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Do higher wages reduce inventors job turnover? The role of utility, status and signaling effects

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Abstract

Building on a full sample of Swedish inventors and their employers observed over the period 1990-2009, this paper analyzes how wages impact on inventor job turnover. We separate the net effect of higher wages on turnover into i) a utility, ii) a status and iii) a wage prospect effect all decreasing turnover and iv) a productivity signaling effect increasing it. We show that the positive productivity signaling effect dominates the other effects, implying that higher wages increase employment turnover. Only for performers with particularly strong productivity signals do we find a mobility-decreasing effect of higher wages. We discuss the implications of these findings for the design of compensation schemes tailored to tie key employees to the firm.

Jelcodes:J62,J31

1 Introduction

In recent years inventor mobility has been an important topic in the literature highlighting its impact on knowledge spillovers (e.g. Breschi and Lissoni, 2009; Hoisl, 2007; Singh and Agrawal, 2011; Zucker *et al.*, 1998). While such spillovers are beneficial from the perspective of the new employer, it constitutes a loss for the previous employer. Accordingly, employment turnover, in particular when involving key individuals, is usually considered to be detrimental to the firm because it implies a loss of knowledge (cf. Adner and Helfat, 2003; Shaw *et al.*, 2013; Trevor, 2001).

Several authors in strategic human capital have analyzed measures retain key employees in the firm and have also highlighted the importance of the characteristics of the wage scheme. In particular the role of wage dispersion, in affecting individual turnover decisions has been discussed arguing that high performers prefer high dispersion, and therefore high dispersion seen as an important instrument to retain these key individuals (Bloom and Michel, 2002; Blyler and Coff, 2003; Carnahan *et al.*, 2012).

In this argument implicit is evidently the assumption that higher wages reduce the individual likelihood of turnover (Pakes and Nitzan, 1983). While this seems intuitive and will usually be the case, if employees prefer higher wages over lower, the empirical literature is less clear on this relationship. Some studies have indeed shown a mobility-reducing effect of higher wages (Falch, 2011; Hammida, 2004), but there are also important studies that have found that higher wages instead induce *higher* mobility (Kim, 1999; le Grand and Tåhlin, 2002; Pfeifer and Schneck, 2012).

The latter results are puzzling because it contradicts conventional models of rational choice and suggest that under reasonable assumptions about employees' utility functions (higher wages are preferred over lower) mobility should decrease when wages increase. The important question is then when and under which conditions this very simple economic reasoning fails.

In this paper we trace the failure of the conventional model to an implicit assumption about the wage-exogeneity of the set of available outside alternatives (in particular, it is silently assumed that the outside alternatives are independent of current wage levels). We argue suggest that this assumption is overly restrictive, if wages create a positive productivity signal (cf. Becchetti *et al.*, 2013; Golan, 2009). Furthermore, if this assumption fails, it is no longer necessarily the case that higher wages have a mobility reducing effect, even under the standard assumption of strictly positive marginal utility of higher wages (Bloom and Michel, 2002).

We test our arguments based on a linked employer-employee panel dataset consisting of an extraordinarily rich dataset of *all* Swedish inventors for the years 1990-2009. The data contain information about wages, turnover patterns, patenting behavior, and other personal information, such as family relations, as well as detailed information about employers.

Our results show that several structural effects of wages on mobility are simultaneously at work, where most are mobility-reducing and indeed fit a theoretical model assuming wage-exogeneity of the available outside opportunities. From these effects we separate a productivity signaling effect, which implies a failure of the wage exogeneity assumption. We show that in our data the signaling effect strongly dominates the other mobility-reducing effects of higher wages.

This mobility-increasing effect of higher wages holds with the exception of inventors with very strong non-wage related signals (in particular strong patent records). For those we find that the mobility-increasing productivity signals of wages are completely crowded out and higher wages indeed *decrease* mobility. The intuition is that the productivity signaling effect of high wages is important for inventors whose other relevant signals are relatively weak, while for extreme performers the other signals are so strong that the productivity signal of higher wages becomes practically irrelevant. This means that, for this group of star inventors, wages can be a key tool for retention.

We contribute to the literature by integrating insights from mobility research in economics into the literature on strategic human capital management dealing with the role of wage schemes. In particular, we extend the literature by focusing on the role of wage levels rather than wage dispersion, which so far has been the most common in this literature (among others Carnahan *et al.*, 2012; Gardner, 2005).

The remainder of the paper is organized as follows. In Section 2 we describe the theoretical arguments underlying the paper. In Section 3 we describe our data and identification strategy. Section 4 presents the results. In Section 5 we conclude with a discussion of the results and their implications for the design of wage policies aimed at retaining inventors.

2 Background

2.1 Theoretical framework

Rational choice models assume that out of a given set of alternatives individuals make their choices by evaluating alternatives according to some target criterion and then select the alternative that best fits their preferences.

In the context of wages and job mobility, wages or some function thereof may be considered a target criterion, while an observed mobility decision is the enactment of a choice of a certain employment alternative.

This kind of model captures the realistic feature that wages help employees rank between outside options and the possibility to stay at the job. It also has explanatory power towards findings that high-earners (Clotfelter *et al.*, 2008; Falch, 2011; Hammida, 2004) have lower mobility than other income groups, but fails to give an explanation of findings that have shown the opposite relationship (Kim, 1999; le Grand and Tåhlin, 2002; Pfeifer and Schneck, 2012).

We argue that the reason for this is that the outlined model implicitly treats the set of available choices as exogenously determined and, in particular, independent of current wages. We will argue that wage related productivity signaling effects lead to a failure of this assumption and cause a structural effect that is mobility-increasing rather than reducing.

2.2 Effects of wages on mobility under exogeneity of the set of alternatives

Assuming that the set of alternatives is exogenously given, and that utility depends positively on wage levels, standard arguments about rational behavior imply that higher current wages are mobility-reducing, because higher wages make outside opportunities ceteris paribus less attractive. Indeed this reasoning is implicit in most works in labor economics (cf. Akerlof, 1982; Pfeifer and Schneck, 2012; Salop and Salop, 1976; Salop, 1979) as well as strategic human capital management literature. For example, Harris and Helfat (1998), Gardner (2005), and Carnahan et al. (2012) argue that companies compete for key human capital, where success in retaining key personnel is (also) determined by the companies' ability to pay higher wages than competing firms. Based on this we form our most simple baseline hypothesis:

H1 (utility effect): The higher the wage, the less likely the inventor is to leave the company.

H1 makes an argument about the impact of absolute wages. Models of social comparisons (Duesenberry, 1949; Festinger, 1954) extend this argument to include relative comparisons. More precisely, they argue for the existence of a *status effect* according to which is not the absolute but the relative level of wages that matters. The main argument is that individuals evaluate their wages by comparing them to those of their peers. This perspective has been frequently picked up also in labor economics (Boyce *et al.*, 2010; Clark *et al.*, 2009; Clark and Oswald, 1996; Clark and Senik, 2010; Ferrer-i-Carbonell, 2005; Wolbring *et al.*, 2013)

With respect to mobility, switching the wage levels from an absolute to a relative measure does not imply any changes in arguments. Just as in the case of H1, mobility should decline, because outside opportunities become less attractive. If we proxy the relevant peer group by the inventors in the same company this leads us to hypothesize:

H2 (status effect): The more an inventor earns in comparison to other inventors in the same company, the more likely he is to stay.

While H1 and H2 refer to contemporaneous wages, some authors have drawn attention to the wage dynamics. Clark et al. (2009) and Pfeifer and Schneck (2012) argue that higher peer wages provide a signal of future wage increases. Thus, colleagues who obtain higher wages may indeed decrease mobility because employees expect their own wages to rise in the future.

This effect can therefore explain why lower (relative) wages are mobility reducing and vice versa. However, this rests on the assumption that lower relative wages are always interpreted as signals of future wage increases. This might be reasonable in cases when e.g. the employee attributes his own relative wages to demographic characteristics, for example to age-dependent seniority or to accumulation of employer-specific human capital and experience (Møen, 2005; Rosen, 1972).

In other cases, this assumption is less credible. An employee with long tenure or above average age with a wage lower than the average wage of his peers would rarely take such an observation as a sign future wage increases. Instead, the signal received should be one of foregone wage opportunities, possibly due to under-performance, harassment, or poor employee-employer-match. In this case, the informational content concerning future wage developments is negative rather than positive. Because of this, relative age is expected to be an important moderator of the status effect.

H3 (wage prospect effect): (a) Employees that are younger than their co-workers take lower relative wages as a signal of future wage increases reducing the mobility propensity.(b) Employees that are older than their co-workers take lower relative wages as a signal of foregone wage opportunities increasing the propensity for mobility.

In summary, H1 and H2 clearly predict a negative impact of higher wages on mobility. H3 is ambiguous in its sign and predicts a mobility decreasing effect of lower wages for younger employees and the opposite for older employees. Since H3 is mobility increasing for older employees H3 does, however, not provide the basis for explaining why higher wages should *on average* increase individual mobility rates in general.

2.3 Effects of wages on mobility with an endogenous set of alternatives

So far we assumed implicitly that changes in wages only change the relative value of the opportunities but is unrelated to the characteristics of outside opportunities. A couple of situations are conceivable where this need not be true. For example, if two firms openly compete for an individual as often hypothesized in strategic human capital research (Adner and Helfat, 2003), they might engage in a wage race where they overbid each other. Clearly then, outside opportunities are a function of current wages. Arguably such a situation is exceptional, but we argue for a mechanism that can lead to failure in of the wage-exogeneity assumption in more ordinary situations. In particular, we think that the exogeneity assumption can be very problematic when wages cause important productivity signals to potential outside employers (Becker, 1975; Lazear, 1986; Lippman and McCall, 1979; Schwab, 1991)

While productivity is a multifaceted phenomenon driven by many factors, several authors have provided evidence for the signaling function of wages. For example, Golan (2009) shows that because highly skilled employees earn higher wages, high earnings also signal high future productivity. Becchetti et al. (2013) also find that individuals with higher wages are intrinsically more motivated, which may give rise to an additional signal effect. In the same vein Weiss (1995) argues that higher wages are related to low absence rates and higher general health, which then might be taken as a positive signal by future employers.

For these reasons, higher wages create several signals related to the prospective employee’s productivity, which create new high-value opportunities in the set of alternatives. Therefore, although higher wages would, under the assumption of an unchanged set of alternatives, reduce mobility, this wage-exogeneity assumption is unlikely to fully capture the effect of wages, since higher wages would tend to create new or better alternatives by signaling productivity. We measure the signaling effect by the wage differential with respect to average industry wages, because this differential is usually observable for the new employer, while the relative wages with respect to internal colleagues (measuring the status effect) is not:

H4 (productivity signaling effect): The more the inventor earns in comparison to other inventors in the same industry, the more likely he is to leave the company.

An important question that follows is if H4 is confirmed, under which conditions the signaling effect will dominate the effects in H1-H3.

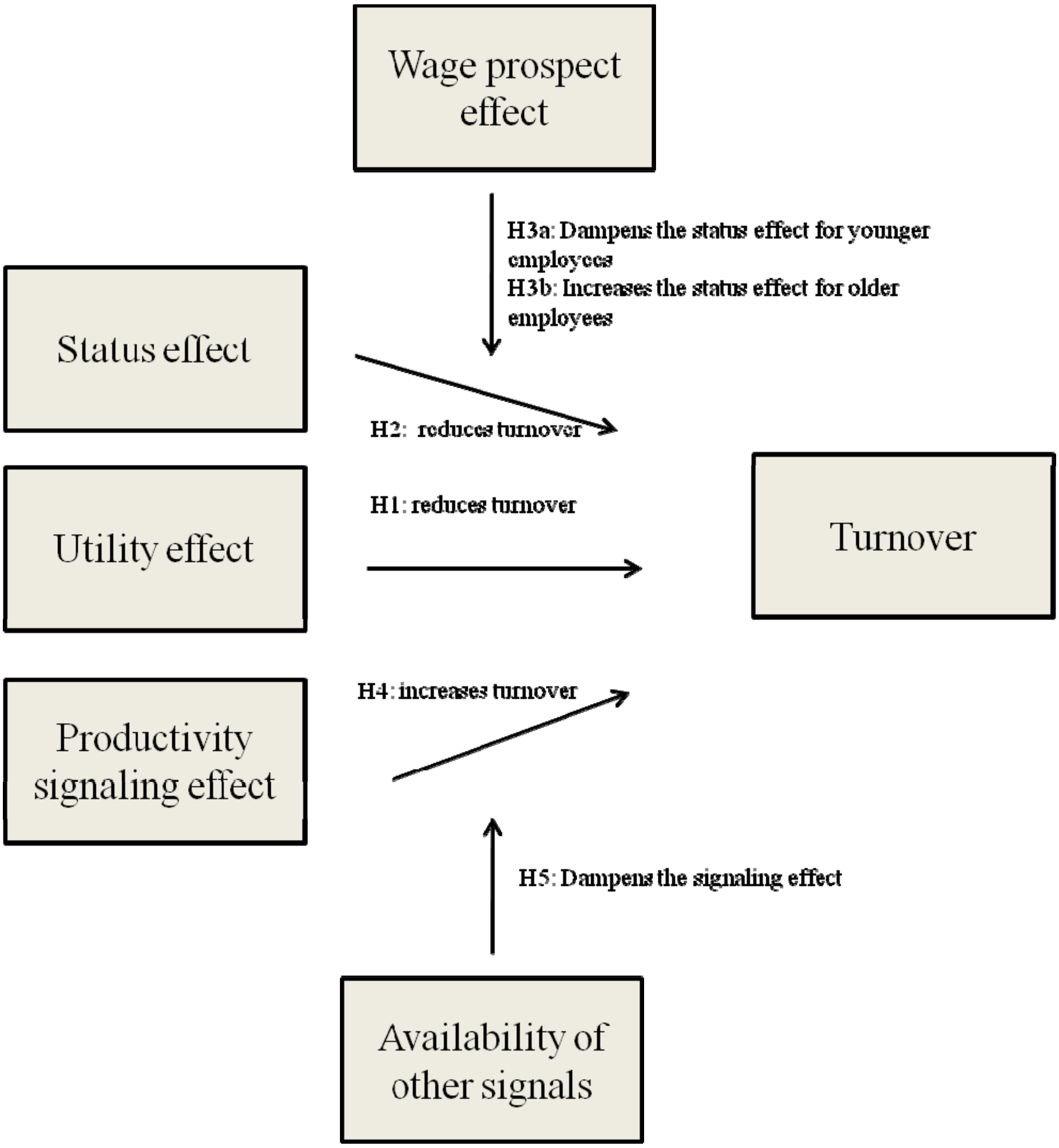
Clearly, the effect in H4 rests on the assumption that wages effectively disclose information about productivity. In this context, it can be argued that wages, although having predictive power for future productivity, are relatively weak signals. Trevor et al. (cf. Trevor *et al.*, 1997 for promotions as weak signals) makes this case for promotions. But wages are likely to be even weaker signals than promotions because they might be confounded by flat compensation dispersion schemes (cf. Carnahan *et al.*, 2012). Flat wage schemes are particularly common in the Swedish case that we will analyze (Hibbs and Locking, 2000). Moreover, wage levels provide only weak signals because changes to them frequently result from other factors than productivity, such as self-selling capabilities, nepotism, devote behavior, a good idiosyncratic match between employer and employee, institutional mechanisms or simply luck (cf. von Wachter and Bender, 2006).

The problem with weak signals is that they are typically crowded out by stronger signals, because these can more accurately disclose information. In line with this argument DeVaro and Waldman (2012) show that job promotions effectively disclose information about employees with Bachelor or Master Degree but not for PhD-graduates. The reason is that while promotions for BA/MA employers are relatively strong signals, the productivity signal effect from the fact that a person has a PhD might be much stronger than any signaling effect that promotion would disclose. Thus, above average wages are much more likely to be regarded as relevant information disclosing mechanisms when stronger signals are unavailable. For inventors a whole range of signals exist. We would thus expect high wages to lose their signaling power, when stronger signals are available. They will therefore have a lower impact on mobility rates for employees with strong alternative productivity signal. Following Bretz et al. (1994) we expect to find those signals primarily in human capital factors related to education (cf. Spence, 1973) and inventors’ individual competence (Gerhart, 1990), where we measure the latter by their actual patenting behavior. This is formalized in H5:

H5: If stronger signals of productivity related to (a) education and (b) patenting behavior are available, inventor wages above the average of inventors from the same industry have a weaker impact on the likelihood of an individual to leave the company.

Figure 1 summarizes the identified effects and the hypotheses.

Figure 1. Summary of the model and derived hypotheses.



3 Data and Identification Strategy

3.1 Data

The basis for our empirical investigation consists of a unique dataset, in which 80% or close to 23,000 inventors listed on European Patent Office applications 1978-2009 with Swedish address were linked by the Swedish social security number (*the "personnummer"*, SSN). This was a labor-intensive effort that involved, first, sending all inventor records to a commercial service provider, which added the SSN. However, provider only linked inventors whose addresses had either a) only changed during the last three years at the time (2011) or b) were old records with inventors' addresses unchanged. Thus the match rate was lower for old patent records, creating biases towards finding non-mobile inventors, which obviously would have created problems for the present paper. Therefore, we then extracted best name-address matches from the DVD "Sveriges befolkning 1990" (Sweden's population in 1990) (Sveriges släktforskarförbund, 2011) records of the population, including their addresses, using the Levenstein algorithm. Name matches together with birth date could then be used to find the SSN, which produced a match rate for the whole period which was fairly even and a material which allows for panel data analysis of inventors. In anonymized form, this material was further linked to individual registers at Statistics Sweden. This link enables further description of inventors' demographic and education characteristics, wage information, data on workplace, and associated firm and business group information. Demographic and education characteristics and developments over time of Swedish inventors have been described in Ejermo (2011) and Jung and Ejermo (2013). Another appealing feature of these data is a FAD-data provided by Statistics Sweden whereby organizational restructuring (such as mergers and acquisitions) or change of organizational form does not affect the firm identifier. This makes the firm id stable over time and enables an accurate characterization of mobility across organizational entities. Using this data we could also delete all cases of observed inventor mobility that were simply due to the closing of the firm and thus had nothing to do with wage induced mobility.

Although, matching of inventors were subjected to a highly conservative judgment, one important caveat need to be pointed out. Inventors sometimes don't report the home address, which has been used for matching. Although this is generally very rare, AstraZeneca (and earlier Astra) inventors consistently report their company's address. This actually concerns about 5% of all inventor records, and would therefore create a bias for medical inventors. To account for that, we have estimated the same models excluding these inventors without however observing qualitative differences. We also tested whether the exclusion of inventors working in the public sector (i.e. NACE>=75) changed the results. Also here the impact was negligible.

3.2 Core explanatory variables

Our analysis mainly builds on regression techniques, where interfirm mobility is modeled as a function of different wage characteristics. Before we turn to the more technical issues of estimation we will now briefly describe the main explanatory variables and then turn to confounding factors.

The utility effect relates to the utility that employees enjoy from their absolute wage levels. We measure this by the yearly gross annual wage income of the main employer.[1] In order not to confound our results we exclude all inventors in years in which they work part-time.

The status effect and the wage prospect effect refer to comparisons that employees make with respect to their colleagues. We assume that a sensible peer benchmark is the average wage level of other inventors within the establishment. Given that we nearly operate on the full population of Swedish inventors, this benchmark can be regarded as accurately measured without having to deal with response bias as would be pertinent to survey data.

The last core variable relates to the productivity signaling effect. We argue that potential new employers cannot observe old employers' internal benchmarks. Hence, they need to construct a different reference benchmark. We assume that this will more likely relate to inventors' wages averaged by industry. Based on this reasoning we create a measure that takes the difference between the focal inventor's wage and the average wage of inventors employed in the same 2-digit NACE sector.

3.3 Confounding factors

Turnover decisions are influenced by a large set of potential confounding factors, where not all are easily observable. In particular, the recent turnover literature has understood individual mobility decisions to be influenced by factors operating and interacting on the individual level of the immediate working context, as well as the level of the organization (Liu et al. 2012).

We continue by describing in detail some of the factors that are particularly interesting. We attempt to be as detailed as possible concerning the explicit inclusion of confounding variables, but we also highlight that unobserved heterogeneity will remain, which we control for by multi-level fixed effects.

3.3.1 Individual factors

Individual turnover propensity. Turnover decisions are usually based on an assessment of benefits and costs associated with the decision, both of which are not fully known before implementation. This assessment is complicated to model for two reasons. First, assessment of benefits and costs are highly subjective and differ from individual to individual. Second, the individual's assessment of costs and benefits is likely to change over time as a result of past decisions. If we could ignore the second issue, it would be sufficient to control for individual specific propensities by including individual fixed effects. However, the second reason renders such an econometric approach incomplete, because individual fixed effects are not constant and therefore cannot be cancelled out or controlled for by standard fixed effects models. Instead, we need a proxy that captures the salient features of this assessment process directly. We propose two ways of achieving this. By default we control for the innate propensity to move (i.e. to change living place), which we measure by the cumulative number of observed moves divided by the number of years the individual is observed. We use the first lag of this variable in order to prevent direct simultaneity between the explained turnover decision and moving propensity. While this is certainly a more or less direct measure of how individuals assess costs and benefits of moving (frequent movers will tend to discount the costs of moving more heavily than infrequent

1 The wages are in nominal terms, but inflation is fully captured by year dummies.

movers), this moving propensity is not the same as their turnover propensity (which necessitates a change of job). Therefore, in one of the models we further control for the turnover trajectory by including the lag of the explained turnover variable itself. This introduces dynamics into the model which allows for past decisions to have a genuine effect on today's decisions. Such a dynamic model can therefore account for the fact that an employee revises his ways of assessing costs and benefits based on in-sample experience. An additional reason for including past mobility decisions is to account for the well- established fact that past turnover generally increases wages (Bartel and Borjas, 1981; Keith and McWilliams, 1995, 1999; Kim, 1999; Topel and Ward, 1992). Not including past turnover may therefore lead to omitted variable bias which would have a particularly drastic effect with respect to the absolute wage level. As we will see below, we handle the endogeneity that is inherent to all dynamic panel data models with fixed effects by ML-models that make use of initial conditions (cf. Wooldridge, 2005).

Family background. One of the most important factors influencing voluntary turnover is family background. It is rarely under the direct control of the employer and is therefore hard to influence, even though it will have a profound impact on the desirability of movement. We control for family background by two variables. The first accounts for the partner residing in a different municipality. This generally means that the inventor commutes, which is likely to increase his desirability to switch jobs. The second variable measures the number of children in the household below the age of 18. Intuitively, having young children would seem to lower mobility. However, counter to such expectations, inventors having children (and getting married) were found to be more mobile in Ahlin and Ejermo That paper argues that number of children may induce (mostly male) inventors to search for a better-paid job, thus increasing mobility.

Other measures and individual specific effects. We include a measure of an individual's patent productivity, measured as quality-adjusted patents on the individual level.[2] This controls for the possibility that patents may be used to strategically retain inventors within the firm (Kim and Marschke, 2005). We also control for inventor age and its square as well as education dummies covering broad majoring subjects. Despite the richness of these data, unobserved heterogeneity is likely to remain. This could potentially bias our estimates. We will therefore control for time-invariant individual specific effects.

3.3.2 Organizational factors

Internal labor markets. One of the central factors impacting on the desirability of movement consists of internal career prospects, because it is against these that potential outside opportunities are valued. In this context, internal labor markets have gained increased attention as an HRM practice to reduce turnover. As pointed out by Doeringer and Piore (1971), internal labor markets and a company's explicit reliance on them is a commitment towards long-term employment and qualification. Additionally, as Haines et al. (2010) make clear, internal labor markets also provide better career opportunities, because job offers are more frequent and career advancement is less dominated by idiosyncracies and luck that are typical in career systems which depend on queuing. We discern internal labor markets on two levels, the firm and the business group, in each case approximated for by the number of employees at the respective level.[3]

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2 See Ejermo O, Kander A. 2011. Swedish business research productivity. Industrial and Corporate Change 20(4): 1081-1118. for an explanation of the method to quality-adjust patents.

3 We also operated with the number of work places (plants) at the firm level and number of firms in the business group. But these seemed to be less effective proxies.

Assortative (performance) matching. Positive assortative matching on performance is a mechanism by which productive individuals match with productive organizations (Becker, 1975). Empirical analysis of the phenomenon is, however, scarce. A notable exception is Woodcock (2011) who uses US Employer-Household data for 1990-1999 and demonstrates that positive assortative matching had an important influence on wage levels. Indeed, assortative performance matching is a special instance of homophilic behavior which is well known to psychology and a dominant feature in many social processes (cf. Lazarsfeld and Merton, 1954). Therefore, there can be other dimensions that appeal to more cognitive levels of assortative matching. However, in the context of this analysis we remain with the matching on performance. Our expectation is that inventors match organizations with other inventors that are on average equally productive measured by patent productivity. Therefore, we create a variable that measures the absolute difference between the focal inventor's productivity and that of the other inventors within the same establishment. If this measure increases, the focal inventor should be more interested in changing jobs.

Other variables and establishment specific effects. On the organizational level we also include sector dummies based on the OECD technology level classification, which is commonly used in innovation studies (cf. Robin and Schubert, 2013). It is based on NACE and classifies firms into four manufacturing and two service categories, based on R&D-intensity. However, as in the case of individual specific effects, recent analyses of voluntary turnover have pointed to the importance of multi-level effects (Liu et al 2012). Given that it was not possible with this dataset to control for many important organization level variables such as the importance of hierarchical structures, employee autonomy or general working climate, it is highly recommendable to control for organizational specific fixed effects. In particular we use the establishment level (rather than more aggregated level effects), because we want to be as close as possible to the respective working conditions. We also include time dummies to control for e.g. cyclical patterns and other time-varying influences that may affect turnover behavior because they impact on general job availability (Trevor, 2001).

3.4 Identification strategy

The discussion about the baseline effects in H1, H2, and H4 (i.e. excluding the moderating wage prospect effect and other signals for the moment) as well as about the confounding factors suggests that the regression model including time and inventor subscripts should be specified as follows:[4]

$$mobility_{it} = \alpha_0 + \alpha_1 \underbrace{w_{it}}_{utility\ \ effect} + \alpha_2 \underbrace{(w_{it} - \overline{w}_{est,it})}_{status\ \ effect} + \alpha_3 \underbrace{(w_{it} - \overline{w}_{ind,it})}_{prod.\ \ signaling\ \ effect} + x_{it}\beta + c_i + u_{it} \qquad (1)$$

where c_i is an individual level unobservable fixed effect and x_{it} subsumes all control variables including the organizational fixed effects.

In our setting our theory leads us to assume that c is correlated with wages (and possibly with the other control variables), because we cannot observe the individuals' exact outside opportunities, because we do not whether and inventor is close contact with competing firms we he has a job offer or could potentially have one. But since we allow the set of alternatives to depend on wage levels through the productivity signaling effect, the unobserved heterogeneity term must

4 The wage prospect effect will be dealt with in a separate model.

be correlated with wages. Therefore, the use of fixed effects estimators is principally warranted. It should be noted, however, that estimators allowing for unspecified time-invariant fixed effects are unavailable because of the incidental parameter problem.[5] A convenient alternative to controlling for fixed effects is, however, to use parametric specifications for them. As Mundlak (1978) has highlighted, it is possible to approximate the individual fixed effects by individual specific time-averages of the explanatory variables.

A further issue concerns the question about directionality of relationship between wages and mobility. It might well be argued that employees choose to be mobile to increase their wages (cf. Oettinger, 1996). Furthermore, the past mobility decisions might impact on the perceptions about the costs of mobility. If this is also true, the mobility history will explain current wages and will also be an explanatory variable in (1). This calls for a dynamic panel data model. While it requires additional assumptions on the distribution of the fixed effects, the Mundlak method also extends to leading examples of non-linear models including the panel probit model (Wooldridge, 2005), where in addition to past lagged mobility and the Mundlak terms also a variable capturing the mobility in the initial period is included.

In all of the models to be presented we include individual and establishment level time averages of *all* included explanatory variables. We will not report these effects in detail, because they are of secondary interest. But we will report tests for the joint significance of individual and establishment level fixed effects.

In addition to the fixed effects probit estimator we also use the dynamic fixed effects probit estimator to test H1, H2, and H4. The result of these tests can be read off from the coefficients on the core variables directly. H3 instead hypothesizes that the relative wage position in the establishment is contingent on the inventor's relative age. We therefore include an interaction term between the wage relative to the establishment average and a dummy for whether the inventor is on average younger than his colleagues.[6] If our hypothesis is true, the interaction coefficient should be positive because then younger employees will tend to take lower relative wages as a sign of wage prospects, while older employees will take it as a sign of foregone chances.

H5 posits that the informatory signaling power of wages deteriorates if inventors have other potential signals. As argued above, these could lie in higher education levels or more potent patent records. To be precise, we single out information on whether an inventor has a tertiary degree as well as three aspects of his/her patents, namely the cumulative oppositions relative to age, cumulative non-patent references relative to age, and forward-citation-weighted patent productivity (quality-adjusted patent productivity) relative to age. The rationale for the latter is clear. The other two require some explanation. In particular, opposition is a strong signal for patent value, because oppositions are signs of perceived patent infringements which are extraordinarily expensive and usually pursued only if one of the parties (holder or opponent) believes that the patent is worth the effort (Harhoff and Reitzig, 2004; Harhoff *et al.*, 2003; Lanjouw and

[5] This holds with the exception of the fixed effects logit model for which the average of the time average of the explained variable is a sufficient statistic allowing to condition out the fixed effect. However, this approach has the undesirable property that it will include only information on those subjects that have a change in status at least once in the panel period. Since more than 80% of the inventors in our sample never change jobs, this would have implied a severe loss in sample size. Even worse, it might have unnecessarily introduced selection towards mobile inventors.

[6] In those cases where only one inventor works at the establishment, the reference wage level is simply that of the inventor him-/herself.

Schankerman, 2004; Schubert, 2011). References to non-patent literature are per se of no economic importance, but they usually refer to scientific publications. This indicates that the knowledge sourcing was more science oriented, potentially a sign of more radical and more valuable inventions. To test H5, we include interaction effects of the industry-level wage position and the three aforementioned signals. If H5 is true there will be a negative coefficient from the interaction, because this indicates a lower importance of the wage signal. We include variables that interact with the industry level wage position with the three listed effects.

H6 builds on the preceding hypothesis, but unlike H5 it relates to the absolute effect of wages on mobility rather than just moderating effects of other signals with respect to industry wage position. We therefore evaluate the total marginal effect of wage increases at different levels with respect to other signals. We evaluate whether for extreme performers the marginal effect of higher wages is compatible with a mobility reduction.

4 Results

Table 4 summarizes the basic descriptive statistics for our sample. Some main features are noteworthy. On average an inventor earned 530,300 SEK per year in wages, which corresponds to about 60,000€. However, the maximum reaches 13.6 million SEK (1.5 million €). The per annum mobility rates are with about 2.8% relatively low.

Table 1: Summary statistics

Variable	Mean	Std. Dev.	Min	Max
Mobility	0.0283	0.1658	0.0000	1.0000
Wage income in 100,000 SEK	5.3035	2.9128	2.7930	136.0510
Wage difference establishment	0.0451	2.4229	-18.2487	125.8366
Wage difference industry sector	0.2141	2.7379	-8.3185	129.8792
Bachelor degree or above	0.6032	0.4892	0.0000	1.0000
Opposition productivity	0.0000	0.0009	0.0000	0.0789
Adjusted patent productivity	0.0002	0.0038	0.0000	0.2731
NP citation propensity	0.0022	0.0293	0.0000	2.5116
#Children below 18	0.9153	1.0678	0.0000	6.0000
Partner lives in different communit	0.0554	0.2287	0.0000	1.0000
Assortative productivity match	0.0007	0.0040	0.0000	0.2707
Moving propensity	0.1022	0.1260	0.0000	1.5000
Age	47.9245	8.8870	23.0000	64.0000
Business group size in 1000	11.2836	11.8713	0.0040	82.9660
Firm size in 1000	5.5388	7.5635	0.0030	68.8290
Education field: humanities	0.0031	0.0558	0.0000	1.0000
Education field: social sciences	0.0173	0.1303	0.0000	1.0000
Education field: natural sciences	0.1062	0.3081	0.0000	1.0000
Education field: engineering and t	0.7451	0.4358	0.0000	1.0000
Education field: agriculture	0.0041	0.0637	0.0000	1.0000
Education field: medicine	0.0820	0.2744	0.0000	1.0000
High-tech manufacturing	0.2275	0.4192	0.0000	1.0000
Medium-high-tech manufacturing	0.3368	0.4726	0.0000	1.0000
Medium-low-tech manufacturing	0.0850	0.2789	0.0000	1.0000
Low-tech manufacturing	0.0677	0.2513	0.0000	1.0000
Knowledge-intensive services	0.2448	0.4300	0.0000	1.0000
Other services	0.0382	0.1918	0.0000	1.0000

Concerning educational background, almost three quarters have a background in engineering and technology, followed by natural sciences with 10.6% and medicine with 8.2%. Not surprisingly, social sciences (1.7%) humanities (0.3%) and agriculture (0.4%) backgrounds are virtually negligible among inventors. With respect to sector affiliation, the majority of inventors are employed by firms in high-tech (22.7%) and medium-high-tech sectors (33.7%) of manufacturing. Given the often cited intangible nature of service innovation (e.g. Miles, 2005), somewhat surprisingly still almost one quarter of the inventors are found in firms that belong to knowledge-intensive services, which is by far more than in the medium-low-tech and low-tech manufacturing sectors.

We now turn to the regression results which address H1 (the utility effect), H2 (the status effect), and H4 (the productivity signaling effect). H3 qualified the wage prospect effect by arguing it to be conditional on age. The corresponding interaction effect will be analyzed in the subsequent table.

M1-M3 refer to total turnover either in terms of cross-establishment turnover or cross-group turnover. We consider alternative specifications with the inclusion of contemporary wages (M1), the lagged wages (M2) and the inclusion of lagged dependent variables (M3). By combining internal and external mobility into total mobility as our investigated variable, we assume that wages work similarly regardless of type of mobility. While H1-H3 are based on an individual's point of reference, and therefore applicable on cross-establishment turnover, managers in firms in the same business group may have more opportunities to observe inventors' work, for instance by 'asking around' or observe their work in joint R&D projects existing between firms within the same business group. This would imply a crowding out of the wage signal with respect to signals observable only to the new employer. In fact, when we focus on across-business group mobility (not presented) we see that the productivity signaling effect is much larger than compared to the overall mobility. This makes us more confident that the effect is as hypothesized associated with signaling mechanisms. Further proof will be added in the discussion of H4 and H5, where we are actually able to demonstrate a crowding out of wage signal when alternative strong observable signals, such as patent records, are available.

As we see in M1, we find strong evidence of all three effects hypothesized in H1, H2, and H4. In particular, the negative effect of higher wages on total mobility indeed gives some indication of the utility effect. Also the negative effect of wages relative to the average in the establishment reduces the propensity to move, giving evidence of the status effect. While these two effects reduce mobility, the productivity signaling effect has a strong positive effect. More or less the same picture emerges in the case of lagged wage variables, even though we note that the evidence of the status effect is not significant anymore. This lower significance could in any case be rationalized by the psychological literature which highlights that turnover as a response to environmental characteristics is usually a rapid process (cf. Holtom *et al.*, 2005).

In Section 3 we argued that mobility decisions exhibit considerable state dependence because past decisions about job changes are likely to influence the perceived associated benefits and costs. Static models like those in M1-M2 are therefore likely to miss an important aspect of the turnover decision. In M3 we therefore included the lagged mobility decision alongside a control for the initial condition, where both are highly positively related to contemporary mobility. The interpretation of this is that mobility decisions are both affected by the in-sample trajectory of mobility decisions because they affect perceptions about costs and benefits, as well as initial conditions that relate to innate and time constant preferences about mobility. This result confirms the proposition by Liu et al. (2012) who argue for the importance of trajectories of job satisfaction as a determinant of turnover decisions. With respect to the impact of wages, we find that our results are confirmed with the exception of the effect from the absolute wage level, which, while having the predicted direction, loses significance. In sum, what remains in this dynamic model are the mobility-reducing status and the mobility increasing productivity signaling effects. These results are in line with an extensive sociological literature, which rests on relative income theory. For instance Wolbring et al. (2013) argue that relative wage rank is much more important for satisfaction than absolute wages.

With respect to H1, H2, and H4, we conclude that there is strong evidence to support H2 and H4. There is also some evidence in favor of H1, but we note that this may be due to the failure to account for dynamics in the wage-mobility relationship.

In any case, while H1 and H2 are mobility reducing, H4 is mobility increasing. Since all of the variables capturing these effects are functions of the focal inventors' wage, by using (2) it can be shown that the average partial effect of wages on expected mobility is given by:[7]

$$\partial \mathrm{E}(mobility_{it} \mid x_{it}, w_{it}, \overline{w}_{est,it}, \overline{w}_{ind,it}) / \partial w = (\alpha_1 + \alpha_2 + \alpha_3)\phi(\cdot) \qquad (3)$$

where $\phi(\cdot)$ is the normal density function and thus strictly bounded between 0 and 1. The sign of the marginal effect is given by the sign of $(\alpha_1 + \alpha_2 + \alpha_3)$. We find that the net effect of higher wages is strongly mobility increasing. The effect is significant at 1% in all of the five models, which casts doubt on the possibility that paying high wages is an effective to achieve retention, at least with respect to inventors.

Also, some of the secondary effects are very interesting. First, we note that both individual- as well as work-place-level fixed effects are jointly highly significant (p<0.0000 in both cases). This has implications both for theory as well as methodology. With respect to the latter, to the degree that unobserved heterogeneity is correlated with observed variables, no random-effects estimator will give reliable results. Not even in this extremely rich dataset were we able to control for many of the confounding factors. Therefore, panel data and fixed effects estimation seems a methodological must. From a theoretical perspective, these results confirm the multi-level structure of voluntary turnover decisions, which has recently become a topic in turnover research (Liu et al. 2012).

With respect to the use of internal labor markets, it was our general expectation that the larger the respective organization at a particular level (firm, business group), the lower the mobility rates at this level. The rationale was that larger organizations provide larger internal labor markets, which reduce turnover. Indeed, the results corroborate this conjecture.

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7 We also retrieved the overall effect by running a simple regression with wages as explanatory variables treating the establishment and industry wages as controls. The results were as expected very similar.

Table 2: Regression results (H1, H2, H4)

	M1 Total mobility	M2 Total mobility	M3 Total mobility
L(0/1).Wage income	-0.002*	-0.002*	-0.001
	(-1.76)	(-1.66)	(-0.43)
L(0/1).Wage difference establishment	-0.001**	-0.001	-0.002***
	(-2.01)	(-1.31)	(-2.67)
L(0/1).Wage difference industry sector	0.004***	0.003**	0.003**
	(3.14)	(2.40)	(1.97)
#Children below 18 years	-0.000845	-0.001024	-0.001192
	(-0.90)	(-1.09)	(-1.24)
Family lives in different community (y/n) (d)	0.038503***	0.039936***	0.040812***
	(4.17)	(4.23)	(3.91)
Quality-adjusted Patent productivity	0.611359	0.593639	-8.285993***
	(0.74)	(0.73)	(-3.01)
L.Moving propensity	0.012085	0.012620	0.000748
	(1.29)	(1.34)	(0.07)
Age	-0.002347	-0.001975	-0.002592*
	(-1.62)	(-1.36)	(-1.67)
Age^2	-0.000034	-0.000428	0.000633
	(-0.02)	(-0.31)	(0.42)
Inventor productivity divergence	-0.550331	-0.532761	7.789576***
	(-0.66)	(-0.65)	(2.77)
Business group size	0.002	0.002	0.002**
	(1.41)	(1.39)	(2.03)
Firm size	-0.001***	-0.001***	-0.001***
	(-3.67)	(-3.64)	(-4.28)
L. Total mobility (d)			0.013539***
			(3.57)
Initial mobility condition (d)			0.007663**
			(2.29)
Education dummies	YES	YES	YES
Individual specific effects	YES	YES	YES
Establishment specific effects	YES	YES	YES
Year dummies	YES	YES	YES
Sector dummies	YES	YES	YES
Observations	52214	52214	41176
R^2			
Number of groups	10068.000000	10068.000000	9023.000000
Pseudo R2	0.082834	0.080586	0.100766
Model significance	0.000000	0.000000	0.000000

As expected, also family background plays an important role. Though we do not see any effect from the number of children, the fact that the partner lives in a different municipality is a strong predictor of mobility. This indicates that turnover decisions extend well beyond purely job-related factors and are strongly influenced by the compatibility of job and social necessities.

Lastly, we want to hint at the mechanism defined by positive assortative performance matching. The variable intended to measure this – the difference between colleagues' and own patent productivity – is not significant in any of the models M1-M3, which seems to suggest that this mechanism is absent. However, once we control for the dynamics of the mobility decisions, it becomes highly significant with the expected sign. One reason for the fact that this association is found only in the last model could be that positive assortative matching is primarily relevant for the subgroup of inventors who change jobs frequently. The failure to account for the (self-enforcing) dynamics in the mobility decisions could imply that this mechanism is 'hidden' by the dominance of mostly immobile inventors in the other models.

We now turn to H4 and H5 which are cast in terms of moderating factors, see Table 3. H4 defines the fourth of the main effects, namely the wage prospect signaling effect which is associated with existing wage differentials. As hypothesized, we did indeed find a positive coefficient from the interaction of wages relative to the average wage level at the establishment with the focal inventor's relative age in M4. This implies that relatively younger inventors are more likely to tolerate lower wages because they take them as a sign of potentially higher future wages. Turning the argument around, relatively older inventors will interpret an inferior relative wage position as a sign of foregone wage potentials, increasing their mobility propensity. Alternatively, and in line with the predictions of Rosen's (1972) human capital accumulation model as described above, younger inventors would accept lower wages in order to accumulate human capital, whereas for older inventor learning is not an important factor and they would tend to leave the company to recoup returns on their human capital investments.

Table 3: Regression results (H3, H5)

	M4 Total mobility	M5 Total mobility	M6 Total mobility	M7 Total mobility	M8 Total mobility
Wage income	-0.002* (-1.67)	-0.002* (-1.86)	-0.002* (-1.78)	-0.002* (-1.76)	-0.002* (-1.75)
Wage difference establishment	-0.002*** (-2.97)	-0.001 (-1.03)	-0.001** (-2.01)	-0.001** (-2.00)	-0.001** (-2.00)
Wage difference industry sector	0.004*** (3.16)	0.005*** (3.71)	0.004*** (3.15)	0.004*** (3.14)	0.004*** (3.14)
(Wage difference establishment)*(Young)	0.002*** (3.99)				
Young (d)	-0.009341*** (-5.15)				
(Wage difference industry sector)*(Tertiary degree)		-0.001** (-2.42)			
Bachelor degree or above (d)		0.002807* (1.91)			
(Wage difference industry sector)*(Opposition productivity)			-59.628*** (-16.79)		
Opposition productivity			-102.852106*** (-17.24)		
(Wage difference industry sector)*(Quality-adjusted Patent productivity)				-0.174 (-1.45)	
(Wage difference industry sector)*(NP citation propensity)					-0.024* (-1.66)
NP citation propensity					-0.040775 (-1.26)
Quality-adjusted Patent productivity	0.598814 (0.69)	0.603769 (0.74)	0.152322 (0.13)	0.264207 (0.34)	0.713435 (0.99)
#Children below 18 years	-0.000304 (-0.32)	-0.000849 (-0.91)	-0.000698 (-0.90)	-0.000832 (-0.89)	-0.000829 (-0.89)
Family lives in different community (y/n) (d)	0.039819*** (4.26)	0.038393*** (4.18)	0.032571*** (4.08)	0.038519*** (4.17)	0.038487*** (4.17)
L.Moving propensity	0.011574 (1.24)	0.011125 (1.19)	0.010118 (1.30)	0.011882 (1.27)	0.012165 (1.30)
Age	-0.003342** (-2.30)	-0.002388* (-1.65)	-0.001929 (-1.61)	-0.002322 (-1.61)	-0.002354 (-1.63)
Age^2	0.000588 (0.42)	0.000055 (0.04)	-0.000045 (-0.04)	-0.000068 (-0.05)	-0.000036 (-0.03)
Inventor productivity divergence	-0.547323 (-0.62)	-0.539731 (-0.65)	-0.073108 (-0.06)	-0.105169 (-0.14)	-0.619888 (-0.86)
Business group size	0.0002 (1.54)	0.0001 (1.39)	0.0003 (1.40)	0.0002 (1.39)	0.0001 (1.42)
Firm size	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***

Education dummies	YES	YES	YES	YES	YES
Individual specific effects	YES	YES	YES	YES	YES
Establishment specific effects	YES	YES	YES	YES	YES
Year dummies	YES	YES	YES	YES	YES
Sector dummies	YES	YES	YES	YES	YES
Observations	52214	52214	52214	52214	52214
R^2					
Number of groups	10068.000000	10068.000000	10068.000000	10068.000000	10068.000000
Pseudo R2	0.086304	0.083690	0.083396	0.083030	0.083143
Model significance	0.000000	0.000000	0.000000	0.000000	0.000000

We have already noted that the net effect of wages is mobility increasing, because the productivity signaling effect on average dominates the combined status and utility effects. The results of M4 should be that this dominance becomes even more pronounced when the inventor is compared to his younger colleagues. However, this reasoning clearly depends on the assumption that wages are really a strong signal for wages. As the literature has highlighted, this depends on the presence or absence of other signals for productivity that potential employers can observe. The expectation would therefore be that the wage productivity receives less weight when other such signals are available. Candidates would be education- or patent-related signals, for which we would expect that the interaction of the wage relative to industry (capturing the wage productivity signal) and other signals is negative.

In particular, we used opposition, citation-adjusted patent productivity, non-patent references and education level as indications of such signals. The results in M5-M8 show that three out of four cases (education, opposition and non-patent references) display the predicted negative relationship, while citation-adjusted patent productivity does not.

Table 4: Average partial effects of wages on turnover at alternative values for other signals

	At signal min.	**At signal mean**	**At signal max.**	**Critical share (%)**
Bachelor degree or above	0.0016***	0.0010***	0.0006***	0.0000
Opposition productivity	0.0006***	-0.0005***	-3.9681***	0.0976
NP citation propensity	0.0007***	0.0006***	-0.0413*	1.3693

The important implication for management practice using payment as a retention mechanism is whether there is a subgroup of inventors (those with strong enough other signals) where higher wages lead to reduced mobility. In order to analyze this question we present the average partial net effects of higher wages at alternative values for the other signals.[8] The results are presented in Table 4. The conclusion that can be drawn is that while education reduces the signal value of wages, it is not strong enough to offset the wage signal. Therefore, even if an inventor has a bachelor degree or above (which is true for 60% in our sample) the wage signal still dominates. The non-patent citations can by contrast be high enough to mitigate the wage signal, so that

8 The average partial effects are equal to the derivative of the expected value function with respect to wages. Given the structure of our model the average partial effect is equal to the terms in equation (3), where we add to the term in brackets the coefficient on the interaction term multiplied by the moderating signal value. In Table 4 we plug in the sample minimum, the mean, and the maximum for the signalling variable under consideration.

higher wages are associated with lower turnover. At the sample maximum the net effect on mobility is not only negative but also significant, albeit weakly. The share of inventors having a high enough score to offset the wage signal is only 1.3%. While we note that also oppositions are capable of offsetting the wage signal once they occur, we note that the share of oppositions is even lower. In particular, only 1 out of 1000 observations a patent was applied for that was later opposed in our sample on a yearly basis. The strength of this signal is thus probably grounded in the fact that it is so rare. We conclude that only for this subgroup of extremely visible inventors the overall effect of wages on mobility has a retention effect.

5 Discussion and limitations

This paper analyzes the issue of the impact of wages on inventors' job mobility decisions, where we believe that our paper makes three major contributions.

From a theoretical perspective, it is often implicitly assumed that higher wages decrease mobility by reducing the value of outside opportunities. As argued, this relies on the assumption that the set and the characteristics of the available outside opportunities are exogenous to the wages received by the individual. Our argument is that this is a strong simplification because wages themselves send signals on the labor market that increase the availability and the value of outside opportunities.

In this respect, our paper makes a strong contribution to strategic human capital from management, because wages are often treated as an instrument that can be applied to reduce turnover. Our work instead demonstrates that this reasoning does not hold for all inventors because it ignores the signaling effect that wages have for potential employers. In fact, the latter effect is so strong that it usually dominates the satisfying utility effects. In addition, we were able to show that the turnover increasing effect of higher wages is even stronger for inventors that are relatively younger than their colleagues with whom they compare. With respect to retention-oriented wage schemes this suggests that payment schemes should be progressive in age or tenure, because younger employees will take lower own wages as a signal for higher future income levels, inducing them to make further investments specific to their current employer. Firms paying young high potentials well in comparison to the firm-internal colleagues might risk their exit because these employees might anticipate only limited wage increases in the future.

The turnover-increasing net effect of higher wages holds with the exception of extremely well-performing inventors, a group that has been lately named “star inventors” in strategic human capital (Liu, 2014). Losing them is, due to highly skewed performance distributions, a particularly serious event potentially harming the firms' future technological development. To the degree that strategic human capital management is focused on keeping these over-performers within the firm, our results indeed show that wages are effective. The reason is that because of their strong portfolio of other performance signals the wage signal itself becomes irrelevant. For them, only the satisfaction increasing effects of higher wages remain.

As concerns the ‘average’ performer optimal wage schemes depend on the goal. If the objective is to reduce their mobility as well, higher wages are not only very costly for the firm but might also turn out to be quite useless, because they can have the opposite effect. A further caveat with respect to the group of stars is that higher general wage levels reduce over-performers' status effects. Taken together, these findings suggest that wage profiles should be flat for average performers, but steeply rising with respect to the relatively few extreme performers.

More generally, our results should be interpreted as a word of caution concerning arguments that assume that higher wages will always reduce mobility. This assumption seems to be implicit in most works in strategic human capital management arguing that high dispersion compensation schemes are a good tool to retain high performers. Indeed our results suggest that this view is right, if high performers are able to signal their value by strong non-wage-related signals; something that is likely to be the case for managers as analyzed by Carnahan et al. (2012) or other highly visible staff. It need, however, not be true for high-performers with less visible or individually less attributable outputs. Our results, at the very least, imply that arguments based on the assumption of a mobility-decreasing effect of wages should not be prematurely generalized for all groups of employees.

There are a couple of limitations to our study. The first concerns data availability. The decision to leave or stay in the company are not only driven by wage considerations but by a much wider range of impact factors, such as characteristics of the task (e.g. routineness, intellectual challenge), personal relations with colleagues and superiors, and career prospects going beyond monetary incentives. Most of these were not explicitly modeled in this paper. In that sense, despite the extraordinary richness of the data with respect to formal employer characteristics, wages, mobility patterns and family background, it is silent about emotional and intraorganizational aspects. While this presents a limitation, we however, think that the general conclusions are still valid because the panel data allowed us to control for unobserved heterogeneity. Nonetheless, richer data on these aspects could not only allow for even more robust estimations but also seek to analyze the relationships between wages and other elements of job satisfaction.

Another concern could be raised with respect to potential simultaneity of mobility decisions and wages. In particular, labor market research has also analyzed the reverse causality of mobility on future wages, establishing a positive relation. So, it is not perfectly clear whether causality is not actually bi-directional, which could again lead to biases in estimation. We have argued that the bi-directionality actually occurs over time, because mobility changes the wages usually after the job change and can thus be assumed to be effectively controlled by our dynamic panel approach. By including an indicator proxying accumulated matching quality, we also believe that we have accounted for gradual improvements in matching quality resulting from past mobility that can raise wages. However, one could still argue that mobility threats can strategically be used to raise current wages. If the mobility decision then occurs despite a granted wage increase, also current wages would depend on latter mobility. A fuller understanding of how wages impact on mobility could be achieved, if we were able to disentangle the dynamic relationship between the two variables over time. While this will require the exploitation of natural experiments, we see this as a promising perspective for future research.

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