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SECTORAL DIFFERENCES IN MANAGERS' COMPENSATION: INSIGHTS FROM A MATCHING MODEL

by Emanuela Ciapanna[*], Marco Taboga[*] and Eliana Viviano[*]

Abstract

We propose a structural model of two-sided matching and a semi-parametric procedure for its estimation that allow us to analyse the determinants of managers' compensation, such as firms' and managers' quality, production technology, bargaining power and inter-temporal preferences. We use the estimated model to study the stylized fact that managers in the financial sector receive higher compensation than their peers in other sectors. Our results suggest that most of this wage gap is explained by differences in production technology, while differences in bargaining power, preferences and quality have a minor impact and are seldom statistically significant.

JEL Classification: C73, D31, J63, J64.
Keywords: managers' compensation, job matching, wage gap.

Contents

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1 Introduction[1]

Why do managers in the financial sector receive higher compensation than their peers in other sectors? Despite a large body of evidence documenting the significance and the persistence of this wage gap[2], there is still no consensus on its determinants. In this paper, we try to shed further light on the phenomenon. We propose a structural model of matching and search on the job market that can explain sectoral differences in compensation in terms of differences in production technologies, intertemporal preferences, bargaining power and distributions of firms' and managers' quality. We estimate the model in order to try to discriminate between these explanations, and we find evidence that in our sample the wage gap is mostly explained by differences in production technology and, in particular, by the fact that increasing the quality of human capital and job positions has higher returns in the financial sector than in the other sectors.

We follow Lu and McAfee (1996) and Shimer and Smith (2000) and model job search as a two-sided matching and Nash-bargaining game. Managers and managerial positions offered by firms are heterogeneous and are ranked according to their quality. Once a manager and a firm are randomly matched, they observe each other's quality and compare the potential output of their partnership with their future expected alternatives. The relation between a matched couple's output and observed qualities is determined by a production technology (the matching function) that satisfies standard regularity conditions and is common knowledge. If gains from partnership are positive, the matched couple engages in bargaining over the conditions of an employment contract. When an agreement is reached, the contract is signed and both agents involved in the trade leave the job market. As is customary in the matching literature, the bargaining process is modelled in reduced form: its outcome depends on bargaining power, an exogenously given

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[2]According to the US Bureau of Labor Statistics, in 2013 in the US the annual mean wage of a manager in the manufacturing sector was around 99,000\$. In the financial sector it was 127,000\$.

variable that measures the ability of managers to claim a fraction of the surplus produced by the match.

We characterize the equilibrium of the model, we prove its existence and uniqueness, and we show that it is numerically solvable by simple fixed point iterations. Once the model is solved, several objects of interest can be easily computed, including conditional and unconditional probabilities of good match, wage functions conditional on types, and probability distributions of types conditional on being in a contract.

To estimate the parameters of the model, we employ data on compensation packages and skill requirements collected by Hay Group, a consulting group specialized in the design of compensation schemes. The dataset refers to a sample of managerial positions at large Italian firms. For each position, the data include the compensation of the manager filling the position and a quantitative valuation of the position, in terms of its complexity and of the level of skills and knowledge required to fill it. The score assigned to each position (in so-called Hay points) is comparable across firms and over time and is calculated independently of the manager who is filling the position and of her compensation. The stylized fact that financial managers earn more than their peers is found also in our dataset.

The solution of our model yields a wage equation that links compensation to the quality of a position and to all the exogenous parameters. The latter describe technology, preferences, bargaining power and the distributions of types in the economy. By identifying the quality variable in the wage equation with Hay points, we are able to estimate the parameters in the equation by non-linear least squares techniques. We perform the estimation separately for the financial and the non-financial sectors.

We find that the marginal productivities of managers and vacancies are on average higher in the financial sector than in the other sectors. This difference is not only statistically significant, but it accounts for the bulk of the wage premium. Also bargaining power is estimated to be higher in the financial sector, which means that financial managers are able to obtain higher shares of surplus than other managers. However, this difference is not statistically significant and it explains a minor fraction of the wage premium. The same is true of estimated differences in the probability distributions of types and in the only preference parameter of our model, which quantifies impatience and determines agents' willingness to wait for better matches.

Our paper has several points of contact with the existing literature on managers' compensation.

Philippon and Reshef (2012) analyze almost a century of US data and find several periods when wages in the financial sector are significantly higher than in the other sectors. They document that this wage gap cannot be explained by education and other individual characteristics. Furthermore, they find that the wage gap is positively correlated with an aggregate index of relative complexity of financial jobs. Despite differences between their reference population and ours[3] and between their measure of job complexity and ours, their findings are in line with those of our preliminary regression analysis. Philippon and Reshef (2012) also find that changes in a measure of financial deregulation account for a significant portion of the temporal evolution of the wage premium. They conjecture that light financial regulation in recent decades, as well as before 1940, may have increased productivity in the financial sector, by encouraging the creativity of skilled workers and by fostering innovation. The results from our structural model can be seen as supportive of their view: according to our estimates, the bulk of the wage premium would be explained by differences in productivity.

Our results can also be seen in accordance with those of Gabaix and Landier (2008), Terviö (2008) and Gabaix, Landier and Sauvagnat (2014), who provide evidence that variation in the compensation of CEOs is mostly explained by demand-side factors, that is, by firms' characteristics that in equilibrium can determine significant differences in output for given level of inputs.

Another important strand of the literature focuses on agency problems[4] (Berle and Means 1932, Jensen and Meckling 1976). According to the so called rent extraction view (e.g., Bertrand and Mullainathan 2001, Bebchuk et al. 2002, Bebchuk and Fried 2004, Gayle and Miller 2009, Acharya and Volpin 2010, Morse

[3] We focus on all managerial positions, while they analyze either the whole population of workers or only the top executives.

[4] Early studies in this area focused on documenting the relation between manager pay and company performance (Murphy 1985, Murphy 1986, Jensen and Murphy 1990, Abowd 1990, Leonard 1990, Weisbach 1988, Warner et al. 1988, Antle and Smith 1986, Gibbons and Murphy 1990).

et al. 2011) managers can control at least part of their compensation and extract rents from their privileged position within firms. Despite several attempts to determine the relative importance of rent extraction, the empirical evidence is mixed (see Frydman and Jenter 2010 for a review). In our model, rent extraction could be seen as a component of bargaining power, a device that describes in reduced form managers' ability to claim a fraction of joint surplus[5]. Our estimates do not provide evidence in favor of sectoral differences in bargaining power and could be interpreted as indirect evidence that rent extraction is not a significant determinant of the wage gap.

Finally, let us mention two recent contributions (Edmans, Gabaix and Landier 2009, and Cao and Wang 2013) to the large literature on the optimality of CEO compensation practices. Edmans, Gabaix and Landier (2009) analyze both the level and the sensitivity of pay in a competitive market equilibrium, by embedding the principal-agent problem into a skill assignment model. They provide evidence that the observed level and scaling of incentives is consistent with optimal contracting, but they note (and this applies also to our results) that there are a large number of factors that are difficult to model and measure (e.g., hidden compensation) and that these factors may indeed result from rent extraction. Cao and Wang (2013) propose a model of CEO compensation that takes into account both agency and search problems in a market equilibrium framework with many firms and CEOs. They show that equilibrium pay and incentives can be affected by firms' idiosyncratic and systematic risks and by their interaction with job mobility. Our paper does not directly model these aspects, which we recognize as potentially important determinants of compensation. However, as already noted above, the surplus sharing rule (which is exogenous in our model and is determined by a reduced-form bargaining power parameter) could be thought of as the equilibrium resulting from the optimal determination of incentive schemes that take into account factors such as risk and job mobility.

We believe that our contribution is innovative in several respects. To our knowl-

[5] How surplus is shared could also be determined by the need to provide managers with appropiate incentives (e.g., Dow and Raposo 2005, Benmelech et al. 2010). We do not model agency problems and manager incentives. However, bargaining power and production technologies in our model could be thought of as the equilibrium resulting from the optimal determination of incentive schemes.

edge, it is the first study that uses a matching model to analyze the determinants of the wage gap. Furthermore, it employs microdata on skill requirements (the Hay points) that has so far been seldom employed to analyze sectoral differences in compensation. Also, we analyze a broad population of managers, while the previous literature has focused mostly on top executives, such as CEOs. Finally, on the technical side, the econometric techniques we employ to estimate the matching model are innovative. Because the model is quite general, these techniques could be applied to other matching problems in different areas of research.

The paper is organized as follows. Section 2 presents the theoretical model. Section 3 describes the data. In Section 4 and 5 we present the estimation strategy and discuss our results. Section 6 concludes.

2 Model

We propose a simplified version of the classical two-sided matching game with search and Nash-bargaining, as in Lu and McAfee (1996), Shimer and Smith (2000) and Moscarini (2005).

Matching process and model timeline

The market for managerial positions is a two-sided market, where two categories of agents, managers (potential employees) and firms (potential employers), search for a partner. The matching technology is a pair-wise random matching process. Once two agents are matched, the object of trading is the implementation of a managerial task that requires a certain skill level (vertical differentiation is assumed).

Both managers and firms are heterogeneous and belong to a distinguishable continuum of types, representing supplied and demanded levels of human capital. Managers are of higher type if they are more skilled, whereas firms are sorted according to the quality of their vacancy. We use x to index the types of worker and y the types of vacancy, where both x and y belong to the interval $[0, 1]$.[6]

[6] Notice that $x, y \in [0, 1]$ is assumed for the sake of simplicity and it is without loss of generality. It is always possible to rescale the interval of types without affecting the results obtained from the model.

We assume discrete time and an infinite horizon:

$$t = 0, 1, ..., T \text{ with } T = \infty$$

At each period, the sequence of play is as follows.

Each agent is randomly matched with a counterpart from the other side of the market. The distributions of types are absolutely continuous. Their probability density functions, denoted by $f(x)$ and $g(y)$ for managers and firms respectively, are such that

$$f(x) > 0 \quad \forall x \in (0,1)$$

and

$$g(y) > 0 \quad \forall y \in (0,1)$$

The corresponding cumulative distribution functions are denoted by $F(x)$ and $G(y)$.

Once two agents are matched, they observe each others' type and compare the value of the current match realization to their expectations over future alternatives. The matching function $m(x,y)$ is the per period potential utility generated by a pair (x,y). It is assumed to be increasing in both of its arguments, concave and with positive second cross-partial derivatives, which implies complementarity.

Because the specification of the matching function and the distributions of types are common knowledge, once two agents are matched, they can optimally decide whether or not to enter the bargaining stage, by comparing the value of their joint production to their expectations over future matches. They solve an optimal stopping problem in order to decide whether to start bargaining with the current partner over a long-term employment contract or to keep searching for a better match in the future. The structure of the game, at this stage, resembles the classical two-sided matching models with heterogeneous agents and endogenous disagreement points (Lu and McAfee 1996, Shimer and Smith 2000, Moscarini 2005). In particular, if the current match results in positive gains from trade, the firm makes a "hiring" offer to the manager, and, in case of acceptance by the counterpart, the spoils generated by the match are shared in a Nash fashion.[7]

[7] We model the bargaining stage in reduced form because the determinants of bargaining

In case an agreement is reached, the contract is signed, the firm hires the worker, and the agents involved in the trade leave the job market. In case of no agreement, each party will wait for a possible deal in the future.

We introduce two simplifying assumptions: first, if a match is judged "good enough", then the parties will remain in the contract indeterminately. Second, the two sides of the market share the same discount factor $\delta \in (0, 1)$ over future values.[8]

The net surplus from a match in period t is

$$s_t(x, y) = \frac{m(x, y)}{1 - \delta} - \delta \overline{V}_x^{t+1} - \delta \overline{V}_y^{t+1} \tag{1}$$

where $\frac{m(x,y)}{1-\delta}$ is the discounted value of the stream of gross payoffs that will be produced by the match, and

$$\overline{V}_x^t = \mathrm{E}\left[V_x^t(y) \,|x\right] \tag{2}$$

$$\overline{V}_y^t = \mathrm{E}\left[V_y^t(x) \,|y\right] \tag{3}$$

are expected values, conditional on the agents' own types, of two endogenous values $V_x^t(y)$ and $V_y^t(x)$, that coincide with the agents' disagreement points and represent potential surpluses from future matches.

Every agent in this economy is endowed with a real option consisting in the possibility to sign a labor contract at every t, that is, every time a match takes place. The joint net surplus represents the decision criterion used by the agents to choose whether or not to exercise their real option. The agents exercise the option every time that

$$s_t(x, y) \geq 0 \tag{4}$$

power are out of the scope of this work. As a matter of fact, we are interested in disentangling the weight of demand and supply-side determinants of managers' compensation. To this aim, it is not relevant whether the bargaining between client and consultant is modeled à la Rubinstein, as an ultimatum game, or in reduced form. Choosing the cooperative solution helps to stress the change of perspective between the stage before the matching occurs (anonymous market) and the ex post realization stage, when the two parties are no longer anonymous and have precise individual characteristics.

[8] We assume that the two agents share the same discount factor for the sake of simplicity, as this hypothesis makes the model symmetric. The assumption is without loss of generality, because all our results hold also with different discount factors.

A stylized sketch of the timeline is provided in Figure 1.

We assume that gains from trade are shared according to a rule that is exogenously given and is common knowledge. The sharing rule is as follows: once the surplus is realized, each player, in case of stopping with the current partner, will receive a payoff equal to a fraction of the net surplus, reflecting the bargaining power of managers and firms in the economy, plus his/its own disagreement point. The manager's and the firm's shares are denoted by γ and $(1-\gamma)$ respectively.

Thus, when the surplus is positive and the contract is signed, the compensation of the manager is

$$W^t(x,y) = \gamma s_t(x,y) + \delta \overline{V}_x^{t+1} \tag{5}$$

Instead, when the surplus is negative, no further negotiation takes place and the two agents will wait for future matches. As a consequence,

$$V_x^t(y) = \gamma \max\{s_t(x,y), 0\} + \delta \overline{V}_x^{t+1} \tag{6}$$

and

$$V_y^t(x) = (1-\gamma) \max\{s_t(x,y), 0\} + \delta \overline{V}_y^{t+1} \tag{7}$$

Because exercising the real option is optimal only when $s_t(x,y) \geq 0$, we also have

$$\overline{V}_x^t = \left(1 - G\left(\mathcal{M}^t(x)\right)\right) \delta \overline{V}_x^{t+1} + \int_{\mathcal{M}^t(x)} W^t(x,y)\, dG(y) \tag{8}$$

where, for a manager of type x at period t,

$$\mathcal{M}^t(x) = \{y \,|\, s_t(x,y) \geq 0\} \tag{9}$$

is the option exercise region, that is, the set of all acceptable firms' types. Similarly, for of a type y firm at t, we have

$$\overline{V}_y^t = \left(1 - F\left(\mathcal{N}^t(y)\right)\right) \delta \overline{V}_y^{t+1} + \int_{\mathcal{N}^t(y)} \left(\frac{m(x,y)}{1-\delta} - W^t(x,y)\right) dF(x) \tag{10}$$

where

$$\mathcal{N}^t(y) = \{x \,|\, s_t(x,y) \geq 0\} \tag{11}$$

represents the region of acceptable managers' profiles.

By substituting the expression for the compensation in (8) and (10), we obtain

$$\begin{cases} \overline{V}_x^t = \delta \overline{V}_x^{t+1} + \gamma \int\limits_{\mathcal{M}^t(x)} s_t(x,y)\, dG(y) \\ \overline{V}_y^t = \delta \overline{V}_y^{t+1} + (1-\gamma) \int\limits_{\mathcal{N}^t(y)} s_t(x,y)\, dF(x) \end{cases} \tag{12}$$

Thus, the expected utility of an agent is the sum of her discounted utility next period and her expected share of positive net surplus from the match generated in the current period. The expected utility in this formulation accounts for both direct and indirect effects. On the one hand, the discount factor and the net surplus share are direct determinants. On the other hand, the expected utility is affected by the so called *interaction effects*. For a manager (firm), these are the effects that future expected utilities of other types of managers (firms) have on the surplus of firms (managers). Moreover, a potential employee will face a stochastic compensation, since the wage offer depends on the type of firm she is matched to.

Strategy profiles and equilibria

This section proposes a definition of equilibrium for the matching game presented in the previous section and proves its existence and uniqueness.

We restrict our attention to equilibria in which the agents' acceptance regions are time invariant.

Definition 1 *A Matching Equilibrium (ME) for this game is a pair of set functions*[9] $\mathcal{M} : [0,1] \to \mathcal{P}([0,1])$ *and* $\mathcal{N} : [0,1] \to \mathcal{P}([0,1])$ *such that*

$$\mathcal{M}^t(x) = \mathcal{M}(x) \quad , \forall t$$
$$\mathcal{N}^t(y) = \mathcal{N}(y) \quad , \forall t$$

and (1), (2), (6), (7), (9), (11) and (12) are simultaneously satisfied. A corre-

[9] $\mathcal{P}([0,1])$ denotes the power set of $[0,1]$.

sponding Matching Equilibrium Outcome is a couple (x^*, y^*) *such that*

$$\begin{cases} x^* \in \mathcal{N}(y^*) \\ y^* \in \mathcal{M}(x^*) \end{cases} \tag{13}$$

A first interesting result is the following.

Proposition 2 *(Reciprocity). In a ME, for every* $x \in [0,1]$ *and* $y \in [0,1]$*, we have that*

$$x \in \mathcal{N}(y) \Longleftrightarrow y \in \mathcal{M}(x) \tag{14}$$

Proof. *This is a consequence of the fact that the decision criterion of the two agents is based on the sign of the joint net surplus.* ■

In other words, if one of the two parties finds it optimal to stop with a given partner, it cannot happen that the latter has an incentive to continue searching. This result considerably simplifies the problem of finding Matching Equilibrium Outcomes, as it implicitly introduces a symmetric structure in the model: there are no unilateral profitable deviations, as both agents' incentives are always perfectly aligned.

Theorem 3 (existence and uniqueness of equilibrium) *For any* $\delta \in (0,1)$*, there exist unique continuous functions* $\overline{V}_X$ *and* $\overline{V}_Y$ *on* $[0,1]$ *such that*

$$\overline{V}_X(x) = \int_0^1 \max\left\{\delta\overline{V}_X(x), \delta\overline{V}_X(x) + \gamma s(x,y)\right\} g(y)\, dy \tag{15}$$

$$\overline{V}_Y(y) = \int_0^1 \max\left\{\delta\overline{V}_Y(y), \delta\overline{V}_Y(y) + (1-\gamma)s(x,y)\right\} f(x)\, dx \tag{16}$$

where

$$s(x,y) = \frac{m(x,y)}{(1-\delta)} - \delta\left(\overline{V}_X(x) + \overline{V}_Y(y)\right)$$

As a consequence, there exists a unique Matching Equilibrium such that

$$\begin{aligned} s_t(x,y) &= s(x,y) \\ \mathcal{M}^t(x) &= \mathcal{M}(x) = \{y \,|s(x,y) \geq 0\} \\ \mathcal{N}^t(y) &= \mathcal{N}(y) = \{x \,|s(x,y) \geq 0\} \end{aligned} \tag{17}$$

Proof. See Appendix. ■

Notice that in a Matching Equilibrium, not only the agents' acceptance regions, but also the surplus function and the expected utilities are time-invariant. Thus, we can think of a Matching equilibrium as a steady-state equilibrium.

The proof of existence and uniqueness of the equilibrium is based on a Banach fixed point theorem and a contraction property that allows to find the solutions $\overline{V}_X(x)$ and $\overline{V}_Y(y)$ via simple fixed point iterations. In particular, given $f(x)$, $g(x)$, $m(x,y)$, δ, γ, and initial guesses $\overline{V}_{0,X}(x)$ and $\overline{V}_{0,Y}(y)$ for $\overline{V}_X(x)$ and $\overline{V}_Y(y)$, the solution is found by performing a series of iterations, where the n-th iteration proceeds in the following order:

$$s_n(x,y) = \frac{m(x,y)}{1-\delta} - \delta\overline{V}_{n,X}(x) - \delta\overline{V}_{n,Y}(y)$$

$$\overline{V}_{n+1,X}(x) = \int_0^1 \max\left\{\delta\overline{V}_{n,X}(x), \delta\overline{V}_{n,X}(x) + \gamma s_n(x,y)\right\} g(y)\,dy$$

$$\overline{V}_{n+1,Y}(y) = \int_0^1 \max\left\{\delta\overline{V}_{n,Y}(y), \delta\overline{V}_{n,Y}(y) + (1-\gamma) s_n(x,y)\right\} f(x)\,dx$$

Whatever the initial guesses, $\overline{V}_{n,X}(x)$ and $\overline{V}_{n,Y}(y)$ converge to the solution.

This solution method is explicitly employed in the estimation algorithm described in Section 4.

3 Data

We estimate the model presented in the previous section by employing a dataset on compensation and skill requirements of Italian managers in the year 2008. The data source is Hay Group, the world's largest consulting group specialized in the design of compensation schemes.

Salary comparisons with other firms are the main service provided by Hay Group to its client firms. In particular, client firms are asked to choose a comparison set of employers and to decide how they would like their overall wage structure to be positioned with respect to this comparison set.

We restrict our attention to data on managers, division presidents and top executives because these workers are more realistically described by our bargaining model[10]. As a matter of fact, in Italy managers are the only workers who are not subject to employment protection legislation and can be fired in case of observed inadequacy, that is, in case of bad match.

The data allow us to distinguish between (1) banks and insurance companies (henceforth, the financial sector) and (2) firms operating in the manufacturing and services sectors (henceforth, the non-financial sector). The data on managers' compensation are presumably very accurate, as they represent the core service provided by Hay Group to its customers. Data on compensation refer to gross compensation paid per year and include both fixed and variable compensation (the latter accounts for about 15% of total compensation). Other pay components, such as stock options and stock grants, not very widespread in Italy, are reported on a voluntary basis.[11] In the cases in which they are reported, these additional pay components account on average for less than 5% of total compensation. In view of their limited quantitative relevance, and in order to keep compensation comparable across firms, we exclude stock grants and stock options from our wage definition. Therefore, we define a manager's compensation as the sum of fixed and variable salary.[12]

Our dataset also provides a quantitative assessment of job complexity, measured by the so-called "Hay points". Hay points are aimed at measuring the autonomy and the complexity of each job, based on the analysis of all managerial positions within a firm.

The construction of Hay points is grounded on an accurate analysis of the tasks entailed by each position: detailed questionnaires are developed specifically for each functional area (e.g., finance, human resources, engineering) in order to establish as precisely as possible what a worker does in a job. For each client firm the process of job analysis is conducted by a team of own managers trained and led by a Hay consultant. For each position, the team analyzes job duties, allocation of time, responsibilities, critical tasks, customer contacts, etc., and provides 3

[10] The Hay Group dataset includes also middle management and white collars, but these workers are subject to employment protection legislation in Italy.

[11] Stock options are calculated at the value they had at the time they were assigned to the manager.

[12] Anyway, including stock options and stock grants in the definition of compensation does not significantly change our empirical results.

sub-indices, corresponding to the following categories: "Know how", "Problem-solving", and "Accountability". The first index measures skills, knowledge (both formal and informal) and techniques needed to perform the tasks required in a job. The second index measures how well-defined and predictable job tasks are. Finally, "Accountability" measures how much autonomy or individual discretion employees have in decision making. The three dimensions are then combined to form an overall score, expressed in Hay points.

To ensure comparability across firms and time, the team identifies a set of "benchmark jobs" whose skill requirements are deemed to be reasonably constant across employers and sectors. The scores assigned by each team to the benchmark jobs are then compared to the scores assigned to the same jobs by other teams. Based on this comparison, a correction factor is applied to the scores assigned by the team (to both benchmark and non-benchmark jobs), in order to correct for team bias. Further consistency checks are made by Hay Group's senior consultants, in order to ensure that scores remain comparable both across client firms and over time.

It needs to be stressed that even when a position is already filled, Hay points are assigned to that position without knowing the salary of the manager who is filling it. Only after having assigned Hay points to managerial positions, Hay Group asks its client firms to provide information on managers' compensation. Furthermore, Hay Points are computed independently of any employee's characteristics. To our purposes, this should be sufficient to avoid endogeneity problems and other *cum hoc ergo propter hoc* fallacies when studying the impact of Hay points on observed salaries.

On the one hand, the use of Hay points to measure job complexity is undoubtedly subject to several criticisms. The process of writing job descriptions, determining which tasks and responsibilities should be included, and deciding how to weight different factors to produce an overall measure of skills is somewhat arbitrary. On the other hand, it is difficult to assess whether other measures of skill requirements widely employed in research, such as job titles, are more effective than Hay points in measuring skill requirements. For instance, Philippon and Reshef (2012) use Census data on workers and measure job complexity by an index based on job duties, codified in the Dictionary of Occupational Titles by a panel of experts of the US National Academy of Sciences in 1970 and assigned to workers on the basis of the job title they declare. However, also job titles are self-reported and might have shortcomings similar to those of Hay points. Moreover, job titles might differ across companies for similar positions, especially for managerial jobs. Workers' education, commonly used in the literature as a proxy for required skills, is often measured as years of completed schooling, and typically not adjusted for the quality or type of education. More importantly, Hay points are what the firms of the Hay sample take into consideration when determining their pay structure. As a matter of fact, the correlation between Hay points and compensation is around 60%.

Hay Group's data have been used before by other authors for economic research. For instance, data on US firms have been used by Cappelli (1993), Gibbs and Hendricks (1995) and O'Shaughnessy, Levine and Cappelli (2000). In this paper we use data on Italian firms in the year 2008. Data refer to 319 firms (67 financial and 252 non-financial) and 10,729 managers. The sample includes all the 10 main Italian firms, as classified by Fortune in 2007[13], all the major Italian banks, covering more than 60 percent of the loan market, and the first 5 insurance firms in terms of total insurance premia. In the manufacturing and services sectors, the value added of Hay Group firms is around 60 percent of the value added produced by all Italian firms with at least 1,000 employees[14].

Table 1 reports the characteristics of the sample by sector. The main characteristics of the distribution of Hay points are similar across sectors: the mean and median values are almost the same, but the standard deviation is slightly higher in the financial sector. However, the median compensation in the financial sector is roughly 20 percent higher than in the other sectors. [15]

Figure 2 plots local regression estimates of the functional relation between

[13] They are Eni, Assicurazioni Generali, Fiat, Unicredit Group, Enel, Telecom Italia, San Paolo IMI, Poste Italiane, Intesa Sanpaolo, Finmeccanica. We would like to stress that for confidentiality reasons we have the list of firms included in the Hay Group sample but in the dataset firms are assigned an anonymous identifier and we do not know the name of the firm each manager works for.

[14] Value added is calculated as the sum of balance-sheet value added of all the firms with at least 1,000 employees (source: Mediobanca).

[15] This differential has not been significantly affected by the financial crisis because the variable part of managers' compensation is relatively small in Italy as compared to other countries, and the fixed part is never subject to downward revision.

compensation and Hay Points (both in logs), for each sector. The preliminary evidence provided by these estimates suggests that the difference in compensation between the financial sector and the other sectors is positive for every level of job complexity. Moreover, the relation between compensation and Hay points is not linear, as the elasticity of compensation to Hay points is increasing in the latter. For a sub-sample (covering less than one third of observations), our dataset contains some individual characteristics, such as sex, age, job tenure and educational attainments. We use this sub-sample to check whether the differential can be explained by workforce heterogeneity. By estimating regressions in which socio-economic variables are used as a control, we find that sectoral differences remain significant[16].

The compensation differential between sectors is persistent through time. Using Hay Group data for the year 2001, we find even larger sectoral differences. Furthermore, these differences are not specific to our dataset. Persistent wage differentials[17] can also be found in administrative data on the whole population of Italian managers, such as those produced by the Italian Social Security Institute (INPS). Furthermore, positive and persistent wage differentials between the financial sector and the other sectors are not specific to Italy (see, e.g., Genre, Momferatou and Mourre 2005 for EU countries, and Philippon and Reshef 2012 for the US). In the next sections we will explain how these differences can be explained by our model.

4 Estimation strategy

We estimate the parameters of the model presented in Section 2 via non-linear least squares. The objective function to be minimized is the sum of squared differences between observed wages W and their model-based expected values conditional on observed skill requirements y (and on having observed a good match). Observed skill requirements are measured by Hay points. Both W and y are standardized

[16] Results are available upon request.

[17] The persistence of these differences could be explained by low sectoral mobility. According to the Labour Force Survey conducted by the Italian national statistical agency (Istat) in the period 2007-2008, only 3 percent of Italian managers changed job during a 12 month time interval. Among them 99 per cent did not change sector.

so that sample values are supported on the unit interval $[0, 1]$. We divide each variable by a constant ζ that is strictly larger than the sample maximum of the variable (more on this later), in order to ensure that observed values fall strictly within the unit interval.

Before estimating our model, we remove outliers from the dataset. The outlier removal strategy is as follows: we regress wages on a second degree polynomial in Hay points, we compute residuals, and we discard the observations whose squared residuals are in the top percentile of the empirical distribution of squared residuals. Different outlier removal strategies (higher order polynomials, different removal thresholds) do not change results significantly. However, removing outliers in this manner has the effect of dropping few observations that have unusually high compensation and Hay points. These observations would otherwise have a strong influence on results. The rationale of our removal strategy is not to sacrifice the ability to accurately model the great majority of the population for the sake of trying to predict a few extreme observations.

We assume that the matching function $m(x, y)$ is a Cobb-Douglas, that is,

$$m(x, y) = x^a y^b$$

This assumption is standard in the matching literature. However, differently from the classical models on search and matching, we do not impose constant returns to scale (as, for instance, Moscarini 2005), leaving the two elasticity parameters free to vary in $\mathbb{R}_{++}$.

As far as the unobserved ex-ante distributions of types are concerned, we reduce the non-parametric problem of estimating these distributions to a semi-parametric one. This is accomplished by imposing a parametric functional form on the Radon-Nykodym derivatives of ex-ante distributions with respect to ex-post ones. The ex-post distribution of skill requirements is approximated by a kernel density estimate $k(y)$ of the distribution of Hay points. In order to ensure that $k(y)$ is supported on the unit interval, we fit Gaussian kernels with optimal bandwidth to the log-transform of y and then recast to the original y-space with a Jacobian transformation. Furthermore, ζ is set to a value which guarantees that - to machine precision - $k(y)$ is equal to zero for $y > 1$. The density $g(y)$ can be written as

$$g(y) = \frac{g(y)}{k(y)} \cdot k(y) \tag{18}$$

where $g(y)/k(y)$ is the Radon-Nikodym derivative of g with respect to k. We assume that $g(y)/k(y)$ is proportional to the density of a Beta distribution, that is,

$$\frac{g(y)}{k(y)} = \omega y^{\alpha_y - 1} (1 - y)^{\beta_y - 1}$$

where ω is a constant of proportionality determined by the fact that the expected value of the Radon-Nykodym derivative under the original probability measure must be equal to 1. Therefore, estimating $g(y)$ boils down to estimating the two parameters α_y and β_y. We choose the Beta density because it is widely considered a flexible functional form that is able to accurately capture perturbations of probability distributions supported on the unit interval (see Alexander et al. 2012 and the references therein). Given that we do not observe skills x, their ex-ante distribution is also modelled as a perturbation of $k(y)$, by using a different Beta density with parameters α_x and β_x. Note that the reciprocity result in equation (14) ensures that the matching preferences of the two agents are perfectly aligned and it excludes unilateral profitable deviations. The implied symmetry of the model, together with the normalization of the two variables in the unit interval, could be seen as a rationale for this parametrization of x. Also note that the Beta distribution is rather flexible, so that results should be relatively insensitive to the initial distribution (the one to be perturbed). Furthermore, the parameter a provides a further source of flexibility because what ultimately determines the equilibrium of the model is the transformation x^a. In other words, a parametrization is adequate as long as the distribution of x^a is not mis-specified.

Given the above assumptions, we need to estimate the following parameters: the shape parameters α_y, β_y, α_x, β_x, the discount factor δ, the bargaining power parameter γ, and the matching function parameters a and b. Additionally, we estimate a scale parameter c, which is used to convert wages from money (in the data) to physical production (in the model), and from annuities (in the data) to life-time wages (in the model). As a consequence, observed wages W in the function to be minimized are set equal to c times the annual compensation recorded in the dataset.

Note that adding a scale parameter is absolutely necessary in order to obtain a specification that can be estimated because the model is silent about the physical units used to measure joint production and the prices used to convert physical production into monetary units. Since inputs belong to the interval $[0, 1]$, without a scale parameter one would obtain that an increase in the elasticities a and b reduces the output of any matched pair. On the contrary, with a scale parameter it is possible to increase the elasticities without reducing average output (this is achieved by simultaneously increasing c).

An iterative algorithm based on the Nelder-Mead Simplex Method is used to find a solution to the least square problem, and a multi-start procedure is adopted in order to avoid local minima. At each iteration of the algorithm a vector of parameter values is passed as an argument to a function that computes numerically the value functions, the surpluses in case of good match, the conditional probabilities of good match, and the conditional expected values of wages (conditional on observed skill requirements). Differences between the latter and observed wages are then used to compute the sum of squared residuals. All the quantities of interest are obtained by fixed point iterations, starting from guesses of the value functions. By the results in previous sections, these fixed point iterations are guaranteed to converge. In order to perform the iterations, the supports of x and y need to be discretized. We employ equally spaced grids and we set the number of points in the grids equal to 50, after observing that finer grids cause only imperceptible changes in the results.

5 Results

Estimates of the parameters of our model are reported in Table 2. The first two columns refer to the financial sector, while the last two refer to the non-financial sector. Standard errors are estimated by bootstrap.[18]

Estimates of the parameters of the matching function (a and b) exhibit features that are shared by the financial sector and the other sectors. In both cases, $a + b >$

[18] 100 replicates for each sector.

1, so that there are increasing returns to scale. There are reasons to believe that this feature of the estimated production function, which refers to manager's ability and required skills, is realistic. As a matter of fact, the larger the scale of production, the more valuable the contribution of highly specialized profiles (e.g., technical managers) can be (without increasing costs); the same can be true of general management profiles if there are scope economies[19]. Since $a < b$, output is less elastic to an improvement in supplied human capital than to an increase in skill requirements. However, the elasticities of the matching function to the two inputs are higher in the financial sector ($a = 0.31, b = 2.18$) than in the other sectors ($a = 0.25, b = 2.10$). As explained in the previous section, an increase in elasticities has the mechanical effect of decreasing output for any matched pair if the scale parameter c is kept constant. However, we also find that c is higher in the financial sector (0.31 vs 0.19 in the other sectors). The joint effect of the differences in a, b and c is to increase average wages in the financial sector (more on this below). Results from a Wald test of the null that productivity parameters are equal across sectors indicate that these structural differences are statistically significant at all conventional levels of confidence.

We estimate how differences in parameters affect wages by conducting numerical comparative statics exercises on our estimated models. We find that if the financial sector had the same production technology of the other sectors[20], the average compensation in the financial sector would decrease by 33 thousand euros (or 103 per cent of the total wage gap, which is equal to 32 thousand euros). This result can be interpreted as evidence that higher productivity in the financial sector might account for the bulk of its wage premium. As a matter of fact, we find that the marginal productivities[21] of x and y are higher in the financial sector for every matched pair.

According to our estimates, the bargaining power parameter γ is slightly higher in the financial sector (0.258) than in the other sectors (0.246). The interpretation

[19]Think, for example, of the financial sector, where specific competencies may be applied to the development and management of multiple financial products.

[20]This is achieved by subsituting the estimates of a, b and c obtained for the financial sector with those obtained for the other sectors, and by recomputing the equilibrium of the estimated model.

[21]Computed as the partial derivatives of cx^ay^b with respect to x and y.

is that financial managers are able to obtain higher shares of surplus than other managers. Overall, our estimates of the bargaining power parameter are consistent with those found in the literature (e.g., Cahuc et al. 2002, Dumont et al. 2006, and Svejnar 1982), which are however not directly comparable to ours because they concern not only managers, but all workers, and are therefore influenced by factors, such as the degree of unionization, that presumably do not affect the bargaining power of managers. Notice, however, that the difference in bargaining power between the financial sector and the other sectors is not statistically significant at a 90 per cent confidence level according to our estimates. By conducting a comparative statics exercise with the same methodology described above, we find that if financial managers had the same bargaining power of managers in the other sectors, their average compensation would decrease by 4 thousand euros (or 13 per cent of the total wage gap).

The difference in the estimated discount factors δ is small (0.989 in the financial sector vs 0.990 in the other sectors) and statistically insignificant at 90 per cent confidence. However, according to our comparative statics methodology, this small difference could generate non-negligible effects: if the financial sector had the same discount factor of the other sectors, compensation would increase by 10 thousand euros (or 25 per cent of the total wage gap). The interpretation of this effect is as follows: if managers and firms have a higher discount factor, they are on average willing to wait longer in order to find a better match, with the consequence that the average surplus of matches increases; since wages are increasing in surpluses, they also increase.

Differences in average compensation not accounted for by the previously mentioned characteristics (i.e., productivity, bargaining power and discount factor) can be thought of as residually explained by differences in the ex-ante distributions of skills and skill requirements. According to this interpretation, the results described above from comparative statics exercises imply that 16 per cent (or 5 thousand euros) of the wage gap is explained by differences in the ex-ante distributions of skills and skill requirements. This evidence supports the implicit assumption (made by estimating the model separately for the two sectors) that there is ex-ante sectoral segregation (managers in the two sectors have different characteristics ex ante and only apply for positions within their sector).

Note that the bootstrapped standard errors of all the estimated parameters are quite small, which hints to the fact that the proposed parametrization does not suffer from lack of identification. Moreover, as reported in Table 3, parameters are identified by their effect not only on the average level but also on the shape of the conditional wage function. For example, an increase in the scale of production c causes a parallel upwards shift of the conditional wage function, while an increase in the discount factor δ also increases wages but it has a more pronounced effect on the wages associated to higher quality positions. Also the other structural parameters (a, b and γ) have non-linear effects on the conditional wage function, that is, an increase in these parameters changes not only the level of the function, but also its slope and curvature.

Parameter estimates can also be used to recover the probability densities of types (both ex-post and ex-ante), as well as equilibrium wage distributions.

We find that model-based wage distributions closely match the observed ones (see Figure 3). Furthermore, in both the financial and the non-financial sector the estimated equilibrium wage density reproduces the three main stylized features of empirical wage distributions, namely, a unique interior mode, positive skewness and a long right tail (e.g., Moscarini 2005).

Figures 4 and 5 display the distributions of managers' and firms' quality by sector. In the financial sector the distribution of managers' quality has larger variance and a fatter right tail than in the non- financial sector. The same holds for the estimated distributions of job quality.

Figure 6 reports the estimated probabilities of good match in the two sectors, conditional on types. In both sectors, and both for managers and firms, the probability of good match is inverse U-shaped: types whose quality is much below or above average are less likely to find a good match.

6 Conclusions

We have studied the stylized fact that managers in the financial sector receive higher compensation than their peers in other sectors. In our dataset, this wage gap cannot be fully explained by observed differences in job complexity and managerial skills. We have used a matching model to try to discriminate among other potential explanations, pertaining to unobservable sectoral differences. In our model, two sectors can differ not only in the average quality of managers and job positions, but also in production technologies, agents' intertemporal preferences and allocation of bargaining power among managers and firms. Of course, as in any structural model, we have provided a stylized and incomplete representation of reality and important elements could have been left out of the picture. For example, our model does not deal with incentive-based pay components that may drive part of the differential. Furthermore, our model does not allow us to evaluate the relative importance of the rent extraction hypothesis proposed by Philippon and Reshef (2012). Finally, our model does not allow to capture the effect of firm size on the pay structure, insofar as a larger firm size does not completely translate into higher job complexity. Our estimates must then be interpreted as model-specific. According to them, production technology is the most important determinant of the wage gap. In particular, any given combination of supplied human capital and quality of the vacancy is estimated to be more productive in the financial sector than in the non-financial sector. This result is in accordance with previous literature (e.g., Philippon and Reshef 2012), that analyzes different datasets with different methodologies, but also provides evidence that differences in productivity could be a major determinant of the wage gap.

Appendix

6.1 Proof of Theorem 1

Consider the set of continuous functions $C\left([0,1],\mathbb{R}^2\right)$ consisting of all continuous functions from $[0,1]$ to $\mathbb{R}^2$, equipped with the sup norm

$$\left\|\left(\overline{V}_X,\overline{V}_Y\right)\right\| = \max\left\{\sup_{x\in[0,1]}\left|\overline{V}_X\left(x\right)\right|, \sup_{y\in[0,1]}\left|\overline{V}_Y\left(y\right)\right|\right\}$$

where $\overline{V}_X$ and $\overline{V}_Y$ are two scalar-valued functions that, taken together, form an element of $C\left([0,1],\mathbb{R}^2\right)$. The latter is a Banach space with respect to the defined norm.

Let T be a mapping from $C([0,1], \mathbb{R}^2)$ into itself defined as

$$T : \left(\overline{V}_X, \overline{V}_Y\right) \to \left(T_1\left(\overline{V}_X, \overline{V}_Y\right), T_2\left(\overline{V}_X, \overline{V}_Y\right)\right)$$

where

$$\begin{aligned} T_1\left(\overline{V}_X, \overline{V}_Y\right) &= \int_0^1 \max\left\{\delta \overline{V}_X(x), \delta \overline{V}_X(x) + \gamma S\left(\overline{V}_X(x), \overline{V}_Y(y)\right)\right\} dG(y) \\ T_2\left(\overline{V}_X, \overline{V}_Y\right) &= \int_0^1 \max\left\{\delta \overline{V}_Y(y), \delta \overline{V}_Y(y) + (1-\gamma) S\left(\overline{V}_X(x), \overline{V}_Y(y)\right)\right\} dF(x) \end{aligned}$$

and

$$S\left(\overline{V}_X(x), \overline{V}_Y(y)\right) = \frac{m(x,y)}{(1-\delta)} - \delta\left(\overline{V}_X(x) + \overline{V}_Y(y)\right)$$

T is continuous, therefore $T_1\left(\overline{V}_X, \overline{V}_Y\right)$ and $T_2\left(\overline{V}_X, \overline{V}_Y\right)$ are continuous in x when both $\overline{V}_X$ and $\overline{V}_Y$ are continuous in x. We are going to show that T is a contraction mapping.

Take two arbitrary members of $C([0,1], \mathbb{R}^2)$ and denote them by $\left(\overline{V}_{X_1}, \overline{V}_{Y_1}\right)$ and $\left(\overline{V}_{X_2}, \overline{V}_{Y_2}\right)$. Then,

$$\begin{aligned} & \left\|T\left(\overline{V}_{X_1}, \overline{V}_{Y_1}\right) - T\left(\overline{V}_{X_2}, \overline{V}_{Y_2}\right)\right\| \\ = \ & \max\left\{\sup_{x\in[0,1]} \left|T_1\left(\overline{V}_{X_1}, \overline{V}_{Y_1}\right) - T_1\left(\overline{V}_{X_2}, \overline{V}_{Y_2}\right)\right|, \sup_{y\in[0,1]} \left|T_2\left(\overline{V}_{X_1}, \overline{V}_{Y_1}\right) - T_2\left(\overline{V}_{X_2}, \overline{V}_{Y_2}\right)\right|\right\} \\ = \ & \max\left\{\sup_{x\in[0,1]} D_1(x), \sup_{y\in[0,1]} D_2(y)\right\} \end{aligned}$$

where

$$\begin{aligned}
D_1(x) &= \left| \int_0^1 \max\left\{\delta\overline{V}_{X_1}(x), \delta\overline{V}_{X_1}(x) + \gamma S\left(\overline{V}_{X_1}(x), \overline{V}_{Y_1}(y)\right)\right\} dG(y) \right. \\
&\quad \left. - \int_0^1 \max\left\{\delta\overline{V}_{X_2}(x), \delta\overline{V}_{X_2}(x) + \gamma S\left(\overline{V}_{X_2}(x), \overline{V}_{Y_2}(y)\right)\right\} dG(y) \right| \\
&\leq \int_0^1 \left| \max\left\{\delta\overline{V}_{X_1}(x), \delta\overline{V}_{X_1}(x) + \gamma S\left(\overline{V}_{X_1}(x), \overline{V}_{Y_1}(y)\right)\right\} \right. \\
&\quad \left. - \max\left\{\delta\overline{V}_{X_2}(x), \delta\overline{V}_{X_2}(x) + \gamma S\left(\overline{V}_{X_2}(x), \overline{V}_{Y_2}(y)\right)\right\} \right| dG(y) \\
&= \int_0^1 I_1(x,y)\, dG(y)
\end{aligned}$$

where we have defined

$$\begin{aligned}
I_1(x,y) &= \left| \delta\overline{V}_{X_1}(x) + \gamma \max\left\{0, S\left(\overline{V}_{X_1}(x), \overline{V}_{Y_1}(y)\right)\right\} \right. \\
&\quad \left. - \delta\overline{V}_{X_2}(x) - \gamma \max\left\{0, S\left(\overline{V}_{X_2}(x), \overline{V}_{Y_2}(y)\right)\right\} \right|
\end{aligned}$$

and

$$\begin{aligned}
D_2(y) &= \left| \int_0^1 \max\left\{\delta\overline{V}_{Y_1}(y), \delta\overline{V}_{Y_1}(y) + (1-\gamma) S\left(\overline{V}_{X_1}(x), \overline{V}_{Y_1}(y)\right)\right\} dF(x) \right. \\
&\quad \left. - \int_0^1 \max\left\{\delta\overline{V}_{Y_2}(y), \delta\overline{V}_{Y_2}(y) + (1-\gamma) S\left(\overline{V}_{X_2}(x), \overline{V}_{Y_2}(y)\right)\right\} dF(x) \right| \\
&\leq \int_0^1 \left| \max\left\{\delta\overline{V}_{Y_1}(y), \delta\overline{V}_{Y_1}(y) + (1-\gamma) S\left(\overline{V}_{X_1}(x), \overline{V}_{Y_1}(y)\right)\right\} \right. \\
&\quad \left. - \max\left\{\delta\overline{V}_{Y_2}(y), \delta\overline{V}_{Y_2}(y) + (1-\gamma) S\left(\overline{V}_{X_2}(x), \overline{V}_{Y_2}(y)\right)\right\} \right| dF(x) \\
&= \int_0^1 I_2(x,y)\, dF(x)
\end{aligned}$$

where we have defined

$$\begin{aligned}
I_2(x,y) &= \left| \delta\overline{V}_{Y_1}(y) + (1-\gamma) \max\left\{0, S\left(\overline{V}_{X_1}(x), \overline{V}_{Y_1}(y)\right)\right\} \right. \\
&\quad \left. - \delta\overline{V}_{Y_2}(y) - (1-\gamma) \max\left\{0, S\left(\overline{V}_{X_2}(x), \overline{V}_{Y_2}(y)\right)\right\} \right|
\end{aligned}$$

Now, we need to distinguish among four possible cases:

Case 1	$S\left(\overline{V}_{X_1}(x), \overline{V}_{Y_1}(y)\right) < 0$	$S\left(\overline{V}_{X_2}(x), \overline{V}_{Y_2}(y)\right) < 0$
Case 2	$S\left(\overline{V}_{X_1}(x), \overline{V}_{Y_1}(y)\right) \geq 0$	$S\left(\overline{V}_{X_2}(x), \overline{V}_{Y_2}(y)\right) \geq 0$
Case 3	$S\left(\overline{V}_{X_1}(x), \overline{V}_{Y_1}(y)\right) < 0$	$S\left(\overline{V}_{X_2}(x), \overline{V}_{Y_2}(y)\right) \geq 0$
Case 4	$S\left(\overline{V}_{X_1}(x), \overline{V}_{Y_1}(y)\right) \geq 0$	$S\left(\overline{V}_{X_2}(x), \overline{V}_{Y_2}(y)\right) < 0$

In case 1, we have

$$I_1(x,y) = \delta\left|\overline{V}_{X_1}(x) - \overline{V}_{X_2}(x)\right|$$

and

$$I_2(x,y) = \delta\left|\overline{V}_{Y_1}(y) - \overline{V}_{Y_2}(y)\right|$$

In case 2, we have

$$\begin{aligned} I_1(x,y) &= \delta\left|(1-\gamma)\left(\overline{V}_{X_1}(x) - \overline{V}_{X_2}(x)\right) - \gamma\left(\overline{V}_{Y_1}(y) - \overline{V}_{Y_2}(y)\right)\right| \\ &\leq \delta\left\{(1-\gamma)\left|\left(\overline{V}_{X_1}(x) - \overline{V}_{X_2}(x)\right)\right| + \gamma\left|\left(\overline{V}_{Y_1}(y) - \overline{V}_{Y_2}(y)\right)\right|\right\} \end{aligned}$$

and

$$\begin{aligned} I_2(x,y) &= \delta\left|\gamma\left(\overline{V}_{Y_1}(y) - \overline{V}_{Y_2}(y)\right) - (1-\gamma)\left(\overline{V}_{X_1}(x) - \overline{V}_{X_2}(x)\right)\right| \\ &\leq \delta\left\{\gamma\left|\left(\overline{V}_{Y_1}(y) - \overline{V}_{Y_2}(y)\right)\right| + (1-\gamma)\left|\left(\overline{V}_{X_1}(x) - \overline{V}_{X_2}(x)\right)\right|\right\} \end{aligned}$$

In case 3, we have that

$$\delta\overline{V}_{X_2}(x) + \delta\overline{V}_{Y_2}(y) \leq \frac{m(x,y)}{1-\delta} < \delta\overline{V}_{X_1}(x) + \delta\overline{V}_{Y_1}(y)$$

and, as a consequence,

$$I_1(x,y) \leq \max\left\{\delta\left|\overline{V}_{X_1}(x) - \overline{V}_{X_2}(x)\right|, \delta\left|\overline{V}_{Y_1}(y) - \overline{V}_{Y_2}(y)\right|\right\}$$

and

$$I_2(x,y) \leq \max\left\{\delta\left|\overline{V}_{X_1}(x) - \overline{V}_{X_2}(x)\right|, \delta\left|\overline{V}_{Y_1}(y) - \overline{V}_{Y_2}(y)\right|\right\}$$

In case 4, the same inequalities found in case 3 hold for $I_1(x,y)$ and $I_2(x,y)$. By considering the four cases together, we obtain

$$\begin{aligned}
& \left\| T\left(\overline{V}_{X_1}, \overline{V}_{Y_1}\right) - T\left(\overline{V}_{X_2}, \overline{V}_{Y_2}\right) \right\| \\
= \; & \max\left\{ \sup_{x\in[0,1]} D_1(x), \sup_{y\in[0,1]} D_2(y) \right\} \\
\leq \; & \max\left\{ \sup_{x\in[0,1]} \delta \left| \overline{V}_{X_1}(x) - \overline{V}_{X_2}(x) \right|, \sup_{y\in[0,1]} \delta \left| \overline{V}_{Y_1}(y) - \overline{V}_{Y_2}(y) \right| \right\} \\
= \; & \delta \left\| \left(\overline{V}_{X_1}, \overline{V}_{Y_1}\right) - \left(\overline{V}_{X_2}, \overline{V}_{Y_2}\right) \right\| \\
< \; & \left\| \left(\overline{V}_{X_1}, \overline{V}_{Y_1}\right) - \left(\overline{V}_{X_2}, \overline{V}_{Y_2}\right) \right\|
\end{aligned}$$

Thus, T is a contraction mapping. Therefore, by Banach's fixed point theorem, there exists a unique pair of continuous functions $\overline{V}_X(x)$ and $\overline{V}_Y(y)$ in $[0,1]$ such that

$$\overline{V}_X(x) = \int_0^1 \max\left\{ \delta\overline{V}_X(x), \delta\overline{V}_X(x) + \gamma S\left(\overline{V}_X(x), \overline{V}_Y(y)\right) \right\} dG(y)$$

$$\overline{V}_Y(y) = \int_0^1 \max\left\{ \delta\overline{V}_Y(y), \delta\overline{V}_Y(y) + (1-\gamma) S\left(\overline{V}_X(x), \overline{V}_Y(y)\right) \right\} dF(x)$$

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Tables and Figures

Table 1 - Descriptive statistics[22]

	Financial	**Non-financial**	**Total**
Compensation			
average	171	139	147
st.dev.	163	89	111
median	134	117	120
min	55	32	32
max	5,208	1,675	5,208
Hay points			
average	912	905	906
st.dev.	465	389	407
median	807	805	807
min	405	291	291
max	13,504	6,144	13,504
Number of managers	2,431	8,298	10,729
Number of firms	67	252	319

[22] Authors' calculations on Hay Group data for the year 2008. Compensation is expressed in thousand euros.

Table 2 - Parameter estimates[23]

	Financial sector		Other sectors	
	Parameter	Std error	Parameter	Std error
Bargaining power γ	0.258	0.021	0.246	0.009
Elasticity to skills a	0.305	0.042	0.250	0.016
Elasticity to vacancy quality b	2.179	0.091	2.099	0.027
Discount factor δ	0.989	0.001	0.990	0.001
Distribution of x - Shape parameter α	0.977	0.089	1.018	0.072
Distribution of x - Shape parameter β	0.569	0.098	0.921	0.047
Distribution of y - Shape parameter α	0.051	0.008	0.056	0.003
Distribution of y - Shape parameter β	1.510	0.075	0.606	0.036
Scale parameter c	0.307	0.040	0.191	0.013

[23] Non-linear least squares estimates of the parameters of the matching model. Standard errors obtained from a bootstrap simulation.

Table 3 - Effect of parameter changes on the conditional wage function[24]

	Δ par.	$\Delta\ \ln(E\,[W\,\|y])$		
		$y = G^{-1}\,(0.1)$	$y = G^{-1}\,(0.5)$	$y = G^{-1}\,(0.9)$
Bargaining power γ	0.012	4%	3%	2%
Discount factor δ	0.001	10%	9%	8%
Elasticity to skills a	0.055	-8%	-6%	-4%
Elasticity to vacancy quality b	0.080	-13%	-13%	-11%
Scale parameter c	0.116	43%	43%	43%

[24]This table reports how shifts in parameters change the conditional wage function in correspondence of the first, fifth and ninth decile of the distribution of Hay points. The baseline is given by the vector of parameter estimates obtained for the non-financial sector, while the parameter change is equal to the estimated difference between the financial and the non-financial sector.

Figure 1 - Timeline of the game

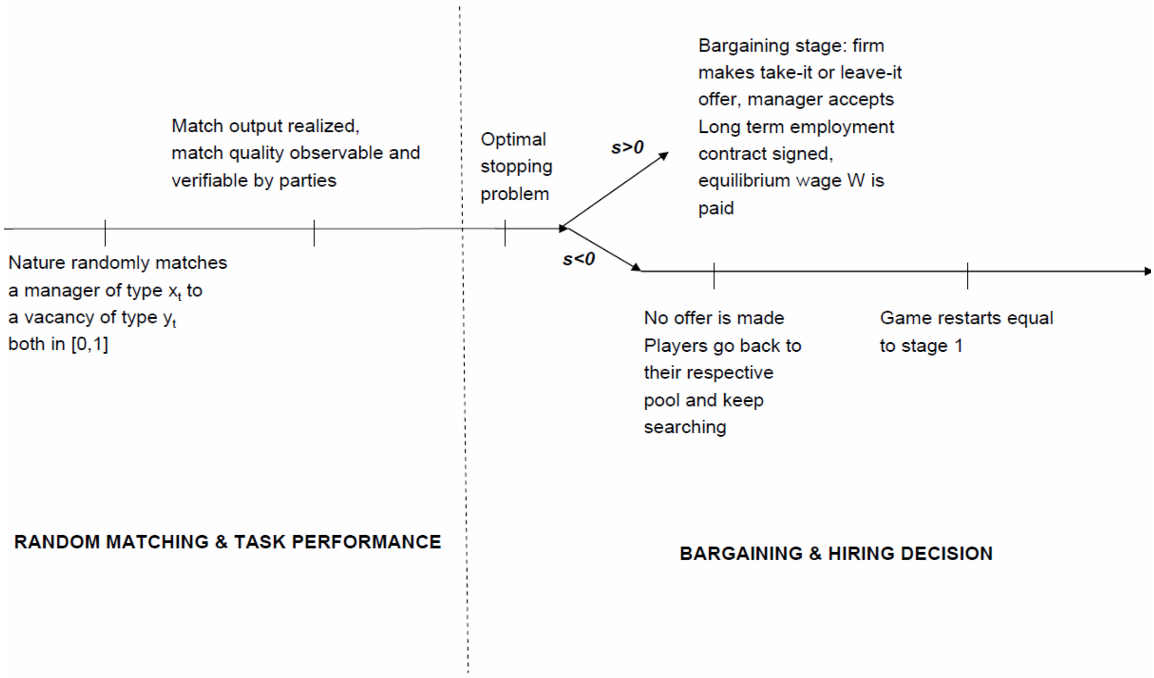
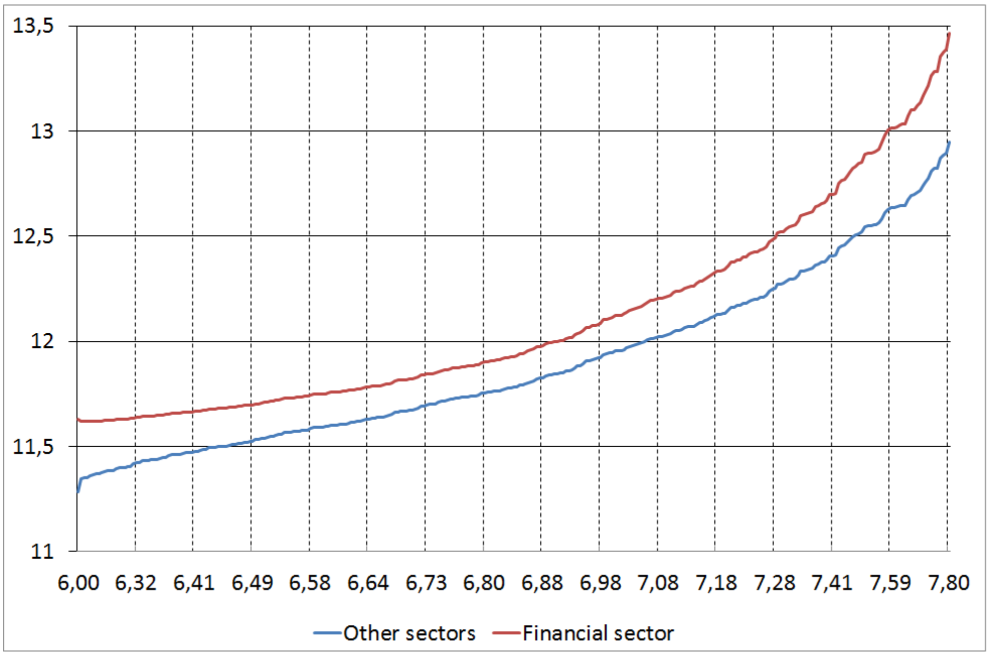


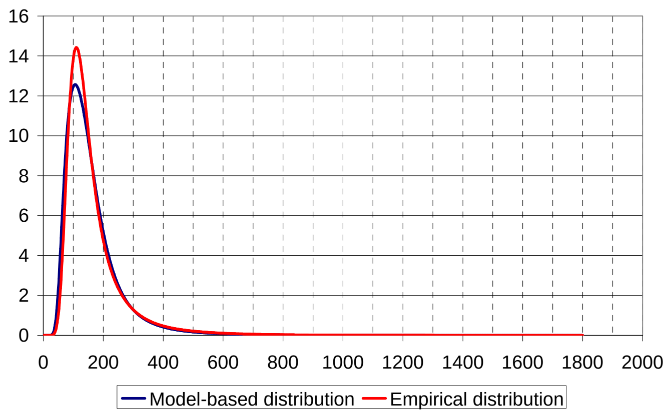
Figure 2 - The relationship between compensation and Hay points[25]



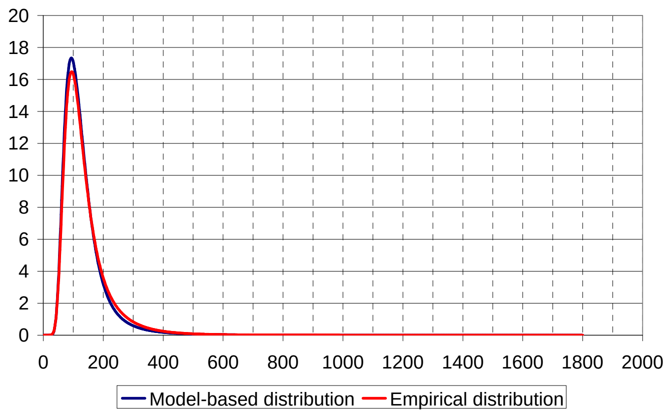
[25] Compensation (on the y-axis) and Hay points (on the x-axis) are in logs. The curves are estimated with local regressions (Lowess).

Figure 3 - Probability density of compensation[26]

Panel A - Financial sector



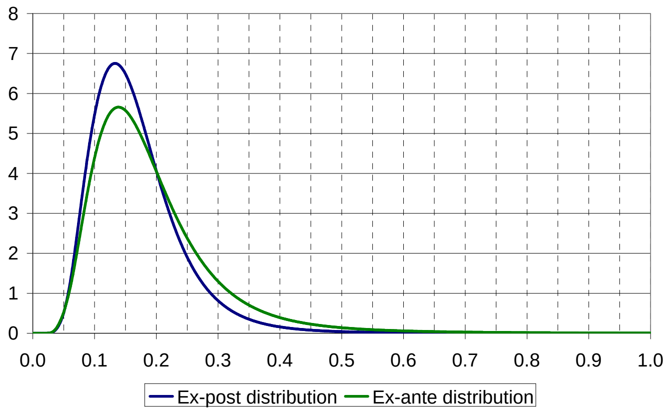
Panel B - Other sectors



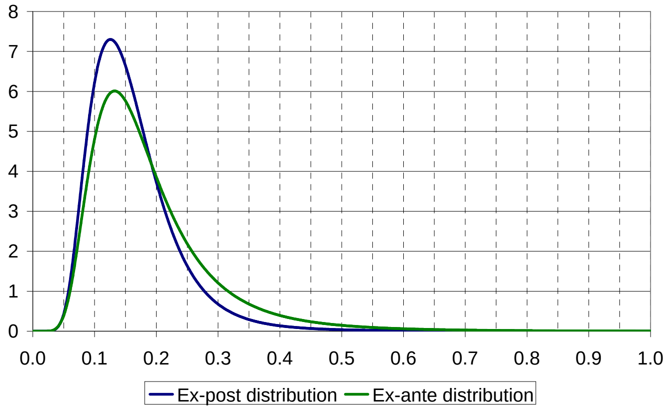
[26] The model-based distribution is the probability density function of annual compensation estimated with the matching model. The empirical distribution is a kernel density estimate of the actual distribution of compensation in the Hay Group sample.

Figure 4 - Probability density of skills[27]

Panel A - Financial sector



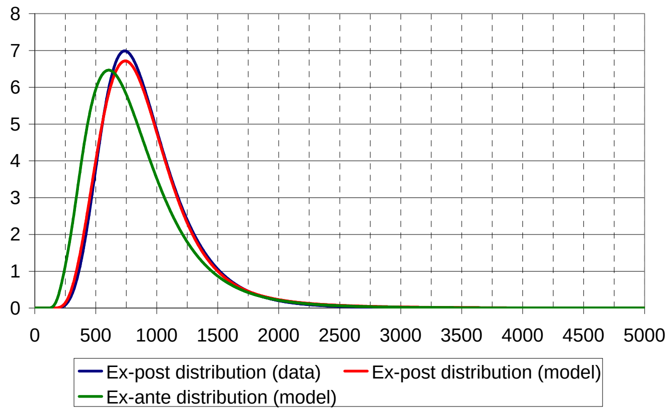
Panel B - Other sectors



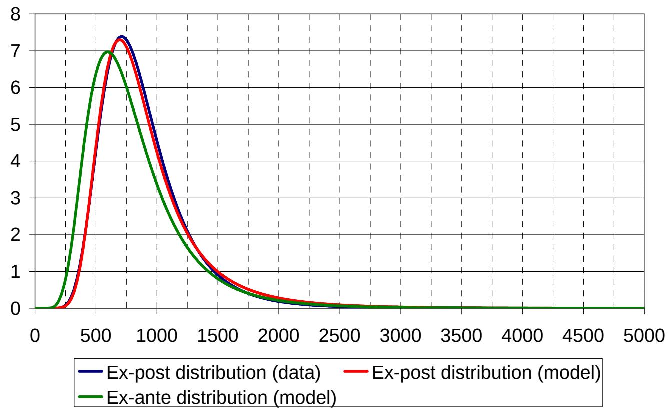
[27] The ex-ante distribution is the probability density function of skills $f(x)$, estimated with the matching model. The ex-post distribution is the conditional distribution $f(x \mid \text{good match})$, also estimated with the matching model.

Figure 5 - Probability density of skill requirements[28]

Panel A - Financial sector



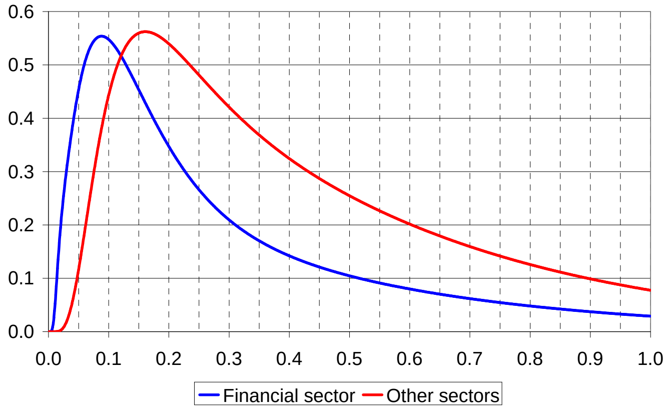
Panel B - Other sectors



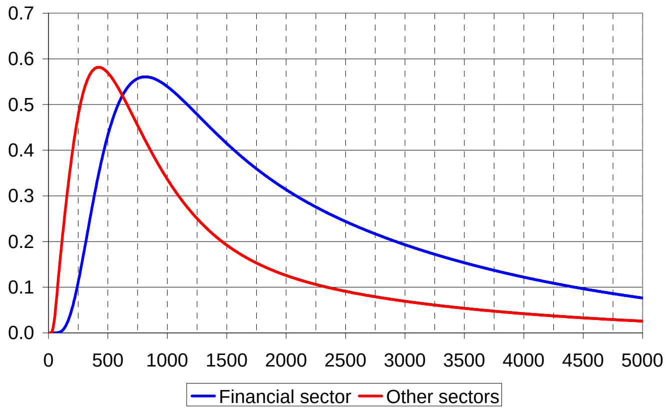
[28] The ex-ante distribution is the probability density function of skill requirements $g(y)$, estimated with the matching model. The ex-post distribution is the conditional distribution $g(y\,|\text{good match})$, also estimated with the matching model. The empirical distribution is a kernel density estimate of the actual distribution of skill requirements in the Hay Group sample.

Figure 6 - Conditional probabilities of good match[29]

Panel A - Conditional on skills



Panel B - Conditional on skill requirements



[29] Panel A: P (good match | x). Panel B: P (good match | y).

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