Fixed Costs and Inter-Industry Wage Differentials

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Abstract

This paper presents a theoretical model which addresses the underlying source of inter-industry wage differentials. Key assumptions are imperfect mobility of workers between industries (on-the job search in a frictional labor market), free entry of firms to all industries, and imperfect substitutability between products from different industries. I show that differences in fixed costs across industries translate into inter-industry wage differentials in this framework. The model is consistent with the positive inter-industry cross-correlations between wages, value-added, average firm size, profitability and firm concentration. Calibrating the model to the US manufacturing sector (NBER-CES) the model quantitatively replicates the observed value-added and wage dispersions. Finally, the model correctly predicts an increase in the upper tail of inter-industry wage dispersion between 1965 and 2005.

Keywords: inter-industry wage differentials; on-the-job search; industry structure
JEL Classification: J20, J31, L16, L60

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1 Introduction

It is a well established fact that different industries pay different wages. This fact is robust to the inclusion of controls for observable worker characteristics, as Krueger and Summers (1987) emphasized in their pioneering work. Many studies have corroborated their findings since then. There is broad evidence that accounting for various measures of unobserved ability on the worker side does not change the picture (Krueger and Summers, 1988; Gibbons and Katz, 1992; Blackburn and Neumark, 1992; Martins, 2004; Björklund et al., 2007). Also, the ranking of industries by average wages is stable across time and space (Dickens and Katz, 1986; Gittleman and Wolff, 1993; Vainiomäki and Laaksonen, 1995) and inter-industry wage differentials cannot be explained by compensating wage differentials (Krueger and Summers, 1988). Latest studies using linked employer-employee data conclude that intrinsic industry heterogeneity is quantitatively more important than worker heterogeneity to explain inter-industry wage differentials (Abowd et al., 2005). Inter-industry wage differentials cannot be explained away. Furthermore, there exist well documented persistent pattern of cross-correlations (Dickens and Katz, 1986; Krueger and Summers, 1987) between industries: wages, value-added, firm-size, profitability, and firm concentration are all pairwise positively correlated. As Dickens and Katz (1986) point out, the correlation pattern suggests that there is *one underlying factor* which can explain the entire distribution of industry characteristics. However, a theoretical model which is consistent with this pattern of correlations and addresses the underlying source of inter-industry wage differentials is still missing in the literature.

This paper proposes a search-theoretic model where *differences in fixed costs* across industries are the underlying source of inter-industry wage differentials. It is well known that on-the-job search models in the spirit of Burdett and Mortensen (1998) generate a positive correlation between firm-size, wages, value-added and profitability.[1] Intuitively, inter-industry wage differentials can persist in a framework with on-the-job search since workers are mobile between industries only to a limited extent because there are frictions in the labor market. However, search theoretic explanations of inter-industry wage differentials generally take the heterogeneity in firms' value-added and the industry structure, namely the firm concentration in different industries, as given, see for example Montgomery (1991).[2] The contribution of this paper is to provide an economic rationale

[1] Firm size is increasing wages in these models, because the higher a firm's wage, the more workers the firm can attract and the less likely it is to lose them to other firms. Firms with a high value-added per worker have a larger benefit of attracting workers and are thus willing to pay higher wages. Given a higher value-added, firms will always make higher operating profits, since they are in the better position to start with.

[2] Exceptions are Acemoglu and Shimer (2000), Postel-Vinay and Robin (2002) and Mortensen (2003), who allow for an endogenous choice of technological efficiency. They do not talk about their models' potential to address inter-industry wage differentials and their mechanism is quite different from the proposed model here, since they do not address goods demand constraints. Implicitly, they assume that output can be sold at a constant price, independent of the quantity. By contrast, my model takes into account that products from different industries are imperfectly substitutable, and therefore the law of demand implies that an industry's output price level decreases

for industry differences in value-added, and to determine the industry structure endogenously. Key assumptions are that industries differ in fixed costs,[3] firms have free entry to all industries in the spirit of Baumol, Panzar and Willig (1982), products from different industries are imperfectly substitutable (the law of demand holds at the industry level) and workers are imperfectly mobile between industries (on-the-job search). These model features interact in the following way. Firms which operate in high fixed cost industries want to be large to recover the high fixed costs. Being large, however, is costly in the frictional labor market, since one has to pay high wages to attract and retain many workers. Firms in a given industry can only afford to pay high wages if the industry's output price, and thereby the value-added per worker, is sufficiently high. An industry's output price is decreasing in the industry's output level, because of the law of demand. This limits room for entry to high fixed cost industries and implies a high firm concentration in these industries in equilibrium.[4] Thus, in equilibrium high fixed cost industries are operated by a few, large firms that pay high wages, can sell their output at high prices and therefore feature high value-added, and make high operating profits which are equal to the fixed costs because of free entry. This is consistent with the correlation patterns documented above and suggests that differences in fixed costs are the underlying source of inter-industry differentials. The proposed model bridges the gap between models of endogenous industry structure and on-the-job search. On-the-job search provides a rationale for increasing marginal costs in the former class of models, while free entry of firms and differences in fixed costs provide a rationale for differences in value-added in the latter.

I assess the ability of the model to explain key features of inter-industry wage dispersion and its evolution over time quantitatively using 6-digit-level industry data (473 industries) for the US manufacturing sector in the years 1965-2005 from the NBER-CES database. The baseline calibration is for the time period 2000-2005. The data show a unimodal hump-shaped wage dispersion. This shape is in line with a large empirical literature which documents that wage dispersion is persistently unimodal hump-shaped at various aggregation levels (Christensen et al., 2004). My model generates a unimodal hump-shaped wage dispersion because of the interaction of two forces: on-the-job search and the law of demand. Note that the pure mechanism of on-the-job search gen-

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as the industry's output increases.

[3]The assumption that industries differ in fixed costs is also motivated by the fact that some industries are more profitable than others in the long run. Profits are typically measured in the data as operating profits ($value\ added - pay$), where $value\ added = (revenues - materialcosts)$. Potential fixed costs (for example capital structure and equipment) are not taken into account. If there is free entry, differences in operating profits should reflect differences in fixed costs in the long run

[4]If industries differ in fixed costs, but within each industry marginal costs of production are constant, in equilibrium only one firm will operate in each industry (Tirole, 1988) and price will equal average costs. This is a result of the theory of perfectly contestable markets (Baumol, Panzar and Willig, 1982). The intuition is, that if the incumbent firm charged higher prices, another firm could enter, charge slightly lower prices (but still above average costs) and make positive profits. As Baumol (1982) pointed out in his seminal paper, if average costs are not monotone decreasing (as it is the case in the presence of fixed costs and constant marginal costs) but U shaped, the number of firms in the industry is pinned down by the most efficient firm scale, i.e. the minimum of the average cost curve. Interestingly, fixed costs and on-the-job search generate a U shaped average cost curve

erates upward sloping wage densities since workers switch to high wage paying employers whenever they have the chance to. Consequently, if there is no scarcity of high wage offers, most workers end up at high wages in equilibrium. I offer an explanation for the scarcity of high wage offers based on the law of demand. As pointed out before, firms in industries with high fixed costs pay high wages and are large in equilibrium. Since high prices are required to keep a high fixed cost industry profitable, the industry's output must be low and only a few workers can work in this industry. Quantitatively, the model fit is very good. Targeting only two selected moments of the value-added dispersion (v_{90}/v_{50} and v_{50}/v_{10}) in the final period 2000-2005, the model generates a very good fit of the wage dispersion, in particular the upper tail (w_{90}/w_{50}). To see if the model is able to predict key dispersion changes over time I recalibrate the model for the time period 1965-1970 and compare it with the baseline calibration for the period 2000-2005. The only parameters changing over time are total factor productivity and the scale but not the relative dispersion of fixed costs. The change in total factor productivity is estimated and the change in the scale of fixed costs is calibrated to target a constant unemployment rate as observed in the data. The model correctly predicts a pronounced increase in the upper tail of both the value-added (v_{90}/v_{50}) and wage dispersions (w_{90}/w_{50}).

The paper is organized as follows. The next section presents some reduced form evidence regarding recent inter-industry patterns within the US manufacturing sector. The model is described in section 3, followed by the calibration in section 4. The quantitative results with respect to the shape of the wage dispersion and its evolution over time are presented in section 5. Section 6 concludes.

2 Reduced form evidence: inter-industry patterns

Table 1 shows some reduced form evidence for inter-industry correlation patterns within the US manufacturing sector (NBER-CES manufacturing database, 473 industries) in the most recent year available, which is 2005. The documented cross-correlations are in line with the previous literature (Dickens and Katz, 1986; Krueger and Summers, 1987). Wages are positively correlated with value-added and average firm-size. The number of firms (source: County Business Patterns) in each industry is negatively correlated with wages, corresponding to a higher firm concentration in high wage industries. Material costs per hour (matcost/hour) are positively correlated with wages. This fact has not been paid attention to so far in the literature. However, it is closely related to the well documented fact that high wage industries are more capital intensive. The reason why I look at the correlation of material costs per hour with wages is that Burnside, Eichenbaum and Rebelo (1995) suggest that material costs are the relevant variable to measure capital utilization while the capital stock (equipment and structure) is not productive per se. Consequently, material costs per hour can be interpreted as the capital utilization per labor unit. The positive correlation between material costs per hour and wages suggests that industries with a higher capital intensity pay higher wages. I consider two alternative measures for average fixed costs per firm in a given industry: operating profits and the real capital stock. Let me briefly discuss the motivation and potential caveats for either one of them. Operating profits are total revenues net of labor and material costs and equal per period fixed costs by definition in my model due to the free entry assumption. However, the model equilibrium refers to the long run steady state. Clearly, operating profits in the data might temporarily differ from fixed costs. An alternative measure for fixed costs is the average real capital stock (equipment and structure) per firm in a given industry. This is motivated by Burnside, Eichenbaum and Rebelo's (1995) observation that the capital stock is not productive per se and capital should therefore be modeled as a fixed cost rather than an input in the production function. There are two caveats to this measure. On the one hand, fixed costs do not exclusively depend on the capital stock but also on expenditures on advertising or research and development. On the other hand, the relevant fixed costs per period also depend on the expected life span of a firm in a given industry. If the expected life span varies by industry there is not necessarily a monotone increasing relationship between the capital stock per firm and per period fixed costs. Bearing these issues in mind, I find a positive correlation between the two fixed costs measures. Also both fixed cost measures show a strong positive correlation with value-added. I conclude that the correlation patterns in table 1 are previously found in the literature and consistent with my model predictions.

Variables	wage	value-added	firm-size	#firms	matcost	profits	capital
wage	1.00						
value-added	0.46	1.00					
	(0.00)						
firm-size	0.32	0.22	1.00				
	(0.00)	(0.00)					
#firms	-0.13	-0.10	-0.17	1.00			
	(0.00)	(0.02)	(0.00)				
matcost/hour	0.43	0.67	0.29	-0.14	1.00		
	(0.00)	(0.00)	(0.00)	(0.00)			
operating profits	0.35	0.82	0.44	-0.07	0.47	1.00	
	(0.00)	(0.00)	(0.00)	(0.12)	(0.00)		
capital stock	0.49	0.53	0.61	-0.13	0.61	0.60	1.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	

Table 1: Cross-correlation table industry characteristics, 443 (6-digit) industries, year 2005
significance of each correlation reported in brackets
source: NBER-CES, CBP, see Appendix 7.2 for details

Table 2 shows the pattern of industry values of different variables at the 2-digit SIC level to illustrate the concrete industry ranking, ordered by wages. First, note that the reported correlation patterns are also reflected at this higher level of aggregation: high wage industries like "Transportation" or "Instruments" generate a higher value-added per hour worked, are operated by larger firms, and use more material per worker in the production process compared to low wage industries like "Apparel", "Leather" or "Textile". Fixed costs are the average operating profits per firm in each industry, reported in thousands of US$ in the year 2005. Not surprisingly, fixed costs are much lower in the textile related industries in comparison to industries like "Transportation" or "Instruments". As mentioned in the introduction, there is a vast literature which shows that the pattern of inter-industry differentials is robust to the inclusion of human capital controls. I can confirm this fact also for more recent years, using CPS data (see Appendix 7.2.4 for details).

industry	**wage**	**value added**	**firm size**	**matcost**	**fixed costs**
Apparel	13.80	37.20	31.25	83.29	1423.97
Leather	14.76	37.77	25.18	86.54	1145.69
Textile	15.32	47.50	26.59	140.02	1757.40
Lumber	15.70	39.75	40.30	111.86	2021.37
Furniture	16.74	46.24	19.65	91.18	1165.40
Food	17.15	90.22	58.18	223.02	8663.81
Rubber	18.17	52.59	59.48	116.93	4225.11
Miscellaneous	18.70	53.60	10.54	84.84	737.62
Stone	19.44	65.56	27.51	107.67	2689.19
Printing	19.89	47.00	17.80	60.16	953.55
Fabricated Metal	20.06	53.59	21.46	106.49	1492.18
Paper	22.25	81.2	90.57	198.34	11362.75
Primary Metal	22.76	80.92	90.19	282.15	11299.05
Machinery	23.00	69.12	53.59	145.34	5056.61
Electronic	24.06	90.28	65.86	138.43	8827.27
Transportation	27.86	87.65	99.61	307.95	11966.25
Instruments	29.46	92.92	109.87	101.45	14075.41
Chemicals	29.54	217.05	54.07	377.49	20819.77
Tobacco	30.36	885.52	5.92	261.27	10239.50
Petroleum	35.48	530.55	42.93	3578.75	46341.96

Table 2: Industry patterns in 2005, 20 (2-digit) industries
hourly wages, value added and material cost in US$, fixed costs per firm per year in 1000 US$
source: NBER-CES, CBP, see Appendix 7.2 for details

3 The Model

3.1 Industries

There is a continuum of different industries, where each industry is indexed by i. I assume that each industry has a particular fixed cost of production $j \in [\underline{j}, \overline{j}]$. For expositional clarity I assume a linear mapping[5] between fixed costs j and industries i, and choose the scale of the industry index i such that it is exactly equal to the fixed cost j:

$$j = i. \tag{1}$$

That is, both industries and fixed costs can be referred to by the i index. The production function is assumed to be linear in labor input:[6]

$$Q_i^S = AL_i, \tag{2}$$

where Q_i^S is total output and L_i total labor input in industry i. The labor productivity A is assumed to be constant for all industries.[7] Note that the fixed cost i does not enter the production function. Following Burnside, Eichenbaum and Rebelo (1995), I interpret the fixed costs as capital structure or equipment which is not productive per se.

3.2 Workers

There is a fixed mass of workers, normalized to $\omega = 1$. Workers supply labor, own capital (i.e. they receive the fixed cost payment from the firms) and consume. Time is continuous and workers receive job offers while employed and while unemployed. Job offers arrive to workers at a finite rate $\lambda < \infty$ and they come randomly from different firms in different industries. This framework is motivated by the fact that not all workers are suited to work in every industry (who is suited to work for which is assumed to be random), and there is limited mobility of workers between industries ($\lambda < \infty$). Matches are destroyed at an exogenous rate δ. The job offer arrival rate $\lambda = \Phi\mu$ depends on some exogenous parameter Φ, which can be interpreted as the contact efficiency, and the labor market tightness μ, which is an endogenous object. Note that labor market tightness is

[5]Changing the mapping of industries i into fixed costs j to be convex (concave) would imply a lower (higher) density of industries at high fixed costs, leaving less room for firms to operate there. While it might be interesting to explore the additional degree of freedom of potential non linear mappings of industries into fixed costs for empirical purposes, I focus on the simple linear case here, i.e. I assume a uniform distribution of industries on the fixed cost support.

[6]For the quantitative part I assume a Cobb-Douglas production function in labor and material input. As including material in the production function does not change the main model mechanics, the details are left to the Appendix.

[7]This assumption will be relaxed later on in the quantitative part, where I allow for material in the production function and labor productivity will hence depend on the firm's optimal material choice.

defined as the ratio of firms to searching workers as standard. Because of on-the-job search the mass of searching workers is equal to the total mass of workers, which is normalized to 1. That is, μ denotes the mass of firms operating in equilibrium (in all industries) and will be determined by free entry.

Preferences are such that (1) there is demand for products from every industry (*taste for industry*), (2) consumers want to consume relatively less of a given industry's output if its price is higher (*law of demand*). Consider standard constant elasticity of substitution (CES) preferences, which exhibit both properties, and in particular give yield the following demand condition:[8]

$$Q_i^D \propto p_i^{-\epsilon} \tag{3}$$

That is: the measure of output demand for a given industry's output Q_i^D is decreasing in its equilibrium price p_i. This effect is increasing in the substitution elasticity ϵ.

3.3 Firms

A crucial assumption is that there is free entry of firms to each industry, and within each industry products are perfect substitutes. Firms therefore take the output price p_i in a given industry i as given. In each industry, firms will choose the wage w to maximize steady state operating profits:

$$(Ap_i - w)l(w) \tag{4}$$

Note that the firm level steady state employment $l(w)$ depends on the firm's wage policy. This is due to the frictional labor market structure. Firms post wages, i.e. a job offer is equivalent to a wage offer from the worker's perspective. Given that a job offer has arrived, unemployed workers are happy to accept any wage offer but employed workers accept an offer only if it makes them better off than their current wage. Hence, the pool of workers a firm can hire from is increasing in the wage the firm pays. To put it differently: the measure of a firm's hires h at any point in time will depend positively on the wage rate w:

$$h'(w) > 0. \tag{5}$$

On the other hand, workers who are employed at a high wage firm are less likely to leave that firm, since they will choose do so only if they receive an offer which makes them better off, which

[8]Similar results can be obtained with any other demand structure featuring the above mentioned properties. The CES preferences are chosen mainly for two reasons: (i) they are standard in the literature, (ii) even though households will have different wage income ex-post due to equilibrium wage dispersion, this does not impact the consumption pattern in the case of CES preferences, since the shares in which different products from different industries are consumed are independent of the income level.

is becoming less likely the higher their current wage. Hence, the separation rate s at any point in time will depend negatively on a firm's wage w:

$$s'(w) < 0. \tag{6}$$

In the steady state firm level employment does not change, i.e. hires equal separations:

$$h(w) = l(w)s(w). \tag{7}$$

It immediately follows that firm size is increasing in the wage rate in steady state:

$$l(w) = \frac{h(w)}{s(w)} \tag{8}$$

The intuition for the positive relationship between firm size and wages is that employers that pay low wages are very unattractive for workers: they will only be able to hire workers who are currently worse off and will be able to retain them only as long as they do not receive a better offer. Hence, inflow of workers to low wage firms is small and outflow is large, which makes low wage firms small in equilibrium. In order to increase their firm size, firms have to pay higher wages. Firms will increase wages up to the point where the gain from higher firm-level employment $l(w)$ is exactly offset by a lower markup $(Ap_i - w)$. Given this structure, the following Burdett and Mortensen (1998) results can be directly applied: (i) firms with higher output prices p_i will make larger operating profits $(Ap_i - w)l(w)$ and (ii) firms with higher output prices p_i will find it optimal to post higher wages. Comparing a low price firm to a high price firm provides the intuition for the results: Assume, that the low price firm chooses their optimal wage policy w^*. Clearly, the high price firm could always adopt the same wage policy w^*, face the same firm-level employment $l(w^*)$, but make a strictly higher markup, because of the higher output price. Hence operating profits will always be larger for the high price firm. It turns out that it is optimal for the high price firms to offer workers higher wages. The intuition is that firms with a high price (i.e. a high revenue productivity) per worker have a high opportunity cost of not filling a position and will hence engage more in wage competition by posting high wages to ensure that they attract many workers. Given the price p_i, firms choose their optimal wage policy $w(p_i)$. Note that free entry of firms to every industry will ensure that in equilibrium:

$$(Ap_i - w(p_i))l(w(p_i)) = i. \tag{9}$$

3.4 Equilibrium

Before I define the equilibrium, I first characterize fundamental properties of the equilibrium, which can be summarized by the following two propositions and are illustrated in Figure 1.

Proposition 3.1 *Industries with higher fixed costs i feature higher prices p_i, higher wages w_i, larger firm-level employment l_i, and a lower firm density f_i*

Proof Using the Burdett and Mortensen (1998) result of the single crossing property, firms with higher prices will always make bigger operating profits. That is, the left hand side of (9) is monotonically increasing in p_i. Implicit differentiation immediately yields that equilibrium prices must be increasing in fixed costs as illustrated in the upper left quadrant of Figure 1. Given $p'(i) > 0$ and as a result of the single crossing property $w'(p) > 0$, illustrated in the upper right quadrant, industries with higher fixed costs feature higher wages $w'(i) > 0$. The larger firm-level employment follows from the fact that firm-level employment is increasing in the wage in steady state, recall (8). The lower left quadrant illustrates the positive relationship between employment and wages in steady state. Since the equilibrium price is monotonically decreasing in the total employment in a given industry L_i, but $p'(i) > 0$, it follows immediately that $L'(i) < 0$, i.e. the measure of workers employed in an industry i must be decreasing in the fixed costs i. Given the above result that the optimal firm size l_i is the same for all firms in an industry i, one can express $L_i \propto l_i f_i$. Since $l'(i) > 0$ and $L'(i) < 0$, it immediately follows that the measure of firms f_i is decreasing in the firm size l_i as illustrated in the bottom right quadrant. Equivalently $f'(i) < 0$, that is, the firm level density f_i is strictly decreasing in the fixed costs i, q.e.d.

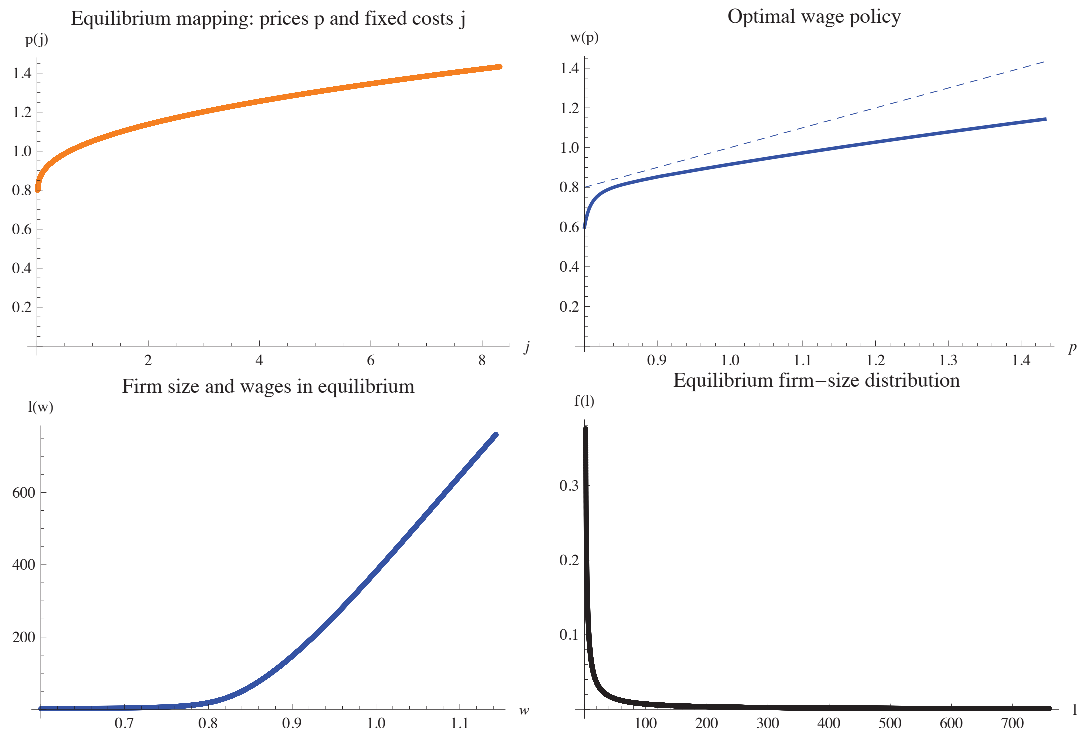

Figure 1: Illustration of equilibrium properties

Proposition 3.2 *Products from all industries $i \in [\underline{i}, \bar{i}]$ are produced in equilibrium.*

Proof Assume industry i's product was not produced. By assumption, the support of fixed costs is bounded on $[\underline{i}, \bar{i}]$ and there is demand for products from all industries. Equilibrium operating profits are monotone increasing in the equilibrium price p_i and in particular $\lim_{p_i \to \infty} (p_i - w_i)l(w_i) = \infty$. For any finite i there exists a price p_i large enough to recover the fixed costs i. In particular, there is room for a measure of f_i firms to operate in this industry, where $f_i = L_i/l_i$ and l_i is the optimal firm level employment and L_i the equilibrium density of workers compatible with the price p_i. Any smaller measure of firms $f < f_i$, which includes the case of a single firm, will hence make positive profits by starting to operate in industry i, q.e.d.

Definition of the Equilibrium

Choosing the lowest price as the numeraire $\underline{p} = 1$, the goods market equilibrium $Q_i^S = Q_i^D$ $\forall i$ pins down an equilibrium distribution of workers over prices p_i:

$$g(p_i) = \frac{(1-\epsilon)p_i^{-\epsilon}}{\bar{p}^{(1-\epsilon)} - 1} \tag{10}$$

and the corresponding cumulative distribution function:

$$G(p_i) = \frac{p_i^{(1-\epsilon)} - 1}{\bar{p}^{(1-\epsilon)} - 1} \tag{11}$$

The equilibrium job offer arrival rate depends on the total mass of operating firms μ relative to the mass of workers, which is fixed to 1, and some exogenous contact efficiency parameter Φ:

$$\lambda = \Phi\mu. \tag{12}$$

Given the optimal wage policy[9] $w(p)$ (20) and the corresponding firm level employment $l(w)$ (18) and the above definitions, equilibrium is pinned down by a job offer arrival rate λ which ensures zero profits (i.e. operating profits equal fixed costs) at the lowest fixed cost industry:

$$\underline{i} = \frac{\Phi/\delta}{(1+\lambda/\delta)^2}(A - \underline{w}) \tag{13}$$

and an upper bound on prices $\bar{p}$, which ensures zero profits at the highest fixed cost industry:

$$\bar{i} = \frac{\Phi/\delta}{(1+\lambda/\delta)^2}\left(\int_1^{\bar{p}} (1 + \frac{\lambda}{\delta}G(x))^2 dx + (A - \underline{w})\right). \tag{14}$$

[9]Since the Burdett and Mortensen (1998) framework is well studied and understood, I refer the interested reader to the Appendix 7.1.1 for a detailed derivation of the corresponding analytical expressions.

The lower bound on wage $\underline{w}$ is taken as an exogenous parameter and can be interpreted as workers' common reservation wage. Alternatively one could interpret $\underline{w}$ as the federal minimum wage if this exists and lies above the workers' reservation wage.

Definition *Given the normalizations of the numeraire* $\underline{p}$ *and the mass of workers* ω *to* 1*, a set of exogenous parameters* $\{\underline{w}, A, \epsilon, \Phi, \delta\}$*, and a bounded support of fixed costs* $[\underline{i}, \bar{i}]$*, equilibrium is defined a set* $\{\overline{p}, \mu, \lambda\}$ *such that conditions* (12), (13) *and* (14) *hold, subject to* (11).

The corresponding equilibrium unemployment rate and distribution of firms are implied by the flow-balance-equations (20) and (22).

3.5 Wage dispersion in equilibrium

The shape of the wage dispersion is the outcome of the interplay of two opposing effects: the on-the-job search (or wage competition) effect, which generates the upward sloping part, and the goods demand constraint effect, which generates the downward sloping part. To see this formally, note that the by the fact that $w'(p) > 0$ we know that:

$$g(w) = \frac{g(p_i)}{w'(p_i)}. \tag{15}$$

This implies that

$$g'(w) > 0 \quad \Leftrightarrow \quad |\frac{w''(p_i)p_i}{w'(p_i)}| > |\frac{g'(p_i)p_i}{g(p_i)}|.$$

That is, the wage density is upward sloping if the curvature of the optimal wage policy is sufficiently high. Let us gain some intuition for why this will be the case only at low wages. Firms are aware of the fact that they will attract and retain more workers in equilibrium if they post higher wages, due to the on-the-job-search environment. That is, firms compete for workers by posting wages. Wage competition is very strong at the low end of the wage distribution, since all firms (that is, low and high price firms) engage in the wage competition here, which is reflected by a strong curvature of the optimal wage policy, i.e. $|\frac{w''(p_i)p_i}{w'(p_i)}|$ is large at low prices, see Figure 2. Note that the x-axis refers to prices in the left but to wages in the right subfigure.

As we have seen in proposition 3.1, the goods demand constraint limits entry to high fixed cost industries, which will be the industries that can sustain high prices in equilibrium and where firms will find it optimal to pay their workers high wages. That is, fewer firms engage in the wage competition at high wages, which is reflected by a decreasing curvature of the optimal wage policy. As illustrated in Figure 2, given that the goods demand constraint is constant, namely equal to the substitution elasticity ϵ $|\frac{g'(p_i)p_i}{g(p_i)}| = \epsilon$, but the wage competition effect is weakening, at some point the former dominates the latter and the wage density is decreasing.

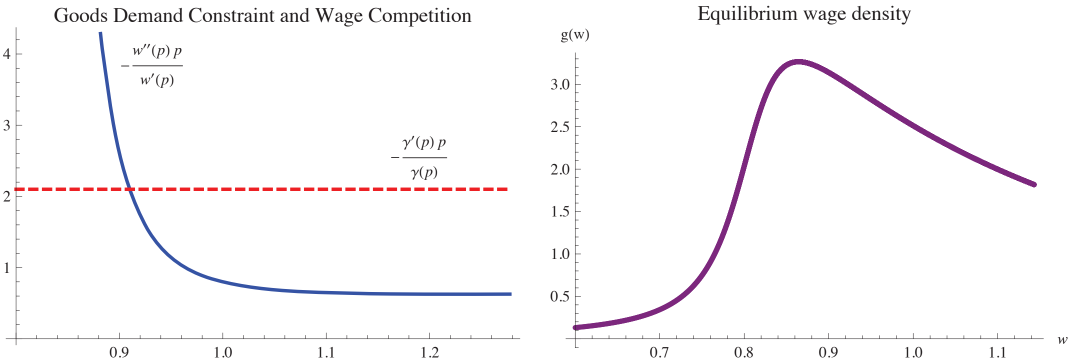

Figure 2: Illustrating wage dispersion in equilibrium

3.6 Comparative statics

This section demonstrates that an increase in total factor productivity A, a decrease in the lowest wage $\underline{w}$ and an increase in the scale of fixed costs translates ceteris paribus[10] into increased price dispersion ($\overline{p}/\underline{p}$) and increased wage dispersion ($\overline{w}/\underline{w}$). The relevant conditions for equilibrium price and wage dispersion are summarized by the free entry condition to the lowest fixed cost industry $\underline{i}$ (13), which pins down the equilibrium offer arrival rate λ, the free entry condition to the highest fixed cost industry (14), and the optimal wage policy (20).

Total factor productivity

Given A increases, the job offer arrival rate λ increases. This is because the lowest wage $\underline{w}$ is fixed in nominal terms, and hence an increase in total factor productivity makes entry more attractive for firms, since the markup $(A - \underline{w})$ is increased. Increased entry means that the mass of firms μ is increased, thereby increasing $\lambda = \Phi\mu$. Given a constant lowest fixed cost $\underline{i}$, the overall effect on firms' profits at the lowest fixed cost industry $\underline{i}$ is zero: markups per worker increase, but due to the increased job offer arrival rate λ firm-level employment decreases, since workers are more likely to switch to higher wage employers. The increased λ in turn will affect equilibrium operating profits of firms at the highest fixed costs $\overline{i}$ in two ways: (i) firm-level employment will increase, (ii) markups per worker will decrease, due to increased wage competition. The first effect is positive for the profits, the second is negative. One can show, that the second effect always dominates the first, that is: equilibrium operating profits in the highest fixed cost industry fall as λ increases.[11] That is, to recover the unchanged fixed costs $\overline{i}$, the corresponding price $\overline{p}$ in the highest fixed cost industry must increase (fewer firms will operate there in equilibrium). Recall that $\underline{p} = 1$ is the numeraire. Hence, the increased $\overline{p}$ increases price dispersion $\frac{\overline{p}}{\underline{p}}$. Given the optimal wage policy

[10] The purpose of this section is to gain some insight into the model mechanics. When it comes to assessing the quantitative performance of the model the parameters will be allowed to change simultaneously and I will keep the mean price level fixed instead of the lowest price $\underline{p}$.

[11] To see this formally, note that the difference in fixed costs is constant and equal to the following expression which can be shown to be decreasing in λ: $(\overline{i} - \underline{i}) = \frac{\Phi/\delta}{(1+\lambda/\delta)^2} \int_1^{\overline{p}} (1 + \frac{\lambda}{\delta} G(x))^2 dx$.

(20), it is evident that increased price dispersion $\frac{\overline{p}}{\underline{p}}$ translates into increased wage dispersion $\frac{\overline{w}}{\underline{w}}$.

Lowest wage

Wage dispersion $\overline{w}/\underline{w}$ increases if the lowest wage $\underline{w}$ falls. There are two parts to this story. The first is very mechanical: if the lowest wage $\underline{w}$ falls and the highest wage $\overline{w}$ is fixed, wage dispersion $\overline{w}/\underline{w}$ will increase. The second is less straightforward and more interesting. If the lowest wage $\underline{w}$ falls, entry becomes more attractive. That is, more firms will operate in equilibrium and the job offer arrival rate λ increases. As we have seen in the previous paragraph, this implies that price dispersion and thereby wage dispersion increases. This amplification mechanism is new and suggests that federal minimum wages (or unemployment benefits, given their influence on workers' reservation wages) might have an impact also on the upper end of wage dispersion.

Scale of fixed costs

Interestingly, the pure scale of fixed costs impacts equilibrium price dispersion. First, note that the contact efficiency Φ acts like a scaling parameter for the fixed costs $[\underline{i}, \overline{i}]$, since technically we can rearrange the free entry condition for each industry i to get $\frac{i}{\Phi}$ on the left hand side. Intuitively, a lower Φ is equivalent to a higher fixed cost i, since ceteris paribus, in particular given a constant λ, a lower contact efficiency Φ implies that more firms are around. Given a higher mass of firms μ, the labor market is tighter from the firm's perspective. Clearly, operating in this tighter labor market is more costly, since attracting workers is harder for all firms. Assume now that the scale of fixed costs increase, i.e. Φ decreases. From the free entry condition (13) it is clear that less firms will operate in equilibrium, i.e. λ falls. In particular, λ will fall sufficiently much to keep $\frac{\Phi/\delta}{(1+\lambda/\delta)^2}$ constant. Note that this expression is constant and the free entry condition to the highest fixed cost industry (14) implies that $\overline{p}$ must increase to keep $(\int_1^{\overline{p}}(1 + \frac{\lambda}{\delta}G(x))^2 dx$ constant. That is, if the scale of fixed costs increases, the job offer arrival rate λ will decrease, and price and wage dispersions will increase.

4 Calibration

4.1 Data

The main data source for the calibration is the NBER-CES manufacturing database, which provides annual information on value-added, pay, working hours, material costs, and price indices at the 6-digit NAICS industry level for the period 1958-2005. More details on the dataset and the variables contained can be found in the Appendix 7.2.2. Given the focus on the long term evolution of price and wage dispersion, I compare the steady state at the beginning of the sample 1965-1970 to the steady state at the end of the sample 2000-2005. I call the former "period 1970" and the latter "period 2005".

4.2 Fixed parameters and normalizations

A model period is considered to be 1 month. I restrict the total factor productivity A to be the same across industries. This assumption is innocuous at any given point in time, since it is just a way of pinning down the relevant unit of output. To give a concrete example, again consider the case of output being linear in labor input. Assume that 10 workers in the car industry produce 1 car per month, while 10 workers in the apparel industry produce 300 shirts in 1 month. Restricting the total factor productivity to be the same is equivalent to saying that 1 car is the same "quantity" as 300 shirts. That is, the quantity is measured in what is the only meaningful comparison across different industries: labor units. To develop this example further: assume, that price of 1 car is 6000 US$, while the price of 1 shirt is 10 US$. Then the price ratio between the two industries for a given "unit of output" is two, since the car is twice as expensive as the 300 shirts. Since workers will receive a share of the higher output prices in form of wages, wages are expected to be higher in the car industry than in the apparel industry, however, generally not exactly twice as high, since markups differ across industries due to the curvature of the optimal wage policy (compare the upper right quadrant in Figure 1). Even though price dispersion is not reported in the data, I can obtain a mapping between value-added and prices by adding material to the production function (see Appendix 7.1.3 for details). While the numeraire was chosen to be the lowest price $\underline{p}$ in the theoretical model, for the quantitative part a more natural choice of the numeraire is the price index P, which is normalized to $P = 1$. The price index is defined as the mean output price level across industries.[12] Using information on total revenues and the inflation of output prices per industry provided in the NBER-CES database, I compute the corresponding real output weighted price index, which turns out to correspond to the official producer price index (OECD), as illustrated in Figure 3. The real lowest wage $\underline{w}$ is held fixed, since the lowest real wage observed in the data (paid in the industry "Women's, Girls', and Infants' Cut and Sew Apparel Contract")

[12]The resulting formula for the price index is: $P = \frac{(2-\epsilon)}{(1-\epsilon)} \frac{(\overline{p}^{(2-\epsilon)} - \underline{p}^{(2-\epsilon)})}{(\overline{p}^{(1-\epsilon)} - \underline{p}^{(1-\epsilon)})}$

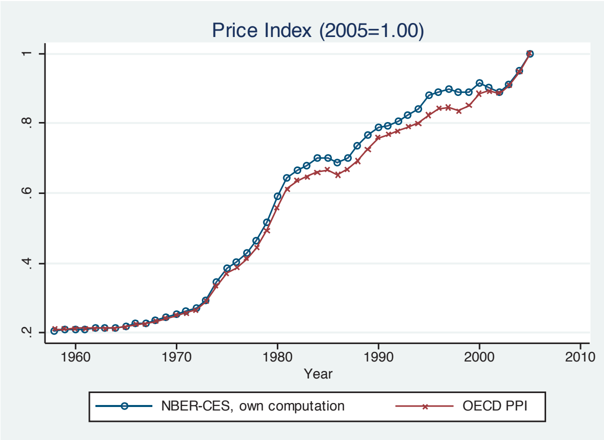

Figure 3: Price Index

Figure 4: Unemployment rate

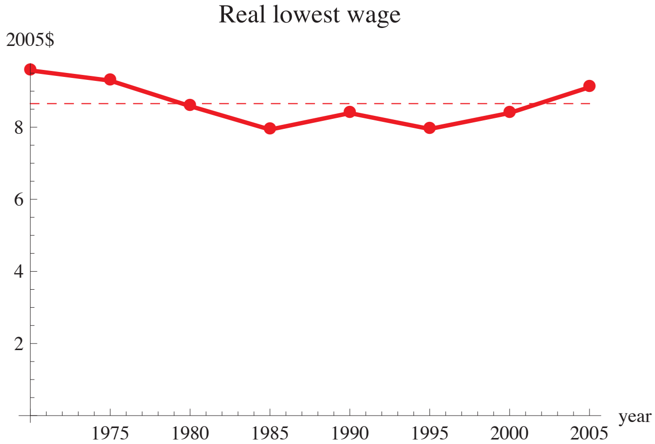

Figure 5: Real minimum wage

does not show a clear time trend and fluctuates only moderately, see Figure 5. The job destruction rate δ is fixed to be equal to the average monthly job destruction in the JOLTS (Job Openings and Labor Turnover Survey) database in the time period 2000-2005. It is held fixed across time, since Shimer (2005), who constructs the corresponding rate using CPS (Current Population Survey) data, documents that the monthly job separation probability exhibits no time trend in the period 1951-2003. His reported average monthly job destruction rate of 0.034 is very close to the JOLTS value of $\delta = 0.035$. The monthly interest rate is fixed to $r = 0.003$ which corresponds to an annual interest rate of 4%. The capital-share $\alpha = 0.81$ is estimated from the NBER-CES database (see Appendix for details).[13] Table 3 provides an overview of the fixed parameters.

[13]The relatively high value for α stems from the fact that the production function was calibrated for the manufacturing sector, where the worker share is low. Consistent with my estimate of α, Kehrig (2011) reports that the labor share is close to 20% in the manufacturing sector.

parameter	*value*	description	data source
r	0.003	interest rate	
δ	0.035	job destruction rate	JOLTS
α	0.81	estimated coefficient on material input	NBER-CES
$\underline{w}$	8.65	lowest wage (in 2005 $)	NBER-CES
P	1	price index	normalization

Table 3: Fixed parameters

4.3 Calibrated parameters

The only explicitly targeted dispersion moments are the p_{90}/p_{50} and the p_{50}/p_{10} ratio of the value-added dispersion in the period 2005. Furthermore, I target a worker share of 0.5 at the lowest end of the wage distribution, that is, I require that workers with the lowest wage $\underline{w}$ receive 50% of their value-added $\underline{w}/\underline{v} = 0.5$, which is the observed worker share for workers in the lowest wage industry ("Women's, Girls', and Infants' Cut and Sew Apparel Contract") in the NBER-CES database, again in the period 2005. I also target the mean unemployment rate in the sample period, which again show no long run time trend and is $u = 6\%$, see Figure 4. Finally, I target the worker-firm ratio $1/\mu$ in the manufacturing sector, which is documented to be 40 workers per firm in the County Business Patterns (2005). The parameters which are chosen such that these moments are matched are: the upper and lower bound on the support of fixed costs $\underline{i}, \bar{i}$, the substitution elasticity ϵ, the level of total factor productivity in the period 2005, A_{2005}, the matching efficiency in the period 2005 and Φ_{2005}. That is, the 5 parameters $\{\underline{i}, \bar{i}, \epsilon, A_{2005}, \Phi_{2005}\}$ are chosen to jointly target the 5 moments $\{p_{90}/p_{50}, p_{50}/p_{10}, \underline{w}/\underline{v}, u, m\}$. The targeted moments are matched perfectly since the 5 parameters are the solution to a system of 5 equations. The values for the lower and upper bound on fixed costs are $\underline{i} = 19.4$ US$ and $\bar{i} = 40957$ US$, respectively. These numbers refer to hourly fixed costs per firm. As firms with high fixed costs employ more workers, these differences look much smaller if they are divided by the respective employment levels. The model's predicted smallest firm size is 2.25, the largest 630 workers. Thus, the hourly fixed costs per firm correspond to hourly fixed costs *per working hour* of 8.65 in the lowest fixed cost industry and 64.87 in the highest fixed cost industry. This implies a fixed-costs per worker ratio of 7.5 in the highest fixed cost industry versus the lowest fixed cost industry. An overview of the calibrated parameters is given in Table 4.

parameter	*value*	*target*	*target value*	*source*
$\underline{i}$	8.65	$\underline{v} = 2\underline{w}$	18.4	NBER-CES
$\bar{i}$	64.87	v_{90}/v_{50}	2.36	NBER-CES
ϵ	2.8	v_{50}/v_{10}	1.51	NBER-CES
A_{2005}	0.044	u	0.05	OECD
Φ_{2005}	26.75	μ	0.025	CBP

Table 4: Parameters calibrated (jointly)

Fixed cost parameters i are reported here as effective hourly fixed costs per worker.

4.4 Measuring wage dispersion

I follow the approach by Christensen et al. (2005) who address inter-firm wage dispersion by computing mean wage levels at each firm and weighting these wages with the respective firm level employment to generate the overall wage distribution. As I am interested in inter-industry wage dispersion, I first compute the mean industry level wages (from the NBER-CES database, at the NAICS 6 digit level) and weight them with the respective hours worked per industry as a measure for labor units. This measure of residual wage dispersion is of course very rough, since it abstracts from the fact that wage differentials across industries might also be driven by observable or unobservable worker characteristics. However, it has been shown by Krueger and Summers (1987) that the raw inter-industry wage differentials are a good proxy for more sophisticated measures of inter-industrial wage dispersion. My wage regression results using CPS data are consistent with their findings (see Appendix 7.2.4 for further details).

5 Quantitative Results

5.1 Wage dispersion in 2005: not targeted

Figure 6 shows the cross sectional wage dispersion in the period 2005 in the data (NBER-CES) and the model counterpart. Recall that no moment of the wage distribution (except for the lowest wage paid $\underline{w}$) has been targeted. The shape of the wage dispersion is matched very well. It is a priori unclear that targeting the value-added dispersion the model is able to predict the wage dispersion correctly. The mapping between the value-added and wage dispersion depends on the optimal wage policy (20), which is a highly non-linear function due to the endogenous markup structure in the random search framework. Targeting only two dispersion moments (p_{90}/p_{50} and p_{50}/p_{10} of value-added dispersion) the calibrated model replicates key properties of the observed wage dispersion. Both data and model feature a unimodal hump-shaped wage density, steeply

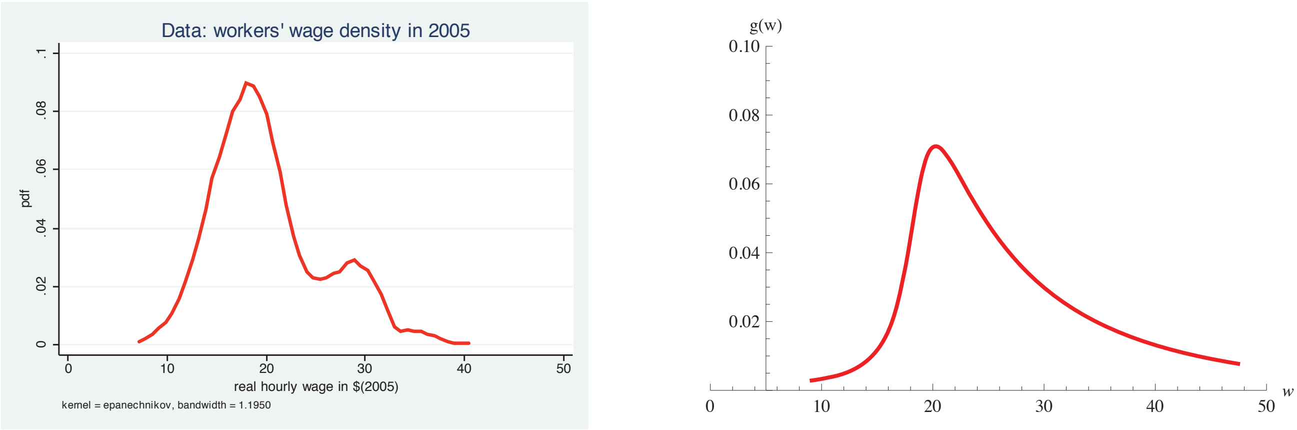

Figure 6: Cross-sectional wage dispersion in 2000-2005, NBER-CES data (left) and model (right)

increasing towards the peak somewhere around 20 US$, and then decreasing with a convex slope, with only few workers earning wages above 40 US$. The intuition for the shape of wage dispersion is the interplay of the law of demand and on-the-job search which is discussed in section 3.5.

5.2 The evolution of value-added and wage dispersion over time

Bell and Freeman (1991) document a pronounced increase in inter-industry value-added and wage dispersion in the 1970s and 1980s. The theoretical model of this paper offers a novel explanation for the sources of this increase. As the comparative statics indicate, increases in total factor productivity and increases in the scale of fixed costs both increase price and wage dispersion (ceteris paribus). Recall from section 3.6 that increases in total factor productivity are accompanied by endogenous increases in the job offer arrival rate λ, whereas increases in the fixed costs are accompanied by endogenous decreases in the job offer arrival rate . As we have seen before, the equilibrium unemployment rate u was quite stable over time and so was the job destruction rate δ. Recall the steady state expression for unemployment from (21): $u = \frac{\delta}{\delta+\lambda}$ to see that the implied job offer arrival rate λ must have also been constant. I estimate the increase in total factor productivity from the NBER-CES database (see Appendix 7.2.3 for details). The change in Φ is calibrated to target a constant unemployment rate $u = 6\%$. Recall from the comparative statics section 3.6 that decreases in the scale of Φ are equivalent to increases in the scale of fixed costs. Thus, the calibrated decrease in the matching efficiency of 91% is equivalent to an increase in the scale of fixed costs by a factor of about twelve. Table 5 reports the implied parameter changes across time. The corresponding value-added and wage dispersion increases are shown in Table 6. First, note that the data reflect a long term increase in the value-added and wage dispersions, which was actually more pronounced for the value added dispersion than for the wage dispersion. While industries at the $90th$ percentile generated only around 50% higher value added per worker at the end of the 1960s, they generated more than 130% higher value added per worker at the beginning of this

parameter	*%change*	*target*	*source*
A	$+25\%$	*estimate*	NBER-CES
Φ	-91%	$u = 6\%$	OECD

Table 5: Parameter changes across time

moment	**data**	**model**
v_{90}/v_{50} in 2005	2.35	2.35*
v_{90}/v_{50} in 1970	1.54	1.51
w_{90}/w_{50} in 2005	1.55	1.57
w_{90}/w_{50} in 1970	1.29	1.27

Table 6: Value-added dispersion and wage dispersion, *targeted

millenium. The corresponding figure for wage dispersion less than doubled from around 30% to 55%. This is consistent with the model's implication of increasing markups at high value-added (or prices, compare Figure 1), which imply that a given increase in value-added dispersion will always translate into a weaker increase in wage dispersion. Table 6 demonstrates that the calibrated model also captures the link between increases in value-added and wage dispersion quantitatively very well. It is not clear that, given the calibrated changes in levels (see Table 5), the model is able to correctly predict changes in dispersion. First, the model replicated the increase in value-added dispersion. Second, the pronounced increase in the upper tail of wage dispersion is also predicted by the model, see Table 5. Figure 7 compares the wage dispersion in 1970 to the wage dispersion in 2005 as observed in the data (left side) and as predicted by the model (right side). Even though the fit in the period 1970 is somewhat worse than the fit in 2005, nevertheless the main change in the shape of wage dispersion, namely the flattening out of the right tail, is correctly predicted by the model.

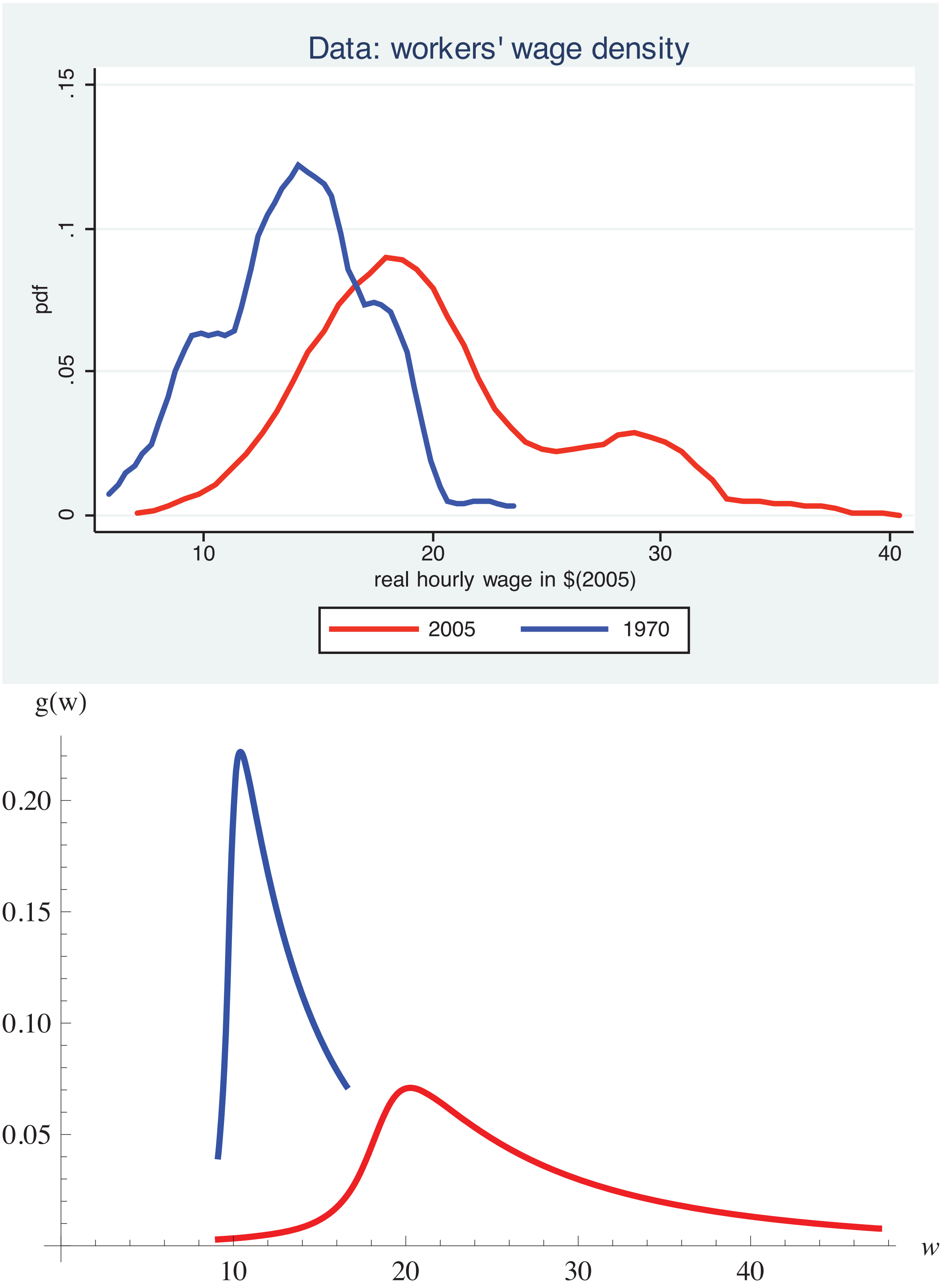

Figure 7: Change in wage dispersion across time, NBER-CES data (top) and model (bottom)

6 Conclusion

This paper develops a theoretical model which touches upon two issues that have received lots of attention in the literature: inter-industrial wage differentials and increasing wage inequality over time.

The presented model is consistent with a number of stylized facts regarding the positive correlation between industry specific wage premia and other industry characteristics such as average firm-sizes and firm concentration. The source of inter-industry wage differentials in the model is differences in fixed costs between industries, combined with search frictions in the labor market. Even in a world where all firms have access to the same technology, and neither workers nor firms differ in any relevant aspect for production, the equilibrium outcome will feature price and wage dispersion in this framework. That is, both firms and workers differ in their revenue productivity ex-post. The inequality is an equilibrium outcome. Firms are indifferent between being high or low revenue firms (i.e. in which industry they operate), since free entry of firms to all industries ensures that higher revenues are exactly offset by higher fixed costs of operation in equilibrium. Workers always want to switch to better paying jobs, but frictions in the labor market make it a question of luck at which wage the worker ends up. In fact, only a few workers earn high wages in equilibrium because good demand constraints limit the amount of jobs in high paying industries. That is a persistent equilibrium feature and explains the decreasing right tail of any empirical wage distribution, despite the constant moving of workers into better paying jobs in the on-the-job search framework. In my model higher valuations of output stem from higher equilibrium prices. Intuitively, industries with high fixed cost of operation (for instance mining, petroleum and gas, or transportation equipment) must feature high prices in equilibrium in order to recover the higher fixed costs of operation. As products from different industries are imperfect substitutes, industry prices are a decreasing function of aggregate industry output. Consequently, demand for high price products is scarce and limits room for entry to these industries. Given the high output valuations, high price firms want to be large. In order to be large they have to pay high wages in the on-the-job search framework. Hence, the model predicts that there will only operate a few, large firms in high wage industries, which is consistent with the empirical evidence. Quantitatively, the calibrated model fits the observed wage dispersion in the US manufacturing sector very well. In particular, targeting only changes in levels the model correctly predicts an increase in the upper tail of wage dispersion over the past decades. The increase in wage dispersion stems from the interplay of three factors: constant lowest real wages (observed in the data), increasing total factor productivity (estimated) and increases in the scale of fixed costs (calibrated).

Note, that for the sake of clarity the present paper abstracts from intra-industry product differentiation. Clearly, one could depart from the assumption of perfect substitutability within a given industry and use the presented model framework to address intra-industry wage dispersion across different firms. Different varieties within a given industry might feature different fixed costs because of different degrees of advertising associated with fixed costs. Similarly one could think about vertical product differentiation within a given industry in this framework, where higher quality products require higher fixed costs of production. One would expect to see the same positive relationship between wages, prices, firm size and profitability on the intra-industry firm level as on the inter-industry level.

7 Appendix

7.1 Theory Appendix

7.1.1 The Burdett-Mortensen Model

Frictions in the labor market prevent vacant positions and workers from meeting instantaneously. IIn the spirit of Burdett and Mortensen (1998), job offers arrive to workers in continuous time at a contact rate $\lambda < \infty$, which is assumed to be the same for employed and unemployed workers. Hence unemployed workers will accept any wage offer $w \geq \underline{w}$, where $\underline{w}$ can be interpreted as a federal minimum wage or workers' reservation wage. Employed workers, who also receive job offers at the same rate $\lambda < \infty$ (on-the-job-search), accept an offer only if it makes them better off than their current wage w. A firm which pays wage w will hence recruit from the pool of unemployed workers and the pool of workers currently employed at a wage below w. Formally, the mass of hires $h(w)$ is:

$$h(w) = \frac{1}{m}\lambda(u + (1 - u)G(w)), \tag{16}$$

where $G(w)$ is the cumulative distribution function of workers over wages, which will be determined in general equilibrium. The mass of workers is normalized to 1, hence $\frac{1}{m}$ denotes the ratio of workers to firms.

Job matches are destroyed at an exogenous rate δ and whenever a worker receives a better offer. That is, the mass of separation at a firm with employment $l(w)$ is given by:

$$s(w) = l(w)(\delta + \lambda(1 - F(w))), \tag{17}$$

where $F(w)$ denotes the equilibrium distribution of wage offers. In steady state hires (16) must equal separations (17). Rearranging the above equation and using the relevant flow-balance conditions (see next subsection) one obtains the following expression for steady state employment at the firm level:

$$l(w) = \frac{1}{m}\frac{\lambda\delta}{(\lambda + \delta)^2}(1 + \frac{\lambda}{\delta}G(w))^2 \tag{18}$$

We see that firm level employment is a strictly increasing function of the wage rate: $l'(w) > 0$, as $G'(w) > 0$ by definition of a cdf. That is, firms that pay high wages are large in equilibrium. This is intuitive, since employers that pay high wages attract more workers ($r'(w) > 0$) and are less likely to lose them to other employers ($s'(w) < 0$). In any industry i firms choose the optimal wage to maximize their operating profits, taken as given the equilibrium price p_i in industry i:

$$\max_{(w \geq \underline{w})} \{(Ap_i - w)l(w) - i, \tag{19}$$

The implied optimal wage policy is:

$$w(p_i) = Ap_i - \frac{1}{(1+\frac{\lambda}{\delta}G(p))^2}\left(\int_{\underline{p}}^{\overline{p}}(1+\frac{\lambda}{\delta}G(p))^2dx + (A\underline{p} - \underline{w})\right) \tag{20}$$

7.1.2 Flow-balance-equations

Due to the dynamic nature of the setup, the pool of unemployed u and the pool of workers employed at a wage w are subject to inflows and outflows at any point in time. It can be shown that the economy converges to a steady state, i.e. there is a unique stationary distribution of workers across employment states and wages. The steady-state is characterized by the following two conditions. First, outflows from unemployment equal inflows to unemployment, which yields:

$$u = \frac{\delta}{\delta + \lambda}. \tag{21}$$

Second, outflows from the pool of workers who are currently employed at a wage w or below equals inflows to this pool of workers:

$$(1-u)G(w)(\delta + \lambda(1 - F(w))) = u\lambda F(w), \tag{22}$$

where $F(w)$ denotes the cumulative distribution of wage offers. In words, there are two reasons for why workers leave the pool who are currently employed at a wage w or below: they can be hit by an exogenous separation shock which happens with probability δ or they receive a higher wage offer, which happens with probability $\lambda(1 - F(w))$. Rearranging yields:

$$F(w) = \frac{G(w)(\delta + \lambda)}{\delta + \lambda G(w)}. \tag{23}$$

Define $\Phi(p)$ as the cdf of wage offers over prices and $\phi(p)$ as the corresponding pdf. Given $w'(p) > 0$ (which will turn out to be the case in equilibrium) the above equality (23) implies:

$$\Phi(p) = \frac{\Gamma(p)(\delta + \lambda)}{\delta + \lambda\Gamma(p)}. \tag{24}$$

and consequently:

$$\phi(p) = \frac{\gamma(p)(\delta + \lambda)\delta}{(\delta + \lambda\Gamma(p))^2}. \tag{25}$$

These equation are key, since they link the equilibrium distribution of workers over prices (that is, across industries) $\Gamma(p)$, pinned down by the goods market equilibrium to the equilibrium distribution of wage offers over prices $\Phi(p)$. As I abstract from endogenous recruiting behavior, the equilibrium distribution of firms over prices is identical to the distribution of wage offers $\Phi(p)$.

7.1.3 Capital in the production function

Consider a standard Cobb-Douglas production function with constant returns to scale:

$$y(k, l) = Ak^{\alpha}l^{(1-\alpha)}, \tag{26}$$

where $0 < \alpha < 1$ denotes the elasticity of the production function with respect to capital k and A is the total factor productivity. Taking the price of their output p_i as well as the operating cost i as given, firms choose their optimal capital k and labor input l to maximize total revenue minus total costs:

$$\max_{(k,l)}\{p_i y(k, l) - wl - rk - i\} \tag{27}$$

The optimal capital choice is linear increasing in labor input l:

$$k_i^* = (\alpha \frac{p_i}{r} A)^{\frac{1}{(1-\alpha)}} l. \tag{28}$$

Note that the capital-to-labor-ratio k_i^*/l is increasing in the equilibrium price p_i. That is, firms in industries with high equilibrium prices will employ more capital per worker in the production process. Define the the value-added per unit of labor as standard:

$$v_i := \frac{p_i y(k_i^*, l) - rk_i^*}{l}. \tag{29}$$

Combine the optimal capital choice (28) with the definition of the value-added (29) to obtain:

$$v_i = [\alpha^{\frac{\alpha}{(1-\alpha)}} - \alpha^{\frac{1}{(1-\alpha)}}][r]^{\frac{\alpha}{(\alpha-1)}} A^{\frac{1}{(1-\alpha)}} p_i^{\frac{1}{(1-\alpha)}}. \tag{30}$$

and observe, that industries i with higher prices p_i feature a higher value-added per worker v_i, i.e. $v'(p) > 0$. Intuitively, a larger output price increases the value-added per worker per se. As firms with a higher output price p_i find it optimal to employ more capital per labor unit in the production process, the already larger value-added is increased even more. The firm's maximization problem in (27) boils down to:

$$\underset{l}{max}\{(v_i - w)l - \phi_i\} \tag{31}$$

Given the fact that $v'(p) > 0$ the equilibrium propositions (3.1) and (3.2) can be directly applied. That is, again, products from all industries will be produced in equilibrium and it will be industries with high fixed costs that feature high prices in equilibrium. The corresponding goods market equilibrium, given CES preferences with substitution elasticity ϵ as before now yields the following equilibrium distribution of workers over value-added γv:

$$\Gamma(v_i) = \frac{v_i^{(1-\alpha)(1-\epsilon)-\alpha} - \underline{v}^{(1-\alpha)(1-\epsilon)-\alpha}}{\overline{v}^{(1-\alpha)(1-\epsilon)-\alpha} - \underline{v}^{(1-\alpha)(1-\epsilon)-\alpha}} \tag{32}$$

It is apparent that in the limit as $\alpha \rightarrow 0$, we are back to the distribution in the version without capital (compare equation (11)). Note, that the pure demand constraint effect from (**??**), which requires low output of high price industries and hence fewer workers employed in production, is reinforced by the endogenous optimal capital choice. Since the optimal capital input per worker is increasing in the price (recall (28)), even fewer workers are needed to serve the already small demand for high price products, as they are more productive due to more capital in the production process. To put it differently, two effects are pushing in the same direction here: (1) the goods demand constraint implies that high price products are demanded only in low quantities and hence only few workers are needed in the production, (2) firms that produce high price products find it optimal to employ more capital in the production process, increasing worker's productivity and thereby further reducing the demand for workers. Note, that as before, the firms in high value-added industries will pay high wages and therefore be large in equilibrium, but entry to these industries is limited to a small measure of firms, because of the demand constraints. Interestingly, this model is consistent with several persistent features of inter-industry wage dispersion that have been documented by Dickens and Katz (1986) and Krueger and Summers (1987): High wage industries feature larger capital-to-labor ratios, higher value-added per worker and larger average establishment sizes than industries with lower wages.

7.2 Data Appendix

7.2.1 County Business Patterns

Information about the number of establishments within industries comes from the County Business Patterns 2005. It covers all registered businesses with paid employees. Records are available on the 6-digit industry level and can therefore be directly merged with the NBER-CES Manufacturing Industry Database. The data is publicly available and can be found here:

$$http://www.census.gov/econ/cbp/$$

7.2.2 NBER-CES Manufacturing Industry Database

The database is a joint effort between the National Bureau of Economic Research (NBER) and U.S. Census Bureau's Center for Economic Studies (CES) and is publicly available online:

$$http://www.nber.org/nberces/.$$

It covers all 6-digit NAICS manufacturing industries (473 in total) and the years range from 1958-2005. The following variables are used in this paper[14]:

[14] A detailed description of all variables is provided by Bartelsman and Gray (1996).

- **EMP** - number of employees in thousands. This includes both production workers and other workers.
- **PAY** - total payroll in millions of dollars. This does not include social security or other legally mandated payments, or employer paymens for some fringe benefits.
- **PRODE** - number of production workers in thousands.
- **PRODH** - number of productions workers hours in millions of hours. This includes all hours worked or paid for, including actual overtime hours, but excluding vacation, holidays or sick leave.
- **VADD** - value added in millions of dollars. This equals (VSHIP-MATCOST+change in finished goods and work-in-process inventories during the year).
- **MATCOST** - cost of materials in millions of dollars, excludes the cost of services used but includes energy spending.
- **VSHIP** - value of industry shipments in millions of dollars. VSHIP is not adjusted for inventory changes and can include large amounts of duplication across industries or even across plants in the same industry.
- **PISHIP** - price deflator for value of shipments (equals 1 in 2005)
- **PIMAT** - price deflator for materials (equals 1 in 2005)

7.2.3 Estimate for the capital share α and the total factor productivity A

I estimate the log version of the production function

$$logY_t = logA_t + \alpha K_t + (1-\alpha)L_t, \tag{33}$$

imposing a common production technology across all industries within the manufacturing sector. Real output Y_t is measured as the deflated revenues (**VSHIP** deflated by **PISHIP**). Labor input L_t is measured in hours of production workers (**PRODH**). The capital input is measured as real material input (**MATCOST**, deflated by **PIMAT**) [15]. The potentially time varying total factor productivity A is captured by year dummies. Results are shown in table (7). Without imposing any restrictions, the coefficients turn out to add up to almost exactly to 1, supporting the constant returns to scale assumption. The implied coefficient is: $\alpha = 0.81$. The estimated time series for

[15] The fact, that I use material inputs rather than the capital stock is consistent with the mapping I defined between the value-added and prices and the notion, that the capital stock is rather a fixed cost than an input in the production function. This is also consistent with the findings from Burnside, Eichenbaum and Rebelo (1995), who stress that that the capital stock is not productive per se, and material input is the appropriate measure for capital utilization.

VARIABLES	Real output (log)
Real capital (log)	0.8090***
	(0.0028)
Working hours (log)	0.1845***
	(0.0033)
Observations	22,275
Adjusted R-squared	0.998

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Note: year dummies (all significant at 1% level) not reported here

Table 7: Production function estimation

total factor productivity A_t is shown in Figure (8). The increase of about 20 percentage points over the entire sample period ($1979-2005$) is consistent with a comparable figure, the historical series for multi factor productivity in the non-farm private business sector, provided by the Bureau of Labor Statistics (BLS).

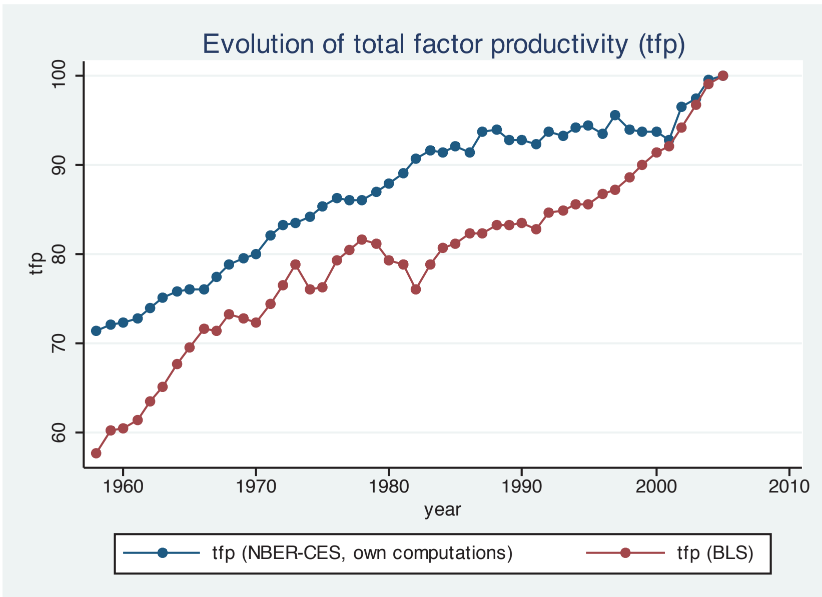

Figure 8: Total factor productivity

7.2.4 CPS ongoing rotation groups

CEPR Uniform Extracts of the CPS ORG are available to download in Stata Version 7 format, for the years $1979-2011$ from the Center for Economic and Policy Research. A detailed documentation can be found on their website *http://ceprdata.org/cps-uniform-data-extracts/*. Table (8) compares the raw log inter-industry wage differentials in the NBER-CES database (column1) with the corresponding raw differentials in the CPS data (column 2) and the industry differentials that remain after controlling for standard human capital controls. Included controls are: . I restrict the sample to workers above 25 who work at least 35 hours. Note, that while in the quantitative part I make use of the finest industry levels (6-digit), I report results on inter-industry wage differentials at a much more aggregated level, namely 2-digit, here, since this is the finest classification available in the CPS ORG data. The comparison is restricted to the final period of the calibration (2000-2005) since the earlier period (1958-1963) is not covered by the CPS ORG sample. A comparison of column1 and column 2 indicates, that the inter-industry wage differentials are of similar magnitude across the two data sources (NBER-CES and CPS). The patterns are very similar. The left out category "Textile/Apparel/Leather" pays the lowest wages on average, followed by "Wood" and "Furnitures/Fixtures". These industries only pay about 10% more. Equipment intensive industries like "Petroleum/Coal", "Chemical" or "Transportation Equipment", on the other end, pay between 50 to 80% higher wages than the "Textile/Apparel/Leather" industry. Controlling for worker characteristics (human capital controls) does not change the picture qualitatively. Quantitatively, wage differentials are roughy halved, once one controls for worker characteristics. The other half of the wage differentials remains as a pure inter-industry differential.

VARIABLES	NBER-CES industry dummies only	CPS industry dummies only	CPS plus controls
Wood	0.09*	0.12***	0.02**
	-0.0499	-0.0091	(0.0077)
Furniture/fixtures	0.14***	0.13***	0.04***
	-0.0499	-0.0088	(0.0074)
Food	0.17***	0.14***	0.07***
	-0.0499	-0.0069	(0.0058)
Plastics/rubber	0.23***	0.24***	0.09***
	-0.0499	-0.0082	(0.0069)
Nonmetallic mineral	0.31***	0.27***	0.12***
	-0.0499	-0.0089	(0.0076)
Paper/printing	0.39***	0.31***	0.12***
	-0.0394	-0.007	(0.0059)
Primary/fabricated metals	0.39***	0.29***	0.12***
	-0.0394	-0.0067	(0.0057)
Miscellaneous	0.45***	0.32***	0.12***
	-0.0394	-0.0072	(0.0061)
Machinery	0.48***	0.41***	0.16***
	-0.0499	-0.0069	(0.0059)
Computer/electronic	0.51***	0.54***	0.23***
	-0.0499	-0.0066	(0.0056)
Transportation equipment	0.65***	0.51***	0.23***
	-0.0499	-0.0064	(0.0055)
Chemical	0.68***	0.57***	0.25***
	-0.0499	-0.0071	(0.0060)
Beverage/tobacco	0.76***	0.44***	0.21***
	-0.0499	-0.0125	(0.0105)
Petroleum/coal	0.82***	0.64***	0.32***
	-0.0499	-0.0133	(0.0112)
Constant	2.60***	2.53***	2.22***
	-0.0249	-0.0055	(0.0066)
Observations	120	212,340	212,340
Adjusted R-squared	0.838	0.078	0.354

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8: Inter-industrial wage dispersion in the period 2000-2005. Textile/Apparel/Leather is the omitted industry. Human capital controls as standard, see text for details.

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