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Wage Heterogeneity as Another Worker Discipline Device

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Motivated by evidence on endogenous labor effort and persistent wage differentials across firms, we develop a labor-market model in which firms differ in their wage-compensation strategies. A firm adopts either a wage-setting strategy, under which it pays an efficiency wage, or a wage-taking strategy, under which it pays the competitive wage determined in the non-efficiency-wage segment of the labor market. In a given production period, the efficiency wage, the competitive wage, the wage premium between them, and the corresponding employment levels in each segment of the labor market are parameterized by the cross-sectional distribution of wage-compensation strategies across firms. This distribution is endogenously time-varying across production periods, as determined by an evolutionary selection protocol. We characterize the resulting dynamic behavior and identify the associated evolutionary equilibria and their stability properties. The formal analysis shows that the unique stable equilibrium is polymorphic, featuring the coexistence of wage-setting and wage-taking firms. We then examine the effects of changes in the polymorphic evolutionary equilibrium on three alternative measures of wage inequality. The model provides a unified framework for analyzing how endogenous on-the-job effort and heterogeneous firm wage-compensation behavior generate persistent wage inequality among observationally equivalent workers.

Keywords: Endogenous effort; efficiency wage; firm wage premium; firm wage differential; labor-market segmentation.

JEL Codes: C73; D21; J31; J33; J42.

Wage Heterogeneity as Another Worker Discipline Device

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I. Introduction

Motivated by considerable experimental and empirical evidence on endogenous labor effort and inter- and intra-industry wage differentials, we develop a labor market model that features the possibility of heterogeneity in wage compensation within the population of firms. In a given production period, a firm adopts either a wage-setting compensation strategy, under which it pays an efficiency wage, or a wage-taking compensation strategy, under which it pays the competitive wage determined in the non-efficiency-wage segment of the labor market. Both the efficiency wage and the competitive wage, as well as the ratio between them, depend on the cross-sectional distribution of wage-compensation strategies within the population of firms. This cross-sectional is endogenously time-varying as governed by an evolutionary selection dynamic.

Firms that adopt the wage-taking strategy operate in the non-efficiency-wage segment of the labor market, where labor supply is determined by the share of the labor force not employed by efficiency-wage firms. The size of the labor force is treated as an exogenously given constant. The non-efficiency-wage segment of the labor market functions as an employer of last resort, thereby ensuring persistent full employment in the overall labor market under the evolutionary equilibrium characterized by the coexistence of both wage-compensation strategies within the population of firms. Under this heterogeneous wage-compensation structure, all workers not employed by wage-setting firms are absorbed by firms adopting the wage-taking compensation strategy, regardless of how low the corresponding wage must decline to clear the non-efficiency wage segment of the labor market, provided that it remains strictly positive.

Following the early empirical contributions of Tarling and Wilkinson (1982), Dickens and Katz (1987), Krueger and Summers (1988) and Katz and Summers (1989), there has been renewed interest in labor economics in the investigation of inter-industry wage differentials. In effect, considerable empirical evidence has accumulated on the persistence of inter- and intra-industry wage differentials, even after controlling for observable worker characteristics such as schooling, human capital, gender, years of experience, and other covariates. Findings from studies covering a large number of countries, different time periods, and a variety of econometric specifications and estimation techniques indicate that inter-industry wage differentials do exist, are nonnegligible in size, and persist over long periods of time.[1] Large and persistent wage differentials have also been found to exist across establishments within industries, even after controlling for standard covariates and individual fixed effects (Groshen, 1991). The factors underlying the existence and persistence of inter- and intra-industry wage differentials remain an unresolved puzzle, and the role of unobserved worker characteristics in explaining such differentials is still unsettled. Nevertheless, persistent wage differentials among observationally similar workers performing similar types of jobs are suggestive of the presence of some form of incentive-based wage-compensation behavior by firms paying higher wages. More broadly, Card et al. (2018) and Kline (2024) demonstrate that persistent wage inequality partly reflects firms' strategic wage-compensation behavior on the part of firms.

The robust empirical finding that some firms pay systematically higher wages than others to workers with identical observed characteristics is commonly referred to as the *firm wage premium* (see Card et al., 2018, for a survey). Evidence of firm-specific wage premia has been documented across a wide range of countries (see, e.g., Abowd, 1999; Card et al., 2013; Alvarez et al., 2018; Bonhomme et al., 2019). With respect to the determinants of the distribution of firm wage premia, the available evidence suggests that cross-firm heterogeneity in labor productivity and wage-setting power constitutes a central determinant of the wage premium paid by a firm relative to its counterparts. Card et al. (2013) and Antonczyk et al. (2010) identify increasing heterogeneity in firm-level wage-setting practices as a key driver of wage inequality. Consistent with this view, several studies find that trends in aggregate wage dispersion closely track trends in the dispersion of labor productivity across firms (Dunne et al., 2004; Faggio, Salvanes and Van Reenen, 2010; Barth et al., 2016).

Against this backdrop, one of the contributions of this paper is to provide an evolutionary game-theoretic explanation for persistent wage differentials grounded in endogenous labor effort and, consequently, endogenous labor productivity. While the wage-compensation strategy

[1] Tarling and Wilkinson (1982), Katz (1986), and Dickens and Katz (1987) review early studies documenting the existence of wage differentials, while Katz and Autor (1999), Carruth et al. (2004), Caju et al. (2005), and Lazear and Shaw (2009) review subsequent contributions and provide additional evidence on this issue. More recent evidence is provided by Card et al. (2024) and Kline (2024).

adopted by an individual firm is predetermined in a given production period, it is revised over time according to an evolutionary selection protocol. This framework makes it possible to investigate which wage-compensation strategy—or whether both strategies—survives in the evolutionary equilibrium, in which the cross-sectional distribution of wage-compensation strategies across firms is stationary. An interesting research issue that arises is whether heterogeneity in wage-compensation strategies, and the resulting inequality in wages and employment across firms, substitute for unemployment as a worker discipline device under full employment of the labor force.

The gift-exchange model set forth in Akerlof (2082) portrays the offer of employment by a firm as an offer to "exchange gifts", with the worker's effort level indicating the size of the reciprocal gift. Indeed, there is evidence from both laboratory experiments (Fehr et. al., 1998; Fehr and Falk, 1999; Charness, 2004, Charness and Kuhn, 2007; Fehr and Gächter, 2008) and field experiments (Gneezy and List, 2006; Bellemare and Shearer, 2009) that higher wages elicit more effort from workers. There is also survey evidence that firms consider wages as affecting on-the-job effort (e.g., Campbell and Kamlani, 1997), while Cappelli and Chauvin (1991), using plant-level data, find evidence that the wage-effort elasticity is positive. Similarly, Goldsmith et al. (2000) and Kube et al. (2013) find empirical evidence that being paid a wage premium (a wage that is above the wage paid by other firms for comparable labor) enhances a workers' effort.

In the efficiency-wage model developed in Shapiro and Stiglitz (1984), firms are unable to monitor workers perfectly, whereas workers care about the possibility of being fired if they are caught shirking. As a result, the cost of job loss depends on both the wage received in the current job and how easy it is to be re-employed and the corresponding alternative job pay. Thus, the level of effort exerted by workers (or the level of labor effort elicited by firms) varies negatively with the employment rate and the wage paid by other firms. In the model developed in this paper, while the employment rate is always equal to one, the alternative wage is proxied by a weighted average of the wage offered by wage-setting and wage-taking firms, with weights given by the proportion of firms that adopt each wage-compensation strategy. Consequently, wage-setting firms, by operating in an environment of (in principle) potential heterogeneity in wage compensation, have to know the cross-sectional distribution of wage-compensation strategies across firms to compute the efficiency wage.

The efficiency-wage model developed by Shapiro and Stiglitz (1984) is premised on the joint—though logically independent—assumptions that workers possess some discretion over their on-the-job performance and that firms are unable to monitor such performance perfectly. Once this form of intra-firm informational asymmetry is acknowledged, it appears natural to extend the same informational assumption to inter-firm strategic behavior, which is not considered in Shapiro and Stiglitz (1984). Analogously, the labor market model developed in this paper is premised on the joint—though likewise logically independent—assumptions that an individual firm has full discretion regarding its choice of wage-compensation strategy and is unable to monitor perfectly the corresponding choice processes of other firms.

Shapiro and Stiglitz (1984) demonstrate how the informational structure of employer–employee relationships, particularly the inability of employers to observe workers' on-the-job effort without cost, can explain involuntary unemployment as an equilibrium outcome. To put it differently, they show that imperfect monitoring necessitates equilibrium unemployment. It thus seems plausible and analytically informative to conjecture that the informational structure of inter-firm relationships—particularly the inability of firms to observe one another's choice of wage-compensation strategy without cost—may also play an important role. The question therefore arises as to whether heterogeneity in wage-compensation strategies across firms—and the resulting equilibrium wage inequality and heterogeneity in employment levels—substitutes for unemployment as a worker discipline device. While, in the model developed by Shapiro and Stiglitz (1984), equilibrium unemployment functions as a worker discipline device by implying a strictly positive expected cost of job loss, can equilibrium wage inequality likewise function as a worker discipline device by implying a strictly positive expected cost of wage-income loss?

Unlike the representative-firm specification of the efficiency-wage model developed by Shapiro and Stiglitz (1984), the model set forth herein assumes that firms adopting the efficiency-wage compensation strategy face an information-gathering and processing cost in determining their best reply in a Nash equilibrium environment populated by firms that instead adopt the wage-taking strategy and operate in the non-efficiency-wage segment of the labor market. Since determining this best reply requires knowledge of the cross-sectional distribution of wage-compensation strategies in the population of firms, potential heterogeneity in these strategies across firms generates an information-gathering and processing cost for the subpopulation of efficiency-wage firms. This is because such firms must monitor prevailing labor-market conditions when setting the efficiency wage. As noted above, once an inevitable asymmetric-information problem involving employers and employees within the firm is acknowledged to exist, it is reasonable and analytically informative to extend an analogous informational asymmetry to inter-firm strategic behavior, which is not the case in the efficiency-wage framework set forth by Shapiro and Stiglitz (1984), or in the efficiency-wage literature more broadly.

The firm-specific information-gathering and processing cost associated with determining the efficiency wage is assumed to be random and heterogeneous across wage-setting firms, thereby capturing empirically documented dispersion in both firms' cognitive abilities and information-processing capabilities. Firms that adopt the wage-taking strategy also differ with respect to such abilities and capabilities. However, an individual wage-taking firm does not incur the information-gathering and processing cost associated with computing the efficiency wage precisely because it refrains from engaging in such computation and instead participates in the non-efficiency-wage segment of the labor market.

Behaviorally oriented research in strategic management has frequently investigated cognition, including heterogeneity in managerial cognition, in terms of information structures and mental representations (Gary and Wood, 2011). Additionally, the key role of firms' cognitive abilities and information-processing capabilities in strategic decision-making is emphasized, for example, by Gavetti (2005) and Gavetti and Rivkin (2007). More recent contributions further stress the importance of cognitive heterogeneity, managerial cognition, and dynamic managerial capabilities in explaining observed variation in firms' sensing, adaptation, and strategic responses to changing environments (Durán and Aguado, 2022; Harvey, 2022; Heubeck, 2024).

In the present model, such idiosyncratic cognitive abilities and information-processing capabilities are treated as exogenous and independently distributed across firms and over time. Importantly, heterogeneity in firms' cognitive abilities and information-processing capabilities affect the costs associated with monitoring other firms, but do not directly impair or preclude profit-maximizing pricing behavior per se. Therefore, wage-taking firms, despite also exhibiting heterogeneous cognitive abilities and information-processing capabilities, choose not to incur the information-gathering and processing cost required to compute the efficiency wage and instead participate in the wage-taking segment of the labor market. Nevertheless, they are able to determine the profit-maximizing level of labor demand. By contrast, wage-setting firms choose to undertake the required information-gathering and processing cost and thereby determine both the efficiency wage and the corresponding profit-maximizing level of labor demand.

Accordingly, in the present model the adoption of the efficiency-wage strategy entails an additional cost that is absent from the representative-firm efficiency-wage framework developed by Shapiro and Stiglitz (1984). In their framework, incomplete information regarding individual worker performance generates the need for firms to pay a wage above the market-clearing level. A natural extension of this informational asymmetry is to assume that firms adopting the wage-setting strategy must also bear an informational cost to ascertain the types of other firms, that is, the wage-compensation strategies adopted by those firms.

In the present model, firms are homogeneous in all respects other than their choice of wage-compensation strategy. In particular, all firms share the same production technology and sell a homogeneous good at a common exogenously given price, reflecting the assumption of perfect competition in the goods market. Workers are likewise homogeneous, except with respect to the level of on-the-job effort supplied in response to a given wage offer received. This assumption is consistent with the robust empirical evidence documenting persistent inter- and intra-industry wage differentials even after controlling for observable worker characteristics, such as gender, schooling, human capital, labor-market experience, and job attributes.

The model exhibits a unique stable evolutionary equilibrium, with coexistence of wage-setting and wage-taking firms. In this equilibrium, the wage premium varies positively with the proportion of wage-setting firms and is increasing in both the effort differential in favor of the wage-setting strategy and the effective-labor elasticity of output, as these parameters raise the proportion of wage-setting firms. By contrast, higher median of firms' information-gathering and processing costs reduce the proportion of wage-setting firms, lowering the equilibrium wage premium. Relative employment between wage-setting and wage-taking firms declines with the proportion of efficiency-wage firms. In the same equilibrium, broader measures of wage inequality, such as the relative wage bill (defined as the ratio of total wages paid by wage-setting firms to total wages paid by wage-taking firms) and the efficiency-wage bill share (defined as the ratio of the wage bill paid by wage-setting firms to the aggregate wage bill), also respond to parameters governing effort, production technology, and inter-firm monitoring costs. While effort differentials and the effective-labor elasticity of output tend to increase these broader inequality measures, the effect of inter-firm monitoring costs is ambiguous.

In the present model, therefore, the labor market is segmented in a *strategic* rather than structural sense. More specifically, the model does not feature a dual labor market in the conventional sense. For example, dual labor markets of the type discussed by Doeringer and Piore (1971) may emerge when the wage-productivity relationship is more relevant in some sectors than in others. Similarly, in Yellen's (1984) treatment of dual labor markets, differential relevance of the wage-productivity nexus across sectors may generate labor-market structural dualism. By contrast, the present framework contains only a single production sector. Any labor-market dualism that emerges is therefore not an exogenously given structural feature of the economy, but rather an endogenous outcome generated by firms' choice of wage-compensation strategy. Specifically, the evolutionary selection dynamic may generate an equilibrium in which both wage-taking and wage-setting firms coexist. We refer to this equilibrium configuration as *strategic segmentation*, or *strategic dualism*. It is precisely this form of strategic segmentation in the labor market that underlies the persistent wage inequality generated by the model.

As is inevitably and appropriately the case in any modelling exercise, we abstract from several other determinants of labor productivity in order to focus on, and isolate, the effect of wage compensation, for which extensive empirical evidence exists. We likewise abstract from a variety of additional channels and mechanisms through which labor productivity may respond positively to wage compensation. As noted above, the persistence of substantial inter- and intra-industry wage differentials has been consistently documented even after controlling for several observable worker characteristics. In this context, our modelling strategy—namely, focusing on a limited set of channels and mechanisms involving imperfectly observable effort in order to derive tractable and economically interpretable results—is analogous, to some extent, to the econometric practice of controlling for other covariates when identifying and estimating a causal relationship.

The remainder of the paper is organized as follows. Section II introduces the set of wage-compensation strategies available to firms and specifies the model's other key endogenous wage and employment variables, which are parameterized by the cross-sectional distribution of wage-compensation strategies in a given production period. Section III characterizes the evolutionary selection dynamic governing changes in this distribution over time across production periods and identifies its evolutionary equilibria together with their stability properties. Section IV examines the effects of changes in the unique stable evolutionary equilibrium—a polymorphic equilibrium featuring the coexistence of both wage-setting and wage-taking firms—for three measures of wage inequality. The final section summarizes the main analytical results and offers concluding remarks.

II. Wage-compensation strategies and related endogenous variables

The economy is populated by a continuum of firms producing a homogeneous good and operating in a perfectly competitive goods market. Accordingly, firms behave as price takers in the product market. Although the analysis examines the qualitative dynamics of the economy over time, capital utilization and capital accumulation are abstracted from. The measure of firms is assumed to remain constant throughout the analysis. In order to isolate more clearly the role of heterogeneity in wage compensation across firms as a potential worker discipline device, the model is constructed so as to generate full employment of the available labor force throughout the analysis. Aggregate unemployment does not arise because a subset of firms operates as employers of last resort, as described below.

At each production period, a proportion $x \in [0,1] \subset \mathbb{R}$ of firms incurs an information-gathering and processing cost to set the efficiency wage, that is, the wage that minimizes the cost of labor per unit of effort. Given this wage, the firm then determines the corresponding profit-maximizing level of labor demand. We refer to these firms as *wage setters*. The remaining proportion, $1-x$, takes as given the wage that clears the non-efficiency-wage segment of the labor market, which we refer to as the competitive wage, and hence determines only the profit-maximizing level of labor demand. These firms decide not to incur the information-gathering and processing cost required to adopt the wage-setting strategy and are therefore referred to as *wage takers*.

Firms that choose to be wage setters are unable to monitor workers perfectly, whereas workers care about the possibility of being fired if they are caught shirking. As a result, the cost of job loss depends on both the wage received in the current job and how easy it is to be re-employed and the corresponding alternative job pay. Therefore, the level of effort exerted by workers (or the level of labor effort elicited by firms) varies positively with the received wage rate $w \in \mathbb{R}_{++}$ (we abstract from price changes and normalize the output price to 1) and negatively with the labor-market conditions (or fallback position or outside option), which is represented by an index of labor-market opportunities $\mu \in \mathbb{R}_{++}$ to be specified latter.

In this alternative model setting with (potential) heterogeneity in wage determination in the population of firms and steady full employment in the labor market, we take as reference the effort provision function proposed by Summers (1988) and re-specify it as follows:

(1)
$$\varphi(w) = \begin{cases} \left(\xi + \dfrac{w-\mu}{\mu}\right)^{\eta}, \text{ if } \ w > \mu, \\ \\ \xi^{\eta}, \text{ if } \ w_c \leq w \leq \mu, \\ \\ 0, \text{ if } \ 0 < w < w_c, \end{cases}$$

where $\varphi(w)$ is the level of effort exerted by workers (or the level of labor effort elicited by firms) for a given received wage rate $w \in \mathbb{R}_{++}$. The parameter $\eta \in (0,1) \subset \mathbb{R}$ is the wage elasticity of effort and $\varphi_n \equiv \xi^{\eta}$ indicates the normal effort level, with $\xi \in (0,\eta) \subset \mathbb{R}$ as a parameter, and w_c is the competitive wage, which clears the non-efficiency-wage segment of the labor market. Note that the competitive wage is a binding constraint for firms which decide to join the non-efficiency-wage segment of the labor market in a given production period, since the strictly positive normal effort $\varphi_n = \xi^{\eta}$ (rather than no effort at all) is exerted by workers only when the earned wage is at least equal to the wage that clears the non-efficiency-wage segment of the labor market. However, any effort over and above the normal level is only exerted by workers when the received wage more than offsets the index of labor-market opportunities μ.

As pointed out earlier, we modify the standard shirking version of the efficiency-wage setting by assuming that firms have to pay a cost to obtain complete information about the labor-market conditions and to compute the efficiency wage. Recall that the shirking version of the efficiency-wage model is premised on the joint (but logically independent) assumptions that workers have some discretion concerning their performance on the job and firms are unable to monitor perfectly such performance. Hence, as such intra-firm asymmetric information is acknowledged to exist, it is only plausible to extend this information imperfection assumption to the inter-firm strategic behavior, which is not the case in the standard shirking version of the efficiency-wage approach. More precisely, the analysis developed here is premised on the joint (but likewise logically independent) assumptions that an individual firm has full discretion regarding its choice of wage-compensation strategy and it is unable to monitor perfectly the same choice process of the other firms.

In other words, differently from the representative-firm version of the efficiency-wage framework featuring endogenous effort on the job, firms that decide to adopt the wage-setting strategy face an information-gathering and processing cost to figure out the best reply in a Nash equilibrium in a game "contaminated" with firms that instead decide to adopt the wage-taking strategy by joining the non-efficiency-wage segment of the labor market. Given that figuring out this best reply requires knowledge of the index of labor-market opportunities μ in (1), which in turn, as specified later, requires knowing the cross-sectional distribution of wage-compensation strategies within the firm population, the potential firm-heterogeneity in such strategies imposes an information-gathering and processing cost on the subpopulation of wage-setting firms. Since workers must also possess knowledge of the same index of labor-market opportunities in order to provide the wage-dependent level of effort specified in (1), wage-setting firms then have an incentive to share with their employees, at no cost, the corresponding labor-market information they acquire through costly information-gathering and processing activities.

Moreover, we suppose that the information-gathering and processing cost associated with figuring out the current labor-market conditions is heterogeneous across wage setters. Hence, the profits of the $i\text{-}th$ wage setter can be expressed as:

(2) $$\pi_{e,i} = (1-c_i)\left[F\left(\varepsilon(w_{e,i})L_{e,i}\right) - w_{e,i}L_{e,i}\right],$$

where $w_{e,i}$ and $L_{e,i}$ are the wage set and the labor demand placed by the $i\text{-}th$ wage-setter firm, respectively, while $c_i \in (0,1) \subset \mathbb{R}$ stands for the fraction of profit of the $i\text{-}th$ wage-setter firm that is incurred with information-gathering and processing and $F(\cdot)$ is a production function with $F'(\cdot) > 0$ and $F''(\cdot) < 0$ in $\mathbb{R}_+$.

As formally detailed in Section III, the individual information-gathering and processing costs are randomly distributed across firms that, in a determined moment, choose to implement the wage-setting strategy. As in Lima and Silveira (2015), this random distribution captures the dispersion in the cognitive abilities and information-processing capabilities of firms, but in the model here it refers to firms that decide to adopt the efficiency-wage strategy in an environment with potential heterogeneity in the choice of wage-compensation strategy across firms.[2] These cognitive idiosyncrasies are assumed to be exogenously given and independent across firms and time. Moreover, this heterogeneity in firms' cognitive abilities and information-processing capabilities are assumed to affect firms' costs of monitoring each other, but not to impose direct costs on the maximizing behavior per se. Consequently, wage takers, despite also possessing heterogeneous cognitive abilities and information-processing capabilities, are nonetheless able to determine the corresponding profit-maximizing demand for labor by choosing not to incur the information-gathering and processing cost and instead relying on the competitive wage.

[2] As firms possess heterogeneous cognitive abilities, it is conceivable that the information-gathering and processing cost associated with the efficiency-wage strategy differs across firms adopting it. Accordingly, heterogeneity in cognitive abilities within the population of firms may be represented through stochastic information-gathering and processing costs. The central importance of cognitive abilities in shaping firms' strategic decision-making is emphasized, for instance, by Gavetti (2005) and Gavetti and Rivkin (2007). Similarly, Helfat and Peteraf (2015), building on Teece's (2007) influential analysis of the microfoundations of dynamic capabilities, examine how heterogeneity in managers' cognitive capabilities can generate differential firm performance under conditions of change.

Assuming that $w > \mu$, the first-order conditions for an interior solution which determine the optimal combination (w_e, L_e) are:

(3) $$\frac{\partial \pi_{e,i}}{\partial L_{e,i}} = (1-c_i)\left[F'\left(\varphi(w_e)L_e\right)\varphi(w_e) - w_e\right] = 0,$$

(4) $$\frac{\partial \pi_{e,i}}{\partial w_{e,i}} = (1-c_i)\left[F'\left(\varphi(w_e)L_e\right)\varphi'(w_e)L_e - L_e\right] = 0.$$

Recalling that $c_i \in (0,1) \subset \mathbb{R}$, we can combine (3) and (4) to obtain the so-called Solow condition:

(5) $$\varphi'(w_e)\frac{w_e}{\varphi(w_e)} = 1,$$

according to which the profit-maximizing efficiency wage is the wage at which the elasticity of effort with respect to the wage is unitary.

Using (1) and (5), we obtain the efficiency wage:[3]

(6) $$w_e = \left(\frac{1-\xi}{1-\eta}\right)\mu.$$

Intuitively, the wage rate which maximizes the profits (and consequently minimizes the cost of a unit of effort or effective labor) of any individual firm taking workers' expected cost of job loss as exogenously given varies positively with the index of labor-market opportunities, μ, and the wage elasticity of effort, η, and negatively with the parameter ξ related to normal effort, $\varphi_n = \xi^\eta$.

By following the optimal rule in (6), wage setters are able to elicit the maximum level of labor effort from their workers. This maximum level of effort can be obtained by substituting (6) into (1), which yields:

[3] Since $F''(\cdot) < 0$ and $\varphi''(w) = -\eta(1-\eta)[w-(1-u)\mu]^{\eta-2} < 0$ for $w > \mu$, it follows that the second-order condition for profit maximization is also satisfied.

(7) $$\varphi(w_e) = \left[\frac{(1-\xi)\eta}{1-\eta}\right]^{\eta} \equiv \varphi_e .$$

Expectedly, under the assumption that $0 < \xi < \eta < 1$, the maximum level of labor effort is greater than the normal level of effort:

(8) $$\varepsilon \equiv \frac{\varphi_e}{\varphi_n} = \left[\frac{(1-\xi)\eta}{\xi(1-\eta)}\right]^{\eta} > 1 ,$$

Moreover, we also expectedly obtain the following comparative-static results:

(9) $$\frac{\partial \varepsilon}{\partial \eta} = \frac{\varepsilon}{1-\eta}\left[1 + \left(\frac{1-\eta}{\eta}\right)\ln \varepsilon\right] > 0 ,$$

and

(10) $$\frac{\partial \varepsilon}{\partial \xi} = \frac{-\varepsilon\eta}{\xi(1-\eta)} < 0 .$$

Expectedly, therefore, the labor effort differential in (8) varies positively with the measure of the effort-enhancing effect of compensating workers with a wage that more than offsets the index of labor-market opportunities, η, and negatively with the parameter associated with the normal level of effort, ξ.

As formalized in (1), effort in excess of the normal level is supplied only when the wage received more than compensates for the worker's outside opportunities, that is, when the labor-market-opportunities index is sufficiently low relative to the wage associated with the current job ($w > \mu$). In a full-employment economy, the cost to a worker employed by a wage-setting firm of being dismissed depends not only on the wage paid by the current job, w_e, but also on the availability of alternative employment at other wage-setting firms and the wage offered by those firms, as well as on the wage paid by wage-taking firms, w_c. Since all wage-taking firms pay the competitive wage w_c and all wage-setting firms pay the common efficiency wage w_e in (6), labor-market conditions can, for analytical convenience and tractability, be summarized by the following index of labor-market opportunities:

(11) $$\mu = xw_e + (1-x)w_c .$$

In the standard shirking model of efficiency wages, the representative firm takes the prevailing market wage as given and is willing to pay that wage, provided that it is sufficient to induce the desired level of worker effort and deter shirking. In the model developed in this paper, however, a wage-setting firm, by paying the information-gathering and processing cost, comes to know the index of labor-market opportunities in (11) through knowledge of the proportion $(1-x) \in [0,1] \subset \mathbb{R}$ of firms that pay the competitive wage and, therefore, can infer (as detailed later) what is the resulting competitive wage. Therefore, an individual efficiency-wage firm can deduce the index of labor-market opportunities (or workers' fallback position or outside option) it will take as given when computing the efficiency wage in (6).

Substituting (11) into (6), we then obtain the profit-maximizing efficiency wage in an environment with heterogeneity in wage-compensation behavior across firms:

(12) $$w_e = w(x;\bar{x})w_c ,$$

where $w(x;\bar{x})$ is the relative wage or wage premium, which is given by:

(13) $$w(x;\bar{x}) = \frac{1-x}{\bar{x}-x}, \text{ with } \bar{x} \equiv \frac{1-\eta}{1-\xi} \in (0,1) \subset \mathbb{R} .$$

Therefore, (12) can be interpreted as the best-reply function of a wage setter in a game in which a fraction $1-x$ of wage takers "contaminates" the game (in the sense used by Droste, Hommes and Tuinstra, 2002, p. 244) by not executing the (costly) interfirm information-gathering and processing required to adopt the wage-setting strategy. In fact, an individual wage setter not only best-replies to other firms, but also takes into account that the other wage setters do the same. Hence, between themselves the wage setters coordinate on a Nash equilibrium.

Note that for (12)-(13), a worker will accept a job offer from a wage setter if $w_e > w_c$ (i.e. $w(x;\bar{x}) > 1$) for any $w_c > 0$, so that the following condition has to be satisfied:[4]

[4] In fact, given that we are assuming $0 < \xi < \eta < 1$, the maximization of (11) was solved under the assumption that $w_e > \mu$, which is trivially satisfied in (12) for any $\mu > 0$.

(14) $$0 \le x < \bar{x} \,.$$

A necessary condition for the wage-setting strategy to be economically viable is that the cost per unit of effort implied by it, given by w_e / φ_e , is lower than the respective cost of wage-taking strategy, given by w_c / φ_n . Taking into account (8) and (12)-(13), this necessary condition is satisfied if, and only if,

(15) $$\frac{w_e / \varepsilon_e}{w_c / \varepsilon_n} = \frac{w(x;\bar{x})}{\varepsilon} \le 1 .$$

It follows from (12)-(13) that the inequality in (15) only holds for any $x \in [0, \underline{x}] \subset [0,1) \subset \mathbb{R}$, where:[5]

(16) $$\underline{x} \equiv \frac{\varepsilon \bar{x} - 1}{\varepsilon - 1} \in (0, \bar{x}) \subset \mathbb{R} \,.$$

Therefore, for any proportion of wage-setting firms above $\underline{x}$, wage setters are required to offer relatively high wages to elicit the desired effort level from workers, implying that the cost per unit of effective labor associated with the wage-setting strategy increases sharply and eventually becomes prohibitively large.

Given that $0 < \underline{x} < \bar{x}$, the interval $[0, \underline{x}] \subset [0, \bar{x}] \subset (0,1) \subset \mathbb{R}$ is taken to constitute the economically relevant range of x considered in the analysis. For any proportion of wage-setting firms within this interval, both wage setters and their employees are willing to enter into a labor contract in which the wage is determined according to (12).

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[5] We have that $\underline{x} \equiv \frac{\varepsilon \bar{x} - 1}{\varepsilon - 1} > 0$, as $\varepsilon = \left[\frac{(1-\xi)\eta}{\xi(1-\eta)}\right]^{\eta} > 1$ and $\bar{x}\varepsilon = \left(\frac{1-\eta}{1-\xi}\right)\left[\frac{(1-\xi)\eta}{\xi(1-\eta)}\right]^{\eta} > 1$. To verify that this last inequality holds, note that it is equivalent to $f(\eta) = (1-\eta)^{1-\eta}\eta^{\eta} > (1-\xi)^{1-\eta}\xi^{\eta} = f(\xi)$, where $f(z) \equiv (1-z)^{1-\eta} z^{\eta}$. The inequality $f(\eta) > f(\xi)$ holds true given that $0 < \xi < \eta < 1$ and $\frac{\partial f(z)}{\partial z} = \frac{\eta - z}{(1-z)^{\eta} z^{1-\eta}} > 0$ for all $z \in (0, \eta) \subset \mathbb{R}$. In turn, we have that $\underline{x} = \frac{\varepsilon \bar{x} - 1}{\varepsilon - 1} < \bar{x}$ if, and only if, $\bar{x} \in (0,1) \subset \mathbb{R}$, which is true since $\bar{x} \equiv \frac{1-\eta}{1-\xi}$ and, by assumption, $0 < \xi < \eta < 1$. Therefore, we can conclude that $0 < \underline{x} < \bar{x}$, if $0 < \xi < \eta < 1$.

Thus, a configuration—let alone an equilibrium one—in which all firms adopt the wage-setting strategy ($x=1$) cannot arise. The intuitive reason is that, in the absence of aggregate unemployment as a worker discipline device, it is profit maximizing for an individual firm to adopt the wage-setting strategy only if a strictly positive mass of firms operates as wage takers, otherwise the cost of job loss is zero. If the economy experiences full employment, workers hired by efficiency-wage firms will not care about the possibility of being dismissed if they are caught providing insufficient effort on the job unless the efficiency wage is strictly greater than the alternative wage. Under full employment, however, a necessary condition for the efficiency wage to be strictly greater than the alternative wage is that the mass of firms that adopt the wage-taking strategy is strictly positive. Under full employment, heterogeneity in wage-compensation strategies across firms, together with the resulting wage dispersion and cross-firm differences in employment levels, serves as an alternative worker discipline device in efficiency-wage firms, effectively replacing unemployment in that role. Even though the probability of re-employment following separation from an efficiency-wage firm is unity, the possibility of re-employment at a lower wage entails a strictly positive expected income loss, thereby preserving the disciplinary effect required for efficiency wages to be profit maximizing. Conversely, a configuration in which no firm adopts the wage-setting strategy ($x=0$) can arise and may constitute an equilibrium. When all firms adopt the wage-taking strategy, the entire labor market operates competitively, and wage flexibility ensures that the competitive wage adjusts to bring in labor market clearing. Under these circumstances, the wage-taking strategy is profit-maximizing for every firm, and the economy operates at a full-employment equilibrium. Thus, unlike the configuration in which all firms adopt the efficiency-wage strategy ($x=1$), a monomorphic situation with all firms adopting the wage-taking strategy ($x=0$) can occur and is consistent with equilibrium behavior.

Note, however, that although the economy operates under full employment—thereby precluding a configuration in which all firms adopt the wage-setting strategy ($x=1$)—the model may nevertheless generate a distinct form of labor-market rationing. In particular, with workers evaluating jobs primarily on the basis of the wage level rather than the wage per unit of effort (i.e., exhibiting a form of wage illusion), all workers will strictly prefer employment in the higher-paying efficiency-wage segment of the labor market. In this case, unless $x=0$, a strictly positive proportion of workers will be unable to obtain employment in that segment and will instead be employed by wage-taking firms receiving a lower wage. Therefore, while the economy exhibits no employment rationing in the conventional sense, a strictly positive proportion of workers may be subject to what could be termed higher-wage rationing, namely, exclusion from employment opportunities in the high-wage segment of the labor market.

From (12)-(13), and given the critical mass $\bar{x}$, it follows not only that the efficiency wage is greater than the competitive wage for all $x \in [0, \underline{x}] \subset \mathbb{R}$, but also that a higher fraction of wage setters implies a higher wage premium:

(17) $$\frac{\partial w(x;\bar{x})}{\partial x} = \frac{1-\bar{x}}{(\bar{x}-x)^2} > 0 \text{ for all } x \in [0, \underline{x}] \subset \mathbb{R}.$$

As all wage setters face the same effort function in (1) and production function $F(\cdot)$, they set the same efficiency wage, w_e, and place the same demand for labor, L_e. As a result, based on the first-order condition in (3), all wage-setting firms hire the same amount of labor, with the efficiency wage equaling the marginal product of labor:

(18) $$w_e = F'(\varphi_e L_e)\varphi_e,$$

recalling that φ_e is the maximum level of labor effort defined in (7).

Similarly, as all wage takers elicit the normal effort level $\varphi_n \equiv \xi^{\eta}$ in (1) from their workers by paying the competitive wage, w_c, and produce according to the same production function $F(\cdot)$, every wage taker hires the same quantity of labor, $L_c = \arg\max\left\{F\left(\varphi_n L_c\right) - w_c L_c\right\}$, with the competitive wage equaling the marginal product of labor:

(19) $$w_c = F'(\varphi_n L_c)\varphi_n.$$

Since all wage setters face the same effort function in (1) and production function $F(\cdot)$, they set the same efficiency wage w_e and employ the same quantity of labor, L_e. Likewise, as all wage takers elicit the normal effort from their workers by paying the competitive wage and undertake production subject to the same production function $F(\cdot)$, every wage taker hires the same amount of labor, L_c. Given this within-group homogeneity and assuming a *continuum* of firms, the full-employment condition can be expressed as follows:

(20) $$\int_0^x L_e di + \int_x^1 L_c di = xL_e + (1-x)L_c = N,$$

where $N \in \mathbb{R}_{++}$ stands for the aggregate labor force, which is taken as an exogenously given constant. Without loss of generality, we normalize $N = 1$.

For specific analytical purposes, we assume that the homogeneous good is produced according to the following production function:

(21) $$F\left(\varphi(w_\tau)L_\tau\right) = \left(\varphi(w_\tau)L_\tau\right)^\alpha, \text{ with } \tau = c, e,$$

where $\alpha \in (0,1) \subset \mathbb{R}$, the effective-labor elasticity of output, is a constant. As we will follow the dynamics of the economy beyond a given production period, we normalize the initial level of capital to one and assume that capital is neither depreciating nor accumulating over time. We further assume that this homogeneous good is sold in a competitive goods market at a constant price, which we also normalize to one.

To obtain the specific endogenous configuration (w_e, L_e, w_c, L_c) implied by (21), we first use the effort differential in (8) together with the production technology in (21) to compute the corresponding marginal products of labor from (18) and (19), and then substitute the resulting expressions into (12). This yields the condition determining the ratio of employment in wage-setting firms to employment in wage-taking firms:

(22) $$\alpha\varphi_e^{\ \alpha}(L_e)^{\alpha-1} = w(x;\overline{x})\alpha\varphi_n^{\ \alpha}(L_c)^{\alpha-1},$$

whose solution is:

(23) $$\frac{L_e}{L_c} = \left[\frac{\varepsilon^\alpha}{w(x;\overline{x})}\right]^{\frac{1}{1-\alpha}} \equiv \ell(x;\overline{x},\varepsilon,\alpha) > 0, \text{ for all } x \in [0,\underline{x}] \subset \mathbb{R}.$$

Based on the sign of the derivative in (17), we have that:

(24) $$\frac{\partial \ell(x;\bar{x},\varepsilon,\alpha)}{\partial x} = -\left(\frac{1}{1-\alpha}\right)\ell(x;\bar{x},\varepsilon,\alpha)\frac{1}{w(x;\bar{x})}\frac{\partial w(x;\bar{x})}{\partial x} < 0, \text{ for all } x \in [0,\underline{x}] \subset \mathbb{R},$$

or, in terms of elasticity:

(24-a) $$\frac{\partial \ell(x;\bar{x},\varepsilon,\alpha)}{\partial x}\frac{x}{\ell(x;\bar{x},\varepsilon,\alpha)} = -\left(\frac{1}{1-\alpha}\right)\frac{\partial w(x;\bar{x})}{\partial x}\frac{x}{w(x;\bar{x})} < 0, \text{ for all } x \in [0,\underline{x}] \subset \mathbb{R}.$$

Next, we use (20) and (23) to obtain the value of the employment level for each type of firm, which is influenced by x:

(25) $$L_c = \frac{1}{1-x+x\ell(x;\bar{x},\varepsilon,\alpha)} > 0, \text{ for all } x \in [0,\underline{x}] \subset \mathbb{R},$$

and

(26) $$L_e = \ell(x;\bar{x},\varepsilon,\alpha)L_c = \frac{\ell(x;\bar{x},\varepsilon,\alpha)}{1-x+x\ell(x;\bar{x},\varepsilon,\alpha)} > 0, \text{ for all } x \in [0,\underline{x}] \subset \mathbb{R}.$$

Finally, combining (19), (21), and (25), the competitive wage can be written as:

(27) $$w_c = \alpha\varphi_n^{\alpha}\left(L_c\right)^{\alpha-1} = \alpha\varphi_n^{\alpha}\left(\frac{1}{1-x+x\ell(x;\bar{x},\varepsilon,\alpha)}\right)^{\alpha-1} > 0, \text{ for all } x \in [0,\underline{x}] \subset \mathbb{R}.$$

Analogously, combining (18), (21), and (26), the efficiency wage can be written as:

(28) $$w_e = \alpha\varphi_e^{\alpha}\left(\ell(x;\bar{x},\varepsilon,\alpha)L_c\right)^{\alpha-1} = \alpha\varphi_e^{\alpha}\left(\frac{\ell(x;\bar{x},\varepsilon,\alpha)}{1-x+x\ell(x;\bar{x},\varepsilon,\alpha)}\right)^{\alpha-1} > 0, \text{ for all } x \in [0,\underline{x}] \subset \mathbb{R}$$

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As expected, the decreasing marginal product of labor implied by the production function in (21) establishes an inverse relationship between w_c and L_c, and between w_e and L_e.

III. Cross-sectional distribution of wage-compensation strategies driven by an evolutionary selection dynamic

The cross-sectional distribution of wage-compensation strategies across the firm population evolves intertemporally via an evolutionary selection dynamic driven by net profit differentials. Since the determination of the vector of variables (w_e, L_e, w_c, L_c) specified in the preceding section depends on the cross-sectional distribution of wage-compensation strategies across the firm population, such vector evolves intertemporally as well. As formally explored in the following, the trajectory of this distribution and the associated vector of other labor-market variables may converge to an evolutionary equilibrium, characterized by the stationarity of these variables.

Using (21) and (27), the gross (equal to net) profit of the wage-taking strategy is given by:

(29) $$\pi_c = (\varphi_n L_c)^\alpha - [\alpha(\varphi_n)^\alpha (L_c)^{\alpha-1}]L_c = (1-\alpha)(\varphi_n L_c)^\alpha .$$

By the same token, using (21) and (28), the gross profit of the wage-setting strategy is expressed as follows:

(30) $$\pi_e = (\varphi_e L_e)^\alpha - [\alpha(\varphi_e)^\alpha (L_e)^{\alpha-1}]L_e = (1-\alpha)(\varphi_e L_e)^\alpha .$$

Meanwhile, combining (2) and (30), the net profit of the $i\text{-}th$ wage setter is given by:

(31) $$\pi_{e,i} = (1-c_i)\pi_e .$$

A wage-setting firm i compares its current net profit, given by (31), with the current gross (equal to net) profit of the wage-taking strategy, given by (29). If $\pi_{e,i} = (1-c_i)\pi_e \geq \pi_c$ or, equivalently, if $\frac{\pi_e}{\pi_c} > \frac{1}{1-c_i}$, the wage-setting firm i has no incentive to revise its wage-compensation strategy in the subsequent production period. Conversely, if $\frac{\pi_e}{\pi_c} \leq \frac{1}{1-c_i}$, wage-setting firm i the firm becomes a candidate for strategy revision. As $c_i \in (0,1) \subset \mathbb{R}$ for any firm wage-setting firm i, the ratio $\frac{1}{1-c_i} \in (1,\infty) \subset \mathbb{R}_{++}$, which may be termed the *information-gathering and processing cost factor* of wage-setting firm i, represents the proportion by which the gross profit associated with the wage-setting strategy must exceed the profit generated by the alternative wage-taking strategy for firm i to expect that the wage-setting strategy will more than cover its required implementation cost in the subsequent production period.

The information-gathering and processing cost factor of a given firm i depends, inter alia, on idiosyncratic characteristics, as suggested by the behaviorally oriented research in strategic management discussed in the Introduction and in subsection II-a. Accordingly, individual cost factors are assumed to be randomly distributed across the population of firms according to a cumulative distribution function $H:(1,\infty)\subset\mathbb{R}\to[0,1]\subset\mathbb{R}$, which is continuously differentiable and satisfies $H'(\cdot)>0$ throughout its domain. As a result, given the gross profit differential π_e/π_c prevailing in the current production period, the probability with which a randomly selected wage-setting firm i believes that its currently adopted wage-compensation strategy will more than cover its associated implementation cost in the subsequent production period is represented by $\Pr\left(\frac{1}{1-c_i}<\frac{\pi_e}{\pi_c}\right)=H\left(\pi_e/\pi_c\right)$. Conversely, the probability with which a randomly selected wage-setting firm i believes that its currently adopted wage-compensation strategy will not more than cover its associated implementation cost in the subsequent production period is represented by $1-H\left(\pi_e/\pi_c\right)$. Accordingly, the measure of wage setters that become strategy revisers and thus potential wage takers in the subsequent production period is given by $x\left[1-H\left(\pi_e/\pi_c\right)\right]$.

Let us assume that a wage-setting firm i that becomes a strategy reviser switches to the alternative wage-taking strategy with probability equal to the proportion of firms currently following that strategy, $1-x$. This specification captures an imitation effect whereby strategies that are more prevalent in the population are more likely to be adopted by revising firms. Such behavior is consistent with the evolutionary-game-theoretic literature, in which agents often rely on social learning and frequency-dependent imitation rather than fully optimizing behavior. As emphasized by Weibull (1995) and Vega-Redondo (1996), the prevalence of a strategy may itself constitute a source of information regarding its relative attractiveness, leading agents to imitate more commonly observed behaviors. Specifically, this imitation effect is consistent with Vega-Redondo's (1996) suggestion that, under bounded rationality, agents may rely on social learning mechanisms, employing the observed prevalence of alternative behaviors as an indicator of their relative attractiveness. Furthermore, as suggested by Weibull (1995), evolutionary adjustment processes are often driven by frequency-dependent imitation, whereby strategies that are more widespread within the population are more likely to be selected by agents undergoing strategy revision. In the present context of boundedly rational decision making, this imitation effect can therefore be interpreted as a manifestation of conventional behavior, whereby firms employ the prevalence of alternative strategies within the population as a reliable heuristic guide for strategy revision. Under this premise, the outflow from the subpopulation of wage-setting firms between the current production period and the subsequent one is given by:

(32) $$x\left[1-H\left(\pi_e/\pi_c\right)\right](1-x).$$

Analogously, the probability with which a randomly selected wage-taking firm i in the current production period believes that the wage-setting compensation strategy will more than cover its required implementation cost in the subsequent production period is represented by $H\left(\pi_e/\pi_c\right)$, so that the measure of wage takers that become strategy revisers and thus potential wage setters in the subsequent production period is given by $(1-x)\left[1-H\left(\pi_e/\pi_c\right)\right]$. Recalling the imitation effect described above, whereby wage takers that become strategy revisers and hence potential wage setters switch to the wage-setting strategy with probability proportional to the prevalence of that strategy in the population, the outflow from the subpopulation of wage takers between the current production period and the subsequent one is given by:

(33) $$(1-x)H\left(\pi_e/\pi_c\right)x.$$

Combining the strategy-switching flows specified in (32) and (33), we obtain the following evolutionary selection dynamic:

(34) $$\dot{x}=x(1-x)\left[2H\left(\pi_e/\pi_c\right)-1\right].$$

This dynamic implies that the growth rate of the proportion of wage setters is strictly increasing in the gross-profit ratio, since $\dfrac{\partial(\dot{x}/x)}{\partial\left(\pi_e/\pi_c\right)}=2(1-x)H'\left(\pi_e/\pi_c\right)>0$ for all $x\in[0,\underline{x}]\subset(0,1)\subset\mathbb{R}$. Intuitively, any increase in the ratio π_e/π_c makes the wage-setting strategy relatively more attractive, thereby increasing the growth rate of the proportion of wage setters for any heterogeneous cross-sectional distribution of wage-compensation strategies across the firm population.

Using (12)-(13) and (23), the profit differential π_e/π_c can be expressed as a function of x as follows:

(35) $$\frac{\pi_e}{\pi_c}=\frac{(1-\alpha)(\varphi_n L_e)^\alpha}{(1-\alpha)(\varphi_n L_c)^\alpha}=\left(\varepsilon\ell(x;\bar{x},\varepsilon,\alpha)\right)^\alpha=\left[\frac{\varepsilon}{w(x;\bar{x})}\right]^{\frac{\alpha}{1-\alpha}}.$$

Finally, substituting this function into (34) yields the following evolutionary selection dynamic governing transitions in the cross-sectional distribution of wage-compensation strategies across the firm population:

(36) $$\dot{x}=x(1-x)\left[2H\left(\left(\frac{\varepsilon}{w(x;\bar{x})}\right)^{\frac{\alpha}{1-\alpha}}\right)-1\right],$$

whose state space is $[0,\underline{x}]\subset(0,1)\subset\mathbb{R}$, where $\underline{x}$ is defined in (16).

An important property of the evolutionary selection dynamic in (36) relates to the distribution of information-gathering and processing cost factors across firms, as characterized by the median of the distribution H. Let $m\in(1,\infty)\subset\mathbb{R}_{++}$ denote the median of this distribution, defined by $H(m)=1/2$, which is unique assuming that $H'(\cdot)>0$ throughout its support.[6]

Considering the evolutionary selection dynamic in (36), it is straightforward to verify that $\dot{x}=0$ at $x=0$, provided that $2H\left(\left(\frac{\varepsilon}{w(0;\bar{x})}\right)^{\alpha/1-\alpha}\right)-1=2H\left(\left(\varepsilon\bar{x}\right)^{\alpha/1-\alpha}\right)-1>0$, that is, if:

(37) $$\left(\varepsilon\bar{x}\right)^{\frac{\alpha}{1-\alpha}}>m.$$

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[6] Consider that individual information-gathering and processing costs are randomly distributed across the population of firms according to a continuous random variable $G:(0,1)\subset\mathbb{R}\to\mathbb{R}$ with $G'(\cdot)>0$ throughout its support and median $c\in(0,1)\subset\mathbb{R}$. Let $\rho:(1,\infty)\subset\mathbb{R}\to(0,1)\subset\mathbb{R}$ be the function mapping H to G, given by $\rho(h)=1-\frac{1}{h}$, which is strictly increasing on the support $(1,\infty)\subset\mathbb{R}$. Thus, it follows that $m=\frac{1}{1-c}$, or equivalently, $c=1-\frac{1}{m}$. Therefore, the two medians are positively related.

In other words, a unique monomorphic evolutionary equilibrium characterized by the extinction of the wage-setting strategy exists whenever the gross-profit ratio associated with a state of full predominance of the wage-taking strategy ($x = 0$) exceeds the median cost factor.

Meanwhile, a polymorphic evolutionary equilibrium of the selection dynamic in (36) exists if there is $x^* \in (0, \underline{x}) \subset (0,1) \subset \mathbb{R}$ such that $x^*(1-x^*)\left[2H\left(\left(\frac{\varepsilon}{w(x^*;\overline{x})}\right)^{\alpha/1-\alpha}\right)-1\right]=0$. Since at a polymorphic evolutionary equilibrium, $x^* \in (0, \underline{x}) \subset (0,1) \subset \mathbb{R}$, we have $x^*(1-x^*)>0$, the preceding equality holds if, and only if, $H\left(\left(\frac{\varepsilon}{w(x^*;\overline{x})}\right)^{\frac{\alpha}{1-\alpha}}\right)=\frac{1}{2}$, or, equivalently:

(38) $$\left(\frac{\varepsilon}{w(x^*;\overline{x})}\right)^{\frac{\alpha}{1-\alpha}} = m .$$

Substituting the expression $w(x^*;\overline{x}) = \frac{1-x^*}{\overline{x}-x^*}$ from (13) into (38) yields the proportion of wage setters in the polymorphic evolutionary equilibrium:

(39) $$x^* = \frac{\varepsilon\overline{x} - m^{\frac{1-\alpha}{\alpha}}}{\varepsilon - m^{\frac{1-\alpha}{\alpha}}} .$$

As $\overline{x} \equiv \frac{1-\eta}{1-\xi} \in (0,1) \subset \mathbb{R}$, it follows that $\varepsilon - m^{(1-\alpha)/\alpha} > \varepsilon\overline{x} - m^{(1-\alpha)/\alpha}$. Since $\varepsilon\overline{x} - m^{(1-\alpha)/\alpha} > 0$ by (37), we have $0 < x^* < 1$. In fact, given the definition of $\underline{x}$ in (16), it is straightforward to verify through simple algebraic manipulation that $x^* < \underline{x}$. Consequently, the existence and uniqueness of the evolutionary equilibrium value x^* defined in (39) are ensured, and this equilibrium is polymorphic (i.e., $x^* \in (0, \underline{x}) \subset (0,1) \subset \mathbb{R}$). From an economic standpoint, the condition in (37) requires that the effort differential ε be sufficiently large or that the median information-gathering and processing cost factor m be sufficiently low.

The stability properties of the two evolutionary equilibria of the evolutionary selection dynamic in (36) can be readily inferred from the sign of $\phi(x;\bar{x},\varepsilon,\alpha) \equiv 2H\left(\left(\frac{\varepsilon}{w(x;\bar{x})}\right)^{\alpha/1-\alpha}\right)-1$, since for all $x \in (0,\underline{x}] \subset (0,1) \subset \mathbb{R}$, we have that $sign(\dot{x}) = sign(\phi(x))$, where $sign(\cdot)$ stands for the sign function. Firstly, it should be noted that $\phi(x;\bar{x},\varepsilon,\alpha)$ is a strictly decreasing function of x, since from (13) and (17) we have for all $x \in (0,\underline{x}] \subset \mathbb{R}$ that:

(40) $$\frac{\partial\phi(x;\bar{x},\varepsilon,\alpha)}{\partial x} = -2\left(\frac{\alpha}{1-\alpha}\right)H'\left(\left(\frac{\varepsilon}{w(x;\bar{x})}\right)^{\alpha/1-\alpha}\right)\left(\frac{\varepsilon}{w(x;\bar{x})}\right)^{\alpha/1-\alpha}\frac{1}{w(x;\bar{x})}\frac{\partial w(x;\bar{x})}{\partial x} < 0 .$$

Given the sign of the derivative above and the fact that $\phi(x^*;\bar{x},\varepsilon,\alpha) = 0$, we have that $\phi(x) > 0$ for all $x \in (0,x^*) \subset [0,\underline{x}] \subset \mathbb{R}$ and $\phi(x) < 0$ for all $x \in (x^*,\underline{x}] \subset [0,\underline{x}] \subset \mathbb{R}$. As a result, $\dot{x} > 0$ for all $x \in (0,x^*) \subset [0,\underline{x}] \subset \mathbb{R}$ and $\dot{x} < 0$ for all $x \in (x^*,\underline{x}] \subset [0,\underline{x}] \subset \mathbb{R}$, so that trajectories converge toward x^* from both sides. Accordingly, the monomorphic evolutionary equilibrium ($x^* = 0$) is unstable (a repulsor), whereas the polymorphic evolutionary equilibrium represented by x^* in (39) is asymptotically stable (an attractor).

A key analytical implication of the model, therefore, is that a fully competitive labor market does not emerge over time from an initial population of firms displaying heterogeneous wage-compensation strategies, even when only a small fraction of firms initially adopts the wage-setting strategy. In particular, the evolutionary selection dynamic specified in (36) does not converge to a configuration in which all firms adopt the wage-taking strategy, despite firms being free to revise their wage-compensation strategies in response to net profitability differentials. Moreover, even if all firms initially adopt the wage-taking strategy, so that the labor market is fully competitive, the exogenous switch to the wage-setting strategy by a nonzero mass of firms is sufficient to move the economy away from that initial configuration. Since the monomorphic evolutionary equilibrium at $x^* = 0$ is unstable, the evolutionary selection dynamics do not drive the economy back to a fully competitive labor market. Interestingly, these results are obtained even though the wage-taking strategy, which is costless with respect to information acquisition, competes against a doubly costly wage-setting strategy, since adoption of the latter entails both the payment of a higher wage and the incurrence of a strictly positive information-gathering and processing cost.

Meanwhile, a configuration—let alone an equilibrium one—in which all firms adopt the wage-setting strategy ($x = 1$) cannot arise. The reason is that, in the absence of aggregate unemployment as a worker discipline device, it is profit maximizing for an individual firm to adopt the wage-setting strategy only if a strictly positive measure of firms operates as wage takers, otherwise the cost of job loss is zero. Therefore, unless all firms initially adopt the wage-taking strategy, the economy converges over time to a stationary configuration in which wage-taking and wage-setting firms coexist. This polymorphic equilibrium emerging from the evolutionary selection dynamic specified in (36) implies that the labor market is characterized by what we term *strategic segmentation*, which constitutes the underlying source of the stationary wage inequality generated by the model.

Given that $x^* \in (0, \underline{x}) \subset (0, \overline{x}) \subset (0,1) \subset \mathbb{R}$ and $m > 1$, and under the stability condition in (40), the polymorphic evolutionary equilibrium in (39) yields the following comparative-static results:

(41) $$\frac{\partial x^*}{\partial \varepsilon} = \frac{\overline{x} - x^*}{\varepsilon - m^{(1-\alpha)/\alpha}} > 0,$$

(42) $$\frac{\partial x^*}{\partial \alpha} = \frac{m(\ln m)(1 - x^*)}{\alpha^2 \left(\varepsilon - m^{(1-\alpha)/\alpha} \right)} > 0,$$

and

(43) $$\frac{\partial x^*}{\partial m} = -\left(\frac{1-\alpha}{\alpha}\right)\left(\frac{m^{(1-2\alpha)/\alpha}}{\varepsilon - m^{(1-\alpha)/\alpha}}\right)(1-x^*) < 0 .$$

As expected, the derivative in (41) shows that, under the stability condition in (40), the proportion of wage-setting firms in the polymorphic evolutionary equilibrium is positively related to the worker effort differential ε, as a larger (smaller) effort differential raises (reduces) the relative attractiveness of the wage-setting strategy. Recalling that $\frac{\partial \varepsilon}{\partial \eta} > 0$ and $\frac{\partial \varepsilon}{\partial \xi} < 0$ (per (10) and (11), respectively), the sign of the derivative in (41) implies that the proportion of wage-setting firms in the polymorphic evolutionary equilibrium is positively related to the magnitude of the effort-enhancing effect of paying a higher-than-the-alternative wage, η, and negatively related to the parameter associated with the normal level of effort, ξ.

In turn, the proportion of wage-setting firms in the polymorphic evolutionary equilibrium varies positively with the parameter α of the production function in (21). As follows from (35), an increase in this parameter reduces the gross profit differential given by π_e/π_c, given that $\frac{\partial \pi_e/\pi_c}{\partial \alpha} = \frac{\pi_e}{\pi_c}\ln\left(\varepsilon \big/ w(x^*;\bar{x})\right)\left(\frac{-1}{\alpha^2}\right) < 0$, recalling from (43) that $\frac{\varepsilon}{w(x^*;\bar{x})} = m > 1$. This decrease in π_e/π_c exerts downward pressure on the wage premium, $w(x^*;\bar{x})$, thereby expanding the relative attractiveness of the wage-setting strategy and leading to an upward adjustment of x^*.

The proportion of wage-setting firms in the polymorphic evolutionary equilibrium is negatively related to the median of firms' information-gathering and processing cost factor, m. Given (35) and the equilibrium condition in (38), an increase in this cost factor raises the gross profit differential represented by π_e/π_c in the same proportion. The resulting increase in this differential exerts upward pressure on the wage premium, $w(x^*;\bar{x})$, thus reducing the relative attractiveness of the wage-setting strategy and inducing a downward adjustment in x^*.

IV. Implications for wage inequality in the polymorphic evolutionary equilibrium

Having established in the preceding subsection how changes in the model's parameters affect the proportion of wage-setting firms in the polymorphic evolutionary equilibrium, we now examine how this proportion influences different measures of wage inequality. We can then combine these effects with the comparative-static relationships derived in (41)–(43) to analyze how variations in the model's parameters translate into changes in these measures of wage inequality.

As a starting point, consider the wage premium arising in the polymorphic evolutionary equilibrium. According to (38), this wage premium is given by:

(38-a) $$w(x^*;\bar{x}) = \frac{\varepsilon}{m^{(1-\alpha)/\alpha}}$$, for all $\varepsilon \in (1,\infty) \subset \mathbb{R}_{++}$, $\alpha \in (0,1) \subset \mathbb{R}_{++}$, and $m \in (1,\infty) \subset \mathbb{R}_{++}$.

Based on (38-a), we obtain the following comparative-static results for the wage premium in the polymorphic evolutionary equilibrium, expressed in both absolute and elasticity terms:

(44) $$\frac{\partial w(x^*;\bar{x})}{\partial \varepsilon} = \frac{1}{m^{(1-\alpha)/\alpha}} > 0 \text{ or } \frac{\partial w(x^*;\bar{x})}{\partial \varepsilon}\frac{\varepsilon}{w(x^*;\bar{x})} = 1,$$

(45) $$\frac{\partial w(x^*;\bar{x})}{\partial \alpha} = \frac{w(x^*;\bar{x})}{\alpha^2}\ln m > 0 \text{ or } \frac{\partial w(x^*;\bar{x})}{\partial \alpha}\frac{\alpha}{w(x^*;\bar{x})} = \frac{\ln m}{\alpha} > 0,$$

and

(46) $$\frac{\partial w(x^*;\bar{x})}{\partial m} = -\left(\frac{1-\alpha}{\alpha}\right)\frac{w(x^*;\bar{x})}{m} < 0 \text{ or } \frac{\partial w(x^*;\bar{x})}{\partial m}\frac{m}{w(x^*;\bar{x})} = -\left(\frac{1-\alpha}{\alpha}\right) < 0.$$

The expressions in (44) show that the wage premium in the polymorphic evolutionary equilibrium is increasing in the effort differential, ε, with a unitary elasticity. This result reflects the combined operation of two transmission channels: in the polymorphic evolutionary equilibrium, a higher effort differential increases the proportion of wage-setting firms (per (41)), which raises the wage premium (per (17)). Recalling that $\frac{\partial \varepsilon}{\partial \eta} > 0$ and $\frac{\partial \varepsilon}{\partial \xi} < 0$ (per (10) and (11), respectively), the sign of the derivative in (44) implies that the wage premium in the polymorphic evolutionary equilibrium is positively related to the magnitude of the effort-enhancing effect of paying a wage higher than the index of labor-market opportunities in (11), η, and negatively related to the parameter associated with the normal level of effort, ξ.

The expressions in (45) indicate that the wage premium in the polymorphic evolutionary equilibrium varies positively with the parameter α of the production function in (21). Thus, in the polymorphic evolutionary equilibrium, an increase in this parameter raises the proportion of wage-setting firms (per (42)) and, consequently, increases the wage premium (per (17)). In turn, the expressions in (46) show that the wage premium in the polymorphic evolutionary equilibrium varies negatively with the median value of the information-gathering and processing factor cost, m. Therefore, in the polymorphic evolutionary equilibrium, an increase in this median value reduces the proportion of wage-setting firms (per (43)), which lowers the wage premium (per (17)).

Another informative measure of wage inequality can be obtained by computing the ratio of the total wages paid to workers employed by wage-setting firms to the corresponding total paid to workers employed by wage-taking firms, which we term the *relative wage bill*. Combining (13), (23), and (38), this ratio in the polymorphic evolutionary equilibrium is given by:

(47) $$\frac{x^* w_e L_e}{(1-x^*) w_c L_c} = \left(\frac{x^*}{1-x^*}\right) w(x^*;\bar{x})\ell(x^*;\bar{x},\varepsilon,\alpha) = \left(\frac{x^*}{1-x^*}\right)\left(\frac{\varepsilon}{w(x^*;\bar{x})}\right)^{\frac{\alpha}{1-\alpha}} = \left(\frac{x^*}{1-x^*}\right) m \equiv \psi(x^*,m).$$

Combining the comparative-static results in (41)–(43) with (47), we derive the following effects of parametric changes on the relative wage bill measure in the polymorphic evolutionary equilibrium:

(48) $$\frac{\partial \psi(x^*,m)}{\partial \varepsilon} = \left(\frac{m}{(1-x^*)^2}\right)\frac{\partial x^*}{\partial \varepsilon} > 0,$$

(49) $$\frac{\partial \psi(x^*,m)}{\partial \alpha} = \left(\frac{m}{(1-x^*)^2}\right)\frac{\partial x^*}{\partial \alpha} > 0,$$

and

(50) $$\frac{\partial \psi(x^*,m)}{\partial m}=\left(\frac{m}{(1-x^*)^2}\right)\frac{\partial x^*}{\partial m}+\left(\frac{x^*}{1-x^*}\right).$$

In the polymorphic evolutionary equilibrium, therefore, the relative wage bill varies positively with the effort differential ε (per (48)), and hence positively with the magnitude of the effort-enhancing effect of paying a wage higher than the index of labor-market opportunities in (11), η, and negatively with the parameter associated with the normal level of effort, ξ. The relative wage bill in the polymorphic evolutionary equilibrium also varies positively with the parameter α of the production function in (21) (per (49)). In turn, according to (50), the net effect of the median value of the information-gathering and processing cost factor, m, on the relative wage bill in the polymorphic evolutionary equilibrium depends on the balance between two opposing forces. On the one hand, an increase in m raises the relative wage bill through the intensive margin, since $\frac{x^*}{1-x^*}>0$. According to (47), this intensive margin effect operates via the ratio of the wage bill of an efficiency-wage firm to the wage bill of a wage-taking firm, which is given by $w_eL_e/w_cL_c=w(x^*;\overline{x})\ell(x^*;\overline{x},\varepsilon,\alpha)$. On the other hand, an increase in m lowers the relative wage bill through the extensive margin by making the wage-setting strategy relatively less attractive to more firms and thereby reducing the proportion of efficiency-wage firms in the polymorphic evolutionary equilibrium, since (43) implies that $\left(\frac{m}{(1-x^*)^2}\right)\frac{\partial x^*}{\partial m}<0$ in (50).

A third informative measure of wage inequality can be constructed as the ratio of the wage bill paid by wage-setting firms to the aggregate wage bill. This distributive measure, which we term *efficiency-wage bill share*, is given by:

(51) $$S_e(x^*,m)\equiv\frac{x^*w_eL_e}{x^*w_eL_e+(1-x^*)w_cL_c}=\frac{\psi(x^*,m)}{\psi(x^*,m)+1}.$$

Using (48)-(50), it follows from (51) that:

(52) $$\frac{\partial S_e(x^*,m)}{\partial \varepsilon}=\frac{\partial S_e(x^*,m)}{\partial \psi}\frac{\partial \psi(x^*,m)}{\partial \varepsilon}=\frac{1}{\left(\psi(x^*,m)+1\right)^2}\left(\frac{m}{(1-x^*)^2}\right)\frac{\partial x^*}{\partial \varepsilon}>0,$$

(53) $$\frac{\partial S_e(x^*,m)}{\partial \alpha}=\frac{\partial S_e(x^*,m)}{\partial \psi}\frac{\partial \psi(x^*,m)}{\partial \alpha}=\frac{1}{\left(\psi(x^*,m)+1\right)^2}\left(\frac{m}{(1-x^*)^2}\right)\frac{\partial x^*}{\partial \alpha}>0,$$

and

(54) $$\frac{\partial S_e(x^*,m)}{\partial m}=\frac{\partial S_e(x^*,m)}{\partial \psi}\frac{\partial \psi(x^*,m)}{\partial m}=\frac{1}{\left(\psi(x^*,m)+1\right)^2}\left[\left(\frac{m}{(1-x^*)^2}\right)\frac{\partial x^*}{\partial m}+\left(\frac{x^*}{1-x^*}\right)\right].$$

In the polymorphic evolutionary equilibrium, therefore, the efficiency-wage bill share varies positively with the effort differential ε (per (52)), and hence positively with the magnitude of the effort-enhancing effect of compensating with a wage higher than the index of labor-market opportunities in (11), η, and negatively with the parameter associated with the normal level of effort, ξ. Meanwhile, the efficiency-wage bill share in the polymorphic evolutionary equilibrium varies positively with the parameter α of the production function in (21) (per (53)). According to (54), the effect of the median value of firms' information-gathering and processing cost factor, m, on the efficiency-wage bill share, $S_e(x^*,m)$, in the polymorphic evolutionary equilibrium is indetermined. Although (43) and (47) imply that the first term in brackets on the right-hand side in (54) is strictly negative, the second term is strictly positive, reflecting that $\psi(x^*,m)/\partial m$ is of ambiguous sign. From (50), this sign depends on the net effect of the cost factor parameter, m, on the relative wage bill, $\psi(x^*,m)$, which serves as an alternative measure of wage inequality, as discussed above.

V. Concluding remarks

This paper develops an evolutionary labor-market model that integrates endogenous labor effort, heterogeneous wage-compensation behavior within the population of firms, and persistent wage inequality across otherwise observationally equivalent workers within a unified analytical framework. Motivated by extensive empirical evidence on firm wage premia and endogenous worker productivity, we consider an economy in which firms adopt either a wage-setting strategy, paying an efficiency wage, or a wage-taking strategy, paying the competitive wage prevailing in the non-efficiency-wage segment of the labor market. In a given production period, the efficiency wage, the competitive wage, the wage premium between them, and the corresponding employment levels are all parameterized by the cross-sectional distribution of compensation strategies within the firm population. Since firms revise their wage-compensation strategic behavior according to an evolutionary selection protocol, this distribution evolves endogenously over time across production periods. We characterize the resulting dynamics and establish that the unique stable evolutionary equilibrium is polymorphic, featuring stationary coexistence of wage-setting and wage-taking firms.

The analysis provides an evolutionary game-theoretic explanation for persistent inter-firm wage and wage bill differentials grounded in endogenous labor effort and productivity. In addition to paying wages above the competitive level, firms adopting the wage-setting strategy incur a firm-specific information-gathering and processing cost associated with monitoring other firms' wage-compensation behavior. This inter-firm monitoring cost is assumed to be random and heterogeneous across wage-setting firms, capturing empirically documented differences in firms' cognitive abilities and information-gathering and processing capabilities. Firms revise their wage-compensation strategies according to an evolutionary selection mechanism driven by net-profit differentials, whereby strategies associated with higher net profits tend to increase their population share over time. The dynamic interaction between the productivity-enhancing effects of efficiency wages, the associated wage and inter-firm monitoring costs, and the resulting net-profit differentials generates a unique stable polymorphic equilibrium characterized by the coexistence of wage-setting and wage-taking firms. In the resulting polymorphic equilibrium, the non-efficiency-wage segment of the labor market functions as an employer of last resort, ensuring persistent full employment while simultaneously sustaining the disciplinary mechanism required for the efficiency-wage strategy to remain profit-maximizing. Under full employment, unemployment ceases to serve as a worker discipline device, and wage dispersion across firms instead performs this role. Although workers separated from efficiency-wage firms face a probability of re-employment equal to unity, the prospect of re-employment at a lower wage generates a strictly positive expected income loss, thereby preserving effort incentives. In this sense, heterogeneity in wage-compensation strategies and the resulting wage inequality across firms substitute for unemployment as the mechanism disciplining labor effort.

The model also yields a number of distributional implications regarding the characteristics of the polymorphic evolutionary equilibrium. The wage premium, measured as the relative wage paid by wage-setting firms vis-à-vis wage-taking firms, varies positively with the proportion of wage-setting firms. This analytical result helps explain how the cross-sectional composition of firms influences the extent of inter-firm wage inequality. Moreover, the wage premium in the polymorphic evolutionary equilibrium is increasing in both the effort differential associated with efficiency wages and the effective-labor elasticity of output. In each case, the effect operates through a common transmission mechanism: a larger effort differential or a higher effective-labor elasticity increases the proportion of wage-setting firms, which in turn raises the equilibrium wage premium. By contrast, the wage premium varies negatively with the median value of the distribution of firms' information-gathering and processing costs. An increase in this median inter-firm monitoring cost reduces the proportion of wage-setting firms and thereby lowers the equilibrium wage premium. Finally, relative employment, measured as the ratio of employment in a wage-setting firm to employment in a wage-taking firm, varies negatively with the proportion of wage-setting firms, implying that greater diffusion of the efficiency-wage compensation strategy is associated with smaller employment differentials across firms.

The model further generates implications for broader measures of wage inequality. One such distributive measure is the relative wage bill, defined as the ratio of the total wages paid by wage-setting firms to the total wages paid by wage-taking firms. In the polymorphic evolutionary equilibrium, the relative wage bill varies positively with both the effort differential associated with efficiency wages and the effective-labor elasticity of output. By contrast, the effect of the median value of the distribution of firms' information-gathering and processing costs associated with inter-firm monitoring is ambiguous, reflecting the interaction of two opposing forces. While an increase in this median value raises the relative wage bill through an intensive-margin effect, it reduces it through an extensive-margin effect, as higher median values of firms' information-gathering and processing costs make the wage-setting strategy relatively less attractive to more firms and thereby reduce the equilibrium proportion of wage-setting firms. A third informative measure of wage inequality is the efficiency-wage bill share, defined as the ratio of the total wages paid by wage-setting firms to the aggregate wage bill. In the polymorphic evolutionary equilibrium, this measure varies positively with the effort differential associated with efficiency wages and negatively with the effective-labor elasticity of output. By contrast, the effect of the median value of firms' information-gathering and processing costs on the efficiency-wage bill share is ambiguous.

More broadly, the model highlights how the dynamic interaction between evolutionary selection and endogenously time-varying strategic labor-market segmentation can generate persistent wage inequality even in the absence of aggregate unemployment. The coexistence of wage-setting and wage-taking firms emerges as a necessary condition for sustaining efficiency wages, whereas a configuration in which all firms adopt the efficiency-wage strategy cannot be supported as an equilibrium because the disciplinary effect of job loss would vanish. By contrast, a fully competitive labor market populated exclusively by wage-taking firms constitutes a feasible equilibrium outcome, albeit an unstable one. The stable evolutionary outcome nevertheless lies between these extremes, combining wage-compensation heterogeneity across firms with full employment of the available labor force. Evolutionary selection ultimately favors the stationary coexistence of heterogeneous wage-compensation strategies over the homogenization of firms implied by a fully competitive labor market. Changes in the composition of firms across wage-compensation strategies therefore have systematic effects on different measures of wage inequality, linking the evolution of firm strategic behavior to the distribution of earnings across workers. These findings contribute to the existing literature on efficiency wages and labor-market heterogeneity by providing a coherent explanation for the persistence of firm wage premia and other varieties of wage inequality, as well as by identifying the conditions under which wage inequality can be sustained as an equilibrium outcome in a full-employment economy.

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