from the Leamer model, perhaps because of the large non-salary compensation.) The corresponding Glassdoor means ($n = 12$) are \$94,210 and \$9,320. In 2009 he earned \$94,000 in salary and \$38,553 in other compensation as a Software Engineer II. The corresponding Glassdoor means ($n = 3$) are \$103,506 and \$10,071. The mean salary difference between the administrative and Glassdoor data is \$5,995. These observations suggest that the Glassdoor data are useful measurements of salaries at colluding firms. The Glassdoor measures of non-salary compensation are noisier, at minimum, and potentially less representative.[16] Leamer's Exhibit 2 permits a few comparisons of report frequencies by job for Pixar Animation. The top five jobs by count of worker-years are "Technical Director," "Animator," "Software Engineer," "Artist–Story," and "Artist–Sketch." In Glassdoor data the top five Pixar jobs by worker-years are "Technical Director," "Production Coordinator," "Software Engineer," "Senior Software Engineer," and "Animator." While these lists do not match perfectly, they are similar.

The above comparisons are suggestive, but quite limited in scope. The Occupational Employment Statistics from the Bureau of Labor Statistics permit a broader set of com-

[16] For non-salary compensation, the mean difference between administrative and Glassdoor data is -\$13,170.

parisons at the occupation-year level, including both treatment and control firms. Figure 1 presents a scatter plot of occupation-years, where occupations are defined by year-2010 SOC codes. Vertical coordinates are nominal mean salaries from my Glassdoor sample. Horizontal coordinates are nominal mean salaries from BLS OES data. The 45-degree line provides a benchmark, but complete agreement is not expected, as Glassdoor occupations were not designed to map exactly onto SOC codes. A local linear fit through the scatter shows the empirical relationship between OES and Glassdoor data and the bands around it represent the 95 percent confidence interval.[17] Glassdoor means are slightly above their OES analogs: the average occupation-year difference is approximately $3,600. But overall the local linear fit hews closely to the 45-degree line throughout the uncensored range of the BLS data.[18] While the Glassdoor sample is not randomly drawn, Figure 1 provides evidence that it is nonetheless reasonably representative.

3 Empirical strategy

I begin from the following difference-in-differences equation.

$$\ln\left(Salary_{iejlt}\right) = \boldsymbol{\alpha_{ej}} + \boldsymbol{\beta_{jt}} + \boldsymbol{\gamma_{lt}} + \delta Num.Agreements_{et} + \varepsilon_{iejlt} \quad (1)$$

Bold font denotes a vector and indices are i~user, e~employer, j~job, l~location (state), and t~year. The parameters in $\boldsymbol{\alpha_{ej}}$ control for cross-sectional differences across employer-job groups. The parameters in $\boldsymbol{\beta_{jt}}$ control for arbitrary job-year time trends, in $\boldsymbol{\gamma_{lt}}$ for arbitrary location-year time trends. The treatment variable $Num.Agreements_{et}$ is a duration-weighted count of no-poach agreements in force. For example, if a firm had 1 agreement in force for 5 months and 2 for 7 months, $Num.Agreements_{et} = \left(\frac{5}{12}\right)1 + \left(\frac{7}{12}\right)2$.[19] It follows that δ is the effect of having one additional no-poach agreement in force for a full year. Parameters are estimated using using the ordinary least squares procedure of Guimaraes and Portugal [2010], which performs well in the presence of high-dimensional fixed effects. Standard errors are clustered in two dimensions, general occupation and employer, except where otherwise noted. This allows for arbitrary covariances in the error term within occupation and employer, both cross-sectionally and over time.

The event study in Figure 2 provides a preliminary view of the treatment effect and allows for evaluation of identifying assumptions. This figure is constructed from a variant

[17] The local linear fit is constructed with an Epanechikov kernel (the Stata default) and $3,000 bandwidth.
[18] Beyond $145,600 some OES means are top-coded, making agreement between the two data sources much less likely.
[19] Details for each treated firm are in Appendix A.

of equation (1), in which treatment is a firm-level ever-treated dummy interacted with year indicators, and the 2015 treatment-control difference is normalized to zero.[20] The treatment group is comprised of Adobe, Apple, eBay, Google, Intel, Intuit, Lucasfilm and Pixar. Table A4 lists the 20 most frequently observed control-group firms, beginning with Amazon, Microsoft, and Cisco. My data begin in 2007, by which time all colluding firms were party to at least one agreement, so there is no staggered entry into treatment.[21] The effect of the no-poach agreements is visible in the left-hand region of Figure 2, where treatment-group salaries are below control-group salaries by approximately five percent. Estimates from 2007 through 2009 are statistically significant at the five percent level. The vertical line just after 2009 marks the end of the treatment period. DOJ documents indicate that the no-poach agreements ended in 2009, but that at least some continued after the investigation was publicly revealed in June [US Department of Justice, 2012]. Therefore I assume that all agreements continued through the end of that year. Treatment-group salaries began to converge to control-group salaries after 2009, but estimates remain substantially negative in 2010 and 2011. By 2012 estimates are consistent with full convergence. As Figure 2 illustrates, my identification strategy relies not on the potentially endogenous introduction of no-poach agreements, but rather on the plausibly exogenous DOJ investigation that ended them. Because neither entry into nor exit from treatment is staggered in my sample, the problems identified by Goodman-Bacon [2021] and Sun and Abraham [2021] do not arise.

Figure 2 also allows indirect evaluation of the common trends assumption required for a difference-in-differences design to identify the causal effect of the no-poach agreements. In the 2007-2009 period covered by the agreements estimates are roughly constant, consistent with common time trends for treated and control firms. In the post-treatment period 2012-2018 there is more variance in point estimates, but there is no evidence of different trends in the two groups. Taken together, the event study results imply that the magnitudes of my estimates based on equation (1) are likely biased downward. My specification ignores the 2010-2011 transition, during which salaries at treatment-group firms may have been reduced by lingering effects of the no-poach agreements. While this is undesirable, the alternative is worse: defining treatment based on observed salary dynamics could introduce endogeneity.

The second important identifying assumption for my research design is SUTVA, or more

[20] In a more typical difference-in-differences event study where control observations of later-treated units precede treated observations, it is common to normalize relative to the last pre-treatment year. In my setting one could plausibly normalize relative to several different post-treatment years and it is not clear how best to choose. Visual inspection of Figure 2, however, reveals that this choice is not consequential: normalizing relative to any year 2014-2018 would not meaningfully change the figure.

[21] As discussed in Appendix A, there is some ambiguity over whether Intel's first no-poach agreement began before or during 2007. In Figure 2 Intel observations are coded as treated treated throughout the period 2007-2009.

colloquially the "no spillovers" assumption. Theory predicts that no-poach agreements may reduce salaries at firms outside those agreements (see Appendix E). If such was the case in my setting, then my empirical estimates are biased downward in magnitude. Empirically, however, Figure A1 shows no evidence of an upward trend break in control-group salaries as the no-poach agreements were being unwound. Limiting the sample to labor markets below the DOJ's threshold for high concentration, where equilibrium salary spillovers are less likely, does not meaningfully change my primary estimates (Table A5). Finally, excluding workers who switch across treatment and control firms similarly produces no substantial change, suggesting that spillovers from workforce composition effects do not introduce large bias in my specifications (Table A5).

4 Empirical results

4.1 Primary results & robustness

Table 1 presents estimated effects of one additional full-year no-poach agreement. Column one ("Primary") corresponds exactly to equation (1). This is my preferred specification because it employs rich cross-sectional and time-series controls while maintaining a large, plausibly representative sample. The estimated effect is approximately -2.5 percent per agreement.[22] It is statistically significant at the one percent level, and the 95 percent confidence interval runs from -3.7 percent to -1.2 percent.

The magnitude of this no-poach effect is striking because these employees are well educated and highly paid. Thirty-one percent have an advanced degree and the mean salary in the larger sample is $93,158 (2009 US$). One might expect these characteristics to make them less vulnerable than other workers to employer market power. In my sample the average treated worker was affected by roughly two no-poach agreements. Doubling the estimates of Table 1 gives results in the range of the firm- and year-specific effects on total compensation estimated by the plaintiffs' expert report from the class action: from -1.6 to -20.1 percent, with most from -1.6 to -10 percent [Leamer, 2012].[23] The defendants' expert report is, to the best of my knowledge, not part of the public court record. However in certifying the plaintiff class Judge Lucy Koh quoted its conclusions: "'Defendants argue that, when Dr. Murphy disaggregated the Conduct Regression, he received dramatically different re-

[22]The exact percentage change is $e^{-.0249} = -.0246$, or 2.46 percent.

[23]The experts in this litigation had access to administrative compensation data from defendant firms, but not from other firms. The research design employed in [Leamer, 2012] may be thought of as a single difference, comparing agreement periods to pre- and post-agreement periods after adjustment for sector-level growth.

sults. See id. at 12-13; Murphy Rep. ¶ 117 (finding that Lucasfilm and Pixar "show[ed] no 'undercompensation' but instead 'overcompensation'... throughout the period," Google, Adobe, and Intel showed overcompensation in some years, and Apple showed "much smaller" undercompensation)"' [Koh, 2013]. My primary estimate is inconsistent with a null effect or "overcompensation."

Previous research on employer market power has estimated effects of similar magnitude. Azar et al. [2020] find that a 10 percent increase in concentration (Herfindahl-Hirschman Index: HHI) is associated with a .3 to 1.3 percent decrease in wages, while Marinescu et al. [2021b] estimate a .5 percent causal decrease from a similar concentration change.[24] Benmelech et al. [2020] find that a one standard deviation increase in HHI is associated with a 1 to 2 percent decrease in wages, and that the relationship is stronger in more recent data. Prager and Schmitt [2021] find that hospital mergers leading to large concentration increases reduce the wages of skilled workers by 4 to 6.8 percent. Finally Naidu et al. [2016] find that when migrant workers in the United Arab Emirates were allowed to change employers at the end of their initial contract, their earnings increased by 10 percent.

The following approximate calculation estimates aggregate damages based on salary alone. The plaintiffs' expert report estimates 109,048 members of the class and $52 billion in affected earnings [Leamer, 2012]. Based on column three of Table 1 and two no-poach agreements (the approximate sample mean), the marginal effect is roughly $2 * -.025 = -.05$, or 5 percent. Earnings in the absence of the agreements would then have been $\frac{\$52bn}{1-.05} = \$54.74bn$ and employee losses were $\$2.74bn$, or approximately $5,000 per employee-year.[25] This estimate should be viewed as a lower bound. It excludes not only non-salary compensation, but also additional job search costs incurred by affected workers. Even ignoring these omissions, my damage estimate is substantially greater than the $435 million the defendants paid to settle the case [Elder, 2015, Settlement Website, 2018].[26] This gap raises the question of whether civil penalties will meaningfully deter future exercise of employer market power.[27]

Theory predicts that earnings damages represent a transfer from labor to owners of other factors [Shy and Stenbacka, 2019]. At macroeconomic scale, the declining labor share has been associated not with an increased capital share, but rather increased profit [Barkai,

[24]Marinescu et al. [2021b] implement an instrumental variables design in French data.

[25]These calculations can instead be performed in levels, using an estimate from Table A6, column four. For the larger all-employee class [Leamer, 2012], damages are then (109,048 employees)(-$3198/agreement-yr)(2 agreements)(5 years), approximately $3.5 billion in 2009 dollars. Alternatively one can assume that only technical and creative salaries were affected (59,550 employees). From the triple-difference regression of Table A8, the effect of the agreements is approximately $2 * -.0319 \approx .064$. Earnings in the absence of the agreements would have been $\frac{\$33bn}{1-.064} = \$35.26bn$ and employee losses were roughly $\$2.25bn$.

[26]Apple, Google, Intel and Adobe settled together for $415 million in 2015. The other defendants settled for $20 million.

[27]This remains true even if one allows for uncertainty in my estimate and non-settlement losses.

2020], though this need not be true in this particular setting. An estimate of the attendant deadweight loss is beyond the scope of this paper.[28] Given the high mean salary among affected workers, one could argue that the welfare consequences of earnings lost to the no-poach agreements are relatively small. For many technology workers this argument is unconvincing because high urban housing costs greatly reduce the real purchasing power of six-figure nominal salaries. For example, in June 2018 the US Department of Housing and Urban Development revised its eligibility threshold for low-income housing assistance to $117,400 for Marin, San Mateo, and San Francisco counties [Sciacca, 2018].

The remaining columns in Table 1 evaluate the robustness of the primary estimate. To test for selection into treatment on observables, column two presents estimates for the subsample in which I observe demographic variables. Controls are as in equation (1), with the addition of a female dummy, age, age squared, and a set of educational attainment dummies. The resulting estimate remains near -2.5 percent. Column three adds user fixed effects, ruling out endogeneity from time-invariant individual characteristics, whether observable or unobservable. This limits the sample to multiple reporters, who may be selected differently than single reporters. The "User FE" estimate is larger at -4.5 percent. Table A6 shows that this increased magnitude comes from the change in sample, not specification; dropping the user fixed effects yields a nearly identical point estimate in the multiple-reporter sample. Selection on time-varying unobservables remains a potential threat to identification. As a check of this concern, I estimate effects on the subsample of "give to get" reports (described in Section 2.1). Previous research has found that "give to get" mitigates selection of employees with highly positive or negative views of their jobs [Marinescu et al., 2021a]. The estimate is modestly smaller, at -2.1 percent, and statistically significant at the five percent rather than the one percent level, but I cannot reject a null hypothesis of equality with my primary estimate at any conventional size.

Table 2 examines non-salary compensation, including cash and stock bonuses. While stock options are commonly used by information-technology firms [Oyer and Schaefer, 2005], the stock bonus variable does not distinguish option from share grants. Note again that Glassdoor does not require responses for these variables, and the sample is a potentially selected subset of the one from Table 1. I observe non-zero supplemental compensation for 51 percent of reports across all firms, while according to Leamer [2012] 93 percent of defendant employee-years included supplemental compensation.[29] The following results should therefore be interpreted with caution. For each compensation type I estimate a linear probability

[28] Sources of deadweight loss could include decreased worker-firm match quality, impaired labor- or product-market function from lost trust, and additional monitoring by workers, firms, or governments.

[29] In my sample the fraction of defendant employee-years with positive supplemental compensation is also 51 percent.

model using a dummy for positive compensation, a linear model with log compensation as the dependent variable, and a Poisson fixed-effects model that subsumes extensive and intensive margins in one equation [Correia et al., 2020].[30] Accordingly, estimates in column three are semi-elasticities. The probability of a positive stock bonus declines by 4.6 percentage points per no-poach agreement. Conditional on a positive stock bonus, the amount declines by 19.7 percent (21.9 log points). The combined effect is an average decline in stock bonus of 22 percent.[31] All three estimates are statistically significant at the one percent level. The estimate for cash bonuses is very small and positive in the linear probability model. Conditional on a positive cash bonus, the amount declines by approximately 6.8 percent, but the estimate is not statistically significant. In the Poisson model the combined effect is positive, but the standard error is again large and the 95 percent confidence interval includes practically important values with both positive and negative signs. The pattern of results in Table 2 is consistent with employee retention as one of the motives for stock-option grants [Core and Guay, 2001, Oyer and Schaefer, 2005].

Last among my primary results, Table 3 presents estimated effects on job satisfaction ratings from the difference-in-differences design of equation (1). As one might expect, the largest negative estimate is for compensation and benefits (column one): -.096 stars per full-year no-poach agreement, or -2.7 percent of the sample mean, statistically significant at the one percent level.[32] In proportional terms the magnitude is strikingly similar to the salary effect from column one of Table 1. This estimate is consistent with employees being aware their salaries were depressed relative to their own counterfactuals or reference points. Standard search models would predict increased search effort in response to such awareness [Chade et al., 2017]. If employees indeed increased search effort, that was an additional welfare loss. In contrast to the salary loss, which was transferred to other factors of production, a loss from additional search would have been a social (deadweight) loss. Column two of Table 3 also shows a negative effect on ratings of opportunities, -.062 stars (-1.9 percent of the mean), statistically significant at the five percent level. This could reflect both decreased internal opportunities, e.g. reduced promotion opportunities from senior employees leaving less frequently, and decreased external opportunities caused directly by the no-poach agreements. In column three the estimate for senior leadership is small (-.009 stars) and not statistically distinguishable from zero. This is consistent with most

[30] Observation counts in column 3 differ from those in column 1 because the PPML estimator drops observations perfectly predicted by the fixed effects.

[31] The event study corresponding to the estimated effect on stock bonuses is Figure A3 and robustness checks are in Table A10.

[32] The event study corresponding to the estimated effect on compensation ratings is Figure A4 and robustness checks are in Table A11.

employees remaining ignorant of the no-poach agreements; it is difficult to imagine that leadership ratings would not have suffered, had the agreements been widely known. Similarly, in column four the estimate for work-life balance is small (-.02 stars) and not statistically distinguishable from zero. In light of the negative effects on ratings of opportunities and compensation, the small negative estimate for overall job rating (column five) is striking: -.012 stars, or .3 percent of the mean. There are many possible reasons for this contrast, but at minimum it suggests that ratings of overall job satisfaction may not be a useful indicator of employer market power.[33]

4.2 Secondary robustness

This section supplements the robustness checks of Table 1 with several additional analyses. To begin, I evaluate robustness to minor sample and specification changes (see Table A6 for full results). Limiting the sample to reports with annual salaries gives an estimate of -2.44 percent, statistically significant at the one percent level and similar to my primary estimate. The inclusion of MSA-year fixed effects yields a coefficient estimate of -2.2 percent, again statistically significant at the one percent level. This is evidence that my primary results do not arise from city-specific time trends within states. Using the level of salary as the dependent variable results in an estimate of -$3197.5, statistically significant at the one percent level. Returning to log salaries, in a quadratic specification the estimated coefficient on the squared agreement count is negative, but not statistically significant. Employing a dummy treatment produces an estimate of -4.8 percent, statistically significant at the one percent level. This demonstrates that the linearity assumption implicit in using agreement count is not responsible for my primary estimates.

I also consider alternative definitions of the treated group. Using agreement start dates from Leamer [2012] rather than the DOJ dates (see Appendix A) produces no meaningful changes in estimates (see Table A7 for full results). Qualitative evidence from the class action suggests the no-poach agreements may have been enforced more vigorously for technical employees [Leamer, 2012]. This implies a triple-difference specification, using non-technical employees at colluding firms to help estimate counterfactual salaries. Table A8 presents estimates from such a specification. The marginal effect of a full-year no-poach agreement on non-technical employees is -.2 percent and one cannot reject a zero null hypothesis at conventional test sizes. The effect on technical employees is -3.2 percent (statistically signif-

[33] Other possibilities include the following. 1) The salary losses from the no-poach agreements might have had a small effect on job satisfaction for this sample of highly paid technology workers. 2) Colluding firms could have compensated workers for salary losses with increased non-pecuniary amenities, though such behavior is not predicted by any model of monopsony with which I am familiar.

icant at the one percent level), consistent with stronger enforcement against this group. The triple-difference specification is not my preferred one because defining the group of technical employees requires either researcher discretion or reliance on the class action plaintiffs, whose definition may have been influenced by pecuniary incentives. Context implies another group of employees at colluding firms who may not have been in the treatment group: recruiters and interviewers, who had detailed knowledge of the no-poach agreements. I estimate a variant of my primary double-difference specification in which the number of agreements interacts with a recruiter indicator. The effect of an agreement on non-recruiters is -2.5 percent, but the coefficient on the recruiter interaction is +3.5 percent, statistically significant at the five percent level.[34] This indicates recruiters were less affected than other employees by the no-poach agreements. There are multiple potential mechanisms for such a difference, including rent sharing and increased job-search effort by recruiters.

5 Conclusion

Economists have long been interested in employer market power [Smith, 1790, Robinson, 1933], but monopsony and oligopsony have attracted renewed interest of late. Using novel compensation data from Glassdoor, this paper estimates the effects of secret, illegal no-poach agreements among Silicon Valley technology companies. Difference-in-differences regressions return negative, statistically significant estimates for both base salaries and stock bonuses. They suggest the increasing market concentration in many US industries creates scope for increased use of employer market power, with potential negative impacts on workers and broad social welfare. My analysis lends weight to calls for greater policy and research scrutiny of employer market power and its sources, including mergers, mobility constraints, information frictions, and non-compete clauses [US CEA, 2016, Krueger and Posner, 2018, Marinescu, 2018].

[34] In a test of the sum of these estimates, one cannot reject a zero null hypothesis at conventional sizes.

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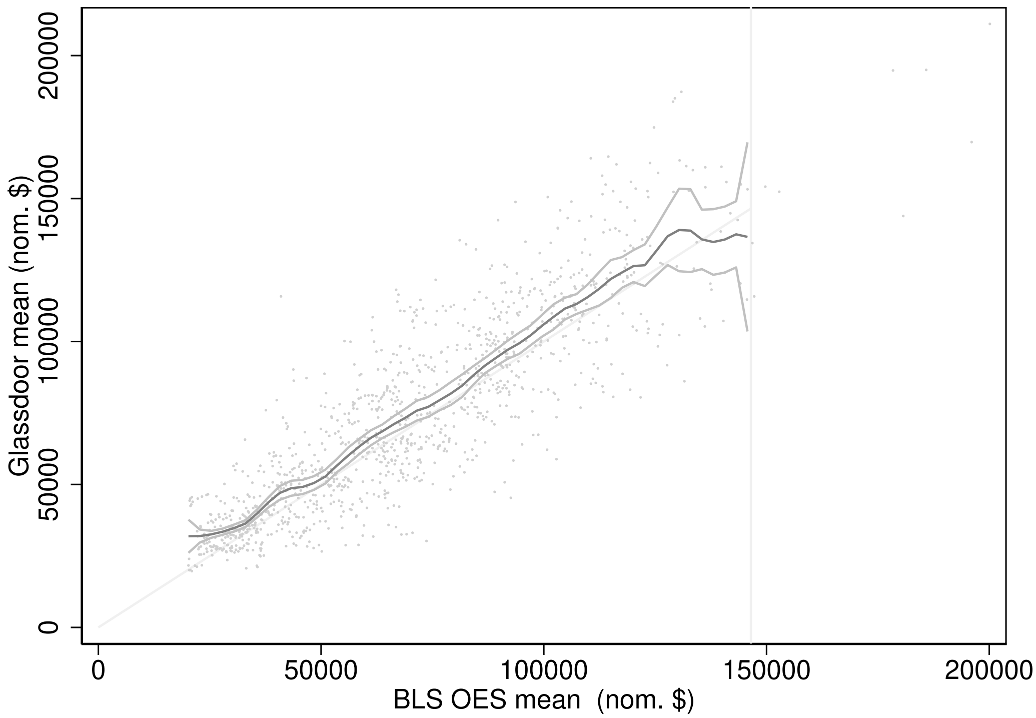
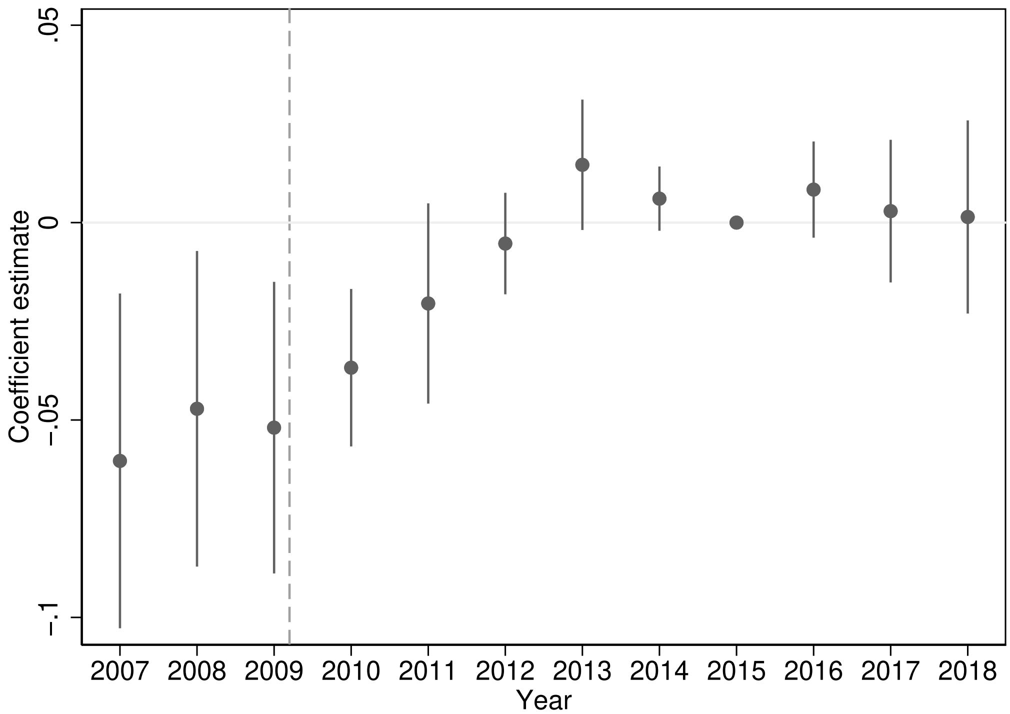
6 Figures

Figure 1: Average salary in Glassdoor and BLS OES data, 2007-2018



Each point on the scatter plot is an occupation-year (minimum ten Glassdoor reports), where occupations are defined by year-2010 SOC codes. Vertical coordinates are nominal mean salaries from Glassdoor data. Horizontal coordinates are nominal mean annual wages from BLS OES data. Included Glassdoor industries are "Computer Hardware & Software", "Internet", and "Motion Picture Production & Distribution." The dark gray fit through the scatter plot is from a local linear estimator, with an Epanechikov kernel and $3,000 bandwidth. The lighter gray lines around the local linear fit represent the 95% confidence interval. The sloped gray line is the function $y = x$. OES data are censored at high values, with thresholds from $145,600 to $208,000 depending on year. The vertical gray line represents the minimum censoring threshold, beyond which agreement of OES and Glassdoor data is much less likely.

Figure 2: Effect of no-poach agreements on salary, dummy treatment



Coefficient estimates are from a variant of equation (1), in which the number of no-poach agreements is replaced by interactions of a firm-level ever-treated dummy with year dummies. The dependent variable is log real annual salary (2009 US$). Controls are job-employer, job-year, and state-year fixed effects. The vertical dashed line represents the end of the no-poach agreements. The 2015 treatment-control difference is normalized to zero. The magnitude of the estimates 2007-2009 is roughly twice that of the primary estimate in Table 1, column one, because the average number of agreements among treated observations is approximately two. Standard errors are two-way clustered on general occupation and employer, and whiskers represent 95 percent confidence intervals.

7 Tables

Table 1: Effect of no-poach agreements on salary

	Primary	Demographics	User FE	Give to get
Num. agreements	-0.0249***	-0.0255***	-0.0446***	-0.0208**
	(0.00650)	(0.00616)	(0.00513)	(0.0102)
Observations	249922	70249	6867	23411

Estimates in column one correspond to equation (1). The dependent variable is log real annual salary (2009 US$). Controls are job-employer, job-year, and state-year fixed effects. Subsequent columns present variants of this primary specification, always including the fixed effects previously mentioned. Column two adds demographic controls: a female dummy, age, age squared, and a set of educational attainment dummies. The sample is smaller because Glassdoor does not require users to disclose demographic information. Column three employs user fixed effects ("user FE") and the sample is comprised only of users who report two or more times. Column four is estimated using only reports elicited by Glassdoor's "give to get" incentive. Standard errors are two-way clustered on general occupation and employer in all columns except three (user FE), where they are two-way clustered on specific occupation and employer to obtain a sufficient number of clusters in the occupation dimension.

Table 2: Effect of no-poach agreements on other labor compensation

	Stock bonus - LPM	ln(Stock bonus)	Stock bonus - PPML
Num. agreements	-0.0463***	-0.219***	-0.218***
	(0.00481)	(0.0251)	(0.0725)
Observations	249922	43775	128588
	Cash bonus - LPM	ln(Cash bonus)	Cash bonus - PPML
Num. agreements	0.00557	-0.0680	0.0310
	(0.00901)	(0.0452)	(0.0725)
Observations	249922	85482	191905

Estimates are from variants of equation (1). The dependent variable is an indicator for positive compensation of a given type in column one, log real compensation of a given type (2009 US$) in column two, and real compensation of a given type (2009 US$) in column three. Controls are job-employer, job-year, and state-year fixed effects. Column three employs the Poisson pseudo-maximum-likelihood estimator of Correia et al. [2020], and estimates are semi-elasticities. Observation counts in column three differ from those in column one because the estimator discards observations for which the outcome is perfectly predicted by the fixed effects. Standard errors are two-way clustered on general occupation and employer.

Table 3: Effect of no-poach agreements on ratings of job satisfaction

	Compensation	Opportunities	Leadership	Work-life	Overall
Num. agreements	-0.096***	-0.062**	-0.0091	-0.020	-0.012
	(0.027)	(0.028)	(0.032)	(0.016)	(0.0082)
Observations	133332	133332	133332	133332	133332

Estimates correspond to variants of equation (1), with ratings of job satisfaction as dependent variables. Ratings range from one to five stars for compensation and benefits, career opportunities, senior leadership, work-life balance, and the job overall. Controls are job-employer, job-year, and state-year fixed effects. Standard errors are two-way clustered on general occupation and employer.

Appendix A Details of no-poach agreements

According to the complaint in the civil class action, "Defendants' conspiracy consisted of an interconnected web of... agreements, each with the active involvement and participation of a company under the control of Steven P. Jobs ("Steve Jobs") and/or a company that shared at least one member of Apple's board 16 of directors" [Saveri, 2011]. All agreements prohibited parties from "cold calling" (recruiting) each other's employees. Many required that if an employee of one party applied to another, the prospective new employer would inform the current one. Many also prohibited the prospective new employer from hiring such an applicant without permission of the current employer. In the event of an offer, bidding wars were generally prohibited [US Department of Justice, 2010b, Saveri, 2011, US Department of Justice, 2012]. Agreements were not limited by geography or employee role [Leamer, 2012], but there is some evidence that they were enforced more rigorously in cases of highly educated, highly paid employees [Leamer, 2012, Koh, 2013].

- Apple-Google. The agreement began no later than 2006 [US Department of Justice, 2010b]. The class action alleged that this agreement began in February 2005 [Leamer, 2012]. As my data begin in 2007, the difference is irrelevant to my analysis.

- Apple-Adobe. The agreement began no later than May 2005 [US Department of Justice, 2010b].

- Apple-Pixar. The agreement began no later than April 2007 [US Department of Justice, 2010a].

- eBay-Intuit. The agreement began no later than August 2006 and lasted until at least June 2009 [US Department of Justice, 2012].

- Google-Intel. The agreement began no later than September 2007 [US Department of Justice, 2010b]. The class action alleged that this agreement began in March 2005 [Leamer, 2012]. In Table 1, I conservatively adopt the DOJ start date of September 2007.

- Google-Intuit. The agreement began no later than June 2007 [US Department of Justice, 2010a].

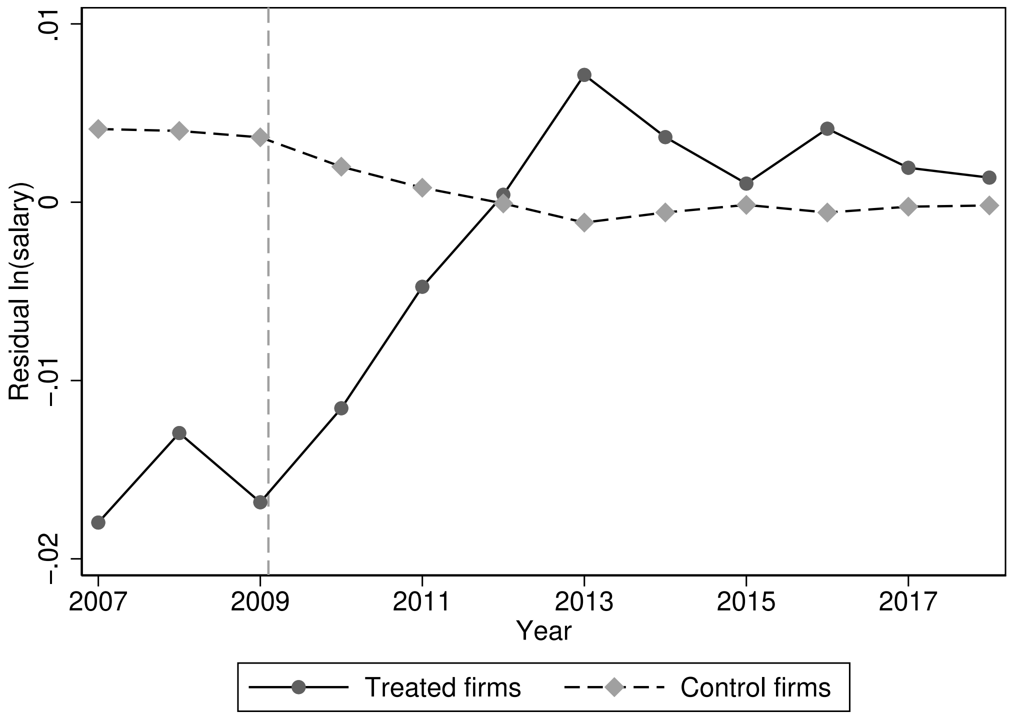
- Lucasfilm-Pixar. The agreement began no later than January 2005 [US Department of Justice, 2010c]. The class action alleged that this agreement began before the year 2000 [Leamer, 2012]. As my data begin in 2007, the difference is irrelevant to my analysis.

Appendix B Litigation timeline

- March 2009. DOJ sends civil investigative demands to technology firms.
- June 3, 2009. DOJ antitrust investigation becomes public [Helft, 2009].
- Sept. 24, 2010. Complaint filed in US v. Adobe [US Department of Justice, 2010b].
- Dec. 21, 2010. Complaint filed in US v. Lucasfilm [US Department of Justice, 2010c].
- March 18, 2011. Final judgment in US v. Adobe.
- May 4, 2011. Civil class action *In re: High-Tech Employee Antitrust Litigation* filed.
- Nov. 6, 2012. Complaint filed in US v. eBay [US Department of Justice, 2012].
- September 2, 2015. Remaining defendants Apple, Google, Intel and Adobe settle class action.

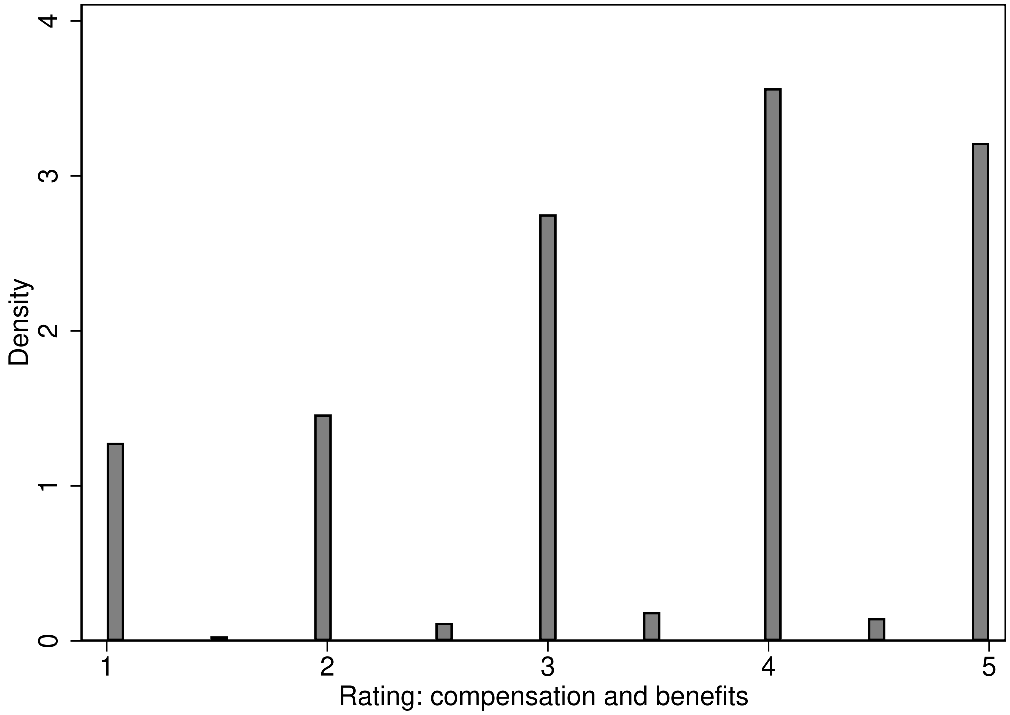
Appendix C Additional figures

Figure A1: Residualized salaries



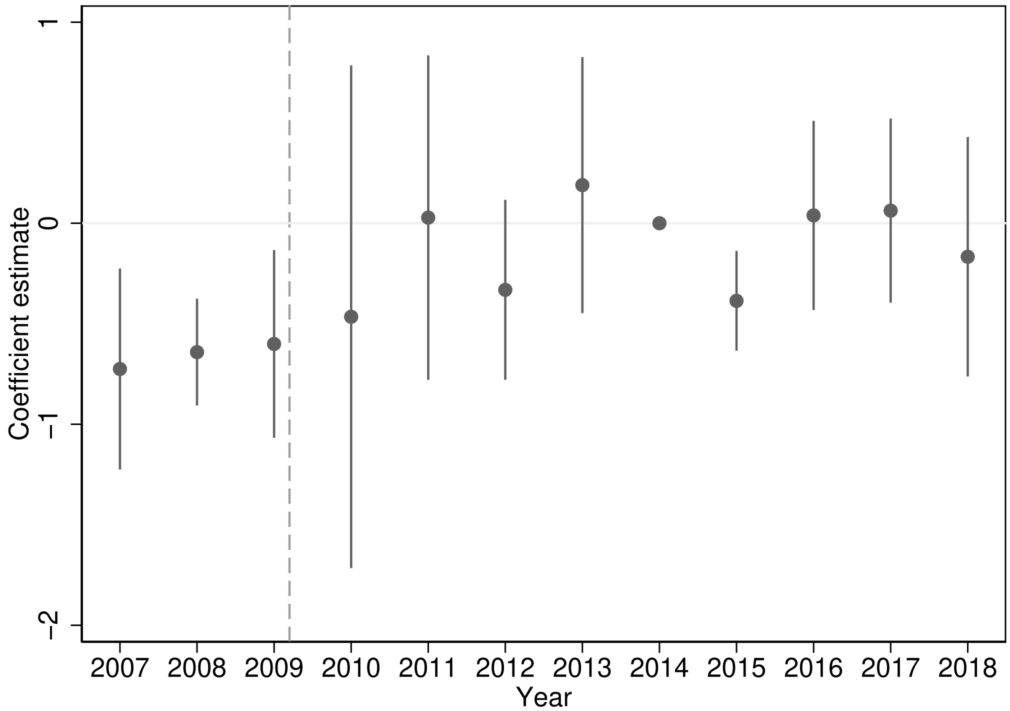
Log real annual salaries (2009 US$) were residualized on the controls from equation (1): job-employer, job-year, and state-year fixed effects. Neither an agreement count nor a dummy treatment variable was included. Each marker in the figure is the average such residual for a given group-year. A simple theoretical model would predict co-movement of treatment and control salaries. That would imply salary increases at control-group firms during the period 2009-2012 when the no-poach agreements were being unwound. While the counterfactual is unobserved, residualized control-group salaries actually fell slightly from 2009 through 2012. The magnitude of the treatment-control difference differs from the primary event study (Figure 2) because after partialling out controls, the difference in the treatment variable across groups is less than one. To obtain an estimated treatment effect one must divide the difference in residualized salaries by the difference in the residualized treatment dummy (roughly .5 in this case).

Figure A2: Rating frequencies, compensation & benefits



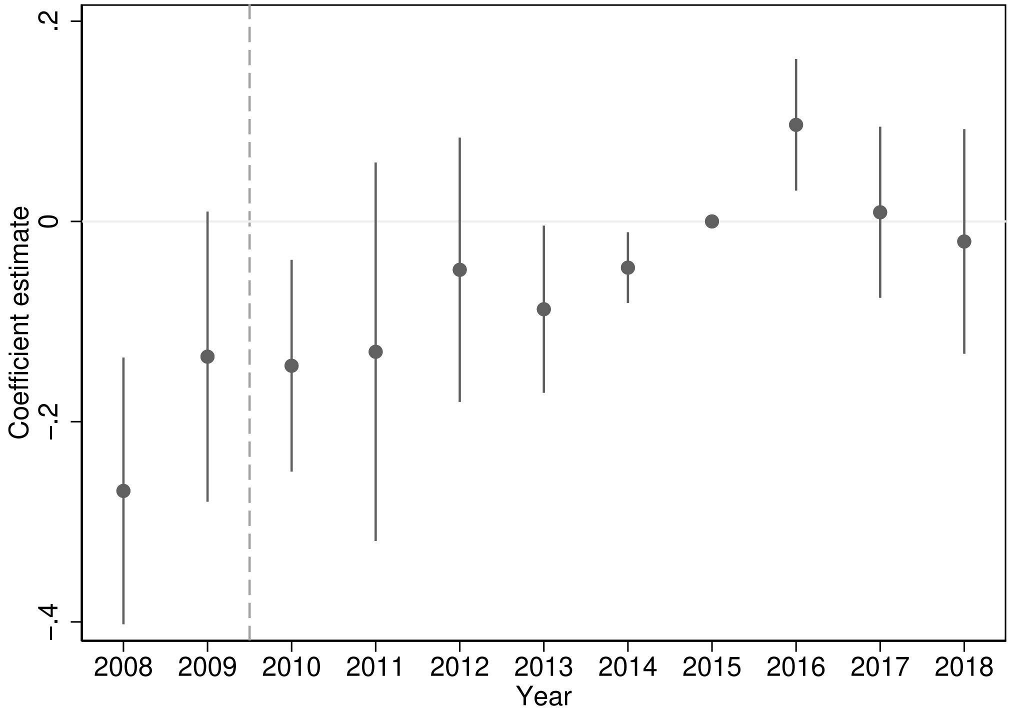
Illustrated are frequencies of star ratings for compensation and benefits. Data cover 2008-2018. Half-star ratings were permitted 2008-2012.

Figure A3: Event study, dummy treatment, stock bonuses



Estimates are from a variant of equation (1), in which the number of no-poach agreements is replaced by interactions of a firm-level ever-treated dummy with year dummies, estimated using the Poisson pseudo-maximum-likelihood estimator of Correia et al. [2020]. Estimates are semi-elasticities. The dependent variable is stock bonuses (2009 US$). Controls are job-employer, job-year, and state-year fixed effects. The vertical dashed line represents the end of the no-poach agreements. The magnitude of the estimates 2007-2009 is roughly twice that of the estimate in Table 2, column three, because the average number of agreements among treated observations is approximately two. Standard errors are two-way clustered on general occupation and employer, and whiskers represent 95 percent confidence intervals.

Figure A4: Event study, dummy treatment, compensation & benefits ratings



Coefficient estimates are from a variant of equation (1), in which the number of no-poach agreements is replaced by interactions of a firm-level ever-treated dummy with year dummies. The dependent variable is a rating of compensation and benefits from one to five stars. Controls are job-employer, job-year, and state-year fixed effects. The vertical dashed line represents the end of the no-poach agreements. Note that Glassdoor ratings are not available for 2007. The magnitude of the estimates 2008-2009 is roughly twice that of the estimate in Table 3, column three, because the average number of agreements among treated observations is approximately two. Standard errors are two-way clustered on general occupation and employer, and whiskers represent 95 percent confidence intervals.

Appendix D Additional tables

Table A1: Descriptive statistics, salary reports

	mean	sd	min	max
Base pay	93157.77	47766.49	13420.76	977254.12
Cash bonus	20139.10	283409.89	0.00	36778968.00
Stock bonus	16201.44	351455.61	0.00	47812660.00
Female	0.29	0.45	0.00	1.00
Age	32.73	8.55	16.00	70.00
High school	0.06	0.23	0.00	1.00
Some college	0.02	0.13	0.00	1.00
College	0.63	0.48	0.00	1.00
Graduate degree	0.30	0.46	0.00	1.00

All forms of compensation in 2009 US$.

Table A2: Descriptive statistics, ratings of job satisfaction

	mean	sd	min	max
Overall	3.44	1.37	1.00	5.00
Opportunities	3.30	1.39	1.00	5.00
Compensation	3.49	1.27	1.00	5.00
Leadership	3.07	1.47	1.00	5.00
Work-life	3.45	1.36	1.00	5.00

Job ratings data begin in 2008 and represent a subset of the users in the salary data.

Table A3: Top 10 jobs in Glassdoor sample, by classification scheme

General occupation	Specific occupation	Job
software engineer	software engineer	software engineer
branch manager	manager	senior software engineer
engineer	software development engineer	account executive
account executive	account executive	account manager
product manager	program manager	project manager
program manager	product manager	director
sales representative	account manager	software development engineer
project manager	project manager	product manager
marketing manager	engineer	software developer
corporate account manager	software developer	program manager

Table A4: Top 20 control-group firms in Glassdoor sample

Employer name	Employer name
Amazon	VMware
Microsoft	Yelp
Cisco Systems	The Walt Disney Company
Qualcomm	Uber
Epic Systems	Facebook
Cerner	Bloomberg
Tata Consultancy Services	Symantec
Yahoo! Inc.	SAP
Salesforce	PayPal
Honeywell	Groupon

Two of the less familiar names, Epic and Cerner, are in health care IT.

Table A5: Effect of no-poach agreements on salary, spillover checks

	HHI<2500	HHI<2000	No switchers
Num. agreements	-0.0232***	-0.0242***	-0.0248***
	(0.00578)	(0.00524)	(0.00660)
Observations	143214	127440	247347

HHIs were computed for markets at the major occupation-state level, treating all colluding firms as a single decision-maker. Column one estimates equation (1) using only reports from markets with HHIs less than 2500, the DOJ threshold for high concentration. Column two uses only reports from markets with HHIs less than 2000. Column three excludes users observed at both treatment and control firms at any two points in time ("switchers"). The dependent variable is log real annual salary (2009 US$). All columns include job-employer, job-year, and state-year fixed effects. Standard errors are two-way clustered on general occupation and employer.

Table A6: Effect of no-poach agreements on salary, secondary robustness

	User FE sample	Annual only	MSA trends	Salary (level)	ln(Salary)	ln(Salary)
Num. agreements	-0.0447***	-0.0244***	-0.0222***	-3197.5***	-0.0132	
	(0.00454)	(0.00676)	(0.00634)	(870.5)	(0.0168)	
Num. agreements^2					-0.00429	
					(0.00575)	
Dummy, 1+ agr.						-0.0478***
						(0.0157)
Observations	6867	215757	248803	249922	249922	249922

Column one (User FE sample) estimates equation (1) using only the sample of multiple reporters, but does not include user fixed effects. Column two limits the sample to users reporting an annual salary. Column three adds state-MSA-year fixed effects (flexible time trends at the location level). It uses the full Glassdoor sample, but the observation count is reduced from column one of Table 1 because the additional fixed effects create more singletons. Column four expresses salary in dollars, instead of using the log transformation. Column five models treatment as a quadratic function of duration-weighted agreement count. Lastly column six models treatment using a simple dummy for being employed at a colluding firm in the period 2007-2009. All columns include job-employer, job-year, and state-year fixed effects. Standard errors are two-way clustered on specific occupation and employer in column one to obtain a sufficient number of clusters in the occupation dimension. In all other columns standard errors are two-way clustered on general occupation and employer.

Table A7: Effect of no-poach agreements on salary, Leamer agreement start dates

	Primary	Demographics	User FE	Give to get
Num. agreements	-0.0250***	-0.0259***	-0.0451***	-0.0206**
	(0.00642)	(0.00624)	(0.00564)	(0.0102)
Observations	249922	70249	6867	23411

This table differs from Table 1 only in that counts of no-poach agreements are based on Leamer [2012]. Estimates in column one correspond to equation (1). The dependent variable is log real annual salary (2009 US$). Controls are job-employer, job-year, and state-year fixed effects. Subsequent columns present variants of this primary specification, always including the fixed effects previously mentioned. Column two adds demographic controls: a female dummy, age, age squared, and a set of educational attainment dummies. The sample is smaller because Glassdoor does not require users to disclose demographic information. Column three employs user fixed effects ("user FE") and the sample is comprised only of users who report two or more times. Column four is estimated using only reports elicited by Glassdoor's "give to get" incentive. Standard errors are two-way clustered on general occupation and employer in all columns except three (user FE), where they are two-way clustered on specific occupation and employer to obtain a sufficient number of clusters in the occupation dimension.

Table A8: Effect of no-poach agreements on salary, triple-difference specification

	ln(Salary)
Num. agreements	-0.00155
	(0.00744)
Num. agreements*technical class	-0.0303***
	(0.00863)
Observations	249856

This table modifies equation (1) by adding a third dimension of difference: technical vs. non-technical employees. The dependent variable is log real annual salary (2009 US$). Controls are job-employer, job-year, and technical class-state-year fixed effects. The sample is slightly smaller than in Table 1, column one, because the triple-difference regression leads to more singletons.

Table A9: Effect of no-poach agreements on salary, interacted with recruiter indicator

	ln(Salary)
Num. agreements	-0.0251***
	(0.00655)
Recruiter=1*Num. agreements	0.0353**
	(0.0175)
Observations	249922

Estimates correspond to equation (1), with the addition of an interaction between the number of agreements and a recruiter/interviewer indicator. Dependent variable is log real annual salary (2009 US$). Controls are job-employer, job-year, and state-year fixed effects. Standard errors are two-way clustered on general occupation and employer.

Table A10: Effect of no-poach agreements on stock bonuses, robustness checks

	Primary	Demographics	User FE	Give to get
Num. agreements	-0.218***	-0.429***	-0.154	-0.713**
	(0.0725)	(0.123)	(0.211)	(0.351)
Observations	128591	35665	3176	11205

Estimates are from variants of equation (1) based on the Poisson pseudo-maximum-likelihood estimator of Correia et al. [2020], which discards observations for which the outcome is perfectly predicted by the fixed effects. Estimates are semi-elasticities. The dependent variable is stock bonuses (2009 US$). Controls are job-employer, job-year, and state-year fixed effects. Subsequent columns make small changes to this primary specification, always including the fixed effects previously mentioned. Column two adds demographic controls: a female dummy, age, age squared, and a set of educational attainment dummies. The sample is smaller because Glassdoor does not require users to disclose demographic information. Column three employs user fixed effects ("user FE") and the sample is comprised only of users who report two or more times. Column four is estimated using only reports elicited by Glassdoor's "give to get" incentive. Standard errors are two-way clustered on general occupation and employer in all columns except three (user FE), where they are two-way clustered on job and employer to obtain a sufficient number of clusters in the occupation dimension.

Table A11: Effect of no-poach agreements on compensation ratings, robustness checks

	Primary	Demographics	User FE
Num. agreements	-0.0955***	-0.117*	-0.133
	(0.0268)	(0.0608)	(0.0870)
Observations	133332	36624	5101

Estimates correspond to variants of equation (1) with ratings of compensation & benefits as the dependent variable. Ratings range from one to five stars. Controls are job-employer, job-year, and state-year fixed effects. Subsequent columns present variants of this primary specification, always including the fixed effects previously mentioned. Column two adds demographic controls: a female dummy, age, age squared, and a set of educational attainment dummies. The sample is smaller because Glassdoor does not require users to disclose demographic information. Column three employs user fixed effects ("user FE") and the sample is comprised only of users who report two or more times. Glassdoor's "give to get" incentive does not apply to ratings, so there is no specification analogous to column four of Table 1. Standard errors are two-way clustered on general occupation and employer in all columns except three (user FE), where they are two-way clustered on specific occupation and employer to obtain a sufficient number of clusters in the occupation dimension.

Appendix E Theory

I extend the model of Shy and Stenbacka [2019] along two dimensions. First, I consider the three-firm case. Second, in keeping with my empirical setting, I define no-poach agreements as quantity restrictions rather than uniform wage restrictions. Consider three firms, a, b, and c, indexed by i and facing output prices p_i. Each firm initially employs n workers, and competes for workers by offering a loyalty wage w_i and a poaching wage v_i. Within each firm workers have switching costs $s \sim U[0,1]$. These switching costs scale by a factor σ that varies by firm pair. A worker's productivity is ϕ at the originating firm and $\phi^{'}$ (potentially different) at the destination firm.

A worker initially employed at firm i maximizes the following utility function.

$$u_i(s) = \begin{cases} w_i & if\ stay \\ v_j - \sigma_{ij}s & if\ leave\ for\ j \\ v_k - \sigma_{ik}s & if\ leave\ for\ k \end{cases}$$

Let l_{ij} denote the supply of firm i labor that moves to firm j, allowing for the case $i = j$ ("stayers"). The firm's optimization problem can then be written compactly.

$$\max_{w_i, v_i} p_i \left[n\phi l_{ii} + n\phi^{'}(l_{ji} + l_{ki})\right] - \left[nw_i l_{ii} + nv_i (l_{ji} + l_{ki})\right]$$

First-order conditions are as follows.

$$(p_i\phi - w_i)\frac{\partial l_{ii}}{\partial w_i} - l_{ii} = 0 \tag{2}$$

$$\left(p_i\phi^{'} - v_i\right)\left(\frac{\partial l_{ji}}{\partial v_i} + \frac{\partial l_{ki}}{\partial v_i}\right) - (l_{ji} + l_{ki}) = 0$$

Empirically, unrestrained markets for technology workers typically feature flows among all firms. Given the theoretical structure above, the only potential equilibrium featuring switching across all three firm pairs is one in which $v_a > v_b > v_c$ and $\sigma_{ab} = \sigma_{ba} > \sigma_{ac} = \sigma_{ca} > \sigma_{bc} = \sigma_{cb}$, as illustrated in Figure A5. Within each firm, wage offers and switching costs divide workers into three types. For example, consider firm a. Workers with values of s on $\left(0, \frac{v_c - v_b}{\sigma_{ac} - \sigma_{ab}}\right)$ switch to firm b. Workers with values of s on $\left(\frac{v_c - v_b}{\sigma_{ac} - \sigma_{ab}}, \frac{v_c - w_a}{\sigma_{ac}}\right)$ switch to firm c. Workers with values of s on $\left(\frac{v_c - w_a}{\sigma_{ac}}, 1\right)$ stay at firm a. Provided $p_a \gg p_b \gg p_c$ and differences in switching costs are small relative to levels of switching costs, an equilibrium exists with $v_a^* > v_b^* > v_c^* > w_a^* > w_b^* > w_c^*$. Closed-form solutions (w_i^*, v_i^*) are below.

Figure A5: Three-firm equilibrium, no agreement

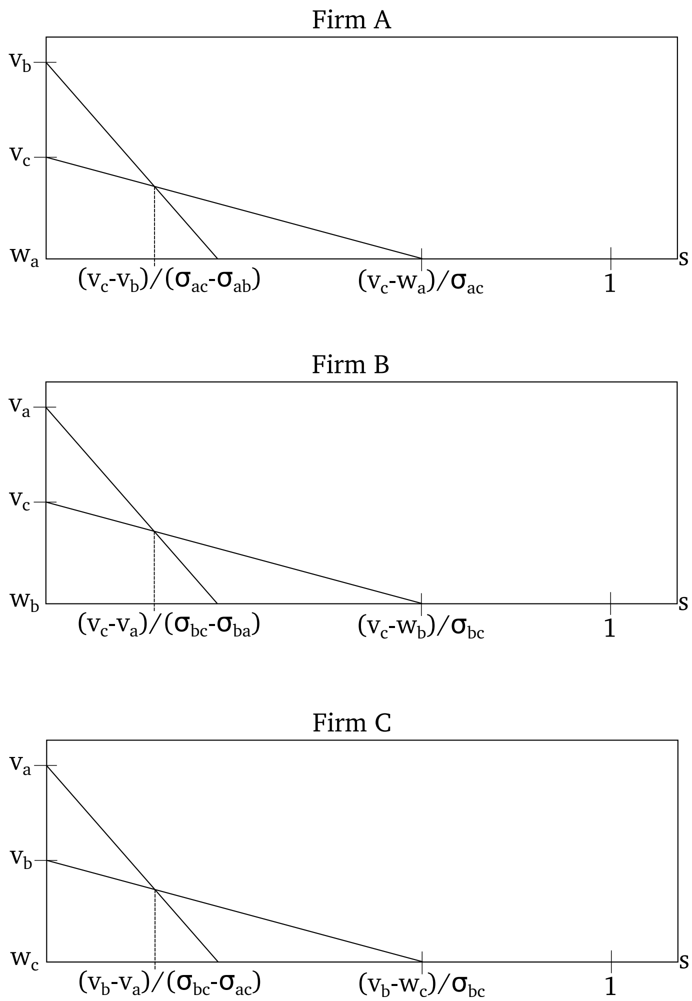


Figure depicts an equilibrium in which poaching occurs in both directions across all three firm pairs. There is no no-poach agreement. Poaching wages are v_i, loyalty wages are w_i, and $s \sim U(0,1)$ is worker switching cost. The figure assumes $v_a > v_b > v_c$ and symmetric switching costs that vary by firm pair, with $\sigma_{ab} > \sigma_{ac} > \sigma_{bc}$. Within each firm, wage offers and switching costs divide workers into three types. For example, consider firm A. Workers with values of s on $\left(0, \frac{v_c - v_b}{\sigma_{ac} - \sigma_{ab}}\right)$ switch to firm B. Workers with values of s on $\left(\frac{v_c - v_b}{\sigma_{ac} - \sigma_{ab}}, \frac{v_c - w_a}{\sigma_{ac}}\right)$ switch to firm C. Workers with values of s on $\left(\frac{v_c - w_a}{\sigma_{ac}}, 1\right)$ stay at firm A.

Given this initial equilibrium, the only potentially incentive-compatible no-poach agreement is between firms b and c. (A deal between firm a and one of the lower-wage firms would not reduce poaching from the lower-wage firm.) I set the corresponding supply functions equal to zero ($l_{bc} = l_{cb} = 0$) and solve for new equilibrium wages (w_i^{np}, v_i^{np}). The DOJ complaint and the class action both allege that the no-poach agreements reduced labor earnings at colluding firms, so I am interested in parameter values that yield this prediction. If switching is strongly productivity-reducing ($\phi' \ll \phi$) or switching costs $\sigma_{ba} + \sigma_{ac}$ are large relative to productivity gains, then both loyalty wages w_i^{np} and poaching wages v_i^{np} fall at the colluding firms b and c (relative to the equilibrium without a no-poach agreement).[35] Under these conditions, the no-poach agreement also reduces both loyalty wages w_a^{np} and poaching wages v_a^{np} at firm a. Details are below.

E.1 Firm A

Firm A's labor shares are as follows.

$$l_{aa} = 1 - \left(\frac{v_c - w_a}{\sigma_{ac}}\right)$$
$$l_{ba} = \frac{v_a - v_c}{\sigma_{ba} - \sigma_{bc}} = \frac{v_a - v_c}{2\delta}$$
$$l_{ca} = \frac{v_a - v_b}{\sigma_{ac} - \sigma_{bc}} = \frac{v_a - v_b}{\delta}$$

Relevant derivatives are as follows.

$$\frac{\partial l_{aa}}{\partial w_a} = \frac{1}{\sigma_{ac}}$$
$$\frac{l_{ba}}{\partial v_a} = \frac{1}{2\delta}$$
$$\frac{l_{ca}}{\partial v_a} = \frac{1}{\delta}$$

These can then be plugged into the general FOCs given in Equations 2.

$$(p_a\phi - w_a)\frac{1}{\sigma_{ac}} - \left(1 - \left(\frac{v_c - w_a}{\sigma_{ac}}\right)\right) = 0$$
$$\left(p_a\phi' - v_a\right)\left(\frac{1}{2\delta} + \frac{1}{\delta}\right) - \left(\frac{v_a - v_c}{2\delta} + \frac{v_a - v_b}{\delta}\right) = 0$$

[35] If switching is productivity-increasing ($\phi' > \phi$) or switching costs $\sigma_{ba} + \sigma_{ac}$ are small, the model predicts increased loyalty wages at firms b and c. The effect on average wages at b and c is then potentially zero or even positive.

The first FOC can be solved for w_a.

$$\begin{aligned}
(p_a\phi - w_a)\frac{1}{\sigma_{ac}} - \left(1 - \left(\frac{v_c - w_a}{\sigma_{ac}}\right)\right) &= 0 \\
\frac{p_a\phi - w_a + v_c - w_a}{\sigma_{ac}} &= 1 \\
p_a\phi - 2w_a + v_c &= \sigma_{ac} \\
2w_a &= p_a\phi + v_c - \sigma_{ac} \\
w_a &= \frac{1}{2}p_a\phi + \frac{1}{2}v_c - \frac{1}{2}\sigma_{ac} \qquad (3)
\end{aligned}$$

The second FOC can be solved for v_a.

$$\begin{aligned}
\left(p_a\phi^{'} - v_a\right)\left(\frac{1}{2\delta} + \frac{1}{\delta}\right) - \left(\frac{v_a - v_c}{2\delta} + \frac{v_a - v_b}{\delta}\right) &= 0 \\
\left(\frac{p_a\phi^{'} - v_a}{2\delta} + \frac{p_a\phi^{'} - v_a}{\delta}\right) - \left(\frac{v_a - v_c}{2\delta} + \frac{v_a - v_b}{\delta}\right) &= 0 \\
\frac{p_a\phi^{'} - v_a - (v_a - v_c)}{2\delta} + \frac{p_a\phi^{'} - v_a - (v_a - v_b)}{\delta} &= 0 \\
\frac{p_a\phi^{'} - 2v_a + v_c}{2\delta} + \frac{p_a\phi^{'} - 2v_a + v_b}{\delta} &= 0 \\
p_a\phi^{'} - 2v_a + v_c + 2\left(p_a\phi^{'} - 2v_a + v_b\right) &= 0 \\
p_a\phi^{'} - 2v_a + v_c + 2p_a\phi^{'} - 4v_a + 2v_b &= 0 \\
3p_a\phi^{'} - 6v_a + v_c + 2v_b &= 0 \\
6v_a &= 3p_a\phi^{'} + v_c + 2v_b \\
v_a &= \frac{1}{2}p_a\phi^{'} + \frac{1}{6}v_c + \frac{1}{3}v_b \qquad (4)
\end{aligned}$$

E.2 Firm B

Firm B's labor shares are as follows.

$$\begin{aligned}
l_{bb} &= 1 - \left(\frac{v_c - w_b}{\sigma_{bc}}\right) \\
l_{ab} &= \frac{v_b - v_c}{\sigma_{ab} - \sigma_{ac}} = \frac{v_b - v_c}{\delta} \\
l_{cb} &= \left(\frac{v_b - w_c}{\sigma_{bc}}\right) - \left(\frac{v_a - v_b}{\sigma_{ac} - \sigma_{bc}}\right) = \left(\frac{v_b - w_c}{\sigma_{bc}}\right) - \left(\frac{v_a - v_b}{\delta}\right)
\end{aligned}$$

Relevant derivatives are as follows.

$$\frac{\partial l_{bb}}{\partial w_b} = \frac{1}{\sigma_{bc}}$$
$$\frac{l_{ab}}{\partial v_b} = \frac{1}{\delta}$$
$$\frac{l_{cb}}{\partial v_b} = \frac{1}{\sigma_{bc}} + \frac{1}{\delta}$$

These can then be plugged into the general FOCs given in Equations 2.

$$\left(p_b\phi - w_b\right)\frac{1}{\sigma_{bc}} - \left(1 - \left(\frac{v_c - w_b}{\sigma_{bc}}\right)\right) = 0$$
$$\left(p_b\phi^{'} - v_b\right)\left(\frac{1}{\delta} + \frac{1}{\sigma_{bc}} + \frac{1}{\delta}\right) - \left[\frac{v_b - v_c}{\delta} + \left(\frac{v_b - w_c}{\sigma_{bc}}\right) - \left(\frac{v_a - v_b}{\delta}\right)\right] = 0$$

The first FOC can be solved for w_b.

$$\begin{aligned}
\left(p_b\phi - w_b\right)\frac{1}{\sigma_{bc}} - \left(1 - \left(\frac{v_c - w_b}{\sigma_{bc}}\right)\right) &= 0 \\
\frac{p_b\phi - w_b + v_c - w_b}{\sigma_{bc}} &= 1 \\
p_b\phi - 2w_b + v_c &= \sigma_{bc} \\
2w_b &= p_b\phi + v_c - \sigma_{bc} \\
w_b &= \frac{1}{2}p_b\phi + \frac{1}{2}v_c - \frac{1}{2}\sigma_{bc}
\end{aligned} \tag{5}$$

The second FOC can be solved for v_b.

$$\begin{aligned}
\left(p_b\phi^{'} - v_b\right)\left(\frac{1}{\delta} + \frac{1}{\sigma_{bc}} + \frac{1}{\delta}\right) - \left[\frac{v_b - v_c}{\delta} + \left(\frac{v_b - w_c}{\sigma_{bc}}\right) - \left(\frac{v_a - v_b}{\delta}\right)\right] &= 0 \\
\left(p_b\phi^{'} - v_b\right)\left(\frac{2}{\delta} + \frac{1}{\sigma_{bc}}\right) - \left(\frac{v_b - v_c - v_a + v_b}{\delta} + \frac{v_b - w_c}{\sigma_{bc}}\right) &= 0 \\
\left(\frac{2p_b\phi^{'} - 2v_b}{\delta} + \frac{p_b\phi^{'} - v_b}{\sigma_{bc}}\right) - \left(\frac{2v_b - v_c - v_a}{\delta} + \frac{v_b - w_c}{\sigma_{bc}}\right) &= 0 \\
\frac{2p_b\phi^{'} - 2v_b - 2v_b + v_c + v_a}{\delta} + \frac{p_b\phi^{'} - v_b - v_b + w_c}{\sigma_{bc}} &= 0 \\
\frac{2p_b\phi^{'} - 4v_b + v_c + v_a}{\delta} + \frac{p_b\phi^{'} - 2v_b + w_c}{\sigma_{bc}} &= 0 \\
2p_b\phi^{'} - 4v_b + v_c + v_a + \left(\frac{\delta}{\sigma_{bc}}\right)\left(p_b\phi^{'} - 2v_b + w_c\right) &= 0 \\
2p_b\phi^{'} - 4v_b + v_c + v_a + \frac{\delta}{\sigma_{bc}}p_b\phi^{'} - 2\frac{\delta}{\sigma_{bc}}v_b + \frac{\delta}{\sigma_{bc}}w_c &= 0 \\
\left(2 + \frac{\delta}{\sigma_{bc}}\right)p_b\phi^{'} - \left(4 + \frac{2\delta}{\sigma_{bc}}\right)v_b + v_c + v_a + \frac{\delta}{\sigma_{bc}}w_c &= 0
\end{aligned}$$

$$\begin{aligned}
\left(4 + \frac{2\delta}{\sigma_{bc}}\right)v_b &= \left(2 + \frac{\delta}{\sigma_{bc}}\right)p_b\phi^{'} + v_c + v_a + \frac{\delta}{\sigma_{bc}}w_c \\
v_b &= \left(\frac{1}{4 + \frac{2\delta}{\sigma_{bc}}}\right)\left[\left(2 + \frac{\delta}{\sigma_{bc}}\right)p_b\phi^{'} + v_c + v_a + \frac{\delta}{\sigma_{bc}}w_c\right] \\
v_b &= \frac{1}{2}\left(\frac{1}{2 + \frac{\delta}{\sigma_{bc}}}\right)\left[\left(2 + \frac{\delta}{\sigma_{bc}}\right)p_b\phi^{'} + v_c + v_a + \frac{\delta}{\sigma_{bc}}w_c\right] \\
v_b &= \frac{1}{2}\left[p_b\phi^{'} + \left(\frac{1}{2 + \frac{\delta}{\sigma_{bc}}}\right)v_c + \left(\frac{1}{2 + \frac{\delta}{\sigma_{bc}}}\right)v_a + \left(\frac{1}{2 + \frac{\delta}{\sigma_{bc}}}\right)\frac{\delta}{\sigma_{bc}}w_c\right]
\end{aligned}$$

Let $\beta_1 \equiv \left(\frac{1}{2+\frac{\delta}{\sigma_{bc}}}\right)$.

$$\begin{aligned}
v_b &= \frac{1}{2}\left[p_b\phi^{'} + \beta_1 v_c + \beta_1 v_a + \beta_1\frac{\delta}{\sigma_{bc}}w_c\right] \\
v_b &= \frac{1}{2}p_b\phi^{'} + \frac{1}{2}\beta_1 v_c + \frac{1}{2}\beta_1 v_a + \frac{1}{2}\beta_1\frac{\delta}{\sigma_{bc}}w_c \qquad (6)
\end{aligned}$$

E.3 Firm C

Firm C's labor shares are as follows.

$$
\begin{aligned}
l_{cc} &= 1 - \left(\frac{v_b - w_c}{\sigma_{bc}}\right) \\
l_{ac} &= \left(\frac{v_c - w_a}{\sigma_{ac}}\right) - \left(\frac{v_b - v_c}{\sigma_{ab} - \sigma_{ac}}\right) = \left(\frac{v_c - w_a}{\sigma_{ac}}\right) - \left(\frac{v_b - v_c}{\delta}\right) \\
l_{bc} &= \left(\frac{v_c - w_b}{\sigma_{bc}}\right) - \left(\frac{v_a - v_c}{\sigma_{ba} - \sigma_{bc}}\right) = \left(\frac{v_c - w_b}{\sigma_{bc}}\right) - \left(\frac{v_a - v_c}{2\delta}\right)
\end{aligned}
$$

Relevant derivatives are as follows.

$$
\begin{aligned}
\frac{\partial l_{cc}}{\partial w_c} &= \frac{1}{\sigma_{bc}} \\
\frac{l_{ac}}{\partial v_c} &= \frac{1}{\sigma_{ac}} + \frac{1}{\delta} \\
\frac{l_{bc}}{\partial v_c} &= \frac{1}{\sigma_{bc}} + \frac{1}{2\delta}
\end{aligned}
$$

These can then be plugged into the general FOCs given in Equations 2.

$$
\begin{aligned}
\left(p_c\phi - w_c\right)\frac{1}{\sigma_{bc}} - \left(1 - \left(\frac{v_b - w_c}{\sigma_{bc}}\right)\right) &= 0 \\
\left(p_c\phi' - v_c\right)\left(\frac{1}{\sigma_{ac}} + \frac{1}{\delta} + \frac{1}{\sigma_{bc}} + \frac{1}{2\delta}\right) - \left[\left(\frac{v_c - w_a}{\sigma_{ac}}\right) - \left(\frac{v_b - v_c}{\delta}\right) + \left(\frac{v_c - w_b}{\sigma_{bc}}\right) - \left(\frac{v_a - v_c}{2\delta}\right)\right] &= 0
\end{aligned}
$$

The first FOC can be solved for w_c.

$$
\begin{aligned}
\left(p_c\phi - w_c\right)\frac{1}{\sigma_{bc}} - \left(-\left(\frac{v_b - w_c}{\sigma_{bc}}\right)\right) &= 0 \\
\frac{p_c\phi - w_c + v_b - w_c}{\sigma_{bc}} &= 1 \\
p_c\phi - 2w_c + v_b &= \sigma_{bc} \\
2w_c &= p_c\phi + v_b - \sigma_{bc} \\
w_c &= \frac{1}{2}p_c\phi + \frac{1}{2}v_b - \frac{1}{2}\sigma_{bc} \qquad (7)
\end{aligned}
$$

The second FOC can be solved for v_c.

$$\left(p_c\phi^{'} - v_c\right)\left(\frac{1}{\sigma_{ac}} + \frac{1}{\delta} + \frac{1}{\sigma_{bc}} + \frac{1}{2\delta}\right) - \left[\left(\frac{v_c - w_a}{\sigma_{ac}}\right) - \left(\frac{v_b - v_c}{\delta}\right) + \left(\frac{v_c - w_b}{\sigma_{bc}}\right) - \left(\frac{v_a - v_c}{2\delta}\right)\right]$$

$$\left(p_c\phi^{'} - v_c\right)\left(\frac{1}{\sigma_{ac}} + \frac{2}{2\delta} + \frac{1}{\sigma_{bc}} + \frac{1}{2\delta}\right) - \left[\left(\frac{v_c - w_a}{\sigma_{ac}}\right) - \left(\frac{2v_b - 2v_c}{2\delta}\right) + \left(\frac{v_c - w_b}{\sigma_{bc}}\right) - \left(\frac{v_a - v_c}{2\delta}\right)\right]$$

$$\left(p_c\phi^{'} - v_c\right)\left(\frac{1}{\sigma_{ac}} + \frac{1}{\sigma_{bc}} + \frac{3}{2\delta}\right) - \left[\left(\frac{v_c - w_a}{\sigma_{ac}}\right) + \left(\frac{v_c - w_b}{\sigma_{bc}}\right) - \left(\frac{v_a + 2v_b - 3v_c}{2\delta}\right)\right]$$

$$\left(p_c\phi^{'} - v_c\right)\left(\frac{\sigma_{bc}}{\sigma_{ac}\sigma_{bc}} + \frac{\sigma_{ac}}{\sigma_{ac}\sigma_{bc}} + \frac{3}{2\delta}\right) - \left[\left(\frac{\sigma_{bc}v_c - \sigma_{bc}w_a}{\sigma_{ac}\sigma_{bc}}\right) + \left(\frac{\sigma_{ac}v_c - \sigma_{ac}w_b}{\sigma_{ac}\sigma_{bc}}\right) - \left(\frac{v_a + 2v_b - 3v_c}{2\delta}\right)\right]$$

$$\left(p_c\phi^{'} - v_c\right)\left(\frac{\sigma_{bc} + \sigma_{ac}}{\sigma_{ac}\sigma_{bc}} + \frac{3}{2\delta}\right) - \left[\left(\frac{\sigma_{bc}v_c - \sigma_{bc}w_a + \sigma_{ac}v_c - \sigma_{ac}w_b}{\sigma_{ac}\sigma_{bc}}\right) - \left(\frac{v_a + 2v_b - 3v_c}{2\delta}\right)\right]$$

$$\left[\frac{(\sigma_{bc} + \sigma_{ac})\left(p_c\phi^{'} - v_c\right)}{\sigma_{ac}\sigma_{bc}} + \frac{3\left(p_c\phi^{'} - v_c\right)}{2\delta}\right] - \left[\left(\frac{\sigma_{bc}v_c - \sigma_{bc}w_a + \sigma_{ac}v_c - \sigma_{ac}w_b}{\sigma_{ac}\sigma_{bc}}\right) - \left(\frac{v_a + 2v_b - 3v_c}{2\delta}\right)\right]$$

$$\left[\frac{(\sigma_{bc} + \sigma_{ac})\,p_c\phi^{'} - (\sigma_{bc} + \sigma_{ac})\,v_c - (\sigma_{bc}v_c - \sigma_{bc}w_a + \sigma_{ac}v_c - \sigma_{ac}w_b)}{\sigma_{ac}\sigma_{bc}} + \frac{3p_c\phi^{'} - 3v_c + (v_a + 2v_b - 3v_c)}{2\delta}\right]$$

$$\left[\frac{(\sigma_{bc} + \sigma_{ac})\,p_c\phi^{'} - (\sigma_{bc} + \sigma_{ac})\,v_c - \sigma_{bc}v_c + \sigma_{bc}w_a - \sigma_{ac}v_c + \sigma_{ac}w_b}{\sigma_{ac}\sigma_{bc}} + \frac{3p_c\phi^{'} - 3v_c + v_a + 2v_b - 3v_c}{2\delta}\right]$$

$$\left[\frac{(\sigma_{bc} + \sigma_{ac})\,p_c\phi^{'} - (\sigma_{bc} + \sigma_{ac} + \sigma_{bc} + \sigma_{ac})\,v_c + \sigma_{bc}w_a + \sigma_{ac}w_b}{\sigma_{ac}\sigma_{bc}} + \frac{3p_c\phi^{'} - 6v_c + v_a + 2v_b}{2\delta}\right]$$

$$\left(\frac{2\delta}{\sigma_{ac}\sigma_{bc}}\right)\left[(\sigma_{bc} + \sigma_{ac})\,p_c\phi^{'} - (2\sigma_{bc} + 2\sigma_{ac})\,v_c + \sigma_{bc}w_a + \sigma_{ac}w_b\right] + \left(3p_c\phi^{'} - 6v_c + v_a + 2v_b\right)$$

$$\left[\left(\frac{2\delta}{\sigma_{ac}\sigma_{bc}}\right)(\sigma_{bc} + \sigma_{ac})\,p_c\phi^{'} - \left(\frac{2\delta}{\sigma_{ac}\sigma_{bc}}\right)(2\sigma_{bc} + 2\sigma_{ac})\,v_c + \left(\frac{2\delta}{\sigma_{ac}\sigma_{bc}}\right)\sigma_{bc}w_a + \left(\frac{2\delta}{\sigma_{ac}\sigma_{bc}}\right)\sigma_{ac}w_b\right] + \left(3p_c\phi^{'} - 6v_c + v_a + 2v_b\right)$$

$$\left(\frac{2\delta\,(\sigma_{bc} + \sigma_{ac})}{\sigma_{ac}\sigma_{bc}}\right)p_c\phi^{'} - \left(\frac{4\delta\,(\sigma_{bc} + \sigma_{ac})}{\sigma_{ac}\sigma_{bc}}\right)v_c + \left(\frac{2\delta\sigma_{bc}}{\sigma_{ac}\sigma_{bc}}\right)w_a + \left(\frac{2\delta\sigma_{ac}}{\sigma_{ac}\sigma_{bc}}\right)w_b + 3p_c\phi^{'} - 6v_c + v_a + 2v_b$$

$$\left(3 + \frac{2\delta\,(\sigma_{bc} + \sigma_{ac})}{\sigma_{ac}\sigma_{bc}}\right)p_c\phi^{'} - \left(6 + \frac{4\delta\,(\sigma_{bc} + \sigma_{ac})}{\sigma_{ac}\sigma_{bc}}\right)v_c + \left(\frac{2\delta}{\sigma_{ac}}\right)w_a + \left(\frac{2\delta}{\sigma_{bc}}\right)w_b + v_a + 2v_b$$

$$\left(6 + \frac{4\delta\,(\sigma_{bc} + \sigma_{ac})}{\sigma_{ac}\sigma_{bc}}\right)v_c = \left(3 + \frac{2\delta\,(\sigma_{bc} + \sigma_{ac})}{\sigma_{ac}\sigma_{bc}}\right)p_c\phi^{'} + \left(\frac{2\delta}{\sigma_{ac}}\right)w_a + \left(\frac{2\delta}{\sigma_{bc}}\right)w_b + v_a + 2v_b$$

$$v_c = \frac{\left(3 + \frac{2\delta(\sigma_{bc}+\sigma_{ac})}{\sigma_{ac}\sigma_{bc}}\right)}{\left(6 + \frac{4\delta(\sigma_{bc}+\sigma_{ac})}{\sigma_{ac}\sigma_{bc}}\right)} p_c\phi^{'} + \frac{\left(\frac{2\delta}{\sigma_{ac}}\right)}{\left(6 + \frac{4\delta(\sigma_{bc}+\sigma_{ac})}{\sigma_{ac}\sigma_{bc}}\right)} w_a + \frac{\left(\frac{2\delta}{\sigma_{bc}}\right)}{\left(6 + \frac{4\delta(\sigma_{bc}+\sigma_{ac})}{\sigma_{ac}\sigma_{bc}}\right)} w_b + \frac{1}{\left(6 + \frac{4\delta(\sigma_{bc}+\sigma_{ac})}{\sigma_{ac}\sigma_{bc}}\right)} v_a + \frac{2}{\left(6 + \frac{4\delta(\sigma_{bc}+\sigma_{ac})}{\sigma_{ac}\sigma_{bc}}\right)} v_b$$

$$v_c = \frac{\left(3 + \frac{2\delta(\sigma_{bc}+\sigma_{ac})}{\sigma_{ac}\sigma_{bc}}\right)}{2\left(3 + \frac{2\delta(\sigma_{bc}+\sigma_{ac})}{\sigma_{ac}\sigma_{bc}}\right)} p_c\phi^{'} + \frac{2\left(\frac{\delta}{\sigma_{ac}}\right)}{2\left(3 + \frac{2\delta(\sigma_{bc}+\sigma_{ac})}{\sigma_{ac}\sigma_{bc}}\right)} w_a + \frac{2\left(\frac{\delta}{\sigma_{bc}}\right)}{2\left(3 + \frac{2\delta(\sigma_{bc}+\sigma_{ac})}{\sigma_{ac}\sigma_{bc}}\right)} w_b + \frac{1}{2\left(3 + \frac{2\delta(\sigma_{bc}+\sigma_{ac})}{\sigma_{ac}\sigma_{bc}}\right)} v_a + \frac{2}{2\left(3 + \frac{2\delta(\sigma_{bc}+\sigma_{ac})}{\sigma_{ac}\sigma_{bc}}\right)}$$

$$v_c = \frac{1}{2} p_c\phi^{'} + \frac{\left(\frac{\delta}{\sigma_{ac}}\right)}{\left(3 + \frac{2\delta(\sigma_{bc}+\sigma_{ac})}{\sigma_{ac}\sigma_{bc}}\right)} w_a + \frac{\left(\frac{\delta}{\sigma_{bc}}\right)}{\left(3 + \frac{2\delta(\sigma_{bc}+\sigma_{ac})}{\sigma_{ac}\sigma_{bc}}\right)} w_b + \frac{1}{2\left(3 + \frac{2\delta(\sigma_{bc}+\sigma_{ac})}{\sigma_{ac}\sigma_{bc}}\right)} v_a + \frac{1}{\left(3 + \frac{2\delta(\sigma_{bc}+\sigma_{ac})}{\sigma_{ac}\sigma_{bc}}\right)} v_b$$

$$v_c = \frac{1}{2} p_c\phi^{'} + \frac{\left(\frac{\delta}{\sigma_{ac}}\right)}{\left(\frac{3\sigma_{ac}\sigma_{bc}}{\sigma_{ac}\sigma_{bc}} + \frac{2\delta(\sigma_{bc}+\sigma_{ac})}{\sigma_{ac}\sigma_{bc}}\right)} w_a + \frac{\left(\frac{\delta}{\sigma_{bc}}\right)}{\left(\frac{3\sigma_{ac}\sigma_{bc}}{\sigma_{ac}\sigma_{bc}} + \frac{2\delta(\sigma_{bc}+\sigma_{ac})}{\sigma_{ac}\sigma_{bc}}\right)} w_b + \frac{1}{2\left(\frac{3\sigma_{ac}\sigma_{bc}}{\sigma_{ac}\sigma_{bc}} + \frac{2\delta(\sigma_{bc}+\sigma_{ac})}{\sigma_{ac}\sigma_{bc}}\right)} v_a + \frac{1}{\left(\frac{3\sigma_{ac}\sigma_{bc}}{\sigma_{ac}\sigma_{bc}} + \frac{2\delta(\sigma_{bc}+\sigma_{ac})}{\sigma_{ac}\sigma_{bc}}\right)}$$

$$v_c = \frac{1}{2} p_c\phi^{'} + \frac{\left(\frac{\delta}{\sigma_{ac}}\right)}{\left(\frac{3\sigma_{ac}\sigma_{bc}+2\delta\sigma_{bc}+2\delta\sigma_{ac}}{\sigma_{ac}\sigma_{bc}}\right)} w_a + \frac{\left(\frac{\delta}{\sigma_{bc}}\right)}{\left(\frac{3\sigma_{ac}\sigma_{bc}+2\delta\sigma_{bc}+2\delta\sigma_{ac}}{\sigma_{ac}\sigma_{bc}}\right)} w_b + \frac{1}{2\left(\frac{3\sigma_{ac}\sigma_{bc}+2\delta\sigma_{bc}+2\delta\sigma_{ac}}{\sigma_{ac}\sigma_{bc}}\right)} v_a + \frac{1}{\left(\frac{3\sigma_{ac}\sigma_{bc}+2\delta\sigma_{bc}+2\delta\sigma_{ac}}{\sigma_{ac}\sigma_{bc}}\right)} v_b$$

$$v_c = \frac{1}{2} p_c\phi^{'} + \left(\frac{\delta}{\sigma_{ac}}\right)\left(\frac{\sigma_{ac}\sigma_{bc}}{3\sigma_{ac}\sigma_{bc} + 2\delta\sigma_{bc} + 2\delta\sigma_{ac}}\right) w_a + \left(\frac{\delta}{\sigma_{bc}}\right)\left(\frac{\sigma_{ac}\sigma_{bc}}{3\sigma_{ac}\sigma_{bc} + 2\delta\sigma_{bc} + 2\delta\sigma_{ac}}\right) w_b + \frac{1}{2}\left(\frac{\sigma_{ac}\sigma_{bc}}{3\sigma_{ac}\sigma_{bc} + 2\delta\sigma_{bc} + 2\delta\sigma_{ac}}\right) v_a + \left(\frac{\sigma_{ac}\sigma_{bc}}{3\sigma_{ac}\sigma_{bc} + 2\delta\sigma_{bc} + 2\delta\sigma_{ac}}\right) v_b$$

Let $\beta_2 \equiv \left(\frac{\sigma_{ac}\sigma_{bc}}{3\sigma_{ac}\sigma_{bc}+2\delta\sigma_{bc}+2\delta\sigma_{ac}}\right)$.

$$v_c = \frac{1}{2} p_c\phi^{'} + \frac{\delta}{\sigma_{ac}}\beta_2 w_a + \frac{\delta}{\sigma_{bc}}\beta_2 w_b + \frac{1}{2}\beta_2 v_a + \beta_2 v_b \qquad (8)$$

E.4 Solving for wages

Equations 3 through 8 comprise a system in six variables $\{w_a, v_a, w_b, v_b, w_c, v_c\}$.

$$\begin{aligned}
w_a &= \frac{1}{2} p_a\phi + \frac{1}{2} v_c - \frac{1}{2}\sigma_{ac} \\
v_a &= \frac{1}{2} p_a\phi^{'} + \frac{1}{6} v_c + \frac{1}{3} v_b \\
w_b &= \frac{1}{2} p_b\phi + \frac{1}{2} v_c - \frac{1}{2}\sigma_{bc} \\
v_b &= \frac{1}{2} p_b\phi^{'} + \frac{1}{2}\beta_1 v_c + \frac{1}{2}\beta_1 v_a + \frac{1}{2}\beta_1 \frac{\delta}{\sigma_{bc}} w_c \\
w_c &= \frac{1}{2} p_c\phi + \frac{1}{2} v_b - \frac{1}{2}\sigma_{bc} \\
v_c &= \frac{1}{2} p_c\phi^{'} + \frac{\delta}{\sigma_{ac}}\beta_2 w_a + \frac{\delta}{\sigma_{bc}}\beta_2 w_b + \frac{1}{2}\beta_2 v_a + \beta_2 v_b
\end{aligned}$$

To begin, substitute the equations for w_i into those for v_i to obtain a 3x3 system.

$$
\begin{aligned}
v_a =& \frac{1}{2}p_a\phi^{'} + \frac{1}{6}v_c + \frac{1}{3}v_b \\
v_b =& \frac{1}{2}p_b\phi^{'} + \frac{1}{2}\beta_1 v_c + \frac{1}{2}\beta_1 v_a + \frac{1}{2}\beta_1\frac{\delta}{\sigma_{bc}}\left(\frac{1}{2}p_c\phi + \frac{1}{2}v_b - \frac{1}{2}\sigma_{bc}\right) \\
v_c =& \frac{1}{2}p_c\phi^{'} + \frac{\delta}{\sigma_{ac}}\beta_2\left(\frac{1}{2}p_a\phi + \frac{1}{2}v_c - \frac{1}{2}\sigma_{ac}\right) + \frac{\delta}{\sigma_{bc}}\beta_2\left(\frac{1}{2}p_b\phi + \frac{1}{2}v_c - \frac{1}{2}\sigma_{bc}\right) + \frac{1}{2}\beta_2 v_a + \beta_2 v_b
\end{aligned}
$$

This can be simplified.

$$
\begin{aligned}
v_a =& \frac{1}{2}p_a\phi^{'} + \frac{1}{6}v_c + \frac{1}{3}v_b \\
v_b =& \frac{1}{2}p_b\phi^{'} + \frac{1}{2}\beta_1 v_c + \frac{1}{2}\beta_1 v_a + \left(\frac{1}{4}\beta_1\frac{\delta}{\sigma_{bc}}p_c\phi + \frac{1}{4}\beta_1\frac{\delta}{\sigma_{bc}}v_b - \frac{1}{4}\beta_1\frac{\delta}{\sigma_{bc}}\sigma_{bc}\right) \\
v_c =& \frac{1}{2}p_c\phi^{'} + \left(\frac{1}{2}\frac{\delta}{\sigma_{ac}}\beta_2 p_a\phi + \frac{1}{2}\frac{\delta}{\sigma_{ac}}\beta_2 v_c - \frac{1}{2}\frac{\delta}{\sigma_{ac}}\beta_2\sigma_{ac}\right) + \left(\frac{1}{2}\frac{\delta}{\sigma_{bc}}\beta_2 p_b\phi + \frac{1}{2}\frac{\delta}{\sigma_{bc}}\beta_2 v_c - \frac{1}{2}\frac{\delta}{\sigma_{bc}}\beta_2\sigma_{bc}\right) + \frac{1}{2}\beta_2 v_a +
\end{aligned}
$$

This can be simplified.

$$
\begin{aligned}
v_a =& \frac{1}{2}p_a\phi^{'} + \frac{1}{6}v_c + \frac{1}{3}v_b \\
v_b =& \frac{1}{2}p_b\phi^{'} + \frac{1}{2}\beta_1 v_c + \frac{1}{2}\beta_1 v_a + \left(\frac{1}{4}\beta_1\frac{\delta}{\sigma_{bc}}p_c\phi + \frac{1}{4}\beta_1\frac{\delta}{\sigma_{bc}}v_b - \frac{1}{4}\beta_1\delta\right) \\
v_c =& \frac{1}{2}p_c\phi^{'} + \left(\frac{1}{2}\frac{\delta}{\sigma_{ac}}\beta_2 p_a\phi + \frac{1}{2}\frac{\delta}{\sigma_{ac}}\beta_2 v_c - \frac{1}{2}\delta\beta_2\right) + \left(\frac{1}{2}\frac{\delta}{\sigma_{bc}}\beta_2 p_b\phi + \frac{1}{2}\frac{\delta}{\sigma_{bc}}\beta_2 v_c - \frac{1}{2}\delta\beta_2\right) + \frac{1}{2}\beta_2 v_a + \beta_2 v_b
\end{aligned}
$$

This can be simplified.

$$
\begin{aligned}
v_a =& \frac{1}{2}p_a\phi^{'} + \frac{1}{3}v_b + \frac{1}{6}v_c \\
v_b =& \left(\frac{1}{2}p_b\phi^{'} + \frac{1}{4}\beta_1\frac{\delta}{\sigma_{bc}}p_c\phi - \frac{1}{4}\beta_1\delta\right) + \frac{1}{2}\beta_1 v_a + \frac{1}{4}\beta_1\frac{\delta}{\sigma_{bc}}v_b + \frac{1}{2}\beta_1 v_c \\
v_c =& \left(\frac{1}{2}p_c\phi^{'} + \frac{1}{2}\frac{\delta}{\sigma_{ac}}\beta_2 p_a\phi + \frac{1}{2}\frac{\delta}{\sigma_{bc}}\beta_2 p_b\phi - \frac{1}{2}\delta\beta_2 - \frac{1}{2}\delta\beta_2\right) + \frac{1}{2}\beta_2 v_a + \beta_2 v_b + \frac{1}{2}\frac{\delta}{\sigma_{ac}}\beta_2 v_c + \frac{1}{2}\frac{\delta}{\sigma_{bc}}\beta_2 v_c
\end{aligned}
$$

This can be simplified.

$$
\begin{aligned}
v_a =& \frac{1}{2}p_a\phi^{'} + \frac{1}{3}v_b + \frac{1}{6}v_c \\
v_b =& \left(\frac{1}{2}p_b\phi^{'} + \frac{1}{4}\beta_1\frac{\delta}{\sigma_{bc}}p_c\phi - \frac{1}{4}\beta_1\delta\right) + \frac{1}{2}\beta_1 v_a + \frac{1}{4}\beta_1\frac{\delta}{\sigma_{bc}}v_b + \frac{1}{2}\beta_1 v_c \\
v_c =& \left(\frac{1}{2}p_c\phi^{'} + \frac{1}{2}\frac{\delta}{\sigma_{ac}}\beta_2 p_a\phi + \frac{1}{2}\frac{\delta}{\sigma_{bc}}\beta_2 p_b\phi - \delta\beta_2\right) + \frac{1}{2}\beta_2 v_a + \beta_2 v_b + \frac{1}{2}\beta_2\left(\frac{\delta}{\sigma_{ac}} + \frac{\delta}{\sigma_{bc}}\right)v_c
\end{aligned}
$$

Substituting the first equation into the second and third yields a 2x2 system.

$$v_b = \left(\frac{1}{2}p_b\phi' + \frac{1}{4}\beta_1\frac{\delta}{\sigma_{bc}}p_c\phi - \frac{1}{4}\beta_1\delta\right) + \frac{1}{2}\beta_1\left(\frac{1}{2}p_a\phi' + \frac{1}{3}v_b + \frac{1}{6}v_c\right) + \frac{1}{4}\beta_1\frac{\delta}{\sigma_{bc}}v_b + \frac{1}{2}\beta_1 v_c$$
$$v_c = \left(\frac{1}{2}p_c\phi' + \frac{1}{2}\frac{\delta}{\sigma_{ac}}\beta_2 p_a\phi + \frac{1}{2}\frac{\delta}{\sigma_{bc}}\beta_2 p_b\phi - \delta\beta_2\right) + \frac{1}{2}\beta_2\left(\frac{1}{2}p_a\phi' + \frac{1}{3}v_b + \frac{1}{6}v_c\right) + \beta_2 v_b + \frac{1}{2}\beta_2\left(\frac{\delta}{\sigma_{ac}} + \frac{\delta}{\sigma_{bc}}\right)v_c$$

This can be simplified.

$$v_b = \left(\frac{1}{2}p_b\phi' + \frac{1}{4}\beta_1\frac{\delta}{\sigma_{bc}}p_c\phi - \frac{1}{4}\beta_1\delta\right) + \frac{1}{4}\beta_1 p_a\phi' + \frac{1}{6}\beta_1 v_b + \frac{1}{12}\beta_1 v_c + \frac{1}{4}\beta_1\frac{\delta}{\sigma_{bc}}v_b + \frac{1}{2}\beta_1 v_c$$
$$v_c = \left(\frac{1}{2}p_c\phi' + \frac{1}{2}\frac{\delta}{\sigma_{ac}}\beta_2 p_a\phi + \frac{1}{2}\frac{\delta}{\sigma_{bc}}\beta_2 p_b\phi - \delta\beta_2\right) + \frac{1}{4}\beta_2 p_a\phi' + \frac{1}{6}\beta_2 v_b + \frac{1}{12}\beta_2 v_c + \beta_2 v_b + \frac{1}{2}\beta_2\left(\frac{\delta}{\sigma_{ac}} + \frac{\delta}{\sigma_{bc}}\right)v_c$$

This can be simplified.

$$v_b = \left(\frac{1}{4}\beta_1 p_a\phi' + \frac{1}{2}p_b\phi' + \frac{1}{4}\beta_1\frac{\delta}{\sigma_{bc}}p_c\phi - \frac{1}{4}\beta_1\delta\right) + \frac{1}{6}\beta_1 v_b + \frac{1}{4}\beta_1\frac{\delta}{\sigma_{bc}}v_b + \frac{1}{2}\beta_1 v_c + \frac{1}{12}\beta_1 v_c$$
$$v_c = \left(\frac{1}{4}\beta_2 p_a\phi' + \frac{1}{2}\frac{\delta}{\sigma_{ac}}\beta_2 p_a\phi + \frac{1}{2}\frac{\delta}{\sigma_{bc}}\beta_2 p_b\phi + \frac{1}{2}p_c\phi' - \delta\beta_2\right) + \frac{1}{6}\beta_2 v_b + \beta_2 v_b + \frac{1}{2}\beta_2\left(\frac{\delta}{\sigma_{ac}} + \frac{\delta}{\sigma_{bc}}\right)v_c + \frac{1}{12}\beta_2 v_c$$

This can be simplified.

$$v_b = \left(\frac{1}{4}\beta_1 p_a\phi' + \frac{1}{2}p_b\phi' + \frac{1}{4}\beta_1\frac{\delta}{\sigma_{bc}}p_c\phi - \frac{1}{4}\beta_1\delta\right) + \left(\frac{1}{6} + \frac{1}{4}\frac{\delta}{\sigma_{bc}}\right)\beta_1 v_b + \left(\frac{1}{2} + \frac{1}{12}\right)\beta_1 v_c$$
$$v_c = \left(\frac{1}{4}\beta_2 p_a\phi' + \frac{1}{2}\frac{\delta}{\sigma_{ac}}\beta_2 p_a\phi + \frac{1}{2}\frac{\delta}{\sigma_{bc}}\beta_2 p_b\phi + \frac{1}{2}p_c\phi' - \delta\beta_2\right) + \left(\frac{1}{6} + 1\right)\beta_2 v_b + \frac{1}{2}\beta_2\left(\frac{\delta}{\sigma_{ac}} + \frac{\delta}{\sigma_{bc}} + \frac{1}{6}\right)v_c$$

This can be simplified.

$$v_b = \left(\frac{1}{4}\beta_1 p_a\phi' + \frac{1}{2}p_b\phi' + \frac{1}{4}\beta_1\frac{\delta}{\sigma_{bc}}p_c\phi - \frac{1}{4}\beta_1\delta\right) + \frac{1}{2}\left(\frac{1}{3} + \frac{1}{2}\frac{\delta}{\sigma_{bc}}\right)\beta_1 v_b + \frac{7}{12}\beta_1 v_c$$
$$v_c = \left(\frac{1}{4}\beta_2 p_a\phi' + \frac{1}{2}\frac{\delta}{\sigma_{ac}}\beta_2 p_a\phi + \frac{1}{2}\frac{\delta}{\sigma_{bc}}\beta_2 p_b\phi + \frac{1}{2}p_c\phi' - \delta\beta_2\right) + \frac{7}{6}\beta_2 v_b + \frac{1}{2}\beta_2\left(\frac{\delta}{\sigma_{ac}} + \frac{\delta}{\sigma_{bc}} + \frac{1}{6}\right)v_c$$

This can be simplified.

$$v_b - \frac{1}{2}\left(\frac{1}{3} + \frac{1}{2}\frac{\delta}{\sigma_{bc}}\right)\beta_1 v_b = \left(\frac{1}{4}\beta_1 p_a\phi' + \frac{1}{2}p_b\phi' + \frac{1}{4}\beta_1\frac{\delta}{\sigma_{bc}}p_c\phi - \frac{1}{4}\beta_1\delta\right) + \frac{7}{12}\beta_1 v_c$$
$$v_c = \left(\frac{1}{4}\beta_2 p_a\phi' + \frac{1}{2}\frac{\delta}{\sigma_{ac}}\beta_2 p_a\phi + \frac{1}{2}\frac{\delta}{\sigma_{bc}}\beta_2 p_b\phi + \frac{1}{2}p_c\phi' - \delta\beta_2\right) + \frac{7}{6}\beta_2 v_b + \frac{1}{2}\beta_2\left(\frac{\delta}{\sigma_{ac}} + \frac{\delta}{\sigma_b}\right.$$

This can be simplified.

$$v_b\left[1-\frac{1}{2}\left(\frac{1}{3}+\frac{1}{2}\frac{\delta}{\sigma_{bc}}\right)\beta_1\right]=\left(\frac{1}{4}\beta_1 p_a\phi^{'}+\frac{1}{2}p_b\phi^{'}+\frac{1}{4}\beta_1\frac{\delta}{\sigma_{bc}}p_c\phi-\frac{1}{4}\beta_1\delta\right)+\frac{7}{12}\beta_1 v_c$$

$$v_c=\left(\frac{1}{4}\beta_2 p_a\phi^{'}+\frac{1}{2}\frac{\delta}{\sigma_{ac}}\beta_2 p_a\phi+\frac{1}{2}\frac{\delta}{\sigma_{bc}}\beta_2 p_b\phi+\frac{1}{2}p_c\phi^{'}-\delta\beta_2\right)+\frac{7}{6}\beta_2 v_b+\frac{1}{2}\beta_2\left(\frac{\delta}{\sigma_{ac}}+\right.$$

This can be simplified.

$$v_b\left(1-\frac{1}{6}\beta_1-\frac{1}{4}\frac{\delta}{\sigma_{bc}}\beta_1\right)=\left(\frac{1}{4}\beta_1 p_a\phi^{'}+\frac{1}{2}p_b\phi^{'}+\frac{1}{4}\beta_1\frac{\delta}{\sigma_{bc}}p_c\phi-\frac{1}{4}\beta_1\delta\right)+\frac{7}{12}\beta_1 v_c$$

$$v_c=\left(\frac{1}{4}\beta_2 p_a\phi^{'}+\frac{1}{2}\frac{\delta}{\sigma_{ac}}\beta_2 p_a\phi+\frac{1}{2}\frac{\delta}{\sigma_{bc}}\beta_2 p_b\phi+\frac{1}{2}p_c\phi^{'}-\delta\beta_2\right)+\frac{7}{6}\beta_2 v_b+\frac{1}{2}\beta_2\left(\frac{\delta}{\sigma_{ac}}+\frac{\delta}{\sigma_{bc}}\right.$$

This can be simplified.

$$v_b=\frac{\left(\frac{1}{4}\beta_1 p_a\phi^{'}+\frac{1}{2}p_b\phi^{'}+\frac{1}{4}\beta_1\frac{\delta}{\sigma_{bc}}p_c\phi-\frac{1}{4}\beta_1\delta\right)}{\left(1-\frac{1}{6}\beta_1-\frac{1}{4}\frac{\delta}{\sigma_{bc}}\beta_1\right)}+\frac{\frac{7}{12}\beta_1}{\left(1-\frac{1}{6}\beta_1-\frac{1}{4}\frac{\delta}{\sigma_{bc}}\beta_1\right)}v_c$$

$$v_c=\left(\frac{1}{4}\beta_2 p_a\phi^{'}+\frac{1}{2}\frac{\delta}{\sigma_{ac}}\beta_2 p_a\phi+\frac{1}{2}\frac{\delta}{\sigma_{bc}}\beta_2 p_b\phi+\frac{1}{2}p_c\phi^{'}-\delta\beta_2\right)+\frac{7}{6}\beta_2 v_b+\frac{1}{2}\beta_2\left(\frac{\delta}{\sigma_{ac}}+\frac{\delta}{\sigma_{bc}}+\frac{1}{6}\right)v_c$$

Finally one can substitute for v_b and solve for v_c in terms of parameters.

$$\begin{aligned}v_c=&\left(\frac{1}{4}\beta_2 p_a\phi^{'}+\frac{1}{2}\frac{\delta}{\sigma_{ac}}\beta_2 p_a\phi+\frac{1}{2}\frac{\delta}{\sigma_{bc}}\beta_2 p_b\phi+\frac{1}{2}p_c\phi^{'}-\delta\beta_2\right)\\&+\frac{7}{6}\beta_2\left[\frac{\left(\frac{1}{4}\beta_1 p_a\phi^{'}+\frac{1}{2}p_b\phi^{'}+\frac{1}{4}\beta_1\frac{\delta}{\sigma_{bc}}p_c\phi-\frac{1}{4}\beta_1\delta\right)}{\left(1-\frac{1}{6}\beta_1-\frac{1}{4}\frac{\delta}{\sigma_{bc}}\beta_1\right)}+\frac{\frac{7}{12}\beta_1}{\left(1-\frac{1}{6}\beta_1-\frac{1}{4}\frac{\delta}{\sigma_{bc}}\beta_1\right)}v_c\right]\\&+\frac{1}{2}\beta_2\left(\frac{\delta}{\sigma_{ac}}+\frac{\delta}{\sigma_{bc}}+\frac{1}{6}\right)v_c\end{aligned}$$

This can be simplified.

$$\begin{aligned}v_c=&\left(\frac{1}{4}\beta_2 p_a\phi^{'}+\frac{1}{2}\frac{\delta}{\sigma_{ac}}\beta_2 p_a\phi+\frac{1}{2}\frac{\delta}{\sigma_{bc}}\beta_2 p_b\phi+\frac{1}{2}p_c\phi^{'}-\delta\beta_2\right)\\&+\frac{7}{6}\beta_2\left[\frac{\left(\frac{1}{4}\beta_1 p_a\phi^{'}+\frac{1}{2}p_b\phi^{'}+\frac{1}{4}\beta_1\frac{\delta}{\sigma_{bc}}p_c\phi-\frac{1}{4}\beta_1\delta\right)}{\left(1-\frac{1}{6}\beta_1-\frac{1}{4}\frac{\delta}{\sigma_{bc}}\beta_1\right)}\right]\\&+\frac{7}{6}\beta_2\frac{\frac{7}{12}\beta_1}{\left(1-\frac{1}{6}\beta_1-\frac{1}{4}\frac{\delta}{\sigma_{bc}}\beta_1\right)}v_c+\frac{1}{2}\beta_2\left(\frac{\delta}{\sigma_{ac}}+\frac{\delta}{\sigma_{bc}}+\frac{1}{6}\right)v_c\end{aligned}$$

This can be simplified.

$$v_c = \left(\frac{1}{4}\beta_2 p_a \phi^{'} + \frac{1}{2}\frac{\delta}{\sigma_{ac}}\beta_2 p_a \phi + \frac{1}{2}\frac{\delta}{\sigma_{bc}}\beta_2 p_b \phi + \frac{1}{2}p_c\phi^{'} - \delta\beta_2\right)$$
$$+ \frac{7}{6}\beta_2 \left[\frac{\left(\frac{1}{4}\beta_1 p_a \phi^{'} + \frac{1}{2}p_b\phi^{'} + \frac{1}{4}\beta_1\frac{\delta}{\sigma_{bc}}p_c\phi - \frac{1}{4}\beta_1\delta\right)}{\left(1 - \frac{1}{6}\beta_1 - \frac{1}{4}\frac{\delta}{\sigma_{bc}}\beta_1\right)}\right]$$
$$+ \frac{1}{2}\beta_2 \left[\frac{7}{3}\frac{\frac{7}{12}\beta_1}{\left(1 - \frac{1}{6}\beta_1 - \frac{1}{4}\frac{\delta}{\sigma_{bc}}\beta_1\right)} + \left(\frac{\delta}{\sigma_{ac}} + \frac{\delta}{\sigma_{bc}} + \frac{1}{6}\right)\right] v_c$$

This can be simplified.

$$v_c - \frac{1}{2}\beta_2 \left[\frac{7}{3}\frac{\frac{7}{12}\beta_1}{\left(1 - \frac{1}{6}\beta_1 - \frac{1}{4}\frac{\delta}{\sigma_{bc}}\beta_1\right)} + \frac{\delta}{\sigma_{ac}} + \frac{\delta}{\sigma_{bc}} + \frac{1}{6}\right] v_c$$
$$= \left(\frac{1}{4}\beta_2 p_a \phi^{'} + \frac{1}{2}\frac{\delta}{\sigma_{ac}}\beta_2 p_a \phi + \frac{1}{2}\frac{\delta}{\sigma_{bc}}\beta_2 p_b \phi + \frac{1}{2}p_c\phi^{'} - \delta\beta_2\right)$$
$$+ \frac{7}{6}\beta_2 \left[\frac{\left(\frac{1}{4}\beta_1 p_a \phi^{'} + \frac{1}{2}p_b\phi^{'} + \frac{1}{4}\beta_1\frac{\delta}{\sigma_{bc}}p_c\phi - \frac{1}{4}\beta_1\delta\right)}{\left(1 - \frac{1}{6}\beta_1 - \frac{1}{4}\frac{\delta}{\sigma_{bc}}\beta_1\right)}\right]$$

This can be simplified.

$$v_c \left(1 - \frac{1}{2}\beta_2 \left[\frac{7}{3}\frac{\frac{7}{12}\beta_1}{\left(1 - \frac{1}{6}\beta_1 - \frac{1}{4}\frac{\delta}{\sigma_{bc}}\beta_1\right)} + \frac{\delta}{\sigma_{ac}} + \frac{\delta}{\sigma_{bc}} + \frac{1}{6}\right]\right)$$
$$= \left(\frac{1}{4}\beta_2 p_a \phi^{'} + \frac{1}{2}\frac{\delta}{\sigma_{ac}}\beta_2 p_a \phi + \frac{1}{2}\frac{\delta}{\sigma_{bc}}\beta_2 p_b \phi + \frac{1}{2}p_c\phi^{'} - \delta\beta_2\right)$$
$$+ \frac{7}{6}\beta_2 \left(\frac{\frac{1}{4}\beta_1 p_a \phi^{'} + \frac{1}{2}p_b\phi^{'} + \frac{1}{4}\beta_1\frac{\delta}{\sigma_{bc}}p_c\phi - \frac{1}{4}\beta_1\delta}{1 - \frac{1}{6}\beta_1 - \frac{1}{4}\frac{\delta}{\sigma_{bc}}\beta_1}\right)$$

This can be simplified.

$$v_c \left(1 - \frac{1}{2}\beta_2 \left[\frac{7}{3}\frac{7}{12}\frac{\beta_1}{\beta_1}\frac{1}{\left(\frac{1}{\beta_1} - \frac{1}{6} - \frac{1}{4}\frac{\delta}{\sigma_{bc}}\right)} + \frac{\delta}{\sigma_{ac}} + \frac{\delta}{\sigma_{bc}} + \frac{1}{6}\right]\right)$$
$$= \left(\frac{1}{4}\beta_2 p_a \phi^{'} + \frac{1}{2}\frac{\delta}{\sigma_{ac}}\beta_2 p_a \phi + \frac{1}{2}\frac{\delta}{\sigma_{bc}}\beta_2 p_b \phi + \frac{1}{2}p_c\phi^{'} - \delta\beta_2\right)$$
$$+ \frac{7}{6}\beta_2 \left(\frac{\beta_1}{\beta_1}\frac{\frac{1}{4}p_a \phi^{'} + \frac{1}{2}\frac{1}{\beta_1}p_b\phi^{'} + \frac{1}{4}\frac{\delta}{\sigma_{bc}}p_c\phi - \frac{1}{4}\delta}{\frac{1}{\beta_1} - \frac{1}{6} - \frac{1}{4}\frac{\delta}{\sigma_{bc}}}\right)$$

This can be simplified.

$$v_c\left(1-\frac{1}{2}\beta_2\left[\frac{49}{36}\frac{1}{\left(\frac{1}{\beta_1}-\frac{1}{6}-\frac{1}{4}\frac{\delta}{\sigma_{bc}}\right)}+\frac{\delta}{\sigma_{ac}}+\frac{\delta}{\sigma_{bc}}+\frac{1}{6}\right]\right)$$
$$=\left(\frac{1}{4}\beta_2 p_a\phi^{'}+\frac{1}{2}\frac{\delta}{\sigma_{ac}}\beta_2 p_a\phi+\frac{1}{2}\frac{\delta}{\sigma_{bc}}\beta_2 p_b\phi+\frac{1}{2}p_c\phi^{'}-\delta\beta_2\right)$$
$$+\frac{7}{6}\beta_2\left(\frac{\frac{1}{4}p_a\phi^{'}+\frac{1}{2}\frac{1}{\beta_1}p_b\phi^{'}+\frac{1}{4}\frac{\delta}{\sigma_{bc}}p_c\phi-\frac{1}{4}\delta}{\frac{1}{\beta_1}-\frac{1}{6}-\frac{1}{4}\frac{\delta}{\sigma_{bc}}}\right)$$

Dividing yields a solution for v_c in terms of parameters.

$$v_c=\frac{\left(\frac{1}{4}\beta_2 p_a\phi^{'}+\frac{1}{2}\frac{\delta}{\sigma_{ac}}\beta_2 p_a\phi+\frac{1}{2}\frac{\delta}{\sigma_{bc}}\beta_2 p_b\phi+\frac{1}{2}p_c\phi^{'}-\delta\beta_2\right)}{\left(1-\frac{1}{2}\beta_2\left[\frac{49}{36}\frac{1}{\left(\frac{1}{\beta_1}-\frac{1}{6}-\frac{1}{4}\frac{\delta}{\sigma_{bc}}\right)}+\frac{\delta}{\sigma_{ac}}+\frac{\delta}{\sigma_{bc}}+\frac{1}{6}\right]\right)}$$
$$+\frac{\frac{7}{6}\beta_2\left(\frac{\frac{1}{4}p_a\phi^{'}+\frac{1}{2}\frac{1}{\beta_1}p_b\phi^{'}+\frac{1}{4}\frac{\delta}{\sigma_{bc}}p_c\phi-\frac{1}{4}\delta}{\frac{1}{\beta_1}-\frac{1}{6}-\frac{1}{4}\frac{\delta}{\sigma_{bc}}}\right)}{\left(1-\frac{1}{2}\beta_2\left[\frac{49}{36}\frac{1}{\left(\frac{1}{\beta_1}-\frac{1}{6}-\frac{1}{4}\frac{\delta}{\sigma_{bc}}\right)}+\frac{\delta}{\sigma_{ac}}+\frac{\delta}{\sigma_{bc}}+\frac{1}{6}\right]\right)}$$

This can be simplified.

$$v_c=\frac{\beta_2\left(\frac{1}{4}p_a\phi^{'}+\frac{1}{2}\frac{\delta}{\sigma_{ac}}p_a\phi+\frac{1}{2}\frac{\delta}{\sigma_{bc}}p_b\phi+\frac{1}{2}\frac{1}{\beta_2}p_c\phi^{'}-\delta\right)}{\beta_2\left(\frac{1}{\beta_2}-\frac{1}{2}\left[\frac{49}{36}\frac{1}{\left(\frac{1}{\beta_1}-\frac{1}{6}-\frac{1}{4}\frac{\delta}{\sigma_{bc}}\right)}+\frac{\delta}{\sigma_{ac}}+\frac{\delta}{\sigma_{bc}}+\frac{1}{6}\right]\right)}$$
$$+\frac{\frac{7}{6}\beta_2\left(\frac{\frac{1}{4}p_a\phi^{'}+\frac{1}{2}\frac{1}{\beta_1}p_b\phi^{'}+\frac{1}{4}\frac{\delta}{\sigma_{bc}}p_c\phi-\frac{1}{4}\delta}{\frac{1}{\beta_1}-\frac{1}{6}-\frac{1}{4}\frac{\delta}{\sigma_{bc}}}\right)}{\beta_2\left(\frac{1}{\beta_2}-\frac{1}{2}\left[\frac{49}{36}\frac{1}{\left(\frac{1}{\beta_1}-\frac{1}{6}-\frac{1}{4}\frac{\delta}{\sigma_{bc}}\right)}+\frac{\delta}{\sigma_{ac}}+\frac{\delta}{\sigma_{bc}}+\frac{1}{6}\right]\right)}$$

This can be simplified.

$$v_c^*=\frac{\frac{1}{4}p_a\phi^{'}+\frac{1}{2}\frac{\delta}{\sigma_{ac}}p_a\phi+\frac{1}{2}\frac{\delta}{\sigma_{bc}}p_b\phi+\frac{1}{2\beta_2}p_c\phi^{'}-\delta}{\frac{1}{\beta_2}-\frac{49}{72}\frac{1}{\left(\frac{1}{\beta_1}-\frac{1}{6}-\frac{\delta}{4\sigma_{bc}}\right)}-\frac{\delta}{2\sigma_{ac}}-\frac{\delta}{2\sigma_{bc}}-\frac{1}{12}}$$
$$+\frac{\frac{7}{6}\left(\frac{\frac{1}{4}p_a\phi^{'}+\frac{1}{2}\frac{1}{\beta_1}p_b\phi^{'}+\frac{1}{4}\frac{\delta}{\sigma_{bc}}p_c\phi-\frac{1}{4}\delta}{\frac{1}{\beta_1}-\frac{1}{6}-\frac{1}{4}\frac{\delta}{\sigma_{bc}}}\right)}{\frac{1}{\beta_2}-\frac{49}{72}\frac{1}{\left(\frac{1}{\beta_1}-\frac{1}{6}-\frac{\delta}{4\sigma_{bc}}\right)}-\frac{\delta}{2\sigma_{ac}}-\frac{\delta}{2\sigma_{bc}}-\frac{1}{12}} \qquad (9)$$

Using previously derived expressions gives solutions for the other endogenous variables.

$$v_b^* = \frac{\frac{1}{4}p_a\phi' + \frac{1}{2\beta_1}p_b\phi' + \frac{1}{4}\frac{\delta}{\sigma_{bc}}p_c\phi - \frac{1}{4}\delta}{\frac{1}{\beta_1} - \frac{1}{6} - \frac{\delta}{4\sigma_{bc}}} + \frac{\frac{7}{12}}{\frac{1}{\beta_1} - \frac{1}{6} - \frac{\delta}{4\sigma_{bc}}}v_c^* \tag{10}$$

$$v_a^* = \frac{1}{2}p_a\phi' + \frac{1}{6}v_c^* + \frac{1}{3}v_b^* \tag{11}$$

$$w_c^* = \frac{1}{2}p_c\phi + \frac{1}{2}v_b^* - \frac{1}{2}\sigma_{bc} \tag{12}$$

$$w_b^* = \frac{1}{2}p_b\phi + \frac{1}{2}v_c^* - \frac{1}{2}\sigma_{bc} \tag{13}$$

$$w_a^* = \frac{1}{2}p_a\phi + \frac{1}{2}v_c^* - \frac{1}{2}\sigma_{ac} \tag{14}$$

I first consider poaching wages. By equations 10 and 11, $v_b^* > v_c^*$ and $v_a^* > v_b^*$ provided $p_a\phi'$ is sufficiently large. Irrespective of how switching affects productivity, one can guarantee this with sufficiently large p_a. From the above solutions, $w_i^* < v_c^*$ provided σ_{bc} and σ_{ac} are sufficiently large.

I next consider loyalty wages. The inequality $w_a^* > w_b^*$ requires the following.

$$\frac{1}{2}p_a\phi + \frac{1}{2}v_c^* - \frac{1}{2}\sigma_{ac} > \frac{1}{2}p_b\phi + \frac{1}{2}v_c^* - \frac{1}{2}\sigma_{bc}$$
$$p_a\phi - \sigma_{ac} > p_b\phi - \sigma_{bc}$$

From the beginning the model assumed $\sigma_{ac} > \sigma_{bc}$, so this condition amounts to $p_a \gg p_b$. That is, the price of firm A's output must exceed that of firm B's output sufficient to offset the greater switching costs that allow firm A to lower its loyalty wages. The inequality$w_b^* > w_c^*$ requires

$$\frac{1}{2}p_b\phi + \frac{1}{2}v_c^* - \frac{1}{2}\sigma_{bc} > \frac{1}{2}p_c\phi + \frac{1}{2}v_b^* - \frac{1}{2}\sigma_{bc}$$
$$p_b\phi + v_c^* > p_c\phi + v_b^*$$

Under the restriction(s) given above $v_b^* > v_c^*$, so this condition amounts to $p_b \gg p_c$. That is, the price of firm B's output must exceed that of firm C's output sufficient to offset B's advantage in facing the weakest marginal poaching threat (firm C; firm C faces a stronger marginal poaching threat in firm B).

Appendix F No-poach agreement between B & C

Given the initial equilibrium, only a no-poach agreement between firms B and C can possibly be incentive-compatible. (If B were to make a deal with A, it would lose the same number of workers, but all to C rather than the combination of A and C. The case of a deal between C and A is similar.) Let superscripts np denote variables under the no-poach agreement. I represent the agreement within the model as a quantity restriction: $l_{cb}^{na} = l_{bc}^{na} = 0$. This is in keeping with my empirical setting.

F.1 Firm A, no-poach agreement between B & C

Firm A's optimization problem does change because it faces different labor supply functions l_{ba}^{na} and l_{ca}^{na}. Firm A's labor shares are as follows.

$$
\begin{aligned}
l_{aa}^{na} &= 1 - \left(\frac{v_c^{np} - w_a^{np}}{\sigma_{ac}}\right) \\
l_{ba}^{na} &= \frac{v_a^{np} - w_b^{np}}{\sigma_{ab}} \\
l_{ca}^{na} &= \frac{v_a^{np} - w_c^{np}}{\sigma_{ac}}
\end{aligned}
$$

Relevant derivatives are as follows.

$$
\begin{aligned}
\frac{\partial l_{aa}^{np}}{\partial w_a} &= \frac{1}{\sigma_{ac}} \\
\frac{l_{ba}^{np}}{\partial v_a} &= \frac{1}{\sigma_{ab}} \\
\frac{l_{ca}^{np}}{\partial v_a} &= \frac{1}{\sigma_{ac}}
\end{aligned}
$$

FOCs are as follows.

$$
\begin{aligned}
(p_a\phi - w_a^{np})\frac{1}{\sigma_{ac}} - \left(1 - \left(\frac{v_c^{np} - w_a^{np}}{\sigma_{ac}}\right)\right) &= 0 \\
\left(p_a\phi^{'} - v_a^{np}\right)\left(\frac{1}{\sigma_{ab}} + \frac{1}{\sigma_{ac}}\right) - \left(\frac{v_a^{np} - w_b^{np}}{\sigma_{ab}} + \frac{v_a^{np} - w_c^{np}}{\sigma_{ac}}\right) &= 0
\end{aligned}
$$

The first condition can be solved for w_a^{np}.

$$\begin{aligned}
(p_a\phi - w_a^{np})\frac{1}{\sigma_{ac}} - \left(1 - \left(\frac{v_c^{np} - w_a^{np}}{\sigma_{ac}}\right)\right) &= 0 \\
(p_a\phi - w_a^{np})\frac{1}{\sigma_{ac}} + \frac{v_c^{np} - w_a^{np}}{\sigma_{ac}} &= 1 \\
p_a\phi - 2w_a^{np} + v_c^{np} &= \sigma_{ac} \\
2w_a^{np} &= p_a\phi + v_c^{np} - \sigma_{ac} \\
w_a^{np} &= \frac{1}{2}p_a\phi + \frac{1}{2}v_c^{np} - \frac{1}{2}\sigma_{ac}
\end{aligned} \tag{15}$$

The second condition can be solved for v_a^{np}.

$$\begin{aligned}
\left(p_a\phi^{'} - v_a^{np}\right)\left(\frac{1}{\sigma_{ab}} + \frac{1}{\sigma_{ac}}\right) - \left(\frac{v_a^{np} - w_b^{np}}{\sigma_{ab}} + \frac{v_a^{np} - w_c^{np}}{\sigma_{ac}}\right) &= 0 \\
\frac{p_a\phi^{'} - v_a^{np} - v_a^{np} + w_b^{np}}{\sigma_{ab}} + \frac{p_a\phi^{'} - v_a^{np} - v_a^{np} + w_c^{np}}{\sigma_{ac}} &= 0 \\
p_a\phi^{'} - 2v_a^{np} + w_b^{np} + \frac{\sigma_{ab}}{\sigma_{ac}}\left(p_a\phi^{'} - 2v_a^{np} + w_c^{np}\right) &= 0 \\
p_a\phi^{'} - 2v_a^{np} + w_b^{np} + \frac{\sigma_{ab}}{\sigma_{ac}}p_a\phi^{'} - 2\frac{\sigma_{ab}}{\sigma_{ac}}v_a^{np} + \frac{\sigma_{ab}}{\sigma_{ac}}w_c^{np} &= 0
\end{aligned}$$

$$\begin{aligned}
2v_a^{np} + 2\frac{\sigma_{ab}}{\sigma_{ac}}v_a^{np} &= p_a\phi^{'} + w_b^{np} + \frac{\sigma_{ab}}{\sigma_{ac}}p_a\phi^{'} + \frac{\sigma_{ab}}{\sigma_{ac}}w_c^{np} \\
2\left(1 + \frac{\sigma_{ab}}{\sigma_{ac}}\right)v_a^{np} &= \left(1 + \frac{\sigma_{ab}}{\sigma_{ac}}\right)p_a\phi^{'} + w_b^{np} + \frac{\sigma_{ab}}{\sigma_{ac}}w_c^{np} \\
v_a^{np} &= \frac{1}{2}p_a\phi^{'} + \frac{1}{2\left(1 + \frac{\sigma_{ab}}{\sigma_{ac}}\right)}w_b^{np} + \frac{1}{2\left(1 + \frac{\sigma_{ab}}{\sigma_{ac}}\right)}\frac{\sigma_{ab}}{\sigma_{ac}}w_c^{np} \\
v_a^{np} &= \frac{1}{2}p_a\phi^{'} + \frac{1}{\left(2\frac{\sigma_{ac}}{\sigma_{ac}} + 2\frac{\sigma_{ab}}{\sigma_{ac}}\right)}w_b^{np} + \frac{1}{\left(2\frac{\sigma_{ac}}{\sigma_{ac}} + 2\frac{\sigma_{ab}}{\sigma_{ac}}\right)}\frac{\sigma_{ab}}{\sigma_{ac}}w_c^{np} \\
v_a^{np} &= \frac{1}{2}p_a\phi^{'} + \frac{1}{\frac{2\sigma_{ac}+2\sigma_{ab}}{\sigma_{ac}}}w_b^{np} + \frac{1}{\frac{2\sigma_{ac}+2\sigma_{ab}}{\sigma_{ac}}}\frac{\sigma_{ab}}{\sigma_{ac}}w_c^{np} \\
v_a^{np} &= \frac{1}{2}p_a\phi^{'} + \frac{\sigma_{ac}}{2\sigma_{ac} + 2\sigma_{ab}}w_b^{np} + \frac{\sigma_{ac}}{2\sigma_{ac} + 2\sigma_{ab}}\frac{\sigma_{ab}}{\sigma_{ac}}w_c^{np} \\
v_a^{np} &= \frac{1}{2}p_a\phi^{'} + \frac{\sigma_{ac}}{2\sigma_{ac} + 2\sigma_{ab}}w_b^{np} + \frac{\sigma_{ab}}{2\sigma_{ac} + 2\sigma_{ab}}w_c^{np}
\end{aligned} \tag{16}$$

F.2 Firm B, no-poach agreement between B & C

Firm B's labor shares are as follows.

$$
\begin{aligned}
l_{bb}^{np} &= 1 - \left(\frac{v_a^{np} - w_b^{np}}{\sigma_{ba}}\right) \\
l_{ab}^{np} &= \frac{v_b^{np} - v_c^{np}}{\sigma_{ab} - \sigma_{ac}} = \frac{v_b^{np} - v_c^{np}}{\delta} \\
l_{cb}^{np} &= 0
\end{aligned}
$$

Relevant derivatives are as follows.

$$
\begin{aligned}
\frac{\partial l_{bb}^{np}}{\partial w_b} &= \frac{1}{\sigma_{ba}} \\
\frac{l_{ab}^{np}}{\partial v_b} &= \frac{1}{\delta} \\
\frac{l_{cb}^{np}}{\partial v_b} &= 0
\end{aligned}
$$

FOCs are as follows.

$$
\begin{aligned}
(p_b\phi - w_b^{np})\frac{1}{\sigma_{ba}} - \left(1 - \left(\frac{v_a^{np} - w_b^{np}}{\sigma_{ba}}\right)\right) &= 0 \\
\left(p_b\phi' - v_b^{np}\right)\left(\frac{1}{\delta}\right) - \left(\frac{v_b^{np} - v_c^{np}}{\delta}\right) &= 0
\end{aligned}
$$

The first condition can be solved for w_b^{np}.

$$
\begin{aligned}
(p_b\phi - w_b^{np})\frac{1}{\sigma_{ba}} - \left(1 - \left(\frac{v_a^{np} - w_b^{np}}{\sigma_{ba}}\right)\right) &= 0 \\
(p_b\phi - w_b^{np})\frac{1}{\sigma_{ba}} + \left(\frac{v_a^{np} - w_b^{np}}{\sigma_{ba}}\right) &= 1 \\
p_b\phi - 2w_b^{np} + v_a^{np} &= \sigma_{ba} \\
2w_b^{np} &= p_b\phi + v_a^{np} - \sigma_{ba} \\
w_b^{np} &= \frac{1}{2}p_b\phi + \frac{1}{2}v_a^{np} - \frac{1}{2}\sigma_{ba} \qquad (17)
\end{aligned}
$$

The second condition can be solved for v_b^{np}.

$$\left(p_b\phi^{'} - v_b^{np}\right)\left(\frac{1}{\delta}\right) - \left(\frac{v_b^{np} - v_c^{np}}{\delta}\right) = 0$$
$$\left(p_b\phi^{'} - v_b^{np}\right) - v_b^{np} + v_c^{np} = 0$$
$$p_b\phi^{'} - 2v_b^{np} + v_c^{np} = 0$$
$$2v_b^{np} = p_b\phi^{'} + v_c^{np}$$
$$v_b^{np} = \frac{1}{2}p_b\phi^{'} + \frac{1}{2}v_c^{np} \tag{18}$$

F.3 Firm C, no-poach agreement between B & C

Firm C's labor shares are as follows.

$$l_{cc}^{np} = 1 - \left(\frac{v_a^{np} - w_c^{np}}{\sigma_{ac}}\right)$$
$$l_{ac}^{np} = \left(\frac{v_c^{np} - w_a^{np}}{\sigma_{ac}}\right) - \left(\frac{v_b^{np} - v_c^{np}}{\sigma_{ab} - \sigma_{ac}}\right) = \left(\frac{v_c^{np} - w_a^{np}}{\sigma_{ac}}\right) - \left(\frac{v_b^{np} - v_c^{np}}{\delta}\right)$$
$$l_{bc}^{np} = 0$$

Relevant derivatives are as follows.

$$\frac{\partial l_{cc}^{np}}{\partial w_c} = \frac{1}{\sigma_{ac}}$$
$$\frac{l_{ac}^{np}}{\partial v_c} = \frac{1}{\sigma_{ac}} + \frac{1}{\delta}$$
$$\frac{l_{bc}^{np}}{\partial v_c} = 0$$

FOCs are as follows.

$$\left(p_c\phi - w_c^{np}\right)\frac{1}{\sigma_{ac}} - \left(1 - \left(\frac{v_a^{np} - w_c^{np}}{\sigma_{ac}}\right)\right) = 0$$
$$\left(p_c\phi^{'} - v_c^{np}\right)\left(\frac{1}{\sigma_{ac}} + \frac{1}{\delta}\right) - \left(\left(\frac{v_c^{np} - w_a^{np}}{\sigma_{ac}}\right) - \left(\frac{v_b^{np} - v_c^{np}}{\delta}\right)\right) = 0$$

The first condition can be solved for w_c^{np}.

$$
\begin{aligned}
(p_c\phi - w_c^{np})\frac{1}{\sigma_{ac}} - \left(1 - \left(\frac{v_a^{np} - w_c^{np}}{\sigma_{ac}}\right)\right) &= 0 \\
(p_c\phi - w_c^{np})\frac{1}{\sigma_{ac}} + \left(\frac{v_a^{np} - w_c^{np}}{\sigma_{ac}}\right) &= 1 \\
(p_c\phi - w_c^{np}) + v_a^{np} - w_c^{np} &= \sigma_{ac} \\
p_c\phi - 2w_c^{np} + v_a^{np} &= \sigma_{ac} \\
2w_c^{np} &= p_c\phi + v_a^{np} - \sigma_{ac} \\
w_c^{np} &= \frac{1}{2}p_c\phi + \frac{1}{2}v_a^{np} - \frac{1}{2}\sigma_{ac} \qquad (19)
\end{aligned}
$$

The second condition can be solved for v_c^{np}.

$$
\begin{aligned}
\left(p_c\phi' - v_c^{np}\right)\left(\frac{1}{\sigma_{ac}} + \frac{1}{\delta}\right) - \left(\left(\frac{v_c^{np} - w_a^{np}}{\sigma_{ac}}\right) - \left(\frac{v_b^{np} - v_c^{np}}{\delta}\right)\right) &= 0 \\
\frac{p_c\phi' - v_c^{np}}{\sigma_{ac}} + \frac{p_c\phi' - v_c^{np}}{\delta} - \frac{v_c^{np} - w_a^{np}}{\sigma_{ac}} + \frac{v_b^{np} - v_c^{np}}{\delta} &= 0 \\
\frac{p_c\phi' - 2v_c^{np} + w_a^{np}}{\sigma_{ac}} + \frac{p_c\phi' - 2v_c^{np} + v_b^{np}}{\delta} &= 0 \\
\frac{p_c\phi' - 2v_c^{np} + w_a^{np}}{\sigma_{ac}} + \frac{p_c\phi' - 2v_c^{np} + v_b^{np}}{\delta} &= 0 \\
\frac{\delta}{\sigma_{ac}}\left(p_c\phi' - 2v_c^{np} + w_a^{np}\right) + p_c\phi' - 2v_c^{np} + v_b^{np} &= 0 \\
\left(\frac{\delta}{\sigma_{ac}}p_c\phi' - 2\frac{\delta}{\sigma_{ac}}v_c^{np} + \frac{\delta}{\sigma_{ac}}w_a^{np}\right) + p_c\phi' - 2v_c^{np} + v_b^{np} &= 0
\end{aligned}
$$

$$2v_c^{np} + 2\frac{\delta}{\sigma_{ac}}v_c^{np} = p_c\phi^{'} + \frac{\delta}{\sigma_{ac}}p_c\phi^{'} + \frac{\delta}{\sigma_{ac}}w_a^{np} + v_b^{np}$$
$$2\left(1 + \frac{\delta}{\sigma_{ac}}\right)v_c^{np} = \left(1 + \frac{\delta}{\sigma_{ac}}\right)p_c\phi^{'} + \frac{\delta}{\sigma_{ac}}w_a^{np} + v_b^{np}$$
$$v_c^{np} = \frac{1}{2}p_c\phi^{'} + \frac{\frac{\delta}{\sigma_{ac}}}{2\left(1 + \frac{\delta}{\sigma_{ac}}\right)}w_a^{np} + \frac{1}{2\left(1 + \frac{\delta}{\sigma_{ac}}\right)}v_b^{np}$$
$$v_c^{np} = \frac{1}{2}p_c\phi^{'} + \frac{\frac{\delta}{\sigma_{ac}}}{2\left(\frac{\sigma_{ac}+\delta}{\sigma_{ac}}\right)}w_a^{np} + \frac{1}{2\left(\frac{\sigma_{ac}+\delta}{\sigma_{ac}}\right)}v_b^{np}$$
$$v_c^{np} = \frac{1}{2}p_c\phi^{'} + \frac{1}{2}\frac{\delta}{\sigma_{ac}}\frac{\sigma_{ac}}{\sigma_{ac}+\delta}w_a^{np} + \frac{1}{2}\frac{\sigma_{ac}}{\sigma_{ac}+\delta}v_b^{np}$$
$$v_c^{np} = \frac{1}{2}p_c\phi^{'} + \frac{\delta}{2\sigma_{ac}+2\delta}w_a^{np} + \frac{\sigma_{ac}}{2\sigma_{ac}+2\delta}v_b^{np} \quad (20)$$

F.4 Solving for wages, no-poach agreement between B & C

Equations 15 through 20 comprise a system in six variables $\{w_a^{np}, v_a^{np}, w_b^{np}, v_b^{np}, w_c^{np}, v_c^{np}\}$.

$$w_a^{np} = \frac{1}{2}p_a\phi + \frac{1}{2}v_c^{np} - \frac{1}{2}\sigma_{ac}$$
$$v_a^{np} = \frac{1}{2}p_a\phi^{'} + \frac{\sigma_{ac}}{2\sigma_{ac}+2\sigma_{ab}}w_b^{np} + \frac{\sigma_{ab}}{2\sigma_{ac}+2\sigma_{ab}}w_c^{np}$$
$$w_b^{np} = \frac{1}{2}p_b\phi + \frac{1}{2}v_a^{np} - \frac{1}{2}\sigma_{ba}$$
$$v_b^{np} = \frac{1}{2}p_b\phi^{'} + \frac{1}{2}v_c^{np}$$
$$w_c^{np} = \frac{1}{2}p_c\phi + \frac{1}{2}v_a^{np} - \frac{1}{2}\sigma_{ac}$$
$$v_c^{np} = \frac{1}{2}p_c\phi^{'} + \frac{\delta}{2\sigma_{ac}+2\delta}w_a^{np} + \frac{\sigma_{ac}}{2\sigma_{ac}+2\delta}v_b^{np}$$

To begin, substitute the equations for w_i^{np} into those for v_i^{np} to obtain a 3x3 system.

$$v_a^{np} = \frac{1}{2}p_a\phi^{'} + \frac{\sigma_{ac}}{2\sigma_{ac}+2\sigma_{ab}}\left(\frac{1}{2}p_b\phi + \frac{1}{2}v_a^{np} - \frac{1}{2}\sigma_{ba}\right) + \frac{\sigma_{ab}}{2\sigma_{ac}+2\sigma_{ab}}\left(\frac{1}{2}p_c\phi + \frac{1}{2}v_a^{np} - \frac{1}{2}\sigma_{ac}\right)$$
$$v_b^{np} = \frac{1}{2}p_b\phi^{'} + \frac{1}{2}v_c^{np}$$
$$v_c^{np} = \frac{1}{2}p_c\phi^{'} + \frac{\delta}{2\sigma_{ac}+2\delta}\left(\frac{1}{2}p_a\phi + \frac{1}{2}v_c^{np} - \frac{1}{2}\sigma_{ac}\right) + \frac{\sigma_{ac}}{2\sigma_{ac}+2\delta}v_b^{np}$$

The first of the previous equations determines v_a by itself.

$$v_a^{np} = \frac{1}{2}p_a\phi^{'} + \frac{\sigma_{ac}}{2\sigma_{ac}+2\sigma_{ab}}\left(\frac{1}{2}p_b\phi + \frac{1}{2}v_a^{np} - \frac{1}{2}\sigma_{ba}\right) + \frac{\sigma_{ab}}{2\sigma_{ac}+2\sigma_{ab}}\left(\frac{1}{2}p_c\phi + \frac{1}{2}v_a^{np} - \frac{1}{2}\sigma_{ac}\right)$$
$$v_a^{np} = \frac{1}{2}p_a\phi^{'} + \frac{1}{2}\frac{\sigma_{ac}}{2\sigma_{ac}+2\sigma_{ab}}p_b\phi + \frac{1}{2}\frac{\sigma_{ac}}{2\sigma_{ac}+2\sigma_{ab}}v_a^{np} - \frac{1}{2}\frac{\sigma_{ac}}{2\sigma_{ac}+2\sigma_{ab}}\sigma_{ba} + \frac{1}{2}\frac{\sigma_{ab}}{2\sigma_{ac}+2\sigma_{ab}}p_c\phi + \frac{1}{2}\frac{\sigma_{ab}}{2\sigma_{ac}+2\sigma_{ab}}v$$
$$v_a^{np} = \frac{1}{2}p_a\phi^{'} + \frac{1}{2}\frac{\sigma_{ac}}{2\sigma_{ac}+2\sigma_{ab}}\left(p_b\phi - \sigma_{ba}\right) + \frac{1}{2}\frac{\sigma_{ab}}{2\sigma_{ac}+2\sigma_{ab}}\left(p_c\phi - \sigma_{ac}\right) + \frac{1}{2}\left(\frac{\sigma_{ac}}{2\sigma_{ac}+2\sigma_{ab}} + \frac{\sigma_{ab}}{2\sigma_{ac}+2\sigma_{ab}}\right)v_a^{np}$$

$$v_a^{np} - \frac{1}{2}\left(\frac{\sigma_{ac}}{2\sigma_{ac}+2\sigma_{ab}} + \frac{\sigma_{ab}}{2\sigma_{ac}+2\sigma_{ab}}\right)v_a^{np} = \frac{1}{2}p_a\phi^{'} + \frac{1}{2}\frac{\sigma_{ac}}{2\sigma_{ac}+2\sigma_{ab}}\left(p_b\phi - \sigma_{ba}\right) + \frac{1}{2}\frac{\sigma_{ab}}{2\sigma_{ac}+2\sigma_{ab}}\left(p_c\phi - \sigma_{ac}\right)$$
$$v_a^{np}\left[1 - \frac{1}{2}\left(\frac{\sigma_{ac}}{2\sigma_{ac}+2\sigma_{ab}} + \frac{\sigma_{ab}}{2\sigma_{ac}+2\sigma_{ab}}\right)\right] = \frac{1}{2}p_a\phi^{'} + \frac{1}{2}\frac{\sigma_{ac}}{2\sigma_{ac}+2\sigma_{ab}}\left(p_b\phi - \sigma_{ba}\right) + \frac{1}{2}\frac{\sigma_{ab}}{2\sigma_{ac}+2\sigma_{ab}}\left(p_c\phi - \sigma_{ac}\right)$$

$$v_a^{np} = \frac{\frac{1}{2}p_a\phi^{'} + \frac{1}{2}\frac{\sigma_{ac}}{2\sigma_{ac}+2\sigma_{ab}}\left(p_b\phi - \sigma_{ba}\right) + \frac{1}{2}\frac{\sigma_{ab}}{2\sigma_{ac}+2\sigma_{ab}}\left(p_c\phi - \sigma_{ac}\right)}{1 - \frac{1}{2}\left(\frac{\sigma_{ac}}{2\sigma_{ac}+2\sigma_{ab}} + \frac{\sigma_{ab}}{2\sigma_{ac}+2\sigma_{ab}}\right)} \quad (21)$$

The remaining equations are a 2x2 system in $v_b$and v_c. Substituting for v_b gives the an equation solely in terms of v_c.

$$v_c^{np} = \frac{1}{2}p_c\phi^{'} + \frac{\delta}{2\sigma_{ac}+2\delta}\left(\frac{1}{2}p_a\phi + \frac{1}{2}v_c^{np} - \frac{1}{2}\sigma_{ac}\right) + \frac{\sigma_{ac}}{2\sigma_{ac}+2\delta}\left(\frac{1}{2}p_b\phi^{'} + \frac{1}{2}v_c^{np}\right)$$
$$v_c^{np} = \frac{1}{2}p_c\phi^{'} + \left(\frac{1}{2}\frac{\delta}{2\sigma_{ac}+2\delta}p_a\phi + \frac{1}{2}\frac{\delta}{2\sigma_{ac}+2\delta}v_c^{np} - \frac{1}{2}\frac{\delta}{2\sigma_{ac}+2\delta}\sigma_{ac}\right) + \left(\frac{1}{2}\frac{\sigma_{ac}}{2\sigma_{ac}+2\delta}p_b\phi^{'} + \frac{1}{2}\frac{\sigma_{ac}}{2\sigma_{ac}+2\delta}v_c^{np}\right)$$

$$v_c^{np} - \frac{1}{2}\frac{\delta}{2\sigma_{ac}+2\delta}v_c^{np} - \frac{1}{2}\frac{\sigma_{ac}}{2\sigma_{ac}+2\delta}v_c^{np} = \frac{1}{2}p_c\phi^{'} + \frac{1}{2}\frac{\delta}{2\sigma_{ac}+2\delta}\left(p_a\phi - \sigma_{ac}\right) + \frac{1}{2}\frac{\sigma_{ac}}{2\sigma_{ac}+2\delta}p_b\phi^{'}$$
$$v_c^{np}\left(1 - \frac{1}{2}\frac{\delta}{2\sigma_{ac}+2\delta} - \frac{1}{2}\frac{\sigma_{ac}}{2\sigma_{ac}+2\delta}\right) = \frac{1}{2}p_c\phi^{'} + \frac{1}{2}\frac{\delta}{2\sigma_{ac}+2\delta}\left(p_a\phi - \sigma_{ac}\right) + \frac{1}{2}\frac{\sigma_{ac}}{2\sigma_{ac}+2\delta}p_b\phi^{'}$$

$$v_c^{np} = \frac{\frac{1}{2}p_c\phi^{'} + \frac{1}{2}\frac{\delta}{2\sigma_{ac}+2\delta}\left(p_a\phi - \sigma_{ac}\right) + \frac{1}{2}\frac{\sigma_{ac}}{2\sigma_{ac}+2\delta}p_b\phi^{'}}{1 - \frac{1}{2}\frac{\delta}{2\sigma_{ac}+2\delta} - \frac{1}{2}\frac{\sigma_{ac}}{2\sigma_{ac}+2\delta}} \quad (22)$$

Using previously derived expressions gives solutions for the other endogenous variables.

$$v_b^{np} = \frac{1}{2}p_b\phi' + \frac{1}{2}v_c^{np} \tag{23}$$

$$w_c^{np} = \frac{1}{2}p_c\phi + \frac{1}{2}v_a^{np} - \frac{1}{2}\sigma_{ac} \tag{24}$$

$$w_b^{np} = \frac{1}{2}p_b\phi + \frac{1}{2}v_a^{np} - \frac{1}{2}\sigma_{ba} \tag{25}$$

$$w_a^{np} = \frac{1}{2}p_a\phi + \frac{1}{2}v_c^{np} - \frac{1}{2}\sigma_{ac} \tag{26}$$

Appendix G Comparing equilibria

Recall that $\sigma_{ba} - \sigma_{ac} = \sigma_{ac} - \sigma_{bc} \equiv \delta$, $\beta_1 \equiv \left(\frac{1}{2+\frac{\delta}{\sigma_{bc}}}\right)$, and $\beta_2 \equiv \left(\frac{\sigma_{ac}\sigma_{bc}}{3\sigma_{ac}\sigma_{bc}+2\delta\sigma_{bc}+2\delta\sigma_{ac}}\right)$. To simplify comparisons, assume differences in cost parameters are small relative to the levels of cost parameters, so that $\beta_1 \approx \frac{1}{2}$ and $\beta_2 \approx \frac{1}{3}$. Additionally, expressions like $\frac{\delta}{2\sigma_{ac}}$ are then approximately equal to zero.

G.1 Poaching wages

To begin I substitute approximations into previously derived solutions.

$$v_c^* = \frac{\frac{1}{4}p_a\phi^{'} + \frac{1}{2}\frac{\delta}{\sigma_{ac}}p_a\phi + \frac{1}{2}\frac{\delta}{\sigma_{bc}}p_b\phi + \frac{1}{2\beta_2}p_c\phi^{'} - \delta}{\frac{1}{\beta_2} - \frac{49}{72}\frac{1}{\left(\frac{1}{\beta_1}-\frac{1}{6}-\frac{\delta}{4\sigma_{bc}}\right)} - \frac{\delta}{2\sigma_{ac}} - \frac{\delta}{2\sigma_{bc}} - \frac{1}{12}} + \frac{\frac{7}{6}\left(\frac{\frac{1}{4}p_a\phi^{'}+\frac{1}{2}\frac{1}{\beta_1}p_b\phi^{'}+\frac{1}{4}\frac{\delta}{\sigma_{bc}}p_c\phi-\frac{1}{4}\delta}{\frac{1}{\beta_1}-\frac{1}{6}-\frac{1}{4}\frac{\delta}{\sigma_{bc}}}\right)}{\frac{1}{\beta_2} - \frac{49}{72}\frac{1}{\left(\frac{1}{\beta_1}-\frac{1}{6}-\frac{\delta}{4\sigma_{bc}}\right)} - \frac{\delta}{2\sigma_{ac}} - \frac{\delta}{2\sigma_{bc}} - \frac{1}{12}}$$

$$v_c^* \approx \frac{\frac{1}{4}p_a\phi^{'} + \frac{3}{2}p_c\phi^{'} - \delta}{2 - \frac{49}{72}\frac{1}{\left(2-\frac{1}{6}\right)} - \frac{1}{12}} + \frac{\frac{7}{6}\left(\frac{\frac{1}{4}p_a\phi^{'}+\frac{1}{2}\frac{1}{\beta_1}p_b\phi^{'}+\frac{1}{4}\frac{\delta}{\sigma_{bc}}p_c\phi-\frac{1}{4}\delta}{2-\frac{1}{6}}\right)}{2 - \frac{49}{72}\frac{1}{\left(2-\frac{1}{6}\right)} - \frac{1}{12}}$$

$$v_c^* \approx \frac{\frac{1}{4}p_a\phi^{'} + \frac{3}{2}p_c\phi^{'} - \delta}{2 - \frac{49}{12}\frac{1}{11} - \frac{1}{12}} + \frac{\frac{7}{11}\left(\frac{1}{4}p_a\phi^{'} + \frac{1}{2}2p_b\phi^{'} - \frac{1}{4}\delta\right)}{2 - \frac{49}{12}\frac{1}{11} - \frac{1}{12}}$$

$$v_c^* \approx \frac{\frac{1}{4}p_a\phi^{'} + \frac{3}{2}p_c\phi^{'} - \delta}{\frac{264}{132} - \frac{49}{132} - \frac{11}{132}} + \frac{\left(\frac{7}{11}\frac{1}{4}p_a\phi^{'} + \frac{7}{11}p_b\phi^{'} - \frac{7}{11}\frac{1}{4}\delta\right)}{\frac{264}{132} - \frac{49}{132} - \frac{11}{132}}$$

$$v_c^* \approx \frac{\frac{1}{4}p_a\phi^{'} + \frac{3}{2}p_c\phi^{'} - \delta + \frac{7}{44}p_a\phi^{'} + \frac{7}{11}p_b\phi^{'} - \frac{7}{44}\delta}{\frac{204}{132}}$$

$$v_c^* \approx \frac{\left(\frac{1}{4} + \frac{7}{44}\right)p_a\phi^{'} + \frac{7}{11}p_b\phi^{'} + \frac{3}{2}p_c\phi^{'} - \left(1 + \frac{7}{44}\right)\delta}{\frac{204}{132}}$$

$$v_c^* \approx \frac{\left(\frac{11}{44} + \frac{7}{44}\right)p_a\phi^{'} + \frac{7}{11}p_b\phi^{'} + \frac{3}{2}p_c\phi^{'} - \left(\frac{44}{44} + \frac{7}{44}\right)\delta}{\frac{204}{132}}$$

$$v_c^* \approx \frac{\frac{9}{22}p_a\phi^{'} + \frac{7}{11}p_b\phi^{'} + \frac{3}{2}p_c\phi^{'} - \frac{51}{44}\delta}{\frac{204}{132}}$$

$$v_c^* \approx \left(\frac{132}{204}\frac{9}{22}\right)p_a\phi^{'} + \frac{132}{204}\frac{7}{11}p_b\phi^{'} + \frac{132}{204}\frac{3}{2}p_c\phi^{'} - \frac{132}{204}\frac{51}{44}\delta$$

$$v_c^* \approx \left(\frac{6}{204}\frac{9}{1}\right)p_a\phi^{'} + \frac{12}{204}\frac{7}{1}p_b\phi^{'} + \frac{66}{204}\frac{3}{1}p_c\phi^{'} - \frac{3}{204}\frac{51}{1}\delta$$

$$v_c^* \approx \frac{54}{204}p_a\phi^{'} + \frac{84}{204}p_b\phi^{'} + \frac{198}{204}p_c\phi^{'} - \frac{153}{204}\delta$$

One can apply the same approximations under the no-poach agreements.

$$v_c^{np} = \frac{\frac{1}{2}\frac{\delta}{2\sigma_{ac}+2\delta}\left(p_a\phi - \sigma_{ac}\right) + \frac{1}{2}\frac{\sigma_{ac}}{2\sigma_{ac}+2\delta}p_b\phi^{'} + \frac{1}{2}p_c\phi^{'}}{1 - \frac{1}{2}\frac{\delta}{2\sigma_{ac}+2\delta} - \frac{1}{2}\frac{\sigma_{ac}}{2\sigma_{ac}+2\delta}}$$
$$v_c^{np} \approx \frac{\frac{1}{2}\frac{1}{2}p_b\phi^{'} + \frac{1}{2}p_c\phi^{'}}{1 - \frac{1}{2}\frac{1}{2}}$$
$$v_c^{np} \approx \frac{\frac{1}{4}p_b\phi^{'} + \frac{1}{2}p_c\phi^{'}}{\frac{3}{4}}$$
$$v_c^{np} \approx \frac{4}{3}\frac{1}{4}p_b\phi^{'} + \frac{4}{3}\frac{1}{2}p_c\phi^{'}$$
$$v_c^{np} \approx \frac{1}{3}p_b\phi^{'} + \frac{2}{3}p_c\phi^{'}$$

Conditional on simplifying assumptions, now one can compare firm C's poaching wage with and without the no-poach agreement. Notice $\frac{84}{204} > \frac{1}{3}$ and $\frac{198}{204} > \frac{2}{3}$. A sufficient condition for $v_c^* > v_c^{np}$ is then $\frac{54}{204}p_a\phi^{'} - \frac{153}{204}\delta > 0$. This will be satisfied provided $p_a\phi^{'}$is sufficiently large. I now adopt this assumption and maintain it hereafter. The poaching wage for firm C falls under the agreement.

Now one can compare poaching wages for firm B.

$$v_b^* = \frac{\frac{1}{4}p_a\phi^{'} + \frac{1}{2\beta_1}p_b\phi^{'} + \frac{1}{4}\frac{\delta}{\sigma_{bc}}p_c\phi - \frac{1}{4}\delta}{\frac{1}{\beta_1} - \frac{1}{6} - \frac{\delta}{4\sigma_{bc}}} + \frac{\frac{7}{12}}{\frac{1}{\beta_1} - \frac{1}{6} - \frac{\delta}{4\sigma_{bc}}}v_c^*$$
$$v_b^* \approx \frac{\frac{1}{4}p_a\phi^{'} + \frac{1}{2\beta_1}p_b\phi^{'} - \frac{1}{4}\delta}{2 - \frac{1}{6}} + \frac{\frac{7}{12}}{2 - \frac{1}{6}}v_c^*$$
$$v_b^* \approx \frac{\frac{1}{4}p_a\phi^{'} + \frac{1}{2}2p_b\phi^{'} - \frac{1}{4}\delta}{\frac{11}{6}} + \frac{\frac{7}{12}}{\frac{11}{6}}v_c^*$$
$$v_b^* \approx \frac{6}{11}\left(\frac{1}{4}p_a\phi^{'} + p_b\phi^{'} - \frac{1}{4}\delta\right) + \frac{6}{11}\frac{7}{12}v_c^*$$
$$v_b^* \approx \frac{3}{11}\frac{1}{2}p_a\phi^{'} + \frac{6}{11}p_b\phi^{'} - \frac{3}{11}\frac{1}{2}\delta + \frac{1}{11}\frac{7}{2}v_c^*$$
$$v_b^* \approx \frac{3}{22}p_a\phi^{'} + \frac{6}{11}p_b\phi^{'} - \frac{3}{22}\delta + \frac{7}{22}v_c^*$$

One can compare to firm B's poaching wage under the no-poach agreements.

$$v_b^{np} = \frac{1}{2}p_b\phi^{'} + \frac{1}{2}v_c^{np}$$

Notice $\frac{6}{11} > \frac{1}{2}$. By the results above $v_c^* > v_{np}$, but $\frac{7}{22} < \frac{1}{2}$, so the effect of the terms involving $v_c$is ambiguous. As before there is a sufficient condition for $v_b^* > v_b^{np}$: $p_a\phi^{'}$ must be large relative to δ so that $\frac{3}{22}\left(p_a\phi' - \delta\right) > \frac{1}{2}v_c^{np} - \frac{7}{22}v_c^*$. Under this condition $v_b^* > v_b^{np}$; the poaching wage for firm B falls under the agreement.

Lastly one can compare poaching wages for firm A. The poaching wage v_a^* in the ordinary equilibrium requires no simplification. To facilitate comparison I substitute for v_b^* and v_c^*.

$$v_a^* = \frac{1}{2}p_a\phi' + \frac{1}{3}v_b^* + \frac{1}{6}v_c^*$$
$$v_a^* \approx \frac{1}{2}p_a\phi' + \frac{1}{3}\left(\frac{3}{22}p_a\phi' + \frac{6}{11}p_b\phi' - \frac{3}{22}\delta + \frac{7}{22}v_c^*\right) + \frac{1}{6}\left(\frac{54}{204}p_a\phi' + \frac{84}{204}p_b\phi' + \frac{198}{204}p_c\phi' - \frac{153}{204}\delta\right)$$
$$v_a^* \approx \frac{1}{2}p_a\phi' + \frac{1}{3}\frac{3}{22}p_a\phi' + \frac{1}{3}\frac{6}{11}p_b\phi' - \frac{1}{3}\frac{3}{22}\delta + \frac{1}{3}\frac{7}{22}v_c^* + \frac{1}{6}\frac{54}{204}p_a\phi' + \frac{1}{6}\frac{84}{204}p_b\phi' + \frac{1}{6}\frac{198}{204}p_c\phi' - \frac{1}{6}\frac{153}{204}\delta$$
$$v_a^* \approx \frac{1}{2}p_a\phi' + \frac{1}{22}p_a\phi' + \frac{2}{11}p_b\phi' - \frac{1}{22}\delta + \frac{7}{66}v_c^* + \frac{9}{204}p_a\phi' + \frac{14}{204}p_b\phi' + \frac{33}{204}p_c\phi' - \frac{153}{1224}\delta$$
$$v_a^* \approx \left(\frac{1}{2} + \frac{1}{22} + \frac{9}{204}\right)p_a\phi' + \left(\frac{2}{11} + \frac{14}{204}\right)p_b\phi' + \frac{33}{204}p_c\phi' + \frac{7}{66}v_c^* - \left(\frac{153}{1224} + \frac{1}{22}\right)\delta$$
$$v_a^* \approx .59p_a\phi' + .25p_b\phi' + .16p_c\phi' + \frac{7}{66}\left(\frac{54}{204}p_a\phi' + \frac{84}{204}p_b\phi' + \frac{198}{204}p_c\phi' - \frac{153}{204}\delta\right) - .17\delta$$
$$v_a^* \approx .59p_a\phi' + .25p_b\phi' + .16p_c\phi' + \left(.028p_a\phi' + .044p_b\phi' + .1p_c\phi' - .08\delta\right) - .17\delta$$
$$v_a^* \approx .62p_a\phi' + .29p_b\phi' + .26p_c\phi' - .25\delta$$

The poaching wage under the agreement can be simplified as before.

$$v_a^{np} = \frac{\frac{1}{2}p_a\phi' + \frac{1}{2}\frac{\sigma_{ac}}{2\sigma_{ac}+2\sigma_{ab}}\left(p_b\phi - \sigma_{ba}\right) + \frac{1}{2}\frac{\sigma_{ab}}{2\sigma_{ac}+2\sigma_{ab}}\left(p_c\phi - \sigma_{ac}\right)}{1 - \frac{1}{2}\left(\frac{\sigma_{ac}}{2\sigma_{ac}+2\sigma_{ab}} + \frac{\sigma_{ab}}{2\sigma_{ac}+2\sigma_{ab}}\right)}$$
$$v_a^{np} \approx \frac{\frac{1}{2}p_a\phi' + \frac{1}{2}\frac{1}{2}\frac{\sigma_{ac}}{\sigma_{ac}+\sigma_{ab}}\left(p_b\phi - \sigma_{ba}\right) + \frac{1}{2}\frac{1}{2}\frac{\sigma_{ab}}{\sigma_{ac}+\sigma_{ab}}\left(p_c\phi - \sigma_{ac}\right)}{1 - \frac{1}{2}\left(\frac{\sigma_{ac}}{\sigma_{ac}+\sigma_{ab}} + \frac{\sigma_{ab}}{\sigma_{ac}+\sigma_{ab}}\right)}$$

I previously assumed $\sigma_{ba} - \sigma_{ac} = \sigma_{ac} - \sigma_{bc} \equiv \delta$ is small relative to both σ_{ac} and σ_{ab}. Then

$\sigma_{ac} + \sigma_{ab} = \sigma_{ac} + (\delta + \sigma_{ac}) \approx 2\sigma_{ac}$ and $\sigma_{ac} + \sigma_{ab} = (\sigma_{ab} - \delta) + \sigma_{ab} \approx 2\sigma_{ab}$.

$$v_a^{np} \approx \frac{\frac{1}{2}p_a\phi' + \frac{1}{4}\frac{1}{2}\left(p_b\phi - \sigma_{ba}\right) + \frac{1}{4}\frac{1}{2}\left(p_c\phi - \sigma_{ac}\right)}{1 - \frac{1}{2}\left(\frac{1}{2} + \frac{1}{2}\right)}$$
$$v_a^{np} \approx \frac{\frac{1}{2}p_a\phi' + \frac{1}{8}\left(p_b\phi - \sigma_{ba}\right) + \frac{1}{8}\left(p_c\phi - \sigma_{ac}\right)}{\frac{1}{2}}$$
$$v_a^{np} \approx 2\left(\frac{1}{2}p_a\phi' + \frac{1}{8}\left(p_b\phi - \sigma_{ba}\right) + \frac{1}{8}\left(p_c\phi - \sigma_{ac}\right)\right)$$
$$v_a^{np} \approx p_a\phi' + \frac{1}{4}\left(p_b\phi - \sigma_{ba}\right) + \frac{1}{4}\left(p_c\phi - \sigma_{ac}\right)$$
$$v_a^{np} \approx p_a\phi' + \frac{1}{4}p_b\phi + \frac{1}{4}p_c\phi - \frac{1}{4}\left(\sigma_{ba} + \sigma_{ac}\right)$$

One can see the effect on firm A's poaching wage is ambiguous. If switching is strongly productivity-reducing ($\phi' \ll \phi$) or switching costs $\sigma_{ba} + \sigma_{ac}$ are large relative to productivity gains, then $v_a^{np} < v_a^*$. I adopt and maintain this assumption. While equilibria with $v_a^{np} > v_a^*$ are possible, they feature increased loyalty wages at firms B and C (see below), inconsistent with the empirical setting under study.

G.2 Loyalty wages

The loyalty wages at firm C are $w_c^* = \frac{1}{2}p_c\phi + \frac{1}{2}v_b^* - \frac{1}{2}\sigma_{bc}$ and $w_c^{np} = \frac{1}{2}p_c\phi + \frac{1}{2}v_a^{np} - \frac{1}{2}\sigma_{ac}$. Under the assumption that differences in switching costs are small, the comparison hinges on the terms $\frac{1}{2}v_b^*$ and $\frac{1}{2}v_a^{np}$. From above, $v_b^* \approx \frac{3}{22}p_a\phi' + \frac{6}{11}p_b\phi' - \frac{3}{22}\delta + \frac{7}{22}v_c^* \approx \frac{3}{22}p_a\phi' + \frac{6}{11}p_b\phi' - \frac{3}{22}\delta + \frac{7}{22}\left(\frac{54}{204}p_a\phi' + \frac{84}{204}p_b\phi' + \frac{198}{204}p_c\phi' - \frac{153}{204}\delta\right) \approx$ and $v_a^{np} \approx p_a\phi' + \frac{1}{4}p_b\phi + \frac{1}{4}p_c\phi - \frac{1}{4}\left(\sigma_{ba} + \sigma_{ac}\right)$. Under the previous assumptions on productivity and switching costs, $w_c^{np} < w_c^*$.

Analysis of loyalty wages at firm B, $w_b^* = \frac{1}{2}p_b\phi + \frac{1}{2}v_c^* - \frac{1}{2}\sigma_{bc}$ and $w_b^{np} = \frac{1}{2}p_b\phi + \frac{1}{2}v_a^{np} - \frac{1}{2}\sigma_{ba}$, is similar. The comparison hinges on $\frac{1}{2}v_c^*$ and $\frac{1}{2}v_a^{np}$. Under the previous assumptions on productivity and switching costs, $w_b^{np} < w_b^*$.

For firm A the comparison of loyalty wages ($w_a^* = \frac{1}{2}p_a\phi + \frac{1}{2}v_c^* - \frac{1}{2}\sigma_{ac}$ and $w_a^{np} = \frac{1}{2}p_a\phi + \frac{1}{2}v_c^{np} - \frac{1}{2}\sigma_{ac}$) is straightforward. From $v_c^* > v_c^{np}$, it follows that $w_a^* > w_a^{np}$.