HRRI Working Paper 01-03
Industrial Relations Center
University of Minnesota

# The Role of Comparative Advantage and Learning in Wage Dynamics and Intra-firm Mobility: Evidence from Germany

Stéphanie Lluis [1]
University of Minnesota[2]

September 2002

[1]I thank Thomas Lemieux and Claude Montmarquette for their enduring support through this project. I am also grateful to Nicole Fortin, Robert Gibbons, Jennifer Hunt, and Daniel Parent for valuable comments. Special thanks to Lars Vilhuber for his help in accessing the GSOEP data. Financial and logistic support by CRDE and CIRANO is gratefully acknowledged.

[2]Industrial Relations Center, 321 19th Avenue South, Minneapolis, MN 55455, USA. Tel: (612) 624-4171, email: slluis@csom.umn.edu, Fax: (612)-624-8360.

**Abstract**

This paper analyzes the dynamics of wages and worker mobility within firms with hierarchical structures of job levels. The paper empirically implements the theoretical model proposed by Gibbons and Waldman (1999) that combines the notions of human capital accumulation, job rank assignment based on comparative advantage and learning about workers' ability. The paper measures the importance of these elements in explaining intra-firm wage and mobility dynamics using survey data from the German Socio-Economic Panel (GSOEP). The use of this data set makes it possible to examine this issue over a large sample of firms and draw conclusions about the common features characterizing firms' wage policy. The GSOEP survey also provides information about workers' job ranks within the firm that is unavailable in most surveys.

The results of the estimation are consistent with non-random selection of workers onto the rungs of the firm's job ladder. There is no direct evidence of learning about workers' unobserved ability but the analysis reveals that unmeasured ability is an important factor driving wage dynamics. Job rank effects remain significant even after controlling for measured and unmeasured characteristics.



**Key words:** Wage dynamics, intra-firm mobility, human capital accumulation, unobserved heterogeneity, learning

# 1 Introduction

The question of how wages are determined is central to the study of labor economics. To date, the empirical literature on this topic has focused on factors such as the return to interfirm mobility on the part of workers (Bartel and Borjas (1981), Neal (1999), Topel and Ward (1992)), the covariance structure of earnings across workers and firms (Topel and Ward (1992), Parent(1995)), and inter-industry and firm-size wage differentials (Krueger and Summers (1988), Gibbons and Katz (1992), Abowd, Kramarz and Margolis (1999)). Thus far, little empirical work has been done on questions relating to the assignment of workers to jobs and the resulting effects on the evolution of intra-firm wage structures and mobility within the firm. Previous studies on the relationship between wages and careers in organizations present results specific to one or a few firms which, while suggestive, can not easily be generalized to firms beyond the type analyzed (Doeringer and Piore (1971), Chiappori, Salanié and Valentin(1999), Baker, Gibbs and Holmstrom (1994 a,b)). Empirical studies on the structure of wages and mobility within firms using large data sets have not related the analysis to a formal theoretical framework (McCue (1996)).

This paper presents an empirical study of the common features characterizing wage and mobility dynamics within firms. The analysis is based on the theoretical framework of Gibbons and Waldman (1999) in which the determination of wages depends on how workers' ability are evaluated within a job rank, given a hierarchical structure of job levels within firms where each job rank has different skill requirements. The model specifies a wage equation integrating the elements of human capital accumulation, job assignment based on comparative advantage and learning about unobserved worker ability to explain the dynamics of wages and promotions inside firms. The objective of this paper is to implement empirically the Gibbons and Waldman model and perform the estimation over a large sample of firms in order to test whether comparative advantage and learning are important determinants of the wage policies of firms. In addition, estimating the model on the sample of workers remaining with their firm and comparing the results to those obtained from the sample that includes firm changers allows one to distinguish between firm specific effects and individual specific effects transferable across firms in the analysis of the wage dynamics.

The estimation is performed using GMM techniques applied to the longitudinal data from the German GSOEP over the period 1986-1996. This survey is uniquely appropriate for the analysis of intra-firm mobility and wage dynamics because it provides information on hierarchical job levels within occupations through a question asking specifically about the rank occupied by the worker within his/her current occupation. To my knowledge, this information is not available in other surveys.[1] The survey also makes it possible to identify movements both within and across firms through a question about changes in a worker's employment situation in the previous year. These two pieces of information are central to the study of wage and mobility dynamics within the firm. Another advantage of the data is that information is collected over a large sample of individuals and therefore, the analysis of wage dynamics and intra-firm mobility can be done over a large sample of firms.

The German case is an interesting application of the model because the German labor market is thought to differ significantly from the U.S labor market (which provides many of the observations which motivate Gibbons and Waldman's research). Particularly, as shown in Simonet (1998), interfirm job mobility declines much earlier in a worker's career in Germany than in the U.S. This suggests the possibility that *intra*-firm mobility may be more important in Germany than in the United States. In addition, because of the strength of trade unions and their close relationship with employer's associations, German firms have to deal with bureaucratic rules governing the setting of wages and job assignments, which could affect the returns to intra-firm mobility on the part of German workers. On the other hand, Bruderl, Diekmann and Preisendorfer (1991) show evidence that early promotions increase the chances of future promotions using panel data on the personnel records of blue-collared workers in a large West German company. Their analysis controls for individual and firm measurable characteristics but not for unobserved individual heterogeneity suggesting that it might play a role in the early promotion hypothesis tested. Therefore it is not clear, a priori, whether the factors of individual ability, comparative advantage and learning, which seem to explain the U.S experience, are more or less important in Germany.

A number of stylized facts have emerged from the empirical literature on internal wage policies and mobility within U.S. firms over the last twenty years. Borrowing from Gibbons (1997), who provides a detailed review of the literature on careers in organizations, the main findings are reported below. First, the main finding on intra-firm mobility concerns serial correlation in promotion rates. Holding tenure in the current job constant, promotion rates decrease with tenure in the previous job.[2] A related finding is that demotions are rare (although this finding

[1]In particular, the PSID and NLSY occupational codes do not provide a natural ranking of job levels comparable across occupations.

[2]Rosenbaum (1984), Baker, Gibbs and Holmstrom (1994 a,b), Podolny and Baron (1997) and Chiappori and al. (1996).

is based on a study of only one firm).[3] Second, nominal wage cuts are rare but real wage cuts are much more common. Partly this is because nominal wage increases are insensitive to inflation and zero nominal increases are not rare.[4] Third, the dynamics of wages within the firm exhibit serial correlation in the sense that a real wage increase (decrease) today is serially correlated with a real wage increase (decrease) tomorrow.[5] Fourth, studies that analyze the relationship between wages and intra-firm mobility find that wage increases received by workers who are promoted exceed increases reported by workers who do not receive promotions.[6] However, wage increases upon promotion are small compared to the difference in average wages between two job levels. In other words, significant variations in wages remain within each level so that wages are not tied to levels. Finally, wage increases forecast promotions in the sense that those who receive larger wage increases get promoted more rapidly.[7]

Collectively, these observations posed a challenge to the existing theoretical literature, as no pre-existing theory could explain all of these stylized facts. In response to this challenge, Gibbons and Waldman (1999) build a synthesized model which combines on the job human capital accumulation, job assignment based on comparative advantage and learning dynamics. The predictions of their model are consistent with most of the stylized facts found in the empirical literature. The main contribution of this paper is to examine the explanatory power of the Gibbons and Waldman theory over a large sample of firms.

The paper is organized as follows. Section 2 sketches the theoretical model of Gibbons and Waldman and establishes the framework of the econometric analysis and how this relates to the theory. Section 3 presents the data and provides a descriptive analysis of intra-firm mobility and wage outcomes in German firms. Section 4 presents the results of the estimation, and Section 5 concludes the paper.

---

[3]Baker, Gibbs and Holmstrom (1994 a,b).

[4]Baker, Gibbs and Holmstrom(1994 a,b) report this in the case of one firm, and Card and Hyslop (1997) arrive at the same conclusions using the CPS and PSID. Peltzman (2000) reports a similar finding using BLS data.

[5]Hause (1980), Lillard and Weiss (1979) and Baker, Gibbs and Holmstrom (1994 a,b).

[6]Murphy (1985) Baker, Gibbs and Holmstrom (1994 a,b) and McCue (1996).

[7]Baker, Gibbs and Holmstrom (1994 a,b). McCue (1996) finds that a high wage today is positively correlated with promotion tomorrow, and Topel and Ward (1992) find that prior wage growth affects mobility even after controlling for current wage.

# 2 Model and Econometric Framework

This section summarizes the Gibbons and Waldman model of intra-firm mobility and wage determination and highlights the model's main predictions. The model characterizes the relationship between a worker's career path and the evolution of his wage within a firm. It integrates wage determination and job assignment in a dynamic context, where the wage policy of the firm is based on comparative advantage and learning. In other words, it endogenizes the allocation of workers to job rank as workers are assigned to job ranks that better reward their productive ability. In addition, it endogenizes mobility between job ranks because, if the productive ability of a worker is not perfectly observed, both the firm and the worker learn about it and changes in expected productive ability lead the worker to move to another rank of the job ladder.

Firms are modelled as consisting of various potential job assignments and, because jobs are differently sensitive to ability, comparative advantage determines the assignment rule on the basis of output maximization. Output grows with the workers' accumulation of human capital or productive ability each period. In addition, output grows at a different speed depending on the level of innate ability of the worker. All the workers end up reaching the upper level of the job ladder but some get there faster than others. When innate ability is not perfectly observed, learning takes place and wages and mobility within the firm are driven by the evolution of expected ability.

## 2.1 Summary of the Model

The model consists of identical firms operating in a competitive environment and producing output using labor as the only input. All firms consist of a three-level job ladder where jobs are indexed by $j = 1, 2$ or 3. Jobs are defined in advance, independent of the people who fill them. Both firms and workers are risk-neutral and have a discount rate of zero.

A worker's career lasts for T periods. Worker $i$ has innate ability, denoted by $\theta_i$, which can be either high ($\theta_H$) or low ($\theta_L$). The worker has also effective ability, $\eta_{it}$, defined as the product of his innate ability and some function $f$ of his labor-market experience $x_{it}$ prior to period $t$:

$$\eta_{it} = \theta_i f(x_{it}) \text{ with } f' > 0 \text{ and } f'' \leq 0 \quad (1)$$

The production technology is such that if worker $i$ is assigned to job $j$ in period $t$ then he produces output $y_{ijt}$ given by:

$$y_{ijt} = d_j + c_j(\eta_{it} + \varepsilon_{ijt}) \tag{2}$$

where $d_j$ is the output produced by a worker in job $j$ that is independent of the worker's characteristics, $c_j$ measures the sensitivity of job $j$ to effective ability and $\varepsilon_{ijt}$ is a random variable drawn independently from a normal distribution with mean zero and variance $\sigma^2$. The constants $c_j$ and $d_j$ are known to all labor-market participants and it is assumed that $c_3 > c_2 > c_1$ and $d_3 < d_2 < d_1$.

Wages are determined by spot-market contracting. At the beginning of each period, all firms simultaneously offer each worker a wage for that period and each worker chooses the firm that offers the highest wage. Competition among firms yields wages equal to expected output.

$$w_{ijt} = Ey_{ijt} = d_j + c_j\eta_{it} = d_j + c_j\theta_i f(x_{it}) \tag{3}$$

Efficient task assignment is obtained in the sense that a worker is assigned to the job that maximizes his expected output.

In the case of perfect information, $\theta_i$, is common knowledge at the beginning of the worker's career and therefore $\eta_{it}$ is always known. In this case, job assignments and wages in equilibrium are given according to the following rule:

1. If $\eta_{it} < \eta'$ then worker $i$ is assigned to job 1 in period t and earns $w_{it} = d_1 + c_1\eta_{it}$.
2. If $\eta' < \eta_{it} < \eta''$ then worker $i$ is assigned to job 2 in period t and earns $w_{it} = d_2 + c_2\eta_{it}$.
3. If $\eta_{it} > \eta''$ then worker $i$ is assigned to job 3 in period t and earns $w_{it} = d_3 + c_3\eta_{it}$.

The critical values, $\eta'$ and $\eta''$, are those levels of effective ability at which a worker is equally productive at jobs 1 and 2 and 2 and 3 respectively. In equilibrium, workers climb the successive rungs of the job ladder as they gain experience.

The model under perfect information can explain most of the stylized facts of the empirical literature. The model exhibits an absence of demotions, serial correlation in wage increases and promotions, and the fact that wage increases predict promotions while explaining only a fraction of the difference in average wages across levels.

There are no demotions in equilibrium because effective ability increases monotonically. Serial correlation in wage increases occurs because effective ability grows differently for each worker due to their differing levels of innate ability. That is, for a given level of experience, high ability workers will get higher wage increases than low ability workers and the same ordering will hold for wage increases at all experience levels. The model generates serial correlation in promotions for the same reasons. If $\eta'$ and $(\eta'' - \eta')$ are both sufficiently large then high ability workers are promoted to job 2 more quickly and also spend less time on job 2 before being promoted to job 3. Moreover, since those who receive larger wage increases are also those who are promoted to job 2 earlier in their careers, wage increases predict promotions.

The model gives predictions consistent with the fact that wage increases predict promotion. A large wage increase indicates an increase in expected innate ability which means that on average effective ability will grow more quickly in the future so that the worker will need less time to reach the target level of expected effective ability needed for promotion.

Finally, wage increases upon promotion explain a fraction of the difference between average wages across levels because, on average, some of the workers at higher job levels are more experienced. The difference between average wages at different levels is given by the average experience or effective ability accumulated. This difference is bigger than the average wage increase at promotion which captures the value of only one year of experience.

The model with perfect information predicts that average wage increases at promotion are higher than average wage increases that would occur if workers remains in their current job levels. This is because increases in effective ability for those who get promoted are valued in part at the rate of the current job level ($c_j$) and in part at the higher rate of the next job level ($c_j$). For the same reason, however, the model predicts that average wage increases after promotion are higher than the average increases at promotion as increases in effective ability are entirely valued at the higher job level. This conflicts with the empirical findings which shows that wage increases at promotion are higher than wage increases before and after promotion. Moreover, the monotonicity of the effective ability accumulation function precludes the possibility of real wage decreases.

When information on innate ability is imperfect (but symmetric in that workers and firms have the same information about ability), workers and firms start with the initial belief $p_0$ that a given worker is of innate ability $\theta_H$ and with $1 - p_0$ that he is $\theta_L$. Learning takes place at the end of each period when the realization of a worker's output for that period is revealed. Learning occurs gradually because of the productivity shock $\varepsilon_{ijt}$, which introduces noise into the output produced.

To be precise, each period a worker's output provides a noisy signal, $z_{it}$, about his effective ability where:

$$z_{it} = (y_{ijt} - d_j)/c_j = \eta_{it} + \varepsilon_{ijt}$$

Note that $z_{it}$ is independent of job assignment so that learning takes place identically across jobs. Expectations of the innate ability of worker $i$ with $x$ years of prior labor-market experience at period $t$ will therefore be conditioned on the history of signals extracted from the observed outputs. Formally, this expectation is defined as:

$$\theta^e_{it} = E(\theta_i | z_{it-x}, ..., z_{it-1})$$

Because output is a linear function of effective ability, expected output at the beginning of period $t$, and therefore wages, will be based on expected effective ability (conditional on the information available at $t - 1$). Task assignment in each period is then based on the maximization of current expected output.

In addition to the stylized facts previously discussed in the perfect information model, the addition of imperfect information and learning allows the model to explain the possibility of real wage decreases. The argument is based on the fact that wages depend on expected innate ability, the evolution of which is now driven by the evolution of agents' beliefs. Because agents have rational expectations, expected innate ability follows a martingale process:

$$\theta^e_{it} = \theta^e_{it-1} + u_{it} \tag{4}$$

This means that the best *prediction* of future expected innate ability is current expected innate ability. In other words, any change in current beliefs is caused by the arrival of new information contained in the observation of current output and could not be predicted from previous realized outputs.

In the model with imperfect information a worker's expected innate ability can fall from one period to the next if $u_{it}$ is negative. If the decrease is sufficiently large, it will dominate the increase in effective ability due to human capital accumulation and next period wage will fall. For the same reason, there will be a positive frequency of demotions.

Average wage increases at promotion are larger than average wage increases before and after promotion. The worker promoted at the end of the period had a larger increase in expected effective ability than the worker not promoted. The wage increase will then be higher for this reason and also because the increase in expected ability will be valued at a bigger rate ($c_{j+1} > c_j$). After the promotion, the expected change in expected innate ability is zero so the wage increase is smaller on average than the wage increase at promotion.

In summary, as a result of comparative advantage in the assignment of workers to job levels, the model can explain that wage increases predict promotions while explaining only a fraction of the difference in average wages across job levels. Individual heterogeneity in human capital accumulation or the growth in effective ability the model also explains the observed serial correlation in wage increases and promotion rates. The introduction of learning allows for the possibility of real wage decreases and that average wage increases are higher upon promotion than before and after promotion. With some restrictions on the parameters of the model, $\eta'$ and $(\eta'' - \eta')$ are such that the model also predicts an absence of demotions. Thus, the model can explain the stylized facts highlighted in the literature on wages and intra-firm mobility.

## 2.2 Econometric Specification

The model of Gibbons and Waldman emphasizes the importance of endogenous choice of job levels or self-selection of workers into the rungs of the firm's job ladder as well as endogenous mobility across job levels both driven by the evolution of an unmeasured ability term. The purpose of this Section is to present an econometric specification of the wage dynamics implied by the model of Gibbons and Waldman where these endogeneity problems can be accounted for and the relative importance of the effects of comparative advantage and learning on the dynamics of wages can be estimated.

In the general case of comparative advantage and learning the process for wages given in equation (3) can be written using the expectation of workers' ability, $\theta^e_{it}$.

$$w_{ijt} = d_j + c_j \theta^e_{it} f(x_{it}) \tag{5}$$

Employing dummies, $D_{ijt}$, indicating the rank $j$ of individual $i$ at time $t$, the equation to be estimated can be written as:

$$w_{ijt} = \sum_{j=1}^{J} D_{ijt} d_j + \sum_{j=1}^{J} D_{ijt} X_{it} \beta_j + \sum_{j=1}^{J} D_{ijt} c_j \theta^e_{it} f(x_{it}) + \mu_{it} \tag{6}$$

where $\mu_{it}$ is a measurement error independent of rank assignment, and $X_{it}$ corresponds to individual characteristics to control for the measurable part of human capital. Comparative advantage is characterized by the fact that the coefficients $\beta_j$ and $c_j$ vary by rank and learning is represented by the conditional expectation $\theta^e_{it}$. In the model with perfect information about innate ability, $\theta^e_{it}$ is a time invariant term $\theta_i$, unmeasurable by the econometrician.

Estimating equation (6) with OLS would give inconsistent estimates. In both the perfect and imperfect information case, the comparative advantage hypothesis implies that rank assignment is endogenous, so $\theta^e_{it}$ is correlated with the rank dummies. In addition, this term cannot be eliminated by first-differencing (6) because it is interacted with the $D_{ijt}$ terms.

Holtz-Eakin, Newey and Rosen (1988) analyze models in which a fixed effect is interacted with year dummies and show that consistent estimates can be obtained by quasi-differencing the equation of interest and using appropriate instrumental-variable techniques. This method will be applied here to estimate the wage equation (6).[8]

## 2.3 Estimation and Interpretation of the Model Specification

This section describes the quasi-difference technique, the estimation method and the choice of instruments in the perfect information case with comparative advantage and the imperfect information case with both comparative advantage and learning. The estimation of the wage equation also requires to specify a functional form for the human capital accumulation function $f$ which will be presented in the last part of this section.

The first step in estimating (6) is to eliminate $\theta^e_{it}$ by quasi-differencing in the following manner:

$$\theta^e_{it} = \frac{w_{ijt} - \sum_j^J D_{ijt}d_j - \sum_j^J D_{ijt}X_{it}\beta_j - \mu_{it}}{\sum_j^J D_{ijt}c_j f(x_{it})} \tag{7}$$

The martingale property of beliefs in innate ability which states that $\theta^e_{it} = \theta^e_{it-1} + u_{it}$, implies that we can substitute a lagged version of equation (7) into (6). The final equation is therefore given by:[9]

$$w_{ijt} \quad = \quad \sum_{j=1}^{J} D_{ijt}d_j + \sum_{j=1}^{J} D_{ijt}X_{it}\beta_j + \frac{\sum_j^J D_{ijt}c_j f(x_{it})}{\sum_j^J D_{ijt-1}c_j f(x_{it-1})}\, w_{ijt-1}$$

[8]This technique has been used previously by Lemieux (1998) in the case where the return to a time-invariant unobserved characteristic is different in the union and non-union sector. Gibbons, Katz and Lemieux (1997) formalize the estimation method in the presence of comparative advantage and learning with an application to the estimation of the wage differentials by industry. Gibbons, Katz, Lemieux and Parent (2002) enrich the preceding results by applying the method to the case of inter-occupation wage differentials.

[9]In the case with comparative advantage only, innate ability is time-invariant so $\theta^e_{it} = \theta^e_{it-1}$ and the lagged version of (7) can be substituted into (6) in the same way. The difference is in the random term $u_{it}$ which drops from (9).

$$- \frac{\sum_j^J D_{ijt} c_j f(x_{it})}{\sum_j^J D_{ijt-1} c_j f(x_{it-1})} [\sum_{j=1}^{J} D_{ijt-1} d_j + \sum_{j=1}^{J} D_{ijt-1} X_{it-1} \beta_j] + e_{it} \quad (8)$$

$$\text{where} \quad e_{it} = \mu_{it} + \sum_{j=1}^{J} D_{ijt} u_{it} - \frac{\sum_j^J D_{ijt} c_j f(x_{it})}{\sum_j^J D_{ijt-1} c_j f(x_{it-1})} \mu_{it-1} \quad (9)$$

This equation cannot be estimated using non-linear least square because $w_{ijt-1}$ is correlated with $\mu_{it-1}$. Moreover, because of the presence of learning, the new information on innate ability at time t, $u_{it}$, is correlated with $D_{ijt}$ since beliefs on ability influence the current rank assignment. These problems can be solved by choosing appropriate instruments for $w_{ijt-1}$ and $D_{ijt}$, in which case consistent estimates will be obtained. The set of instruments, $Z_i$, has to satisfy the following condition:

$$E(e_{it} Z_i) = 0 \quad (10)$$

The objective is then to minimize the following quadratic form:

$$\min_{\gamma} e(\gamma)' Z (Z' \Omega Z)^{-1} Z' e(\gamma) \quad (11)$$

where $Z'\Omega Z$ is the covariance matrix of the vector of moments $Z'e(\gamma)$, $\Omega$ is the covariance matrix of the error term $e_{it}$ and $\gamma$ is the vector of parameters. An efficient estimator can be obtained by estimating equation (6) in a first step with $\Omega = I$.

Finally, the unmeasured ability term $\theta_{it}^e$ in the error term of equation (6) is normalized to zero for the parameters to be identified.[10] This is done by adding the following equation as a constraint on the optimization of (11):

$$(1/TN) \sum_i \sum_t \theta_{it} = 0 \quad (12)$$

where $N$ is the number of individuals, $T$ is the number of periods for each individual and $\theta_{it}$ satisfies equation (7).

Instruments are chosen using the identification assumption for estimation of panel data equations that imposes strict exogeneity of right-hand side variables. More formally:

$$E(\mu_{it} / X_{i1} ... X_{iT}, D_{ij1} ... D_{ijT}, \theta_i) = 0 \quad (13)$$

The estimation is done in two parts. First the role of comparative advantage under the assumption of perfect information is examined. Then the combined impact of comparative advantage and learning is estimated under the assumption of imperfect information.

[10] A proof of the necessity of this constraint is given in Lemieux (1998).

Under the assumption of perfect information, the random shock $u_{it}$ drops from the error term of equation (6). The elimination of $\theta_i$ resulting from the quasi-difference corrects the problem of endogeneity in the assignment of workers to ranks. The equation still needs to be instrumented due to the presence of lagged wage on the right-hand side, correlated with $\mu_{it-1}$ given (5). With imperfect information about innate ability, mobility is driven by the learning process so $D_{ijt}$ is correlated with the new information obtained from the observation of current output, $u_{it}$.

Equation (13) states that conditional on observed innate ability, individual characteristics and rank assignments each period are uncorrelated with the error term in the wage equation (6). Therefore, this condition provides a set of potentially valid instruments with the property that they are not correlated with the $\mu$ terms in the $e$ term from equation (8).

In the perfect information case, given the assumption of workers' comparative advantage in a given job rank and the fact that wages are linearly related to effective ability, the history of previous period rank assignment should help predict wages. In particular, interaction terms between $D_{ijt-1}$ and $D_{ijt}$ help predict $w_{ijt-1}$. Consider a high and a low ability worker with the same experience and the same rank in period $t-1$. Because of different levels of innate ability, the workers have different wages and so contemporaneous rank assignment is not informative enough to identify differences in wages. On the other hand, the high ability worker may be at the level of effective ability required to get promoted next period. Therefore, having additional information on next period rank helps to make inferences on each worker's ability level (for a given level of experience) and therefore on their wage.

Under imperfect information, expected innate ability evolves over time as beliefs change. In this case, changes in expected effective ability resulting from a positive (or negative) realization of $u_{it}$ affect rank assignment and therefore $D_{ijt}$. To find instruments for $D_{ijt}$, one can rely on the characteristics of the martingale process for beliefs. Agents have rational expectations so changes in beliefs are serially uncorrelated. Therefore $D_{ijt-1}$ and also $D_{ijt-2}$ are not correlated with $u_{it}$ as they result from the realizations of $u_{it-1}$ and $u_{it-2}$ respectively. Moreover as before, condition (13) applies so they are not correlated with the $\mu$'s error terms of the wage equation. They then represent potentially valid instruments for $D_{ijt}$. The interaction between $D_{ijt-2}$ and $D_{ijt-1}$ constitutes a good predictor of current rank affiliation because it helps identify differences in expected ability in period $t-1$ (using the same argument as in the perfect information case) as well as in period $t$.[11]

[11] Given the martingale hypothesis for the evolution of the beliefs, expected ability at the beginning of period $t$ (before the realization of output in $t$) is not expected to be different from expected ability at $t-1$.

A final consideration in the specification of the model involves the choice of a functional form for $\frac{f(x_{it})}{f(x_{it-1})}$, the ratio of accumulated experience in $t$ compared to $t-1$, which appears in the estimation equation under both the perfect and imperfect information cases. The Mincer wage equation specifies log wages as a polynomial function of experience, implying that the level of wages is an exponential function of experience. Since wages here are in levels, it is reasonable to assume an exponential function of this same polynomial in experience. This leads to the following functional form for the ratio $g(x_{it}) = \frac{f(x_{it})}{f(x_{it-1})}$ :[12]

$$g(x_{it}) = b_0 e^{-b_1 x_{it}} \tag{14}$$

This ratio links to the model's predictions of serial correlation in wage increases and promotions in the following way. According to the wage equation (5), it is the experience accumulation term $f$ which, interacted with ability $\theta$, drives the results on serial correlation in wage increases and promotions (low and high ability workers accumulate experience at different rates). In terms of the ratio (14), an estimated coefficient $b_1$ different from 0 and $b_0$ different from unity shows evidence of experience accumulation (or a non constant function $f$) and as a result, evidence of serial correlation in wage increases and promotions. On the other hand, a constant function $f$ (corresponding to an estimated ratio of one) implies that individual unobserved (or unmeasured) ability does not affect the rate of human capital accumulation. This in turn implies an absence of serial correlation in wage increases and promotions.

In terms of the interpretation of the remaining parameters, the Gibbons and Waldman model predicts that if comparative advantage based on unmeasured ability matters, the slope parameters $c_j$ will be significantly different from one another. Because unmeasured ability is likely to be correlated with measured ability, one expects the same result for the $\beta_j$. One also expects the magnitude of these parameters to increase from lowest for the lower job level to highest for the top job level, reflecting the differences in sensitivity of the different job levels to ability. The constant terms $d_j$ should also be significant from one another and, due to the characterization of the technology, should rank from higher in the lowest job rank to lower in the highest one.

## 3 The Data

The data for the analysis come from the German Socio-Economic Panel. The GSOEP is a representative longitudinal study of private households conducted every year in Germany since

[12]Assuming $f(x_{it}) = e^{\alpha_0+\alpha_1 x_{it}-\alpha_2 x_{it}^2}$ and given that $x_{it} = x_{it-1}+1$ then $g(x_{it}) = e^{\alpha_1+\alpha_2-2\alpha_2 x_{it}}$ .

1984. The panel used in this paper spans the years 1985 to 1996 because information on workers mobility is not available in 1984. Since the period covers the German reunification, I have excluded data on the former East German population to keep the pre and post unification samples comparable.

The GSOEP is unique for the analysis hereafter because it provides information on movements between and within firms through a question about changes in the worker's employment situation in the previous year. Most importantly, there is detailed information on the rank occupied by the worker within his current occupation. These two pieces of information are central to the study of wage and mobility dynamics within the firm. Another advantage is that information is collected over a large sample of individuals and therefore, the analysis of wage dynamics and intra-firm mobility can be done for a large sample firms (although survey data do not provide as many details about firm characteristics as for individuals).

### 3.1 Variable and Data Selection

The GSOEP provides information on individual characteristics such as age, education, sex, marital status, nationality and employment status. Wages are given on a monthly basis, corresponding to the month preceding the time of the survey.[13]

Firm characteristics include the type of industry, whether the firm belongs to the public sector, firm size and the duration of the employment contract (unlimited or limited length). Information about unionization is not available on a longitudinal basis as the question is asked only twice over the sample period (1989 and 1993). Although I cannot control for the presence of unions, the variable indicating whether individuals work in a public or private sector firm should partially pick up differences in wage policies between unionized and non unionized firms. Moreover, given that unions have a predominant impact in the German economy at the industry and national level, controlling for treatment differences for unionized and non-unionized workers across firms is not as critical as it would be in an economy where both play a significantly different role at the firm level.

I have selected individuals aged between 20 and 65 who are working at the time of the survey on a full-time basis. I have excluded self-employed workers and put a restriction on wages excluding any observations below 500 DM per month.[14] The resulting sample contains

[13]I used wages after deductions for tax and social security because it is the earning variable most frequently reported.

[14]Since in Germany, the minimum wage varies by industry, this bound should give a reasonable minimum in

32492 observations (6171 workers). Appendix A describes the data selection in more details and provides sample means of the main variables used in the analysis hereafter.

The GSOEP contains two sources of information to describe workers' careers within a firm. First, the survey contains a question on job changes. Each year, individuals are asked to report whether they have experienced a change in job situation since the previous year's survey. This question makes it possible to identify workers' careers within and across firms.[15] Appendix B1 provides information on inter and intra firm mobility frequencies by experience and associated wage growth. Overall, 11.2% of the observations report mobility, 2.9% of the observations report intra-firm mobility. Although intra-firm mobility is low, it is comparable to the U.S. as a proportion of the total reported moves.[16]

Second, there is a question in which individuals are asked to identify their current position with a choice among five categories: blue-collar, white-collar, civil servant, trainee and self-employed. I considered the first three given that self-employment is not relevant for the analysis and that the trainee category is not in itself an occupation.[17] Each position is subdivided into a hierarchical structure of job levels or ranks according to the level of skills and responsibilities required for the job. Appendix B2 describes in more details the occupational rank variables and provides average characteristics by job changes and rank changes.

### 3.2 Summary Statistics on Intra-Firm Mobility and Wage Outcomes

A natural starting point before assessing the importance of the comparative advantage and learning assumptions in explaining mobility and wage dynamics is to see whether the German data exhibit the stylized facts of the U.S. data which motivated the Gibbons and Waldman model.

Because the question on job change within the firm does not provide information on the type of job change experienced, I use the information on job rank comparing current and previous job rank to categorize job changes as promotions.[18] Table 1 presents average wage

order to exclude outliers for wages without losing observations on low wage workers such as trainees.

[15]When considering the sample of workers remaining with their firm over the period (reporting either a job change within the firm or no change in job situation), the sample size becomes 11159 observations (3487 workers).

[16]McCue (1996) uses the PSID and finds that about 1/4 of the reported moves are promotions within a firm.

[17]Individuals identified as trainees at any point during the sample period were excluded unless they reported the occupation for which they were training.

[18]The question on job change is used to identify the sub-sample of workers who remain within their firms,

growth by type of job change and rank change for workers who do not change firms. The first two columns report average wage growth for those who changed jobs within the firm and those who did not. The last three present average wage growth of job changers by type of job changes.

Not surprisingly, the main difference associated with a change in rank among job changers is the average wage growth which is 16.25% for workers who receive promotions.[19] Like the findings for the U.S, this suggests that hierarchical rank effects play an important role in the wage determination process in German firms. There is also evidence that previous wage growth predict promotions. The average wage growth the period before a reported change in rank or job (columns 3 or 2) is higher than it is when there is no change in rank or job (column 5 or column 1).

Note that the percentage of changes involving a change to a lower rank is high relative to previous findings on demotions. However, these changes are associated with positive wage growth suggesting that they may not in fact be demotions and may instead result from misclassification in job ranks. This would not be surprising given the known sensitivity of survey data to this type of problem. Given that rank changes are central to the estimation of the Gibbons and Waldman model, I corrected for possible classification errors using the information on job changes and wage growth.[20] The resulting data, which will be used for the remaining of the analysis, present similar average characteristics for firms and individuals as the one without corrections. Average wage growth associated with demotion is now lower (-1.52%) and average wage growth with no change in rank (but a change in job) is now higher (4.67%).

To see whether there is evidence of individual variation in wages within a rank, I compare average wage growth at promotion with the difference in average wages for workers in two consecutive ranks. To do so, I need to compute wage growth at promotion at the different ranks. Because rank definitions and subdivisions are similar across the three occupations considered, they can be summarized in a single hierarchical job ladder using the following 4 generic rank definitions:[21]

either experiencing no change in job or a change within.

[19]Note also that job changers that do not experience a change in rank receive on average a wage growth of 2.94% which is higher than the average wage growth associated with no change in job suggesting that part of the change in job would be pay related.

[20]Details about the correction method and resulting changes in the data are presented in Appendix B3.

[21]The blue-collar occupation is originally divided into 5 ranks, distinguishing unskilled from semi-skilled work. I grouped the two categories into one corresponding to the lower occupational rank. See appendix B for details

1. Low rank = unskilled or semi-skilled work
2. Middle rank = skilled work
3. Upper rank = highly skilled work
4. Executive rank = executive work

Table 2 presents average wage growth associated with transitions from one rank to the next between two periods for all workers and by occupation. The diagonal shows the average wage growth of workers who did not change rank. The last column computes the average wage (in level) of all workers in a given rank at time t. Note that average wage growth associated with a promotion is slightly higher for promotion from the middle to the upper rank and upper to executive rank than it is for the low to middle rank. On the other hand, there remains individual variations in wage changes within each rank. Comparing the difference in wage level between rank L and M, there is a difference of 483 marks, which corresponds to a 30% difference in average wage between the two ranks. It is 57% between rank M and U and 24% between U and EX.

Concerning the evidence on serial correlation in wage increases and promotions, the analysis is limited by the fact that the sample period is not long enough to observe several episodes of mobility per worker. On average, the number of years workers stay in the sample is about 8 years. Over that period, the average number of time a worker experience a change is 1.1. As a result, the sample size when considering the workers who experience a change twice or more is very small. This limits the possibility of making reliable inferences on serial correlation in promotions and wage increases.

Summarizing the findings, average wage growth at promotion is higher than without promotion but is lower than the average difference in wage growth between two consecutive ranks. There is also some evidence that previous wage growth predicts promotion as previous period average wage growth for those experiencing a promotion or a job change the following period is higher than for those experiencing no change in job within the firm. These findings suggest that promotion to a higher rank plays an important role in the wage determination process in German firms. The last two findings suggest that individual-specific variations in wage changes are also important. Overall, these findings show evidence that individual and job characteristics are both important factors in determining wage outcomes within German firms.

on the occupational rank variables.

This preliminary look at the data suggests that German data seem to share some of the same stylized facts as the U.S. data which makes it worth pursuing the analysis by estimating the Gibbons and Waldman model using these data. According to the model, the joint effects of job and individual characteristics in the wage determination process can be explained by the assumption of the workers' comparative advantage in a given rank and the fact that individual skills are differently rewarded in each rank. Going further in assessing the role of comparative advantage, the next subsection provides preliminary evidence on the joint impact of the rank variables and individual skills on wage outcomes. Also given the primary role of unmeasured (by the econometrician) ability (unobserved in the case of learning) in the Gibbons and Waldman model, the next subsection provides preliminary evidence on the presence of unmeasured ability in the wage determination process.

### 3.3 Preliminary Evidence on the Role of Comparative Advantage and Unmeasured Ability

In this section, I analyze whether comparative advantage based on measured ability is important. To do so, I estimate the joint effect of rank and individual characteristics in an estimation of inter-rank wage differentials. I also consider the importance of unmeasured ability by comparing the results of an OLS estimation of the rank wage premia with the results of a fixed-effect estimation. The idea is that if comparative advantage based on measured individual characteristics matters and if there is evidence of unmeasured ability in the wage determination process, one can expect to find some evidence of comparative advantage based on unmeasured ability and therefore proceed to the estimation of the Gibbons and Waldman model.

Differences in average individual characteristics across ranks are presented in the Appendix C Table which reports average education, potential experience, marital status, woman and German percentages together with the raw wage differentials (relative to the lower rank) by rank. As observed in Table 2, the wage differentials increase within job rank in different proportions that depend on the type of occupation, with white-collared workers showing the highest differentials in each rank. While these rank wage premia might reflect the increasing responsibilities and task complexity of higher rank jobs, there is a positive correlation between rank premia and measures of individual ability such as education. From the results of the appendix C Table, the link with other characteristics is however less clear. A global measure of the workers's individual characteristics would be more convenient for analyzing interaction effects of the worker's ability and his job rank in the wage determination process.

In order to obtain a global impact of individual characteristics on wages, I summarize the individual characteristics into one variable interpreted as the worker's skill.[22] To do so, I estimated a regression of the log wage on education, marital status, sex, nationality, experience and squared experience, industry and occupation type for the entire original sample of workers. I used the estimated coefficients related to education, marital status, gender, nationality and experience to compute the estimated or predicted log wage based on these characteristics.[23] The resulting skill variable has been normalized to 0 and the average of the resulting skill index by job rank is reported in the last column of the Appendix C Table.

Column 1 of Table 3 presents the results of a regression of wages on rank dummies with controls for occupation and industry, large firm size, public sector and length of the employment contract. Given that wages are in level, the rank coefficients can be interpreted as additional dollars value per month from being in a higher rank in the base category for the control variables.[24] Notice that those coefficients are significant and lower than the raw wage differentials of the Appendix C Table with no controls for worker and firm characteristics.

Column 2 of Table 3 considers the impact of adding the skill variable on rank effects.[25] On can see that controlling for skills reduces the impact of the rank dummies but that they remain significant and important.

In order to assess the presence of unmeasured (by the econometrician) individual ability, the next column of Table 3 presents the results of a fixed-effect estimation. Assuming that unobserved individual heterogeneity is time invariant and equally valued in the different ranks, it is possible to eliminate (or control for) this term by using first difference method. If unmeasured ability does not matter in the determination of wages, the fixed-effect estimation results should be similar to the OLS results. One can see from Column 3 that the fixed-effect coefficients on ranks significantly lower, and remain significant. This suggests that part of the rank wage premia is explained by unmeasured ability and part of it still reflects rank effects.

[22]Given the focus on the role of comparative advantage, this technique, also used in the studies mentioned earlier applying the quasi-difference and IV method, provides a way to minimize the number of parameters to be estimated.

[23]To remain consistent with the Gibbons and Waldman model which focuses on expected productivity equals to wages in level, the skill variable (estimated with the wage in log) is the exponential of the predicted log wage.

[24]The base category for occupation and industry is blue collars in the mining and quarrying industry. The dummy for large firm size is one for firms with more than 500 workers.

[25]Given that the skill variable is the exponential of the predicted wages, regressing wages on the log of the skill variable would give a coefficient of 1.

The notion that workers have a comparative advantage in some job ranks is equivalent to saying that skills are differently rewarded along the successive rungs of the job ladder, and that workers sort into a given rank according to their level of ability or skills. Column 4 of Table 3 considers the possibility that comparative advantage and non random selection operate on measured skills. To take this into account, I added interactions of the skill index and the worker's job rank to the baseline regression of column 1. One can see that the coefficients on the interactions are significant. A test of equality of these coefficients shows a value of 2.09) for the $\chi^2(3)$ statistic. This shows evidence of the existence of distinct evaluations of measured skills in each rank. Finally, column (5) shows the results of a fixed-effect estimation of the specification with comparative advantage in column (4). The rank coefficients decreases substantially compared to column (4) and resemble more those of column (3) obtained with a fixed-effect estimation. This suggests that unmeasured ability matters, even in the presence of comparative advantage based on measurable skills.

The second panel of Table 3 show the results of a similar analysis applied to the sub-sample of workers in the private sector only. Results are very similar to those based on the entire sample. Given that a larger majority of workers in the private sector experience a change in rank, [26] the similarity in the results is not surprising.

This section has shown evidence that workers self-select into the different levels having a comparative advantage in a given level based on their level of measured skills. In addition, the results of the first difference estimation lead us to suspect that unmeasured ability may also matter in the explanation of the inter-rank wage differentials and thus, in the wage dynamics within firms.

These results are consistent with the Gibbons and Waldman framework of analysis of wage and mobility dynamics inside firms. Given that unmeasured ability is likely to be correlated with measured ability, it is reasonable to expect to find evidence on the fact that workers also have a comparative advantage based on unmeasured ability. The next section presents the results based on the Gibbons and Waldman model specification presented in Section 2.

# 4 Results

This section proceeds in three parts. The first part presents the estimation of the comparative advantage and learning effects on wage dynamics for the sample of workers staying with their

[26] See Appendix Table B2.1

firms. The second part describes the results in terms of the validity and predictive power of the instruments. The last part compares wage and mobility dynamics within and between firms estimating the effects of comparative advantage and learning on the sample consisting of firm stayers and firm changers.

## 4.1 Comparative Advantage and Learning Within Firms

The estimation results, shown in Table 4, are presented in two parts. First, equation (8) is estimated under the assumption of perfect information to emphasize the impact of comparative advantage on $\theta_i$, observed by the market but unmeasured by the econometrician. Second, the estimation is performed for the model under imperfect information about $\theta_i$, where both comparative advantage and learning effects are possible.

Results from the first part of Table 4 confirm the importance of the non random selection of workers based on unmeasured ability. The $c_j$ coefficients which evaluate the impact of unmeasured ability in each rank $j$ are all significant. More importantly for the comparative advantage hypothesis, they are significantly different from one another. The joint test for equality of slopes shows a value of 9.36 for the $\chi^2(3)$ statistics which is significant at the 5% level. The coefficients related to measured skills by rank (the $\beta_j$) are still significantly different from one another ($\chi^2(3)$ of 9.71 for the joint test) implying that comparative advantage based on measured ability is still important. Compared to column (4) of Table 3 however, the impact is smaller when comparative advantage based on unmeasured ability is controlled for.

For rank to rank differences in the coefficients on measured and unmeasured ability, the effect of unmeasured ability is significantly different between the middle and upper rank ($\chi^2$ of 5.11 significant at the 5% level) implying that it is at that level of the job hierarchy that comparative advantage based on unmeasured ability plays the most significant role. From the results on measured skills, rank to rank differences in coefficients are significant between the lower and middle rank of the hierarchy. Together these results suggest that measured and unmeasured ability play significant roles in determining the assignment of workers into ranks, but have different effects at different levels of the job hierarchy with unmeasured ability being important when moving to the upper part of the hierarchy while measured skills are important when moving from the lower to middle part. Note that the pure rank effects, $d_j$'s, all remain significant implying that measured and unmeasured skills are not the only determinants of wage increases.

Given the different patterns of transition between ranks for blue and white collared workers shown in appendix Table B2.2 with a higher proportion of blue-collar moving from the low to the middle level and a higher proportion of white-collars moving from the middle to upper level, the different impacts of measured and unmeasured skills at different levels of the job hierarchy suggest that measured skills would be more important in the assignment of blue-collared workers whereas unmeasured ability would be more important for white-collared workers.

The second panel of Table 4 show the estimation results when learning about unobserved innate ability is introduced. One can see that assuming that mobility is generated by learning about unobserved ability changes substantially the preceding results. Overall, the coefficients are less precisely estimated with most of the standard errors doubling in magnitude. None of the tests of equality in the slope coefficients reject the null implying no evidence of comparative advantage.

These results cast some doubt on the ability of the learning hypothesis to be supported by the data. Note that with the introduction of learning, the pure rank effects cease to be significant. Taken in isolation this result would suggest that mobility generated by learning about unobserved ability explains all of the rank effects in the wage dynamics. On the other hand, it is difficult to reconcile with the absence of evidence on the workers' comparative advantage in a given rank. A better explanation for this result would be that mobility of German workers across ranks is not important enough to identify any differential rank effects, either pure rank effects or differential skills and ability effects across ranks. This result is consistent with Bauer and Haisken-Denew (2001) who use the same data to analyze the covariance structure of wages resulting from learning about workers' unobserved ability and do not find evidence of learning effects in the estimated covariance structure.

Concerning the estimation of the human capital ratio, in both specifications, the results correspond to the estimation of a ratio defined as a constant $b_0$. Estimations based on the functional form given in (14), either using experience or tenure with the firm, all lead to an estimated ratio close to 1 with the $b_0$ estimate varying between 0.99 and 1.01 and the $b_1$ estimate of .001 suggesting the ratio is independent of experience or tenure.[27] For that reason I re-estimated the model focusing on the estimation of the constant term in (14) and present the results associated with a simpler functional form defined as the constant $b_0$.

From the two panels of Table 4, one can see that the ratio is significantly different from zero but not significantly different from unity. As mentioned previously, a ratio of unity implies that the function of accumulation of human capital (proxied by years of experience) is constant

[27]Results available upon request.

over time and across individuals. This implies that serial correlation in wage increases and promotion is not a prediction supported by the data. These results are in line with other studies using survey data.[28]

Summarizing the results, the dynamics of wages within German firms reflect the importance of non random selection of workers into the different rungs of the firm's job ladder. Measured and unmeasured ability both play an important role in the workers' assignment into ranks with unmeasured ability being more important at higher levels of the hierarchical job structure.

There is no evidence of learning effects generating workers mobility across ranks. Neither is there evidence of serial correlation in wage increases and promotion. These results are not surprising given the few episodes of mobility of German workers observed in the data. This in turn may result from the importance of the apprenticeship system in Germany, in which firms and individuals can learn about the quality of the employment relationship before individuals finish school and enter the job market, reducing the need to experience job mobility to learn about individual ability. It may also result from collective bargaining agreements which may regulate the workers' career progression.

To assess the robustness of the preceding results, the next Section presents the results of tests performed to establish the validity of the instruments as well as their predictive power in explaining the variables instrumented.

### 4.2 Instruments

In the estimation of the perfect information model with comparative advantage, the variables used to instrument previous period wage (other than the exogenous right hand side variables of the wage equation) correspond to the interactions in job rank at t-1 and t. This choice of instrument is based on the idea that effective ability, as defined in (1)according to the Gibbons and Waldman model, and therefore wages differ among workers because of innate ability. As a result, the way to capture differences in innate ability and therefore in wages is through the observation of the worker's career path.

When learning is considered, current job rank and previous period wage have to be instrumented. Rank affiliation in $t-1$ and $t-2$ helps predict current affiliation using the same argument about the informativeness of the worker's career path to capture differences in innate ability. As mentioned previously, differences in innate ability help predict wages and, in the

[28] Abowd and Card (1989) and Topel and Ward (1992)

case of the model with imperfect information, also explain the worker's rank affiliation each period.

To analyze the predictive power of these instruments, I performed a F-test for the joint significance of the instruments when the instrumented variables (previous wage on the one hand and current rank on the other) are regressed on the instruments and including all the exogenous variables in the right-hand side of the wage equation. The Appendix D table shows the results of the test. One can conclude from the table that rank affiliation either between $t-1$ and $t$ or $t-2$ and $t-1$ are good instruments for the worker's current job rank and the previous period's wage.

In terms of the validity of the instruments used to perform the estimation, note that in the estimations with comparative advantage, the overidentification test rejects the hypothesis that the instruments used are valid. Because this might be due to the importance of classification errors in rank between two periods, I re-estimated the model using a second rather than a first quasi-difference of the wage equation.[29] The idea is that if classification errors are important and if they are serially uncorrelated, one can re-estimate the model and find similar results when comparing observations in $t$ and $t-2$. Results are presented in table 5.

Results on the coefficients are similar to those of Table 4 implying that the preceding results on comparative advantage and learning still hold. On the other hand, the result on the validity of the instruments are better. The value of the statistic has substantially decreased suggesting that it is sensitive to mis-classifications in rank.[30] It also suggests that if there are errors in rank classifications, they don't seem to be serially correlated.

[29] False classifications may affect the estimated value of the objective function through the estimation of the weighting matrix as the covariance of the moments. See Altonji and Segal (1996) for an analysis of the small sample properties of the GMM estimator when the weighting matrix is the variance of the moments. Since the statistic of the overidentification test is a linear function of the value function, conclusions from the test may be sensitive to the presence of classification errors in ranks.

[30] Another possibility is related to the model's assumption of a single ability index to generate non random selection and learning. Given the possibility of transitions between non consecutive ranks, there exists several identification strategies to estimate the rank coefficients which leads to the failure of the overidentification test. See Gibbons, Katz, Lemieux and Parent (2002) for a discussion of this point. Here however, there are too few transitions between non consecutive ranks to consider this as a possible explanation for the high value of the estimated objective function.

### 4.3 Comparative Advantage and Learning Within and Between Firms

In the analysis so far, I have considered the sample of workers remaining with their firms. As a result, the $b_j\theta_i$ term representing the quality of the match worker-rank is defined as being firm-specific. It would be interesting to see whether the unmeasured $\theta$ term that is driving the results is transferable across firms (that is, individual rather than firm-specific). Using the information on job changes, I re-estimate the model over the sample of workers moving within and between firms. Results are presented in Table 6.

Results are similar to those obtained using the sample of firm stayers. The similarity in the results over the two samples suggests that the unmeasured quality of the match between a worker and his rank would be more individual than firm-specific. Note that the analysis is based on survey data which do not allow one to identify firms and therefore to control for firm unobserved heterogeneity. Having matched employer-employee data with similar information on job mobility and hierarchical job structure as in the GSOEP would allow for more precise conclusions about individual versus firm specificity in the unmeasured quality term driving the self-selection of workers into ranks.

## 5 Conclusion

In this paper, I have analyzed the relative importance of different factors explaining the dynamics of wages and workers mobility within firms with data from the German Socio-Economic Panel survey over the years 1986 to 1996. Using survey data for a large sample of workers within their firm, I can draw conclusions on the common features arising from the relationship between workers' career inside the firm and wage outcomes over a large sample of firms. In addition, the longitudinal aspect of the data allows me to study wage and mobility dynamics.

A preliminary analysis of the data shows that, similarly to the U.S. findings on career and wage outcomes inside firms, average wage growth at promotion is higher than without promotion. At the same time, individual differences in wages seem to remain important within each level of the job hierarchy as average wage growth at promotion is lower than the percentage difference in average wages between two job levels. There is also some evidence that wage growth predicts promotion as average previous-period wage growth is higher for those experiencing a promotion (or a change in job) the following period than for those who do not. On the other hand, the data show that German workers experience very few episodes of successive mobility within the firm over the sample period.

From the estimation of the model, the dynamics of wages within German firms reveal the importance of unmeasured (by the econometrician) ability driving the assignment of workers to the different rungs of the firm's job ladder with higher ability workers assigned to the top level positions. On the other hand, I do not find evidence that learning about workers unobserved ability generates mobility across job levels. This may be due to the importance of the apprenticeship system in Germany in which most of the learning about the quality of the match worker-firm would take place before individuals finish school. Finally, the results obtained when including firm changers are similar to those over the sample of firm stayers. This suggests that the unmeasured quality of the match between the worker and his job level in the job hierarchy is not entirely firm-specific.

The results of this paper show the importance of the question of assignment of workers to job ranks on our understanding of wage dynamics within as well as between firms. The evidence on the presence of non-random selection of workers onto the rungs of the job ladder brings an additional explanation for the fact that the distribution of wages differ from the distribution of individual productivity at the level of the firm. These results show that wage dynamics within the firm depend not only on the worker's ability (innate ability or quality of the match worker-firm) but also on how productive this ability (or match) is within a specific job rank. The importance of self-selection of workers based on unmeasured ability in the determination of German wages may seem surprising given that the German labor market is regulated by unions and employers' associations which would suggest that pay settings are more related to bureaucratic rules. On the other hand, pure rank wage premia remain significant even after controlling for measured and unmeasured individual heterogeneity. This would suggest that administrative rules resulting from collective bargaining agreements remains a significant factor explaining the wage dynamics within German firms.

The estimation of the model of Gibbons and Waldman over a large sample of firms made it possible to draw general conclusions on the common features characterizing mobility and wage dynamics for German workers. It would obviously be interesting to compare them with US data. To my knowledge, there is no American survey data with a question on the job rank of the worker. However, it would be possible to construct variables on job levels by using the three-digit codes from the U.S. Census which provide a detailed classification of occupations. Future research should investigate this issue because if the model of Gibbons and Waldman provides a reasonable explanation of wage dynamics in German firms it may be even more relevant in U.S. firms (where the mobility of workers, on which the model is based, is higher than in Germany).

One limitation of the analysis comes from the fact that survey data includes many heterogenous firms. While the analysis controls for the main characteristics of firms, it does not address the question of unobserved firm heterogeneity which may play a significant role in the determination of the wage and mobility processes inside firms. Using matched employer-employee data would make it possible to correct for that aspect.

The model of Gibbons and Waldman is based on the assumption that all firms are identical with the same production technology and hierarchical job structure. Future research could investigate the possibility that firms of different size differ in their internal organization as suggested by the empirical evidence on the impact of firm size on wage outcomes (see for example Brown and Medoff (1989) and Abowd, Kramarz and Margolis (1999)). In this case, the productivity of a given worker-job-level match would be different in large and small firms.

## References


[1] Abowd, J. and D. Card (1989) "On the Covariance Structure of Earnings and Hours Changes," *Econometrica* **57**, 411–445.

[2] Abowd, J., F. Kramarz, and D. Margolis (1999) "High Wage Workers and High Wage Firms," *Econometrica* **67**, 251–333.

[3] Altonji, J. G. and L. M. Segal (1996) "Small-Sample Bias in GMM Estimation of Covariance Structures," *Journal of Business and Economic Statistics* **14**, 353–366.

[4] Baker, G., M. Gibbs, and B. Holmstrom (1994a) "The Internal Economics of the Firm: Evidence from personnel Data," *Quarterly Journal of Economics* **109**, 881–919.

[5] ——(1994b) "The Wage Policy of a Firm," *Quarterly Journal of Economics* **109**, 921–955.

[6] Baker, M. (1997) "Growth-Rate Heterogeneity and the Covariance Structure of Life-Cycle Earnings," *Journal of Labor Economics* **15**, 338–375.

[7] Bartel, A. and G. Borjas (1981) "Wage Growth and Job Turnover: An Empirical Analysis," in *Studies in Labor Markets*. University of Chicago Press.

[8] Bauer, T. and JP. Haisken-Denew (2001) "Employer Learning and Returns to Schooling," *Labor Economics* **8**, 161–180.

[9] Becker, G. (1975) *Human Capital: A Theoretical and Empirical Analysis With Special Reference to Education*. University of Chicago Press.

[10] Bruderl, J., Diekmann A., and P. Preisendorfer (1991) "Patterns of Intraorganizational Mobility: Tournament Models, Path Dependency, and Early Promotion Effects," *Social Science Research* **20**, 197–216.

[11] Card, D. and D. Hyslop (1997) "Does Inflation 'Grease the Wheels of the Labor Market'," in Romer, C. and D. Romer, eds., *Reducing Inflation: Motivation and Strategy*, pages 71–114. Chicago IL: University of Chicago Press.

[12] Chiappori, P-A, B. Salanié, and J. Valentin (1999) "Early Starter versus Late Beginners," *Journal of Political Economy* **107**, 731–760.

[13] Doeringer, P. and M. Piore (1971) *Internal Labor Markets and Manpower Analysis*. Health Lexington Books.

[14] Farber, H and R. Gibbons (1996) "Learning and Wage Dynamics," *Quarterly Journal of Economics* **111**, 1007–1047.

[15] Gibbons, R. (1997) "Incentives and Careers in Organizations," in Kreps, D. and K. Wallis, eds., *Advances in Economics and Econometrics: Theory and Applications*, chapter 1, pages 1–37. New York, NY: Cambridge University Press.

[16] Gibbons, R. and L. Katz (1992) "Does Unmeasured Ability Explain Inter-Industry Wage Differentials?," *Review of Economics Studies* **59**, 515–535.

[17] Gibbons, R., L. Katz, and T. Lemieux (1997) "Unmeasured Ability, Unobserved Ability, and Inter-Industry Wage Differentials," unpublished manuscript.

[18] Gibbons, R., L. Katz, T. Lemieux, and D. Parent (2002) "Comparative Advantage, Learning and Sectoral Wage Determination," NBER Working Paper 8889.

[19] Gibbons, R. and M. Waldman (1999) "A Theory of Wage and Promotion Dynamics in Internal Labor Markets," *Quarterly Journal of Economics* **114**, 1321–1358.

[20] Harris, M. and B. Holmstrom (1982) "A Theory of Wage Dynamics," *Review of Economic Studies* **49**, 315–333.

[21] Hashimoto, M. (1981) "Firm-Specific Human Capital as a Shared Investment," *American Economic Review* **71**, 475–481.

[22] Hause, J. (1980) "The Fine Structure of Earnings and the On-the-Job Training Hypothesis," *Econometrica* **48**, 1013–1030.

[23] Holtz-Eakin, D., W. Newey, and H. Rosen (1988) "Estimating Vector Autoregressions with Panel Data," *Econometrica* **1**, 1371–1396.

[24] Katz, L. (1986) "Efficiency Wage Theories : A partial Evaluation," NBER Macroeconomics Annual 1.

[25] Krueger, A. and L. Summers (1988) "Efficiency Wages and the Inter-Industry Wage Structure," *Econometrica* **56**, 259–293.

[26] Lazear, E. (2001) "The Peter Principle: Promotions and Declining Productivity," NBER Working Paper 8094.

[27] Lazear, E. and S. Rosen (1981) "Rank Order Tournaments as Optimum Labor Contracts," *Journal of Political Economy* **89**.

[28] Lemieux, T. (1998) "Estimating the Effects of Unions on Wage Inequality in a Panel Data Model with Comparative Advantage and Nonrandom Selection," *Journal of Labor Economics* **16**(2), 261–291.

[29] Lillard, L. and Y. Weiss (1979) "Components of Variation in Panel Data: American Scientists 1960-1970," *Econometrica* pages 437–454.

[30] McCue, K. (1996) "Promotions and Wage Growth," *Journal of Labor Economics* **14**, 175–209.

[31] Murphy, K.J. (1985) "Corporate Performance and Managerial Remuneration: An empirical Analysis," *Journal of Accounting and Economics* **7**, 11–42.

[32] Neal, D. (1999) "The Complexity of Job Mobility among Young Men," *Journal of Labor Economics* **17**, 237–261.

[33] Parent, D. (1995) "Matching, Human Capital, and the Covariance Structure of Earnings," CRDE Working Paper 0995.

[34] Peltzman, S. (2000) "Prices Rise Faster than They Fall," *Journal of Political Economy* **108**, 466–502.

[35] Podolny, J. and J. Baron (1997) "Resources and relationships: Social Networks and Mobility in the Workplace," *American Sociological Review* **62**, 673–693.

[36] Prendergast, C. (1999) "The Provision of Incentives in Firms," *Journal of Economic Literature* **37**, 7–63.

[37] Rosenbaum, J. (1984) *Career Mobility in a Corporate Hierarchy.* New York Academic Press.

[38] Simonet, V. (1998) "The Role of Unobservables in the Measurement of Wage Effects of Job Mobility : Evidence from Germany and the United States,".

[39] Topel, R. (1991) "Specific Capital, Mobility and Wages : Wages Rise with Seniority," *Journal of Political Economy* **99**, 145–176.

[40] Topel, R. and M. Ward (1992) "Job Mobility and the Careers of Young Men," *Quarterly Journal of Economics* **107**, 255–267.

Table 1: Average Current and Lagged Wage growth by Type of Intra-firm Mobility[a]

| | Job Change | | Job and Rank Change[b] | | |
|---|---|---|---|---|---|
| | No | Yes | Up[c] | Down | Same |
| Current Wage Growth[d] (%) | 1.92 | 6.02 | 16.25 | 3.84 | 2.94 |
| | (0.001) | (0.009) | (0.02) | (0.04) | (0.01) |
| Previous[d] Wage Growth (%) | 2.54 | 5.93 | 5.10 | 4.53 | 4.70 |
| | (0.001) | (0.008) | (0.02) | (0.03) | (0.01) |
| Frequency[e] of Observations | 91.6 | 2.9 | 21.7 | 8.2 | 70.1 |

a-Based on a sample of 11159 observations (3487 workers). Standard errors in parenthesis.
b- Rank change conditional on reported intra-firm job change.
c-Rank change up (down or same) is a dummy indicating a higher (lower or same) rank in period t compared to t-1.
d-Average difference in log wages between t and t-1 for current growth and t-2 and t-1 for previous wage growth. The period t-1 is the period before reported job (and rank) change.
f-The percentages for the first two columns on job change do not add up to 100 because frequencies are computed over the total sample which also includes between firms job changers.

Table 2: Average[a] Wage Growth by Rank Transitions[b]

| *t* | *t-1* | Low | Medium | Upper | EXec. | Average Wage[c] |
|---|---|---|---|---|---|---|
| Low | *All* | 0.89 (*.002*) | - | - | - | 1.610 |
| | Blue-collar | 0.78 (*.002*) | - | - | - | 1.674 |
| | White-collar | 1.16 (*.005*) | - | - | - | 1.451 |
| | Civil servant | 2.25 (*.018*) | - | - | - | 2.172 |
| Medium | *All* | 15.99 (*.008*) | 1.83 (*.002*) | - | - | 2.093 |
| | Blue-collar | 15.82 (*.008*) | 1.89 (*.003*) | - | - | 2.105 |
| | White-collar | 16.19 (*.015*) | 1.74 (*.003*) | - | - | 2.054 |
| | Civil servant | 14.43 (*.062*) | 2.42(*.006*) | - | - | 2.430 |
| Upper | *All* | - | 18.93 (*.015*) | 2.37 (*.004*) | - | 3.287 |
| | Blue-collar | - | 22.08 (*.026*) | 1.10 (*.011*) | - | 2.548 |
| | White-collar | - | 19.06 (*.020*) | 2.70 (*.005*) | - | 3.537 |
| | Civil servant | - | 9.05 (*.025*) | 2.35 (*.006*) | - | 3.160 |
| EXec. | *All* | - | - | 18.10 (*.030*) | 3.33 (*.005*) | 4.106 |
| | Blue-collar | - | - | 31.1 (*.160*) | 8.48 (*.024*) | 2.860 |
| | White-collar | - | - | 16.65 (*.035*) | 4.12 (*.010*) | 4.331 |
| | Civil servant | - | - | 14.73 (*.018*) | 2.52 (*.006*) | 4.174 |

a-Based on a sample of 11159 observations (3487 workers). Standard errors in parenthesis.
b-Transitions from rank $j$ in period $t-1$ to rank $j' > j$ in period $t$ ,$j, j'$ =(L,M,U,EX).
c-Monthly wage (after tax) in levels in thousands of marks. Average over all workers in rank j at time t.

Table 3: Estimation of Rank Wage Differentials

| Models[a] | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Variables[b] | OLS | OLS | Fixed-Effect | OLS with CA | Fixed-Effect with CA |
| **All Firms** | | | | | |
| Skill | - | 1.747*** | 1.758*** | - | - |
| | | (0.044) | (0.150) | | |
| Rank L | | - | - | - | - |
| Rank M | 0.366*** | 0.157*** | 0.086*** | 0.172*** | 0.092*** |
| | (0.019) | (0.017) | (0.015) | (0.019) | (0.016) |
| Rank U | 1.445*** | 0.813*** | 0.364*** | 0.818*** | 0.344*** |
| | (0.043) | (0.042) | (0.022) | (0.043) | (0.024) |
| Rank EX | 2.311*** | 1.281*** | 0.580*** | 1.250*** | 0.508*** |
| | (0.078) | (0.079) | (0.035) | (0.124) | (0.043) |
| Skill*Rank L | - | - | - | 1.658*** | 1.520*** |
| | | | | (0.052) | (0.165) |
| Skill*Rank M | - | - | - | 1.722*** | 1.535*** |
| | | | | (0.065) | (0.157) |
| Skill*Rank U | - | - | - | 1.810*** | 1.898*** |
| | | | | (0.089) | (0.154) |
| Skill*Rank EX | - | - | - | 1.852*** | 2.065*** |
| | | | | (0.188) | (0.174) |
| Adj. R2 | 0.49 | 0.64 | 0.94 | 0.64 | 0.94 |
| **Private Sector**[c] | | | | | |
| Skill | - | 1.929*** | 1.799*** | - | - |
| | | (0.053) | (0.150) | | |
| Rank L | | - | - | - | - |
| Rank M | 0.376*** | 0.132*** | 0.071*** | 0.170*** | 0.075*** |
| | (0.022) | (0.019) | (0.017) | (0.021) | (0.018) |
| Rank U | 1.503*** | 0.768*** | 0.363*** | 0.794*** | 0.334*** |
| | (0.056) | (0.017) | (0.025) | (0.017) | (0.027) |
| Rank EX | 2.203*** | 1.358*** | 0.514*** | 0.891*** | 0.469*** |
| | (0.152) | (0.127) | (0.041) | (0.151) | (0.052) |
| Skill*Rank L | - | - | - | 1.730*** | 1.594*** |
| | | | | (0.060) | (0.195) |
| Skill*Rank M | - | - | - | 1.841*** | 1.595*** |
| | | | | (0.082) | (0.184) |
| Skill*Rank U | - | - | - | 2.032*** | 2.033*** |
| | | | | (0.121) | (0.186) |
| Skill*Rank EX | - | - | - | 3.808*** | 2.067*** |
| | | | | (0.453) | (0.218) |
| Adj. R2 | 0.45 | 0.61 | 0.94 | 0.62 | 0.94 |

a-Dependent variable is wage in level in thousands of marks. Standard errors have been computed using the White correction.
b-Also included are dummies for the type of contract, large firm size, public sector, occupations, industries and years.
Sub-sample of 8511 observations.

Table 4: Wage Dynamics Within Firms[a]
Comparative Advantage

| Specification[b] 1 | Low Rank L | Middle Rank M | Upper Rank U | EXecutive Rank EX |
|---|---|---|---|---|
| **Rank Dummies** | $d_L$ | $d_M$ | $d_U$ | $d_{EX}$ |
| | - | 0.208*** | 0.499*** | 0.695*** |
| | | (0.029) | (0.044) | (0.088) |
| **Skill*Ranks** | | | | |
| Unmeasured | $c_L$ | $c_M$ | $c_U$ | $c_{EX}$ |
| | 1 | 0.932*** | 1.261*** | 1.467*** |
| | | (0.080) | (0.131) | (0.223) |
| Measured | $\beta_L$ | $\beta_M$ | $\beta_U$ | $\beta_{EX}$ |
| | 0.813*** | 1.154*** | 1.087*** | 1.159*** |
| | (0.220) | (0.194) | (0.233) | (0.328) |
| **Ratio** | $b_0$ | | | |
| $b_0$ | 0.999*** | | | |
| | (0.008) | | | |
| Tests[c] for Equality | Joint | M=L | U=M | EX=U |
| of Slopes $c_j$ | 9.36 (0.02) | 0.58 (0.44) | 5.11 (0.02) | 0.89 (0.34) |
| of Slopes $\beta_j$ | 9.71 (0.02) | 9.69 (0.00) | 0.27 (0.60) | 0.11 (0.73) |
| of Ratio $b_0 = 1$ | 0.00 (0.969) | | | |
| Overidentification Test | 108.15 (0.00) | | | |

Comparative Advantage and Learning

| Specification[b] 2 | Low Rank L | Middle Rank M | Upper Rank U | EXecutive Rank EX |
|---|---|---|---|---|
| **Ranks** | $d_L$ | $d_M$ | $d_U$ | $d_{EX}$ |
| | - | 0.065 | 0.008 | 0.11 |
| | | (0.083) | (0.233) | (0.17) |
| **Skill*Ranks** | | | | |
| Unobserved | $c_L$ | $c_M$ | $c_U$ | $c_{EX}$ |
| | 1 | 1.119*** | 1.556*** | 1.793*** |
| | | (0.254) | (0.384) | (0.468) |
| Measured | $\beta_L$ | $\beta_M$ | $\beta_U$ | $\beta_{EX}$ |
| | 0.908** | 0.716** | 0.890*** | 0.770 |
| | (0.468) | (0.310) | (0.313) | (0.526) |
| **Ratio** | $b_0$ | | | |
| $b_0$ | 1.017*** | | | |
| | (0.006) | | | |
| Tests[c] for Equality | Joint | M=L | U=M | EX=U |
| of Slopes $c_j$ | 3.03 (0.38) | 0.22 (0.63) | 1.22 (0.27) | 0.57 (0.44) |
| of Slopes $\beta_j$ | 0.62 (0.89) | 0.37 (0.54) | 0.17 (0.68) | 0.08 (0.78) |
| of Ratio $b_0 = 1$ | 2.00 (0.15) | | | |
| Overidentification Test | 56.16 (0.25) | | | |

a-Dependent variable is wage in level in thousands of marks. Also included are dummies for the type of contract, large firm size, public sector, occupations, industries and years.
b-Estimation of $\Omega$ using the residuals from NLIV with $\Omega = I$ in a first step. Number of observations is 11159 in the comparative advantage case and 9891 in the learning case. The instruments for previous wage in the comparative advantage case include all the rank interactions between t and t-1 as well skills interacted with rank. In the learning case, current rank affiliation is instrumented using rank affiliation in t-2.

Table 5: Wage[a] Dynamics using Second[b] Quasi-Difference

| Specification[c] 1 | Low Rank L | Middle Rank M | Upper Rank U | EXecutive Rank EX |
|---|---|---|---|---|
| **Ranks** | $d_L$ | $d_M$ | $d_U$ | $d_{EX}$ |
| | - | 0.064* | 0.189*** | 0.241*** |
| | | (0.035) | (0.054) | (0.084) |
| **Skill*Ranks** | | | | |
| Unmeasured | $c_L$ | $c_M$ | $c_U$ | $c_{EX}$ |
| | 1 | 0.914*** | 1.228*** | 1.310*** |
| | | (0.099) | (0.166) | (0.230) |
| Measured | $\beta_L$ | $\beta_M$ | $\beta_U$ | $\beta_{EX}$ |
| | 1.146*** | 1.356*** | 1.206*** | 1.302*** |
| | (0.214) | (0.175) | (0.250) | (0.311) |
| **Ratio** | $b_0$ | | | |
| $b_0$ | 1.049*** | | | |
| | (0.016) | | | |
| Tests[c] for Equality | Joint | M=L | U=M | EX=U |
| of Slopes $c_j$ | 5.89 (0.11) | 0.75 (0.39) | 5.10 (0.02) | 0.31 (0.57) |
| of Slopes $\beta_j$ | 5.48 (0.14) | 4.56 (0.03) | 0.80 (0.37) | 0.35 (0.55) |
| of Ratio $b_0 = 1$ | 9.39 (0.00) | | | |
| Overidentification Test | 62.42 (0.18) | | | |

COMPARATIVE ADVANTAGE AND LEARNING

| Specification[c] 2 | Low Rank L | Middle Rank M | Upper Rank U | EXecutive Rank EX |
|---|---|---|---|---|
| **Ranks** | $d_L$ | $d_M$ | $d_U$ | $d_{EX}$ |
| | - | 0.184*** | 0.301** | 0.438*** |
| | | (0.067) | (0.128) | (0.158) |
| **Skill*Ranks** | | | | |
| Unobserved | $c_L$ | $c_M$ | $c_U$ | $c_{EX}$ |
| | 1 | 1.414*** | 2.104*** | 2.08*** |
| | | (0.244) | (0.367) | (0.477) |
| Measured | $\beta_L$ | $\beta_M$ | $\beta_U$ | $\beta_{EX}$ |
| | 1.587*** | 1.450*** | 1.117*** | 0.998* |
| | (0.267) | (0.259) | (0.309) | (0.446) |
| **Ratio** | $b_0$ | | | |
| $b_0$ | 1.000*** | | | |
| | (0.184) | | | |
| Tests[c] for Equality | Joint | M=L | U=M | EX=U |
| of Slopes $c_j$ | 11.73 (0.00) | 2.88 (0.08) | 11.29 (0.00) | 0.01(0.93) |
| of Slopes $\beta_j$ | 2.78 (0.42) | 0.60 (0.43) | 1.93 (0.16) | 0.12 (0.72) |
| of Ratio $b_0 = 1$ | 20.00 (0.99) | | | |
| Overidentification Test | 57.25 (0.23) | | | |

a-Dependent variable is wage in level in thousands of marks. Also included are dummies for the type of contract, large firm size, public sector, occupations, industries and years.
b-Estimation using variables in $t$ and $t-2$ in the wage equation.
c-Estimation of $\Omega$ using the residuals from NLIV with $\Omega = I$ in a first step. Number of observations is 7775 in the comparative advantage case and 6904 in the learning case. The instruments for previous wage in the comparative advantage case include all the rank interactions between t and t-2 as well skills interacted with rank. In the learning case, current rank affiliation is instrumented using rank affiliation in t-3.

Table 6: Wage Dynamics Within and Between Firms[a]
Comparative Advantage

| Specification[b] 1 | Low Rank L | Middle Rank M | Upper Rank U | EXecutive Rank EX |
|---|---|---|---|---|
| **Rank Dummies** | $d_L$ | $d_M$ | $d_U$ | $d_{EX}$ |
| | - | 0.188*** | 0.469*** | 0.643*** |
| | | (0.034) | (0.054) | (0.088) |
| **Skill*Ranks** | | | | |
| Unmeasured | $c_L$ | $c_M$ | $c_U$ | $c_{EX}$ |
| | 1 | 1.041*** | 1.461*** | 1.774*** |
| | | (0.107) | (0.136) | (0.220) |
| Measured | $\beta_L$ | $\beta_M$ | $\beta_U$ | $\beta_{EX}$ |
| | 1.522*** | 1.663*** | 1.772*** | 2.001*** |
| | (0.204) | (0.204) | (0.278) | (0.358 ) |
| **Ratio** | $b_0$ | | | |
| $b_0$ | 0.990*** | | | |
| | (0.012) | | | |
| Tests[c] for Equality | Joint | M=L | U=M | EX=U |
| of Slopes $c_j$ | 19.66 (0.00) | 0.15 (0.70) | 6.59 (0.01) | 2.00 (0.15) |
| of Slopes $\beta_j$ | 5.95 (0.11) | 4.23 (0.04) | 0.82 (0.36) | 1.82 (0.18) |
| of Ratio $b_0 = 1$ | 0.61 (0.434) | | | |
| Overidentification Test | 112.48 (0.00) | | | |

Comparative Advantage and Learning

| Specification[b] 2 | Low Rank L | Middle Rank M | Upper Rank U | EXecutive Rank EX |
|---|---|---|---|---|
| **Ranks** | $d_L$ | $d_M$ | $d_U$ | $d_{EX}$ |
| | - | 0.054 | 0.024 | -0.04 |
| | | (0.079) | (0.227) | (0.19) |
| **Skill*Ranks** | | | | |
| Unobserved | $c_L$ | $c_M$ | $c_U$ | $c_{EX}$ |
| | 1 | 1.092*** | 1.449*** | 1.823*** |
| | | (0.223) | (0.436) | (0.509) |
| Measured | $\beta_L$ | $\beta_M$ | $\beta_U$ | $\beta_{EX}$ |
| | 1.223*** | 1.111*** | 1.308*** | 0.812 |
| | (0.422) | (0.310) | (0.298) | (0.556) |
| **Ratio** | $b_0$ | | | |
| $b_0$ | 1.017*** | | | |
| | (0.008) | | | |
| Tests[c] for Equality | Joint | M=L | U=M | EX=U |
| of Slopes $c_j$ | 2.80 (0.42) | 0.17 (0.68) | 0.70 (0.40) | 1.33 (0.25) |
| of Slopes $\beta_j$ | 0.62 (0.89) | 0.37 (0.54) | 0.17 (0.68) | 0.08 (0.78) |
| of Ratio $b_0 = 1$ | 2.00 (0.15) | | | |
| Overidentification Test | 57.25 (0.23) | | | |

a-Dependent variable is wage in level in thousands of marks. Also included are dummies for the type of contract, large firm size, public sector, occupations, industries and years.
b-Estimation of $\Omega$ using the residuals from NLIV with $\Omega = I$ in a first step. Number of observations is 11932 in the comparative advantage case and 10439 in the learning case. The instruments for previous wage in the comparative advantage case include all the rank interactions between t and t-1 as well skills interacted with rank. In the learning case, current rank affiliation is instrumented using rank affiliation in t-2.

## Appendix A: Data Selection

This appendix details the different steps of the data selection process. First selection on age and employment status (full-time, regular part-time or training within the firm). Exclusion of self-employed workers and computation of weights as relative to the mean weight. The sample size is 32493 observations (6171 workers).

Missing variables on firm characteristics (especially firm size) and corrections for intersections between industries and between occupations reduced the sample size substantially. Moreover, the construction of dummies for ranks within occupations and the use of first and second lag of the variables lead to supplementary exclusions of observations. The final number of observations is 11929. Further selection of workers who remain within their firm (without change or with intra-firm job change) gives a sample size of 11159 observations (3487 workers).

### Sample Statistics (Weighted) GSOEP- All Workers

| | |
|---|---|
| Real monthly Wage (DM 1985) after Tax | 2280.9 |
| Years in School | 11.5 |
| Age | 36.2 |
| Percentage Female | 42.3 |
| Percentage German | 90.9 |
| Percentage Blue-Collars | 40.2 |
| Percentage White-Collars | 47.5 |
| Percentage Civil Servant | 9.8 |
| Percentage Trainees | 2.5 |
| Number of Observations | 32492 |
| Number of Individuals | 6171 |

### Sample Statistics (Weighted) GSOEP- Workers Within Firm

| | |
|---|---|
| Real monthly Wage (DM 1985) after Tax | 2177.72 |
| Years in School | 11.1 |
| Age | 41.7 |
| Percentage Female | 38.5 |
| Percentage German | 70.3 |
| Percentage Blue-Collars | 53.4 |
| Percentage White-Collars | 38.4 |
| Percentage Civil Servant | 8.2 |
| Number of Observations | 11159 |
| Number of Workers | 3487 |

## Appendix B1: Job Changes Within and Across Firms

The possible answers to the question on the changes in employment situation since the preceding year are as follows: (1) no change - (2) have a job with a new employer - (3) became self-employed - (4) have changed position within the firm - (5) took up a job for the first time in my life - (6) gone back to work after a break.

I have categorized the different changes in employment situation into four groups: "No changes" "Separations", "Intra-firm Mobility" and "Other". Answers 2 and 3 are considered as separations, 4 as intra-firm mobility and 6 as other types of moves. I considered workers in the firm for at least one period so observations on answer 5 have been excluded from the sample. Frequencies conditional on potential experience and gender are presented in table B1.1 below.

Appendix Table B1.1: Frequency of Mobility by Experience (GSOEP)

| Experience | No Change | Separation | Intra-firm Mobility | Other | N |
|---|---|---|---|---|---|
| Men | | | | | |
| 0-10 | 70.6 | 17.6 | 5.7 | 6.2 | 2869 |
| 11-20 | 87.6 | 7.4 | 3.6 | 1.5 | 5368 |
| 21-30 | 94.3 | 2.6 | 2.2 | 0.9 | 5483 |
| 31- | 96.7 | 1.8 | 1.3 | 0.7 | 7010 |
| Total | 90.1 | 5.5 | 2.7 | 1.7 | 20730 |
| Women | | | | | |
| 0-10 | 73.2 | 15.9 | 5.8 | 5.1 | 2468 |
| 11-20 | 84.2 | 6.5 | 3.2 | 6.0 | 2983 |
| 21-30 | 89.4 | 4.8 | 1.9 | 3.9 | 2955 |
| 31- | 95.5 | 1.2 | 1.3 | 0.4 | 3356 |
| Total | 86.4 | 6.7 | 2.8 | 4.1 | 11762 |
| | | | | | |
| Total | 88.8 | 5.9 | 2.7 | 2.5 | 32492 |

On can see that 89% of the workers surveyed experience no changes in employment situation. Among the 11% who are mobile, one half experienced separations while intra-firm mobility accounts for one fourth of the moves. Note also that all types of mobility decline with experience. The percentage of separations is high during the first ten years of experience but decreases rapidly after. Intra-firm mobility declines less rapidly than separations. Mean wage growth associated with the four categories of changes is provided in table B1.2 below.

Appendix Table B1.2: Wage Growth Associated with Mobility (GSOEP)

| Experience | No Change | Separation | Internal Mobility | Other | N |
|---|---|---|---|---|---|
| Men | | | | | |
| 0-10 | .049 (*.005*) | .113 (*.02*) | .102 (*.02*) | .073 (*.04*) | .063 (*.005*) |
| 11-20 | .029 (*.002*) | .072 (*.01*) | .080 (*.01*) | .031 (*.14*) | .033 (*.002*) |
| 21-30 | .016 (*.002*) | .059 (*.03*) | .033 (*.01*) | .056 (*.04*) | .017 (*.002*) |
| 31- | .009 (*.002*) | .010 (*.04*) | .045 (*.01*) | -.213 (*.14*) | .010 (*.002*) |
| Total | .020 (*.001*) | .082 (*.01*) | .071 (*.008*) | .024 (*.04*) | .025 (*.001*) |
| Women | | | | | |
| 0-10 | .039 (*.004*) | .125 (*.02*) | .158 (*.03*) | .036 (*.09*) | .060 (*.005*) |
| 11-20 | .026 (*.003*) | .111 (*.03*) | .078 (*.02*) | .065 (*.05*) | .034 (*.004*) |
| 21-30 | .022 (*.003*) | .048 (*.02*) | .042 (*.02*) | .061 (*.08*) | .024 (*.003*) |
| 31- | .014 (*.003*) | .144 (*.05*) | .029 (*.01*) | .149 (*.04*) | .016 (*.003*) |
| Total | .023 (*.002*) | .107 (*.01*) | .099 (*.01*) | .077 (*.03*) | .030 (*.001*) |
| | | | | | |
| Total | .021 (*.001*) | .092 (*.008*) | .081 (*.007*) | .048 (*.03*) | .027 (*.001*) |

The Table shows that average wage growth resulting from intra-firm mobility is relatively important and quite close to the average wage growth workers experience after separations. Since separations include moves to a new employer or to self-employment, one might suspect that most of those separations are voluntary and therefore associated with important wage growth.

## Appendix B2: Hierarchical Job Structure Within Firms

The possible answers to the question about the individual's current position are given below:

| Blue-collar worker: | White-collar worker: |
|---|---|
| 1-unskilled worker | 1-industry and works foreman in non tenured employment |
| 2-semi-skilled worker | 2-employee with simple duties (e.g., salesperson, clerk) |
| 3-skilled worker | 3-employee with qualified duties (e.g., bookkeeper, technical drawer) |
| 4-foreman | 4-employee with highly qualified duties (e.g., scientific , worker, attorney, head of department) |
| 5-master craftsman, foreman | 5-employee with managerial duties (e.g., managing director, head of a large firm or concern) |

| Civil servant (including judges and professional soldiers) | General Ranking for all occupations |
|---|---|
| 1-lower level | Lower rank (B.C. 1 & 2, W.C. 2 and C.S. 1) |
| 2-middle level | Middle rank (B.C. 3 , W.C. 3 and C.S. 2) |
| 3-upper level | Upper rank (B.C. 4, W.C. 4 and C.S. 3) |
| 4-executive level | Executive rank (B.C. 5, W.C. 5 and C.S. 4) |

Note that the first subcategory in the white-collar case is non tenured foreman. This category is not easily comparable to any of the subcategories of the other occupations. I therefore excluded workers reporting in that category.

Other possible answers not considered in the analysis here are:

| Trainee | Self-employed (including family members) |
|---|---|
| 1-student trainee | 1-self-employed farmer |
| 2-trainee | 2-self-employed academic |
| | 3-other s-e persons with or without up to 9 employees |
| | 4-other s-e persons with 10 or more employees |
| | 5-family member helping out |

Self-employed workers have been excluded from the sample and individuals reporting they were trainees without mentioning any occupations (blue-collar, white-collar or civil servant) have also been excluded since there is no way to categorize them within the hierarchical job structure implied by the other three occupations. Trainees that also reported being in one of the occupations below were retained.
Finally, no individuals (observations) switched occupations when switching ranks over the sample period. This is an important point for the identification of the rank coefficients in the estimation of the Gibbons and Waldman model. Table B2.1 below presents average characteristics by job changes.

Appendix Table B2.1 : Average Individual Characteristics by Type of Intra-firm Mobility[a]

| | Job Change | | Job Change and | |
|---|---|---|---|---|
| | No | Yes | No Rank Change | Rank Change[b] |
| Education | 11.72 | 12.93 | 13.31 | 12.05 |
| | (0.02) | (0.15) | (0.19) | (0.28) |
| Age | 42.57 | 36.33 | 36.34 | 36.48 |
| | (0.10) | (0.47) | (0.54) | (1.00) |
| Experience | 24.85 | 17.40 | 17.03 | 18.43 |
| | (0.10) | (0.49) | (0.55) | (1.05) |
| Tenure | 12.82 | 8.29 | 8.71 | 7.38 |
| | (0.08) | (0.40) | (0.46) | (0.81) |
| Women (%) | 40.14 | 39.06 | 43.81 | 27.99 |
| | (0.004) | (0.02) | (0.03) | (0.04) |
| German (%) | 90.57 | 95.13 | 97.06 | 90.38 |
| | (0.002) | (0.01) | (0.01) | (0.03) |
| Blue-Collar (%) | 40.41 | 22.99 | 21.73 | 26.55 |
| | (0.004) | (0.02) | (0.02) | (0.04) |
| White-Collar (%) | 48.48 | 56.55 | 51.55 | 68.15 |
| | (0.004) | (0.02) | (0.03) | (0.04) |
| Civil Servant (%) | 11.09 | 20.45 | 26.71 | 5.28 |
| | (0.003) | (0.02) | (0.02) | (0.02) |
| Private Sector (%) | 72.60 | 74.30 | 56.14 | 83.95 |
| | (0.004) | (0.02) | (0.03) | (0.03) |
| Employment Contract | 95.86 | 95.21 | 97.84 | 88.59 |
| | (0.002) | (0.01) | (0.009) | (0.03) |
| Large Firms | 37.23 | 48.37 | 52.29 | 39.51 |
| | (0.004) | (0.02) | (0.03) | (0.05) |
| Wage Growth | 1.92 | 6.02 | 2.94 | 13.97 |
| | (0.001) | (0.009) | (0.01) | (0.01) |
| Number of Years in Sample | 8.93 | 8.86 | 9.02 | 8.53 |
| | (0.02) | (0.15) | (0.17) | (0.28) |
| Frequency[c] | 91.6 | 2.9 | 70.06 | 29.94 |

a-Based on a sample of 11159 observations (3487 workers).
b-Rank changes include change up or down. It is is a dummy indicating a higher or lower rank in period t compared to t-1. Rank changes for those reporting a change in job.
c-The percentages do not add up to 100 because frequencies are computed over the total sample which also includes between firms job changers.

On average, intra-firm job changers are younger, more educated and more predominantly German men. Among the three types of occupation, white-collar workers are the most likely to experience intra-firm job changes. Overall, 91.6% of the observations correspond to no change in job and 2.9% to a change in job within the firm. Finally, average wage growth associated with a job change is 6.02%, more than 3 times higher than with no reported job changes (1.92%). Workers experiencing a change in rank in addition to a change in job have similar average characteristics than job changers. About 70% of the job changers don't experience a change in rank and 21.5 % correspond to a change to a higher rank (or what I define a promotion). The remaining 8.7% are changes to a lower rank which seems relatively high for demotions but not surprising given that the analysis is based on survey data which are sensitive to miss-classification errors. This point is addressed in appendix B3. The main difference with a change in rank is the associated wage growth which more than doubles.

Rank transition frequencies are given in the table below:

Appendix Table B2.2: Intra-firm Rank Transition Frequencies

| t-1 | t | Low | Middle | Upper | EXec. | Total |
|---|---|---|---|---|---|---|
| Low | *All* | 36.96 | 2.37 | 0.21 | 0.00 | 39.54 |
| | *Private* | 41.54 | 2.51 | 0.26 | 0.00 | 44.32 |
| | *Public* | 22.24 | 1.89 | 0.04 | 0.00 | 24.17 |
| | Blue-collar | 56.87 | 2.62 | 0.35 | 0.00 | 59.84 |
| | White-collar | 16.63 | 2.43 | 0.02 | 0.00 | 19.08 |
| | Civil servant | 2.63 | 0.44 | 0.11 | 0.00 | 3.17 |
| Middle | *All* | 2.40 | 38.62 | 1.27 | 0.07 | 42.37 |
| | *Private* | 2.50 | 37.84 | 1.32 | 0.08 | 41.74 |
| | *Public* | 2.08 | 41.13 | 1.13 | 0.04 | 44.37 |
| | Blue-collar | 2.47 | 30.67 | 0.74 | 0.08 | 33.97 |
| | White-collar | 2.75 | 51.97 | 2.12 | 0.07 | 56.92 |
| | Civil servant | 0.33 | 27.79 | 0.77 | 0.00 | 28.88 |
| Upper | *All* | 0.14 | 0.87 | 12.79 | 0.31 | 14.12 |
| | *Private* | 0.19 | 0.93 | 10.60 | 0.28 | 12.00 |
| | *Public* | 0.00 | 0.68 | 19.83 | 0.42 | 20.92 |
| | Blue-collar | 0.24 | 0.49 | 4.50 | 0.08 | 5.31 |
| | White-collar | 0.05 | 1.49 | 19.15 | 0.44 | 21.13 |
| | Civil servant | 0.00 | 0.44 | 36.98 | 1.20 | 38.62 |
| EXec. | *All* | 0.04 | 0.05 | 0.31 | 3.57 | 3.98 |
| | *Private* | 0.06 | 0.07 | 0.25 | 1.56 | 1.94 |
| | *Public* | 0 | 0.00 | 0.53 | 10.01 | 10.54 |
| | Blue-collar | 0.02 | 0.10 | 0.07 | 0.71 | 0.89 |
| | White-collar | 0.09 | 0.00 | 0.42 | 2.36 | 2.87 |
| | Civil servant | 0.00 | 0.00 | 1.42 | 27.90 | 29.32 |

## Appendix B3: Job Change and Rank Variables

This appendix provides details on the procedure used to minimize classification errors in the rank variables and in the job change variable. 25% of the observations reporting no change in job are associated with a change in rank ( 15% for a change up and 8% a change down). This shows inconsistency in the information provided in the two variables on job change and rank affiliation. This inconsistency results probably from errors in rank classification (reflected in the high percentage of demotion and the high average wage growth associated with these demotions).

On the other hand, it may also be the case that some of the changes in rank affiliation between two periods are "true" changes and the error is in the variable indicating no change in job situation. Note that for some years, the information on job change is provided in two separate questions. A first question asking whether the worker's job situation has changed, another question asking about the type of job change, increasing the chances of inconsistency in the answers provided. Moreover, errors in the no job change information are suspected based on the fact that average wage growth for those who report no change in job but for which there is a change in rank (up or down) is 3.28% which is substantially higher than the average wage growth of the non job and non rank changers of 1.92%. Some of the reported non job changes must in fact be job changes associated with a rank change.

To decide when to correct for a possibly false change in rank I used the information on wage growth. Any observations about non job changers associated with a change in rank up (promotion) for which workers are receiving a wage growth of more than 5% is treated as a real change in rank. If it is less than 5% then it is considered as a no change in rank and the current rank is set equal to the previous period rank. In the case of demotion, wage growth has to be less than 0 for the observation to be considered as a change in rank.

The first two columns of Table B3 below reports average characteristics for job changers who experience or not a rank change with the corrections done on the rank variables. Comparing with the last two columns of Table B2.1 (before correction), one can see that average individual characteristics and the differences among rank changers and non rank changers did not change much implying that the correction did not change the informational content of the sample. Only average wage growth is now higher for rank changers and lower for non rank changers. The remaining of the analysis will be done based on these rank corrections.

For informational purpose, average characteristics for job changers by type of rank change are presented in the next three columns. Also since the Gibbons and Waldman model focuses on rank changes, average characteristics by rank changes (including job change) are provided in the last three columns.

Appendix Table B3: Average Individual Characteristics by Job and/or Rank Changes

| | Job Change and | | Job Change and Rank Change | | | Rank Change Include Job Change | | |
|---|---|---|---|---|---|---|---|---|
| | No Rank Change | Rank Change[b] | Up | Down | Same | Up | Down | Same |
| Education | 13.24 | 12.13 | 12.19 | 11.39 | 12.38 | 11.88 | 10.76 | 11.76 |
| | (0.18) | (0.35) | (0.33) | (0.51) | (0.22) | (0.09) | (0.09) | (0.03) |
| Age | 36.62 | 35.73 | 35.63 | 40.74 | 35.85 | 40.56 | 42.93 | 42.40 |
| | (0.55) | (1.13) | (1.09) | (2.30) | (0.64) | (0.34) | (0.41) | (0.11) |
| Women | 44.01 | 27.74 | 37.68 | 31.38 | 40.82 | 41.03 | 42.82 | 39.87 |
| | (0.03) | (0.05) | (0.05) | (0.08) | (0.03) | (0.02) | (0.02) | (0.004) |
| German | 97.12 | 87.98 | 91.86 | 61.90 | 88.16 | 90.09 | 83.61 | 91.10 |
| | (0.01) | (0.04) | (0.03) | (0.11) | (0.02) | (0.01) | (0.02) | (0.002) |
| Blue-Collar (%) | 20.79 | 24.44 | 19.56 | 24.74 | 27.22 | 32.50 | 46.21 | 53.42 |
| | (0.02) | (0.05) | (0.04) | (0.08) | (0.03) | (0.01) | (0.02) | (0.005) |
| White-Collar (%) | 53.19 | 69.28 | 66.83 | 71.76 | 52.66 | 62.61 | 46.73 | 37.66 |
| | (0.03) | (0.06) | (0.05) | (0.08) | (0.04) | (0.01) | (0.02) | (0.005) |
| Civil Servant (%) | 26.02 | 6.27 | 13.60 | 3.50 | 20.11 | 4.87 | 7.05 | 8.91 |
| | (0.02) | (0.06) | (0.04) | (0.03) | (0.03) | (0.008) | (0.007) | (0.002) |
| Current Wage | 2.63 | 17.34 | 14.40 | -1.52 | 4.67 | 16.38 | -8.82 | 1.50 |
| Growth (%) | (0.01) | (0.02) | (0.02) | (0.05) | (0.009) | (0.005) | (0.004) | (0.001) |
| Frequency of Observations | 80.2 | 19.8 | 21.5 | 8.7 | 69.8 | 6.71 | 4.80 | 88.5 |

Appendix C: Average Characteristics by Rank [a]

| Position | Wage Diff[b] | Edu. (Yr) | Exp. (Yr) | Woman (%) | German (%) | Married (%) | Skill Index |
|---|---|---|---|---|---|---|---|
| Blue-C | | | | | | | |
| Unskilled | 0 | 9.4 | 27.8 | 63.3 | 64.5 | 63.7 | -0.23 |
| Semi-skilled | 0.37 | 9.8 | 26.8 | 41.1 | 79.2 | 60.8 | -0.10 |
| Skilled | 0.66 | 10.6 | 22.4 | 9.5 | 89.2 | 49.5 | 0.02 |
| Foreman | 1.05 | 10.4 | 26.6 | 3.1 | 92.8 | 80.5 | 0.07 |
| Master Crafts. | 1.11 | 10.9 | 25.9 | 1.42 | 98.4 | 61.3 | 0.10 |
| White-C | | | | | | | |
| Simple duties | 0 | 10.9 | 22.2 | 81.8 | 94.6 | 48.4 | -0.26 |
| Qualified | 0.64 | 11.8 | 21.7 | 62.7 | 96.5 | 50.7 | -0.12 |
| Managerial | 2.09 | 14.3 | 21.9 | 25.1 | 96.2 | 65.5 | 0.27 |
| C.E.O | 2.85 | 13.8 | 27.0 | 0.59 | 98.2 | 48.9 | 0.30 |
| Civil Servant | | | | | | | |
| Lower | 0 | 10.7 | 25.4 | 14.4 | 100 | 64.5 | 0.01 |
| Middle | 0.50 | 11.5 | 21.5 | 23.1 | 100 | 58.2 | 0.06 |
| Upper | 1.23 | 14.9 | 22.3 | 36.7 | 99.6 | 64.2 | 0.23 |
| Executive | 2.24 | 17.7 | 24.6 | 14.8 | 99.8 | 77.5 | 0.60 |
| Generic[c] | | | | | | | |
| Lower rank | 0 | 10.1 | 25.5 | 58.9 | 82.7 | 56.9 | -0.17 |
| Middle rank | 0.49 | 11.3 | 21.9 | 39.0 | 94.0 | 50.8 | -0.05 |
| Upper rank | 1.67 | 13.9 | 22.7 | 25.1 | 96.6 | 67.1 | 0.23 |
| Executive rank | 2.46 | 16.1 | 25.3 | 14.4 | 99.1 | 66.2 | 0.48 |

a-Based on a sample of 11159 observations (3487 workers).
b-Mean wage differentials relative to the first rank monthly average real wage is (in thousands of marks) 1.37 for blue-collared, 1.41 for white-collared, 1.93 for civil servants and 1.58 for level 1 of the aggregate positions.
c-For the blue-collars, rank 1 is composed of unskilled and semi-skilled work.

Appendix D: Test[a] of the Predictive Power of Instruments

| | Within | | Within & Between | |
|---|---|---|---|---|
| | CA | CA + Learning | CA | CA + Learning |
| $w_{t-1}$ | 6.31 | 12.99 | 5.24 | 10.50 |
| | (0.0001) | (0.0001) | (0.0001) | (0.0001) |
| Rank $M_t$ | - | 3.48 | - | 5.22 |
| | | (0.0008) | | (0.0001) |
| Rank $U_t$ | - | 3.29 | - | 13.17 |
| | | (0.0005) | | (0.0001) |
| Rank $EX_t$ | - | 14.72 | - | 20.56 |
| | | (0.0001) | | (0.0001) |

a- F-test from regressions of the instrumented variables on the exogenous variables and the instruments. p-value are in parenthesis.