Inter-Industry Wage Inequality: Persistent differences and turbulent equalization

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Abstract

Persistent inter-industry wage differentials are an enduring puzzle for neoclassical economics. This paper applies the classical theory of 'real competition' to inter-industry wage differentials. Theoretically, we argue that competitive wage determination can be decomposed into equalizing, dispersing and turbulently equalizing factors. Empirically, we show graphically and econometrically for 31 U.S. industries in 1987-2016 that wage differentials, like regulating profit rates, are governed by turbulent equalization. Furthermore, we apply a fixed effects OLS as well as a hierarchical Bayesian inference model and find that the link between regulating profit rates and wage differentials is positive, significant and robust.

1. Introduction

Inequality in income and wages is a crucial challenge for economic, social, and, increasingly, political reasons. Economic research has consequently focused both on the functional and on the personal distribution of income. However, inter-industry wage differentials have not attracted a comparable surge of interest. This despite the fact that inter-industry wage differentials remain a puzzle from a neoclassical perspective: They cannot be fully explained by differentials in skills, labor productivity or other individual factors.

Independently, the literature on the turbulent equalization of profit rates explains industry-level differences in profit rates through competition within and between industries in a process of 'real competition' (Shaikh 2008, 2016). We apply the concept of turbulent equalization to wages, drawing on Marx' analysis, who argues that "*competition among workers is only another form of the competition among capitalists*" [Marx, 1993 [1857]: 651]. Similar views are expressed by Botwinick (1993), Kurz and Salvadori (1995) and Shaikh (2016: 750). Nonetheless, this avenue remains largely unexplored. This paper aims to close this gap by, first, providing a theoretical rationale for a part of inter-industry wage differentials being governed by turbulent equalization, and second, assessing this impact empirically.

We argue that wage differentials are influenced by equalizing, dispersing and turbulently equalizing factors in a framework of competitive but institutionally determined wage setting. We investigate graphically and econometrically, whether wage differentials gravitate around, or converge to, a center of gravity. This turns out to be the case for 31 out of 48 industries. Furthermore, we use a fixed effects OLS panel regression and a hierarchical Bayesian inference model to investigate whether they are linked to regulating profit rates (which we find to be turbulently equalizing). Here, we find a positive, statistically significant and robust correlation. Finally, we confirm persistent wage inequality between industries, which is detected almost universally by the literature.

The rest of the paper is structured as follows. Section 2 reviews the empirical literature on inter-industry wage differentials and the theoretical literature on turbulent equalization of profit rates and wages. Section 3 discusses our theoretical framework, Section 4 shows our data and descriptive and econometric evidence on turbulent equalization in wages, and Section 5 presents the fixed effects and Bayesian regression results. Section 6 concludes.

2. The Literature on Inter-Industry Wage Differentials and Turbulent Equalization

There is a large empirical literature on inter-industry wage differentials by institutionalist economists and labor economists. Howell (1989) and Howell and Wolff (1991) observe increasing and significant wage differentials between 1947 - 1970, as well as 1970 - 1984 and at the same time notice diminishing skill differentials between manufacturing industries. However, they find inter-industrial capital intensity as the apparent reason for unequal wages. Hedström and Swedberg (1985) emphasize the institutional forces behind dynamics in wage developments, i.e. the role of organizational strength of workers in equalizing wages. They find persistent inter-industrial inequality in wages of 14 industries 1957 – 1979, and reject unionization as a significant equalizing factor. Recent contributions by Du Caju et al. (2011a, 2011b) provide evidence that firm profitability matters for inter-industry wage differentials.

The role of collective bargaining is at the heart of the institutionalist argument in labor economics. Commons notes that collective action determines the maneuvering room for all individual action (1931: 650). McConell (1955: 348) and Rubery (1978) formalize the argument. The more recent empirical literature finds ample evidence that stronger trade unions raise wages (Blanchflower and Bryson, 2002; Hirsch, 2004). In combination with structural characteristics, this has consequences for the analysis of inter-industry wage differentials: Dunlop (1948: 350-365) notes the role of different labor cost shares in total cost and different skill and occupational structures in setting limits in wage bargaining. In the years after, institutionalists noted the close relationship between differential profit rates and differential wage rates but did not extend their analysis to the role of competitive forces (Botwinick, 1993: 32).

The empirical neoclassical literature on wage inequality has also consistently documented the elusive explanatory power of individual characteristics for inter-industry differentials in compensation for similar-skill jobs for decades. Krueger and Summers show evidence for substantial inequalities between industries (1986) and test for wage differentials due to unobserved characteristics in a human capital earning function framework (1988). This yields strong evidence for persistent inter-industrial dispersion, but none for unobserved characteristics as the driving force (Krueger and Summers, 1986, 1988). Gibbons and Katz (1992) also note wage differentials and support for unmeasured productive abilities as the driving force in a job-change micro model. Using microdata, Gittleman and Pierce (2012) show that inter-industrial dispersion in fact increases substantially when non-wage compensation is included in the analysis. The recent neoclassical micro literature points to mobility of workers in the wage distribution (Neumuller, 2015; Bachmann et al. 2016) for inequality-reducing effects.

The 'real competition' literature provides a theoretical underpinning for persistent differences in industry-level average profit rates with firms operating in a competitive framework with capital mobility. Profit rates differ within an industry because prices equalize but capitals are of different vintages and thus produce at different unit costs. Other idiosyncratic factors can lead to differentiated profit rates, such as uncertainty (D'Agata and Mori, 2016).

Between industries, however, profit rates equalize. This is because new capital is generally invested into the highest-yielding industry, driving its average profit rate down (Marx 1993 [1894]: 274ff). Consequently, industry-level rates of return on a reproducible condition of production ('regulating capital') gravitate around an attractor of the 'normal' profit rate, while industries alternate as the most profitable in cycles of fat and lean years. This yields a characteristic ‘crossing-over’ pattern of profit rates across industries (Shaikh, 2008: 168; Shaikh, 2016: 260-265).

There is an ample empirical literature investigating turbulent equalization of profit rates, of which Vaona (2012: 125ff) provides a very useful overview. Rates of return are typically used as proxies for the regulating profit rates (Schroeder, 2004; Tsoulfidis and Tsaliki, 2005; Shaikh, 2008; Shaikh, 2016). Shaikh (2008, 2016) finds persistent inequality of industrial average profit rates, and the crossing-over pattern of turbulent equalization between industries. Yet, the distribution of firm-level profit rates is stationary, as Scharfenaker and Semieniuk (2017) and Scharfenaker and Foley (2017) show in a statistical equilibrium framework.

Particularly relevant for this paper are Vaona (2011, 2012), which apply Mueller’s (1986) test for differences in profitability across manufacturing firms. They find empirical support for gravitation and convergence in OECD industry-level data, which is substantially stronger when the sample is restricted to manufacturing industries. Tescari and Vaona (2013) confirm this finding for the US, Bahçe and Eres (2013) for Turkey, and Tsoulfidis and Tsaliki (2005) for Greece.

However, the “*competition among workers is only another form of the competition among capitalists*” (Marx, 1993 [1857]: 651). Kurz and Salvadori (1995: 322) note that, for homogenous labor, “any differences in pay within and across industries would lead to movements of some workers seeking to benefit from the more favorable conditions elsewhere”. Shaikh (2016) states explicitly that turbulent equalization also applies to wages (Shaikh, 2016: 750). Yet, this has not been explored in detail. Notable exceptions are Julius (2009), who develops a model of industry-level capital intensity and workers’ bargaining power, and in particular Botwinick (1993), who derives a theoretical model of competitive wage determination from real competition within and between industries. He combines the institutional insights to structural differences with the key argument of ‘real competition’ authors: that these exist not despite but because of competitive behavior.

In his framework, the potential for wage increases by regulating (i.e. price-setting) capitalists is bounded by two limits: first, the profit margin of regulating capital, and second, the cost differential between regulating and the second-best (’subdominant’) production technique (Botwinick, 1993: 178). Both limits can be reduced to functions of industry-level composition of capital (the ratio of fixed to variable capital) and labor productivity. This demonstrates the role of regulating profit rates in shifting upper limits to wage increases in the turbulent fashion characteristic for real competition. The limits to wage increases in regulating capitals are essential since they represent the relations of production that will be replicated in expansion.

However, the turbulent aspect in competitive wage determination has not yet been formalized, and the empirical questions of whether (incremental) industrial wages are governed by turbulent equalization has not been investigated. This is the gap in the literature that this paper intends to close.

3. Determinants of Wage Growth

We expand Botwinick's (1993) framework to develop a theory of wage determination in a 'real competition' framework. Three dynamics, summarized in Table 1, govern wages: equalization, dispersion and turbulent equalization.

[TABLE 1 HERE]

For wages, the most powerful attractor ensuring their equalization across industries is the generally accepted standard of living. This is the reason wages do not range from infinitesimal to infinite amounts, corresponding to the bargaining power of workers. (Cartter, 1959: 7). The cost of living for workers includes physical subsistence, upbringing of offspring, and participation in some average cultural and social life (Marx, 1990: 274ff, Botwinick, 1993: 70). The general living standard changes slowly over time, and *ceteris paribus* wages trend towards it (i.e., the growth rate of wages will be positively correlated with the change in living standards).

Industry-level average wages differ due to variations in the occupational structure and the share of labor costs in total costs across industries (Dunlop, 1948). Wages vary across jobs due to the required skills, which in turn imply different cost of training, as well as socially determined parameters like reputation. Key aspects are collective bargaining power and institutional arrangements like minimum wages, average labor hours and the concrete organization of production. They result in persistent inter-industry wage differentials. The occupational structure of industries changes in response to technological advances, which is likely to be a slow process. Furthermore, structural differences in production, like labor intensity of the production process, can lead to systematically higher limits to wage increases and thus have wages diverge.

Wage increases are the result of a dynamic bargaining process between labor and capital. (Organized) labor pushes for wage increases (quantified by their 'potential of obstruction'), while capitalists are unwilling, and for high demands also unable, to give in. Following Botwinick (1993: 178), we identify three constraints (in an increasingly narrow order). (1) The profit margins of regulating capital; (2) the cost differentials between regulating and 'subdominant' capital as the maximal additional labor cost which the regulating capital can suffer while still retaining its dominant position; and (3) the cost of obstruction to the capitalist not yielding to workers' demands. The latter is determined by relative unionization rates, which vary across industries in the US.

The third process governing the change in industry-level wages is turbulent equalization. Two aspects play a role here: the turbulent equalization of profit rates, and the mobility of labor across industries.

First, the turbulent movement of profit rates alternatively expands and contracts the limits to wages. In an industry with above-average regulating profit rates, capitalists will expand production, which will increase demand for both fixed and variable capital. Simply put, the industry will hire more workers, which raises workers' bargaining power within the industry. At the same time, the increasing regulating profit rate of this industry lifts the limit for wage growth. Conversely, an industry facing falling regulating profit rates has an ever-tightening margin for workers' demands for wage increases. This process moves relatively fast.

The second effect, labor mobility, should reinforce this crossing-over pattern of changes in wages. If one set of firms offers higher wage rates than another in general, labor supply will increase in the first and decrease in the second. Since the possible wage increases in new jobs are governed by profit margins of the industry-specific regulating capitals, this implies turbulent equalization of wages across industries (Shaikh, 2016: 750). Due to institutional constraints, norms, and the insecurities facing workers leaving their jobs, this effect is likely to be realized in the medium run. The result is a turbulent process of equalization of wage changes between industries, in which profitability of regulating capital and labor mobility play a key role.

4. Are Wages Turbulently Equalizing?

Next, we empirically investigate whether wages turbulently equalize, using BEA industry economic accounts (U.S. Bureau of Economic Analysis 2018). Our data contains information on yearly compensation of employees; the number of employees in full-time equivalents; the capital stock; and gross output, profits, and investment from 1987 to 2016 for 66 industries. We exclude industries with missing data; government and the non-profit sector; and financial, insurance and real estate ('FIRE') industries due to difficulties in estimating inventory. In identifying industries not governed by a profit motive, we follow the argument in Shaikh (2008: 191). This leaves us with 48 industries and a total of 1392 observations.

We use compensation rather than wages since the former includes non-wage benefits. Inter-industrial pay disparities are larger for compensation than for wages excluding non-wage benefits (Gittleman et al. 2012: 2, 11). Following the empirical literature on real competition (Shaikh 1997, 2008), which employs the incremental profit rate, our variable of interest is thus incremental compensation of full-time employees, i.e. the growth rate of yearly compensation of employees divided by full-time employee equivalents. For simplicity, we denote it henceforth as 'growth in wages', $\widehat{w}$:

$$\widehat{w_j} = \frac{{EC_{t,j}}/{N_{t,j}} - {EC_{t-1,j}}/{N_{t-1,j}}}{{EC_{t-1,j}}/{N_{t-1,j}}} \tag{1}$$

where EC is employee compensation and N are full-time equivalents of workers at time t for industry j.

We choose industry-level average capital-labor ratios λ and gross output y as structural control variables. These are the industry-specific structural parameters governing persistent inequalities in limits to wage increases as described by Botwinick (1993: 301).

In order to assess the effect of turbulent equalization of profit rates on wages, we approximate regulating rates of return by incremental profit rates as established by Shaikh (1997: 9, 2008, 2016), Vaona (2011) and Tescari and Vaona (2013). That is, we estimate gross profits on new capital as the change in overall profits ΔP at time t for industry j, and the rate of return on investment r as the ratio of incremental profits over gross investment I (Shaikh 2008: 173f):[1]

$$r_j \approx \frac{\Delta P_{t,j}}{I_{t,j}} \tag{2}$$

[TABLE 2 HERE]

Table 2 reports summary statistics for all variables. Note that the standard deviation is the mean of yearly standard deviations, since we are interested in the dispersion across industries rather than over time. The high standard deviation compared to the mean in both the level and the rate of change of wages suggests high dispersion, both persistent and dynamic.

Next, we show descriptive evidence for persistent industry-level wage differentials on the one hand, and for the turbulent equalization of wages, on the other. Figure 1 plots full time compensation in each industry against time. The broadly parallel movement of wages indicates persistent inequalities, consistent with the empirical literature on inter-industry wage differentials and the theoretical arguments of different occupational structures and organizational strength of labor between industries.

[FIGURE 1 HERE]

Figure 2 plots the deviations of regulating profit rates and wage growth from the respective yearly averages to illustrate the dynamics of turbulent equalization.[2] Both rates of return and wages show relatively compact movements around a yearly average, i.e. the gravitational center. The perpetual crossing of curves illustrates the turbulence of the process: industries with a competitive advantage in profit rates and, subsequently, above-average wage growth alternate.

[FIGURE 2 HERE]

This indicates that although inter-industry disparities in wages levels persist in the long run, there is a simultaneous, fast process generating turbulent inequalities in wage changes on the industrial level. As discussed above, our hypothesis is that the profitability of regulating capitals sets limits to wage growth, which is itself governed by turbulent equalization.

[1] For a detailed discussion of the rationale behind incremental profit rates, see Appendix A.

[2] Figure A.1 in Appendix A.2 shows deviations of regulating profit rates and wage growth at the country level.

Next, we investigate whether the descriptive evidence for turbulent equalization holds up econometrically. As before, the center of gravitation is the normal growth rate in wages approximated by the cross-industrial average, and the relevant variable is the deviation of the industry-level wages from this average.

Turbulent equalization is given when either gravitation, i.e. a stochastic movement around a cross-industry center, or convergence, that is, wage rates moving towards a gravitational center, can be confirmed.[3] We follow Vaona (2011, 2012) and Tescari and Vaona's (2013) in testing for convergence and gravitation by applying Mueller's (1986) model to wage rates with a non-linear time trend. Concretely, we first estimate the following model with a non-linear time trend:

$$\acute{w}_{t.j} = \alpha_j + \beta_{j,1}\frac{1}{t} + \beta_{j,2}\frac{1}{t^2} + \beta_{j,3}\frac{1}{t^3} + \varepsilon \tag{3}$$

where $\acute{w}$ is the deviation of wage growth from the yearly mean, α the intercept, t time, j industry and ε a white noise error term. Restrictions on the parameters then allow us to assess whether the process is best characterized as looser convergence (Equation 4) or the more restrictive gravitation (Equation 5).

$$\alpha_j = 0 \ \& \ \left(\beta_{j,1} \ | \ \text{or} \ | \ \beta_{j,2} \ | \ \beta_{j,3} \neq 0\right) \tag{4}$$

$$\alpha_j = \beta_{t,1} = \beta_{t,2} = \beta_{t,3} = 0 \tag{5}$$

That is, for convergence, a t-test performed on the time coefficients shows whether they are individually (not) different from zero. For gravitation, we apply a Wald Test for joint insignificance.

As shown in Table A.1 in Appendix A.2, we observe gravitation of wage rates in 26 industries, and another 5 industries fulfill the looser definition of convergence of wage rates (out of a total of 48 industries).

We also perform the above-mentioned tests for regulating profit rates (defined as the deviation of industry-level profit rates from average profit rates). Here, we find gravitation in profit rates in 40 industries, and convergence in another two industries. We therefore confirm the results found in the literature (Vaona 2012); if anything, we find slightly more prevalence of turbulent equalization in industry-level regulating profit rates.

For econometric analysis in the next section, we thus further restrict the dataset to industries in which we find evidence for turbulent equalization of wages, since we hypothesize that turbulently equalizing profit rates are driving the turbulent equalization of wage differentials. Our full sample thus consists of 31 industries and 899 observations for the years 1987 to 2016.

[3] Note that it is sufficient for turbulent equalization that wage-deviations behave like random variables in this respect; they do not have to be random variables.

5. What Affects Wage Differentials?

5.1. Fixed-Effects OLS

The results in the previous section provide evidence for the turbulent equalization of wage rates, much like the literature has found for regulating rates of return, in most but not all profit-dominated industries. This section tests whether regulating profit rates do indeed play a role in determining turbulently equalizing wage growth rates. To do so, we first use a fixed effects regression using the data discussed in Section 4, controlling for the factors discussed in Section 3.

Concretely, the model we formulate is

$$\widehat{w}_{t,j} = \beta_{0,j} + \beta_1 \, \hat{r}_{t,j} + \beta_2 \, \hat{r}_{t-1,j} + \beta_3 \, \lambda_{t,j} + \beta_4 \, y_{t,j} + \varepsilon_{t,j} \tag{6}$$

where the change in wage rates $\widehat{w}$ is regressed on industry-level intercepts $\beta_{0,j}$, the regulating profit rate $\widehat{r}$ both current and lagged, the logarithm of the capital-output ratio λ, and gross output y. As above, t denotes time and j the industry.[4]

Table 3 summarizes the estimation results[5]. First, the industry-level fixed effects are all statistically significantly different from zero. Economically, the high standard deviation of 0.0253 indicates that persistent inequality (i.e. dispersing factors) is crucial for relative industry-level wage changes. This finding is in line both with the empirical literature on inter-industry wage differentials, and our theory.

However, turbulent equalization also plays a role, since the parameters for current and lagged regulating profit rates are positive and statistically significantly different from zero. Their level suggests that wages grow by 0.08 or 0.09 percentage points with a 10% increase in regulating profitability in the current or previous period, respectively. Recall from Table 2 that the mean value for wage growth in the sample is 3.9% and for regulating profit rates is 11.3%. We consider this an economically significant effect.

Regarding controls, both the capital-labor-ratio and gross output seem to have a negative effect statistically significantly different from zero. However, their economic significance is negligible (0.00008% and 0.0002%, respectively), bearing in mind that for logarithmic covariates on level dependent variables, the percentage impact of a one unit increase is 1% of the parameter estimate. We interpret these to indicate that the time-invariant structural effects are mostly captured by the industry-level intercepts.

[TABLE 3 HERE]

[4] Panel unit root tests indicate stationarity of all variables.

[5] These findings are robust to restricting our sample to manufacturing industries, as documented in Appendix B

5.2. Bayesian estimation

The literature has shown that the assumption of a normally distributed dependent variable, which underlies the OLS fixed effects estimation in the previous section[6], does not describe the empirical evidence for firm-level profit rates (Scharfenaker and Semieniuk 2017: 467) nor for firm-level growth rates (Stanley 1996: p.804) well, but that they are rather Laplace (double exponentially) distributed. Visual inspection suggests that this appears to be the case for the rates of wage growth, as well.

We therefore make use of the larger flexibility of Bayesian econometric modeling to implement a Laplace Likelihood function in a simulation-based estimation next. To do so, we estimate the distribution of wage growth rates around a mean μ (given by Equation 8) with variance σ. Controls are, as above, natural logarithms of the capital-labor-ratio and of gross output.

$$\widehat{\mathrm{w}}_{\mathrm{t,j}} \sim \mathrm{Laplace}\left(\mu_{t,j}, \sigma\right\} = \frac{1}{2\sigma} \exp\left(-\frac{\left|\widehat{\mathrm{w}}_{\mathrm{t,j}} - \mu_{\mathrm{t,j}}\right|}{\sigma}\right) \tag{7}$$

$$\mu_{\mathrm{t,j}} = \beta_{0,\mathrm{j}} + \beta_1\, \hat{\mathrm{r}}_{\mathrm{t,j}} + \beta_2\, \hat{\mathrm{r}}_{\mathrm{t-1,j}} + \beta_3\, \lambda_{\mathrm{j}} + \beta_4\, \mathrm{y}_{\mathrm{j}} \tag{8}$$

$$\sigma \sim \mathrm{Half-Cauchy}(0, 2.5) \tag{9}$$

For flexibility, we furthermore assume a joint prior distribution on the distribution of the $\beta_{0,j}$ parameters, and separate but identical prior distributions for all other covariate parameters. Since we do not have prior knowledge on the effects of either regulating profit rates or the structural controls, we implement Gaussian Normal priors with mean 0 on the parameters as uninformative priors as suggested by Greenberg (2008: p53) and half-Cauchy priors on the variances as suggested by Gelman (2006: p528). We choose a relatively high scale parameter allowing for high variance of the coefficients due to the fat tails of the Cauchy distribution. We assume that no parameter has an impact of more than 100%, and use the property of the Gaussian Normal distribution, where 97% of the probability mass are within 3 standard deviations distance from the mean, to effectively bound the mean of each parameter estimate between -0.3 and 0.3 (corresponding to the minimum and maximum observation of $\widehat{\mathrm{w}}$).

$$\beta_i \sim \mathrm{Normal}\left(\mu_{\beta i}, \sigma_{\beta i}\right) \tag{10}$$

$$\mu_{\beta i} \sim \mathrm{Normal}\ (0, 0.1) \tag{11}$$

$$\sigma_{\beta \mathrm{i}} \sim \mathrm{Half-Cauchy}(0, 2.5) \tag{12}$$

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[6] In Bayesian terms, a linear regression with a normally distributed error term is denoted as the dependent variable being distributed around a Gaussian Normal likelihood function with a mean given by the linear term and some variance, e.g. y ~ Normal $(\alpha + \beta x, \sigma)$; and a fully uninformative prior distribution on all parameters. (Greenberg, 2008: 41f)

Table 4 reports the mean and standard deviation of the estimated parameters. We estimate using a Hybrid Markov Chain algorithm in the software package STAN, in 5000 iterations of 3 chains and with a warm-up period of 500 iterations (cf. Carpenter et al., 2017).

Bayesian certainty retrieved from quantile analysis and direction of the recovered parameter estimates point in a similar direction as the fixed effects OLS model of the previous section. We find a mean of industry-level effects of 0.1752, and parameter estimates of 0.0054 for current and 0.0119 for lagged regulating rates of return. As in the fixed-effects model, the controls have negative mean estimates. Quantile analysis of the parameter estimates shows that all parameters are different from zero with 80% probability.

[TABLE 4 HERE]

Figure 3 plots predictions of a model using a Gaussian Normal likelihood function (equivalent to the fixed effect model estimated in Section 6.1) in dark grey, and those of a Laplace likelihood model in light grey against the estimated density function of empirically observed values for wage growth. Visual inspection suggests that the posterior predictive power of the Laplace likelihood function is superior.

[FIGURE 3 HERE]

To conclude, our main results carried through relaxing the key assumption of normally distributed wage growth rates. We showed not only that wage growth is turbulently equalizing, but that it appears to be correlated – both statistically and economically significantly – to contemporaneous and lagged regulating rates of profit, as our theory suggests. Furthermore, we found persistent dispersion of wage growth rates indicated by industry-level intercept parameters.

As always, caution should be exercised in interpreting our empirical finding. First, our industry-level data covers the U.S. for the years 1987 to 2016. Similar dynamics might not hold for other countries or time periods. Second, while we formulate weakly informative priors, these do co-determine posterior estimates. Third, due to the novelty of investigating turbulent equalization of wage growth, there is little prior empirical work on which to base our prior assumptions about the relationship between regulating profitability and wage growth. The next section checks the robustness of our results.

5.3. Robustness Checks

We perform three robustness checks on our findings. Details are shown in Appendix B. First, it might be assumed that manufacturing industries represent the process of turbulent equalization of profit rates better, and thus also better capture their effect on the turbulent equalization of wage rates. We therefore ran the fixed-effects OLS estimation on a restricted sample of just manufacturing industries. The results remain largely unchanged for direction, effect size and statistical significance.

Second, we show that our Bayesian estimates are not sensitive to the exclusion of controls, and therefore present a bare-bones formulation in Appendix B. Parameter estimates for regulating profit rates vary by less than one standard deviation of the parameter estimation density, and signs remain unchanged.

Third, to ensure that non-stationarity of our wage growth data does not affect our results, we formulate an ARMA (1,1) model. While there is variation in the level of parameter estimates, none of the parameter signs change, and the statistical significance of estimates for current and lagged regulating profit rates remain unaffected, as Appendix B documents.

6. Conclusion

This paper applies the concept of turbulent equalization, which was developed for profit rates, to wages. We argue that inter-industry wage dynamics depend on (1) accepted living standards, which act as a powerful gravitational center that tends to equalize wages; (2) dispersing factors that lead to persistent inter-industry wage differentials, which are well described in the literature; but also (3) turbulently equalizing factors, which are closely linked to firm profitability and possibly labor mobility. All three factors operate in an institutional environment, in which wages are negotiated between organized labor and capital.

Using BEA industry economic accounts data, we find evidence that wage growth rates fluctuate around a gravitational center. Graphically, there is perpetual crossing-over of wage growth rates, which illustrates the turbulence of the process: industries with a competitive advantage in profit rates and, subsequently, in wage growth rates constantly alternate. Econometrically, we show that there is gravitation or convergence in wage rates in 31 of 48 profit-oriented industries with viable data in the U.S. over the years 1987-2016.

For these 31 industries, we then perform a time-series fixed effects panel estimation on the impact of regulating profit rates on wage growth rates, and find a substantial and positive link while controlling for capital intensity and output. For both current and lagged regulating profit rates, an increase by 100 percent implies one additional percent in wage growth. That is, wage growth rates are correlated – both statistically and economically significantly – to contemporaneous and lagged regulating rates of profit, as our theory suggests. We also find evidence for both a center of gravity and for persistent inequality in inter-industry wage growth rates in the parameters of industry fixed effects.

Finally, we observe that our wage growth data does not appear to be normally distributed. We therefore relax the assumption of normally distributed errors using simulation-based Bayesian inference. This model has a higher predictive power, while our main findings carry over qualitatively. It is also robust to restricting our sample to just manufacturing industries, to the inclusion of an ARMA term, and to varying the specification.

To the best of our knowledge, this is the first paper empirically applying the theory of turbulent equalization to wages. Much, therefore, remains to be done. An obvious first step is to investigate whether our results hold over longer time series and a broader set of countries. Second, more detailed controls might improve our insights into the driving forces of turbulent equalization in wages. In particular, industry-level trade union indicators would be an interesting extension. Third, a causal analysis would strengthen our case for the effect of profitability on wage growth. Finally, institutional analysis – which would probably need to come from the intra-industry, firm level – would permit teasing out the concrete channels through which firm profitability is transmitted to wage changes.

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Appendix A: Incremental Wagesand Regulating Profit Rates

Appendix A.1: Deriving Regulating Rates of Return

Following Shaikh (2008, 2016) and Vaona (2011, 2012), we use incremental profit rates as proxies for regulating rates of return, i.e. rates of return on new capital. First, profits in period t, P_t, consist of profits on capital stock from period $t-1$ (old capital), P'_t, and profits on newly invested capital $P_{I,t}$.

$$P_t = P_{I,t} + \mathrm{P'}_{\mathrm{t}} \tag{A1}$$

Deducting profits on old capital from both sides and expanding by the previous year's profits, we can express profits on new capital as the increment in total profits and effects of adjustment in wages, prices, efficiency and capacity utilization of old capital.

$$P_{I,t} = (P_t - \mathrm{P_{t-1}}) + (\mathrm{P_{t-1}} - \mathrm{P'}_{\mathrm{t}}) = \Delta\mathrm{P_t} + \mathrm{P_{t-1}}\left(1 - \frac{P'_t}{P_{t-1}}\right) \tag{A2}$$

The profit rate on new capital is then a residual in the change of profits on old capital, expressed by the ratio ${P'_t}/{P_{t-1}}$. This can be written as a product of ratios of output prices p, economic capacity Y_{cr}, capacity utilization rates u, and profit margins m, all on old capitals in period t and $t-1$.

$$\frac{P'_t}{P_{t-1}} = \left(\frac{p'_t}{p_{t-1}}\right)\left(\frac{Y'_{cr,t}}{Y'_{cr,t-1}}\right)\left(\frac{u'_t}{u_{t-1}}\right)\left(\frac{m'_t}{m_{t-1}}\right) \tag{A2}$$

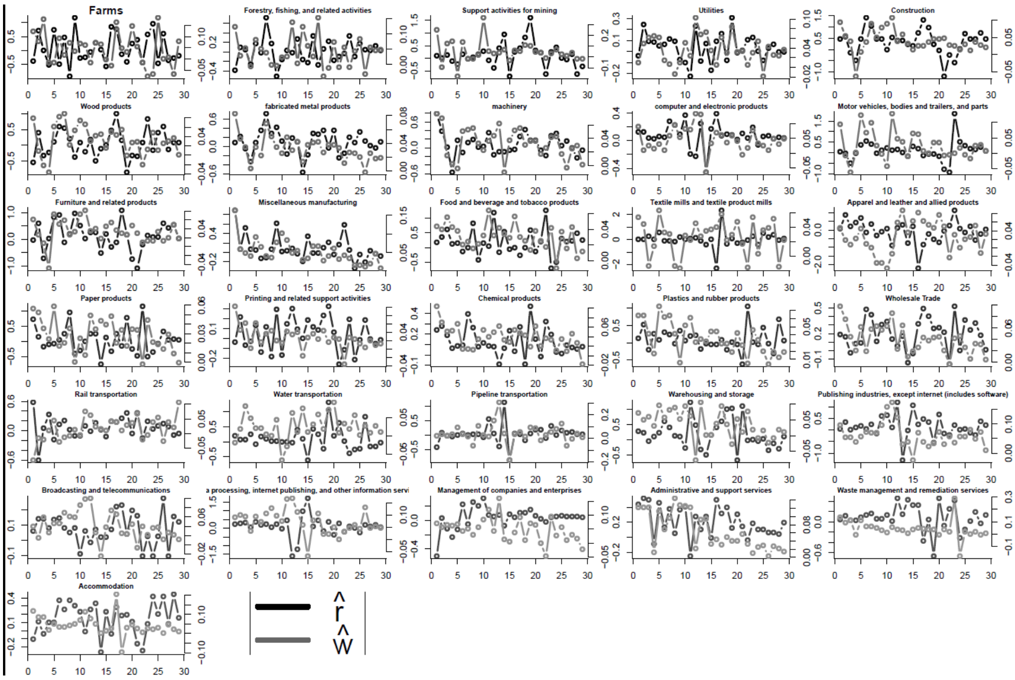
While the first term, the ratio of product prices, will generally increase over time due to inflation, the ratio of output capacity will decrease with the regular retirement of capital assets. In the spirit of real competition, we expect the ratio of capital utilization to gravitate around some normal level and thus to have a neutral impact on average. The ratio of profit margins is linked to labor productivity and taxes, which both tend to be stable and thus can be assumed to also have neutral impact on normal levels. Empirical evidence (Shaikh, 2008) suggests that the dynamics of the first two factors is sum close to one. In this case, gross profits on new capital can be estimated as the change in overall profits, and the rate of return on investment as the ratio of incremental profits over gross investment (Shaikh, 2008: 173f).

Duménil and Lévy (2012) argue against the incremental rates of return as estimators for the profitability of new capital. However, Tescari and Vaona (2013) show that adapting the alternative model proposed, including variations in capital utilization and changes in the wage rate, still provides evidence for gravitation found when using incremental rates of return (Tescari and Vaona, 2013: 17).

$$r_{I,t} \approx \frac{\Delta P_t}{I_t} \tag{A3}$$

Appendix A.2: Gravitation and Convergence in Incremental Wage Rates and in Regulating Profit Rates

Figure A.1: Incremental Wage Rates and Regulating Profit Rates 1987-2016, by Industry



Note: This graph shows deviations from yearly averages of the ratio of change in overall profits over gross investment, i.e. the regulating profit rate $\hat{r}$ (dark) and the growth rate of yearly compensation of employees divided by full-time employee equivalents, i.e. the change in the wage rate $\hat{w}$ (light) for 31 industries in the years 1987-2016.

Source: own calculations, data: BEA Industry Economic Accounts

Table A.1: Gravitation and Convergence in Wage Growth and in Regulating Profit Rates

Industry	IFTC	RKT	$\overline{IFTC}$	$\overline{RKT}$	$\overline{FTC}$
Manufacturing					
Wood products	Convergence	Gravitation	0.0332	0.0604	38.7031
Nonmetallic mineral products	None	Gravitation	0.0284	0.1228	50.5970
primary metals	None	Gravitation	0.0256	0.1575	62.1990
fabricated metal products	Gravitation	Gravitation	0.0320	0.1020	49.4648
machinery	Gravitation	Convergence	0.0328	0.0770	60.3131
computer and electronic products	Gravitation	Gravitation	0.0458	0.0712	83.8007
Electrical equipment, appliances, and components	None	Gravitation	0.0297	0.0656	61.8030
Motor vehicles, bodies and trailers, and parts	Gravitation	Gravitation	0.0255	0.0933	61.6784
Other transportation equipment	None	Gravitation	0.0282	0.0437	78.6765
Furniture and related products	Gravitation	Gravitation	0.0335	0.1372	38.0504
Miscellaneous manufacturing	Convergence	None	0.0507	0.0922	57.2927
Food and beverage and tobacco products	Gravitation	Gravitation	0.0304	0.1828	44.7983
Textile mills and textile product mills	Gravitation	Gravitation	0.0267	0.0232	38.8899
Apparel and leather and allied products	Gravitation	Gravitation	0.0262	-0.0903	36.4178
Paper products	Gravitation	Gravitation	0.0284	0.0534	61.1439
Printing and related support activities	Gravitation	Gravitation	0.0269	0.0487	47.0751
Petroleum and coal products	None	Gravitation	0.0343	0.4189	114.1238
Chemical products	Gravitation	Gravitation	0.0382	0.1330	84.5883
Plastics and rubber products	Gravitation	Gravitation	0.0358	0.0986	46.0181
Non-Manufacturing					
Farms	Gravitation	Gravitation	0.0440	0.0738	29.0828
Forestry, fishing, and related activities	Gravitation	Gravitation	0.0424	0.0174	29.9662
Oil and gas extraction	None	Gravitation	0.0290	0.0998	130.9652
Mining, except oil and gas	None	None	0.0222	0.1911	67.1806
Support activities for mining	Gravitation	Gravitation	0.0492	0.1259	64.0140
Utilities	Gravitation	Gravitation	0.0366	0.0366	95.1816
Construction	Gravitation	Gravitation	0.0394	0.3445	48.0757
Wholesale Trade	Gravitation	Gravitation	0.0401	0.1992	61.1452
Air transportation	None	None	0.0527	0.0808	72.3029
Rail transportation	Convergence	Convergence	0.0174	0.0700	90.8492
Water transportation	Gravitation	Gravitation	0.0254	0.0979	80.2754
Truck transportation	None	Gravitation	0.0373	0.1304	45.3111
Transit and ground passenger transportation	None	Gravitation	0.0471	0.1639	29.0169
Pipeline transportation	Gravitation	Gravitation	0.0409	0.0344	102.0224
Other transportation and support activities	None	Gravitation	0.0362	0.1634	45.7673
Warehousing and storage	Gravitation	Gravitation	0.0369	0.1958	41.5489
Publishing industries, except internet (includes software)	Gravitation	Gravitation	0.0617	0.1546	79.7146
Motion picture and sound recording industries	None	Gravitation	0.0471	0.0768	66.8455
Broadcasting and telecommunications	Convergence	Gravitation	0.0406	0.0767	71.2066
Data processing, internet publishing, and other information services	Gravitation	Gravitation	0.0709	0.1012	79.3763
Computer systems design and related services	None	Gravitation	0.0702	0.0761	82.5228
Miscellaneous professional, scientific, and technical services	None	None	0.0544	0.1497	66.0984
Management of companies and enterprises	Gravitation	None	0.0476	0.0357	93.1283
Administrative and support services	Convergence	Gravitation	0.0636	0.2097	30.0461
Waste management and remediation services	Gravitation	Gravitation	0.0413	0.0853	51.7558
Amusements, gambling, and recreation industries	None	None	0.0478	0.1439	26.7096
Accommodation	Gravitation	None	0.0431	0.1511	30.5757
Food services and drinking places	None	Gravitation	0.0441	0.1387	19.8847
Other services, except government	None	Gravitation	0.0457	0.1184	32.0065
Total			**0.0393**	**0.1132**	**59.9627**

Note: This table shows convergence (i.e., wage rates moving towards a gravitational center) and gravitation (i.e., a stochastic movement around a cross-industry center) for all 48 industries in the years 1987-2016

Source: own calculations, data: BEA Industry Economic Accounts

Appendix B: Robustness

This appendix presents three detailed robustness checks of our model: First, a frequentist OLS model with a sample restricted to manufacturing industries; second, a Bayesian model excluding structural controls; and third, a model including both an autoregressive and a moving average process. Overall, we find that while significance (respectively certainty intervals for the Bayesian models) varies, the signs of the coefficients remain the same. The results presented in the paper are thus qualitatively robust to alternative model formulations and specifications.

Appendix B.1: OLS for Manufacturing Sector Only

The tendency of incremental rates of return to equalize is stronger for manufacturing industries (Vaona, 2011: p21). We therefore restrict our sample to manufacturing industries, and estimate the following regression:

$$\widehat{\mathrm{w}}_{\mathrm{t,j}} = \beta_{0,\mathrm{j}} + \beta_1\, \hat{\mathrm{r}}_{\mathrm{t,j}} + \beta_2\, \hat{\mathrm{r}}_{\mathrm{t-1,j}} + \beta_3\, \lambda_{\mathrm{j}} + \beta_4\, \mathrm{y}_{\mathrm{j}} + \varepsilon_{\mathrm{t,j}} \tag{B1}$$

$\widehat{\mathrm{w}}_{\mathrm{t,j}} = \beta_{0,\mathrm{j}} + \beta_1\, \hat{\mathrm{r}}_{\mathrm{t,j}} + \beta_2\, \hat{\mathrm{r}}_{\mathrm{t-1,j}} + \beta_3\, \lambda_{\mathrm{j}} + \beta_4\, \mathrm{y}_{\mathrm{j}} + \varepsilon_{\mathrm{t,j}}$ B1

[TABLE B1 HERE]

Table B1 shows the results. Regulating profit rates both in the current and in the last period retain their positive and highly statistically significant impact on the change in the wage rate. Indeed, as expected, profitability in the current period seems to be linked to wage increases more strongly when only manufacturing industries are considered. Furthermore, the standard deviation of fixed effects remains fairly high and the capital-labour ratio is statistically significantly negatively related to wage growth; only gross output loses its statistical significance in this model.

Appendix B.2: Bayesian Rump Model

Next, we exclude controls in order to investigate whether the findings of our Bayesian model are robust alternative specifications. This Bayesian model is formulated as follows:

$$\widehat{\mathrm{w}}_{\mathrm{t,j}} \sim \mathrm{Laplace}\left(\mu_{t,j}, \sigma\right\} = \frac{1}{2\sigma} \exp\left(-\frac{\left|\widehat{\mathrm{w}}_{\mathrm{t,j}} - \mu_{\mathrm{t,j}}\right|}{\sigma}\right) \tag{B2}$$

$$\mu_{\mathrm{t,j}} = \beta_{0,\mathrm{j}}\mathrm{FE} + \beta_1\, \hat{\mathrm{r}}_{\mathrm{t,j}} + \beta_2\, \hat{\mathrm{r}}_{\mathrm{t-1,j}}\varepsilon_{\mathrm{t,j}} \tag{B3}$$

$$\sigma \sim \mathrm{Half} - \mathrm{Cauchy}(0, 2.5) \tag{B4}$$

$$\beta_i \sim \mathrm{Normal}\ \left(\mu_{\beta i}, \sigma_{\beta i}\right) \tag{B5}$$

$$\mu_{\beta i} \sim \mathrm{Normal}\ (0{,}0.1) \tag{B6}$$

$$\sigma_{\beta i} \sim \mathrm{Half-Cauchy}(0, 2.5) \tag{B7}$$

[TABLE B2 HERE]

Table B2 shows the results. Both signs and certainty of the coefficients corresponding to regulating profit rates in the current and foregone period remain the same when the model is reduced to these covariates. This indicates that the choice of structural controls did not bias the estimation results.

Appendix B.3: ARMA(1,1) Process

Finally, to check whether non-stationarity of our wage growth data affects our Bayesian results, we include a time series process in the model. The number of lags both in the autoregressive and in the moving average process is chosen due to certainty intervals.

$$\widehat{\mathrm{w}}_{\mathrm{t,j}} \sim \mathrm{Laplace}\big(\mu_{t,j}, \sigma\big\} = \frac{1}{2\sigma} \exp\left(-\frac{\left|\widehat{\mathrm{w}}_{\mathrm{t,j}} - \mu_{\mathrm{t,j}}\right|}{\sigma}\right) \tag{B8}$$

$$\mu_{\mathrm{t,j}} = \beta_{0\,j} + \beta_{1_1}\hat{\mathrm{r}}_{t,j} + \beta_2\hat{r}_{t-1,j} + \beta_3\lambda_{t,j} + \beta_4 y_{t,j} + \beta_5\widehat{w}_{t-1,j} + \epsilon_t \tag{B9}$$

$$\varepsilon_t = (\alpha_j + \beta\,\widehat{\mathrm{w}}_{t-1,j} + \gamma_1\hat{\mathrm{r}}_{t,j} + \gamma_2\hat{r}_{t-1,j}) - \widehat{w}_{t,j} - \theta\varepsilon_{t-1} \quad \text{(B10}$$

$$\sigma \sim \mathrm{Half-Cauchy}(0, 2.5) \tag{B11}$$

$$\beta_i \sim \mathrm{Normal}\,\big(\mu_{\beta i}, \sigma_{\beta i}\big) \tag{B12}$$

$$\mu_{\beta i} \sim \mathrm{Normal}\ (0{,}0.1) \tag{B13}$$

$$\sigma_{\beta i} \sim \mathrm{Half-Cauchy}(0, 2.5) \tag{B14}$$

[TABLE B3 HERE]Estimation results are reported in Table B3. While we find both processes to co-determine wage increases, the sign and certainty intervals corresponding to the other covariates do not change. This indicates that not including the underlying time series process did not bias our findings.

Tables and Figures

Table 1: Factors affecting wage changes

Component	Level	Effect
Living standards	National	Equalization
Occupational structure	Industry	Dispersion
Profitability	Industry	Turbulent equalization

Source: own elaboration

Table 2: Descriptive Statistics

	Mean	Std. dev.	Min.	Median	Max.
$\widehat{w}$	0.0393	0.03928	-0.1866	0.0353	0.3626
r	0.1132	0.3566	-2.2970	0.0888	3.5556
w	59.9630	22.64	9.2920	52.9710	202.9900
λ	0.438950	0.7017	0.009004	0.168784	4.391121
y	253183	257874	13551	149360	1577759

Note: This table shows mean, standard deviation, minimum, median and maximum observation for (1) the growth rate of yearly compensation of employees divided by full-time employee equivalents, i.e. the change in the wage rate $\widehat{w}$, (2) the ratio of change in overall profits over gross investment, i.e. the regulating profit rate r, (3) the average industry wage level w, (4) the industry-level average capital-labor ratio λ and (5) industry-level average gross output y. Standard deviations are the mean of yearly standard deviations.

Source: own calculations, data: BEA Industry Economic Accounts

Table 3: Estimation of wage changes (OLS)

	Dependent variable $\widehat{w}_t$
FE (mean)	0.2536
	(0.0253)
$\hat{r}_t$	0.0078**
	(0.0038)
$\hat{r}_{t-1}$	0.0093**
	(0.0037)
λ	-0.0084*
	(0.0044)
y	-0.0200***
	(0.0039)
N	868
R^2	0.045659

Note: This table shows the OLS estimate for the change in the wage rate $\widehat{w}$. Independent variables are (1) the mean of the fixed effects dummies (*FE*), the (2) contemporaneous and (3) lagged industry regulating profit rate $\hat{r}_t$ and $\hat{r}_{t-1}$, (4) the industry capital-output ratio λ, and (5) industry gross output y. Standard deviations in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

Source: own calculations, data: BEA Industry Economic Accounts

Table 4: Estimation of wage changes (Bayesian)

	Dependent variable $\hat{w}_t$
$\hat{r}_t$	0.0054**
	(0.0033)
$\hat{r}_{t-1}$	0.0119***
	(0.0027)
λ	-0.0037*
	(0.0024)
y	-0.0124***
	(0.0035)

Note: This table shows the Bayesian estimate for the change in the wage rate $\hat{w}$ using 5000 iterations. Independent variables are the (1) contemporaneous and (2) lagged industry regulating profit rate $\hat{r}_t$ and $\hat{r}_{t-1}$, (3) the industry capital-output ratio λ, and (4) industry gross output y. Standard deviations in parentheses. *** certainty > 99 %, ** certainty > 95 %, * certainty > 90 %.

Source: own calculations, data: BEA Industry Economic Accounts

Table B.1: Estimation of wage changes (OLS restricted sample)

	Dependent variable $\widehat{w}_t$
FE (mean)	-0.415
	(0.0164)
$\hat{r}_t$	0.0125***
	(0.0026)
$\hat{r}_{t-1}$	0.0092***
	(0.0027)
λ	-0.0193***
	(0.0049)
y	0.0033
	(0.0052)
N	377
R^2	(0.12176)

Note: This table shows the OLS estimate for the change in the wage rate $\widehat{w}$ for manufacturing industries. Independent variables are (1) the mean of the fixed effects dummies (*FE*), the (2) contemporaneous and (3) lagged industry regulating profit rate $\hat{r}_t$ and $\hat{r}_{t-1}$, (4) the industry capital-output ratio λ, and (5) industry gross output y. Standard deviations in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Source: own calculations, data: BEA Industry Economic Accounts

Table B.2: Estimation of wage changes (Bayesian Rump Model)

	Dependent variable $\hat{w}_t$
FE (mean)	0.0329
	(0.0057)
$\hat{r}_t$	0.0070**
	(0.0034)
$\hat{r}_{t-1}$	0.0118***
	(0.0030)
N	868

Note: This table shows the Bayesian estimate for the change in the wage rate $\hat{w}$ using 5000 iterations. Independent variables are the (1) contemporaneous and (2) lagged industry regulating profit rate $\hat{r}_t$ and $\hat{r}_{t-1}$. Standard deviations in parentheses. *** certainty > 99 %, ** certainty > 95 %, * certainty > 90 %.

Source: own calculations, data: BEA Industry Economic Accounts

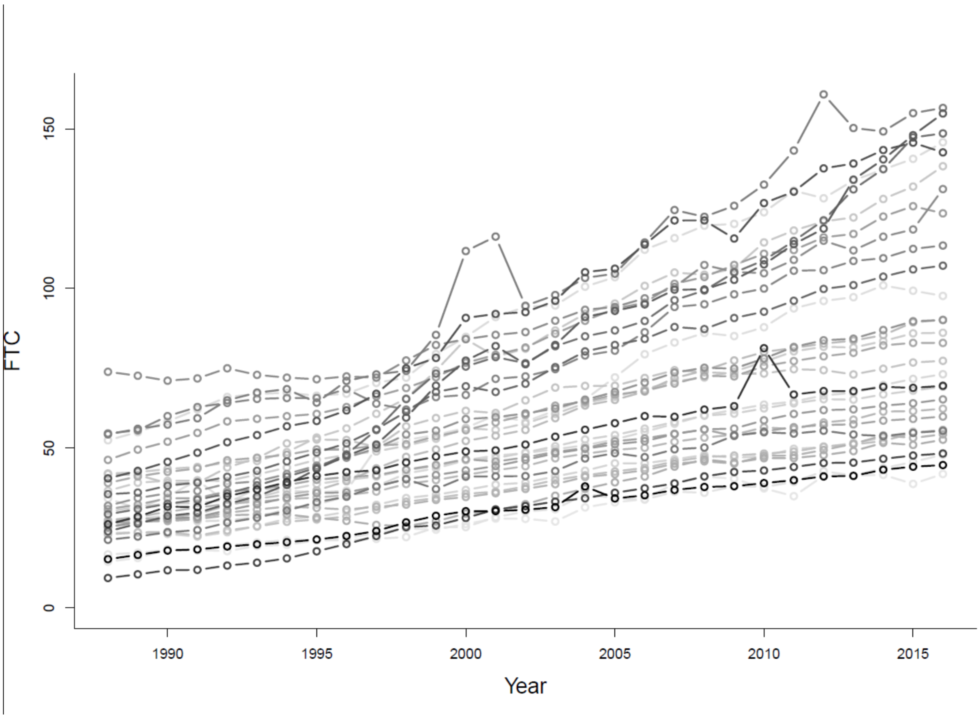
Table B.3: Estimation of wage changes (Bayesian including ARMA(1,1)

	Dependent variable $\widehat{\mathrm{w}}_t$
FE (mean)	0.0938
	(0.0078)
$\hat{\mathrm{r}}_t$	0.0053**
	(0.0031)
$\hat{\mathrm{r}}_{t-1}$	0.0089***
	(0.0033)
λ	-0.0014
	(0.0017)
y	-0.0058***
	(0.0034)
$\widehat{\mathrm{w}}_{t-1}$	0.2728***
	(0.1211)
MA	-0.1967**
	(0.1129)
N	868

Note: This table shows the OLS estimate for the change in the wage rate $\widehat{w}$. Independent variables are (1) the mean of the fixed effects dummies (*FE*), the (2) contemporaneous and (3) lagged industry regulating profit rate $\hat{\mathrm{r}}_t$ and $\hat{\mathrm{r}}_{t-1}$, (4) the industry capital-output ratio λ, (5) industry gross output y, (6) the lagged change in the wage rate $\widehat{w}_{t-1}$, and (7) a moving average term MA. Standard deviations in parentheses. *** certainty > 99 %, ** certainty > 95 %, * certainty > 90 %.

Source: own calculations, data: BEA Industry Economic Accounts

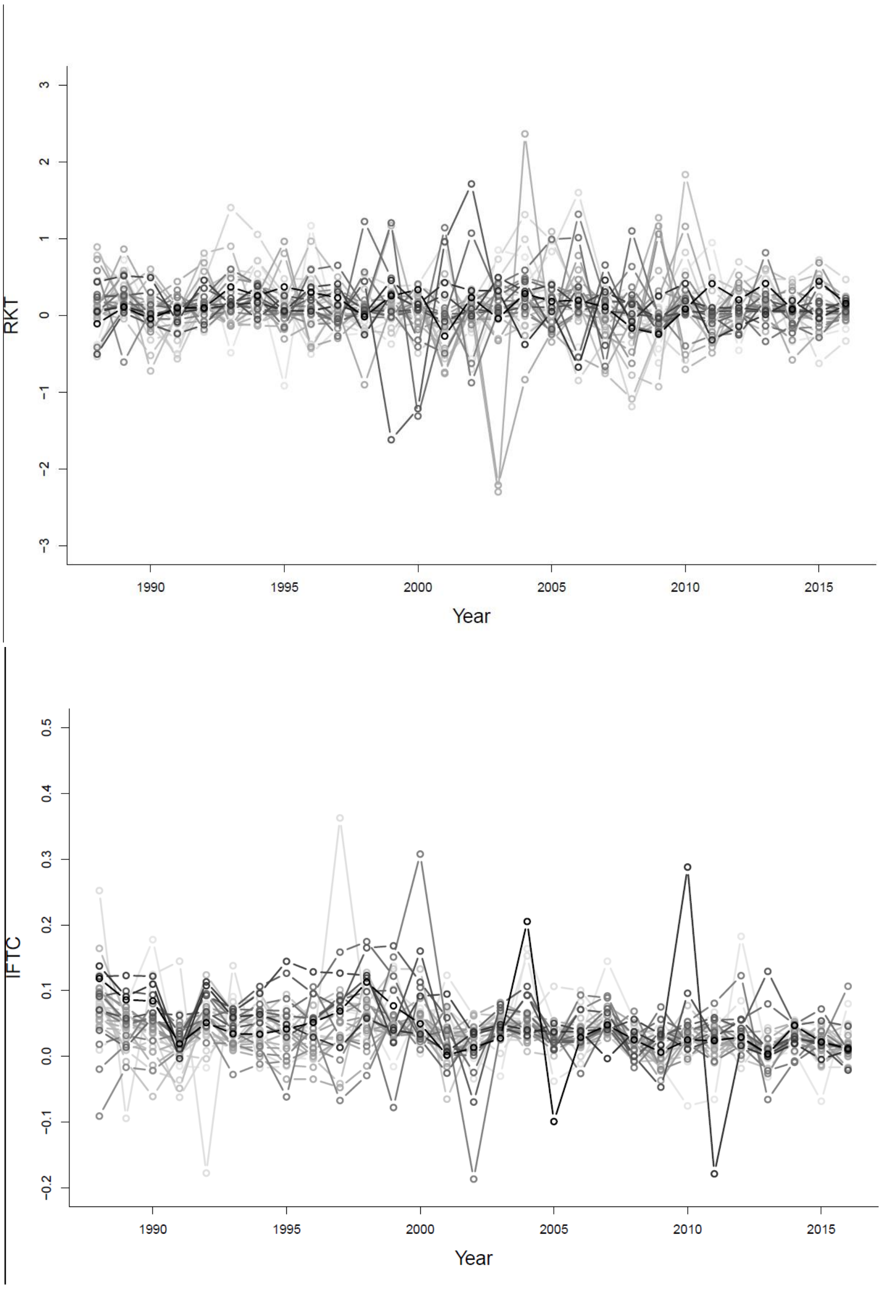
Figure 1: Wage Levels in 48 Industries, 1987-2016



Note: This graph shows industry-level compensation per full time employee equivalent.

Source: own calculations, data: BEA Industry Economic Accounts

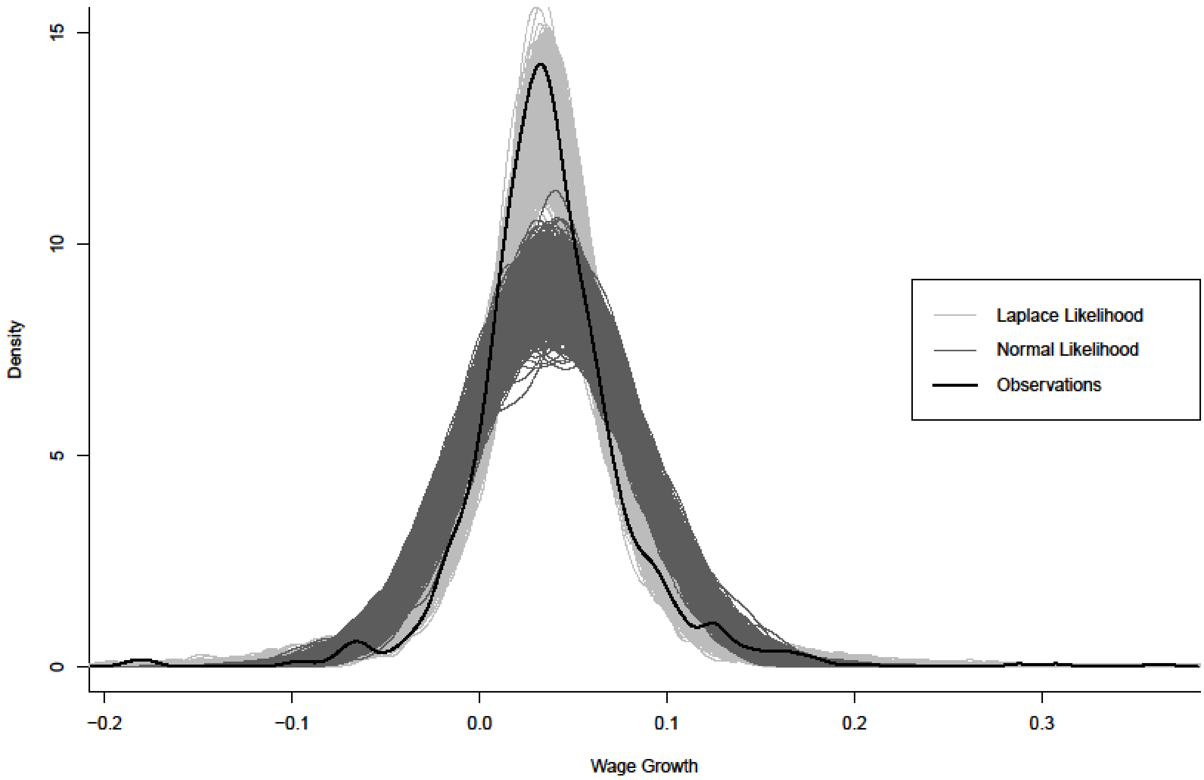
Figure 2: Deviations of Regulating Rates of Return (top) and Incremental Wages (bottom) from Yearly Averages for 48 Industries, 1987-2016



Note: This graph shows deviations from yearly averages of (1) the ratio of change in overall profits over gross investment, i.e. the regulating profit rate (top) and (2) the growth rate of yearly compensation of employees divided by full-time employee equivalents, i.e. the change in the wage rate for 48 industries in the years 1987-2016.

Source: own calculations, data: BEA Industry Economic Accounts

Figure 3:



Note: This figure plots (1) the density function of empirically observed values for the growth rate of yearly compensation of employees divided by full-time employee equivalents, i.e. the change in the wage rate, and the predictions of a model using (2) a Gaussian Normal likelihood function (dark grey), and (3) a Laplace likelihood model (light grey).

Source: own calculations, data: BEA Industry Economic Accounts