



Too many theories, too few facts? What the data tell us about the link between span of control, compensation and career dynamics

Valerie Smeets, Frederic Warzynski*

Universidad Carlos III de Madrid and CCP, Aarhus School of Business

Received 30 December 2006; received in revised form 6 September 2007; accepted 7 September 2007

Available online 15 September 2007

Abstract

In this paper, we use a unique personnel dataset from a large European firm in an high tech manufacturing industry that provides information about hierarchical relationships. This unusually rare feature allows us to identify the chain of command. We provide a few stylized facts about the link between span of control, compensation and career dynamics and relate our findings to the existing theoretical literature of hierarchies in organizations: the assignment model, the incentives model, the information processing model, the supervision model, and the knowledge-based hierarchy model. We observe an increase in the span, an increase in wage inequality between job levels, and the introduction of a new hierarchical level. We also find that higher spans of control are associated with higher wages. The knowledge-based hierarchy provides the most likely explanation for these results when communication costs are decreasing. However, we also find evidence of learning and reallocation of talent within and across job levels, a finding that can not be explained by a static model of knowledge based hierarchy but rather by dynamic models of careers in organizations. Finally, we provide a few suggestions to enrich the existing theoretical literature and reconcile it with the facts.

© 2008 Elsevier B.V. All rights reserved.

JEL Codes: J24; J31; M5

Keywords: Hierarchy; Span of control; Wage determination; Promotions; Careers

* Corresponding author.

E-mail address: fwarzyns@emp.uc3m.es (F. Warzynski).

1. Introduction

The modern firm is typically organized internally as an hierarchy. Previous theoretical attempts to understand the concept of hierarchy have led to a large body of literature emphasizing different mechanisms and trade offs that firms face (for an early survey, see [Holmström and Tirole, 1989](#), pp. 106–126.) They stress among others the use of hierarchies (i) as information processors ([Bolton and Dewatripont, 1994](#); see also [Radner, 1992](#) and [Van Zandt, 1998](#)), (ii) as incentive mechanisms ([Lazear and Rosen, 1981](#); [Rosen, 1986](#); [Lazear, 2004](#)), (iii) as supervision technologies ([Qian, 1994](#)), (iv) as assignment and learning mechanism ([Rosen, 1982](#); [Gibbons and Waldman, 1999](#)) and (v) as knowledge-based ([Garicano, 2000](#); [Garicano and Rossi-Hansberg, 2006](#)).

The literature on hierarchies as information processors considers hierarchies as a way to minimize the costs of processing and communicating information inside the firm. The basic trade-off in this model is that workers can specialize in processing similar information but at a higher communication cost due to coordination issues. Hierarchies can also be seen as a way to alleviate moral hazard problems. Either because hierarchies are powerful incentives mechanisms, as promotions provide ex ante incentives to workers (hierarchies as incentives mechanisms), or because, in a hierarchical organization, some workers play the role of supervisors and are responsible to monitor workers, mitigating the moral hazard problem (hierarchies as supervision technologies). Another strand of the literature sees hierarchies as assignment and learning mechanisms where the objective of hierarchies is to assign individuals of higher ability to positions where they are more productive at. Finally, the recent theory of knowledge based hierarchy studies how firms use hierarchies to organize knowledge optimally and to solve coordination problems in the presence of specialization. This theory also considers the effect of a change in information technology (where knowledge becomes easier to acquire or transfer) on the hierarchical organization of the firm.

Surprisingly, there have been few attempts to study this topic empirically, probably because data about hierarchical relationships are extremely hard to get. Despite the fact that firms' personnel records have become increasingly available to researchers (see e.g. [Gibbs and Hendricks, 2004](#) and the papers referenced therein), a drawback of the existing datasets is the lack of information on the hierarchical organization of the firm such as managers' span of control or detailed chains of command inside the firm. In this paper, we explore a brand-new dataset providing a clear description of the hierarchical structure and reporting relationships of a large European firm. Our main goal is to generate a few facts about the relationship between span of control, wages and careers. We empirically investigate (i) the evolution of the wage inequality between hierarchical levels, (ii) the evolution of the span of control, (iii) the link between compensation and the span of control and (iv) the link between career dynamics and the span of control. We then relate our findings to the key predictions from various theories of hierarchies and try to distinguish between them.

Empirical evidence about these theories of hierarchy has been scarce and has mostly used survey data. [Ortín-Ángel and Salas-Fumás \(2002\)](#) use survey data from a repeated cross-section of 669 Spanish firms for the period 1990–1992. They find that the wage difference between layers is lower than the span of control at any position, and that manager's human capital explains a large fraction of wage differences between layers, suggesting an allocation process of talent along the hierarchy. [Rajan and Wulf \(2003\)](#) document the evolution of the shape of the hierarchy using survey data from a panel of more than 300 large U.S. companies over the period 1986–1999. They observe a flattening of the firm: more individuals report directly to the CEO, the span of control has increased and the number of layers has diminished. Moreover, the structure of pay has changed as well, as organizations are moving towards more pay inequality. They discuss potential explanations for their

results, including technological change and change in product market competition. [Garicano and Hubbard \(2005a\)](#) discuss various forms of production functions with equilibrium assignment and then describe the hierarchical production function in a human capital intensive industry. They use census data about U.S. law firms and find that these exhibit organizational patterns consistent with the knowledge hierarchy type of production function: positive sorting, scale of operations effect. Using the same dataset, [Garicano and Hubbard \(2005b\)](#) test their theory of positive sorting with on the job training. They find that partners and associates are sorted by law school quality but not by experience. In a third paper ([Garicano and Hubbard, 2006](#)), they estimate the gains from organizing as a hierarchical organization, or specializing vertically. They find that this form of organization leads to an increase in production of 30%, and also to an increase in wage inequality. Finally, [Fox \(2006\)](#) uses the Swedish linked employer-employee dataset and provides some evidence consistent with the [Garicano and Rossi-Hansberg \(2006\)](#) model, as firm-size wage gaps increase with job responsibility for managerial employees.

In our empirical analysis, we first document the evolution of the hierarchy and the average span of control. The company's hierarchy has become flatter and the span of control for each layer has increased over time, consistent with previous evidence on the evolution of firms' hierarchy in the U.S. ([Rajan and Wulf, 2003](#)). Second, we describe the evolution of the wage gap between job levels. We find that wage gaps between levels have become wider over time, again in line with the evidence in Rajan and Wulf. Third, we test whether managerial compensation is related to the span of control; and we also analyze the relationship between bonuses and numbers of subordinates, as firms could have more flexibility to reward supervision using bonuses rather than wages. We find that wages and bonuses are positively related to the span of control. While each fact could be explained by various theories of hierarchies (see Section 5 for a detailed discussion), the most likely candidate for these three combined results seems to be the knowledge based hierarchy model. Moreover, the fact that our firm has been through a major change in information technology during the period of study (which has helped to alleviate communication costs) reinforces this belief.

We then turn to the dynamic reallocation of workers along the hierarchy. We look at the relationship between a manager's probability of being promoted to the next hierarchical level and his current span of control. We find that the number of subordinates in a layer is positively related to the probability of being promoted to the next layer. We also investigate whether the manager's current span of control predicts his future span of control once he reaches the next level in the hierarchy. We find that the number of subordinates in the previous layer has a positive effect on the number of subordinates in the current layer. These findings tend to indicate that the firm learns about individuals' general and managerial ability and allocate them over time to positions where they have increased responsibilities. We provide a detailed discussion on this issue in Section 5 and also discuss how we can interpret our findings on career dynamics and span of control.

The rest of the paper is structured as follows. Next section discusses the empirical predictions from the various models of hierarchy. Section 3 provides a detailed description of the dataset, as well as summary statistics. Section 4 shows our results, while Section 5 provides an extensive discussion about how our results may fit into the alternative models of hierarchies. Finally, Section 6 concludes.

2. Span of Control, Wages and Career Dynamics

A potential problem with the theories of hierarchies aforementioned is that many of them generate similar predictions (a similar concern was raised when testing incentives theories, see

e.g. Prendergast, 1999; or when explaining careers in organizations, see Baker and Holmström, 1995, where we borrow part of the title). It can therefore be empirically difficult to identify clear tests to disentangle the various mechanisms at play. To address this problem, we center our analysis on testing four theoretical predictions: (i) the evolution of the wage inequality between hierarchical levels, (ii) the evolution of the span of control, (iii) the link between compensation and the span of control and (iv) the link between career dynamics and the span of control. Our empirical strategy is that, even if each prediction can be explained by more than one theory, confronting all four predictions may help us to assess which theory best fits the new facts presented in this paper.

In the literature about hierarchies, increased wage inequality can arise through different mechanisms. First, it can be due to the desire to increase incentives for workers through an increase in the prize associated with the promotion (hierarchies as incentives mechanisms). Second, wage inequality may increase with the size of the firm, because, when the size of the hierarchy increases, the marginal productivity, effort and wage of managers at the top increase, while the opposite is true for workers (hierarchies as supervision technologies). Third, a decrease in the costs of communicating information may lead to larger differences in the knowledge acquired by workers between levels, which may translate into a higher wage inequality between levels (knowledge based hierarchy).

Two theories make predictions on the evolution of the span of control, both related to a reduction in communications costs inside the firm. The knowledge based hierarchy predicts that the span of control will increase with improvement in communication: the knowledge of workers higher in the hierarchy becomes easier to transfer to production workers and is better leveraged with more subordinates. When hierarchies are used as information processors, a reduction in communication costs implies that workers can process more information, which in turn leads to a flatter and smaller organization.

Different models offer different explanations for the positive correlation between span of control and wage level. Individuals at the top of the hierarchy have higher ability, provide positive externalities on the workers that they manage, and therefore command higher wages the higher the span of control (hierarchies as assignment mechanism). A higher span of control generates an increase in the wage difference between the manager and the workers if more competitors make it harder to get the promotion, as a larger prize increases incentives to work hard (hierarchies as incentives mechanism). Finally, if wage are convex in ability and more talented individuals manage larger teams, the span of control can be seen as a proxy for ability, hitherto implying a positive relationship between span of control and wage (knowledge based hierarchies)¹.

None of the existing theories of hierarchies makes predictions on the link between career dynamics and span of control, as they are either static theories of hierarchies which leave aside careers in organizations or dynamic theories of careers which leave implications for the span of control unmodelled (Gibbons and Waldman, 1999). However, if firms want to allocate talented individuals higher up in the hierarchy (as in the assignment model) and if managing more individuals requires higher managerial ability, then higher span of control

¹ In the theory of hierarchies as assignment mechanism, namely Qian's (1994) model, the effect of the span of control on wages is also positive but is not straightforward to interpret because he assumes homogenous managers and constant span of control in any tier.

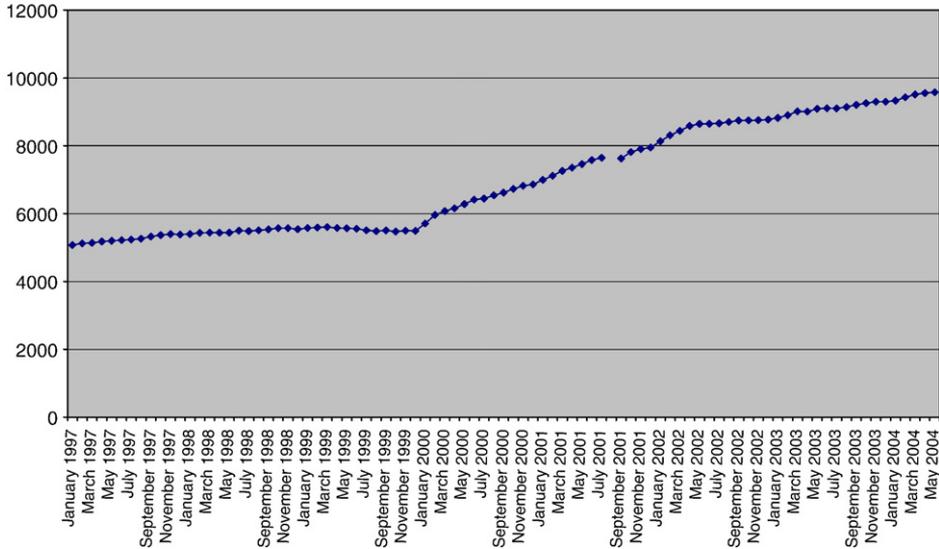


Fig. 1. Evolution of the Size of the Firm.

could signal higher managerial ability, which in turn could lead to higher probability of promotion.

3. Data

The dataset we use in this paper provides confidential personnel records for all domestic² employees from a large European firm. To protect the anonymity of the firm, we can only disclose a few elements describing its activities. The firm operates in an high tech manufacturing industry, has grown significantly over the last decade, has been very innovative and has remained one of the world leaders in its product line. The frequency of observations is monthly and covers the period from January 1997 to May 2004. The dataset was provided in two waves: January 1997–July 2001, and September 2001–May 2004. The second wave provides data after the company switched to another Enterprise Resource Planning (ERP) system. As such, it can be seen as a major technological change facilitating communication and the circulation of information within the firm. Fig. 1 shows the evolution of the size of the company (we only consider the mother company and not the smaller subsidiaries). Over this 8-years period, the company has almost doubled the number of employees, starting from over 5,000 in January 1997 to reach nearly 10,000 employees in May 2004.

3.1. Job Levels

The distribution of formal authority in the firm is relatively simple. There are only five job levels based on job description: non managerial employees (job level 0), lower management (job level 1), middle management (job level 2), upper management (job level 3) and top management (job level 4). For the last two levels, wage information was not provided, so we do not include them in the analysis.

² Although the percentage is declining, a large bulk of the firm's activities still takes place within the country.

Moreover, the company uses a dual career ladder: for the first two managerial positions, they also employ professional managers (job level 1b) and professional middle managers (job level 2b) in addition to the previous five job levels mentioned above. The reason for making this distinction is that the company wants to offer career opportunities for individuals with technical skills, but who might not be suited for managerial positions. As a consequence, they rarely supervise teams of workers, but a promotion to these job titles leads to an important wage increase, and therefore ex ante motivation.

Finally, the firm decided to add a new informal layer in 2001. We refer to these individuals as assistant managers (job level 0.5). They help managers in their supervisory tasks and facilitate a more intensive production process.

As Fig. 2 shows, the number of managers has increased over time, but at a slower rate than workers' employment, implying a dramatic increase in the span of control (see more on this below). In September 2001, the company tried to remedy this situation by first hiring a significant amount of new managers. When introducing the new informal layer mentioned hereinbefore, the firm also decided to allocate these new assistant managers to those departments where managers had the highest span of control.

3.2. Job Transition

Fig. 3 shows the number of promotions along the hierarchical career for the two periods of study. During the first period, there were about two promotions a month from worker to manager; three promotions a month from worker to professional manager. While the average number of promotions remained relatively stable for managers in the second period, it increased dramatically for professional managers to an average of 4.5 promotions a month (compared to around 3.2 in the first period). Another striking observation is that professional managers are much less likely to be promoted further along the hierarchy. On the contrary, the average number of managers being

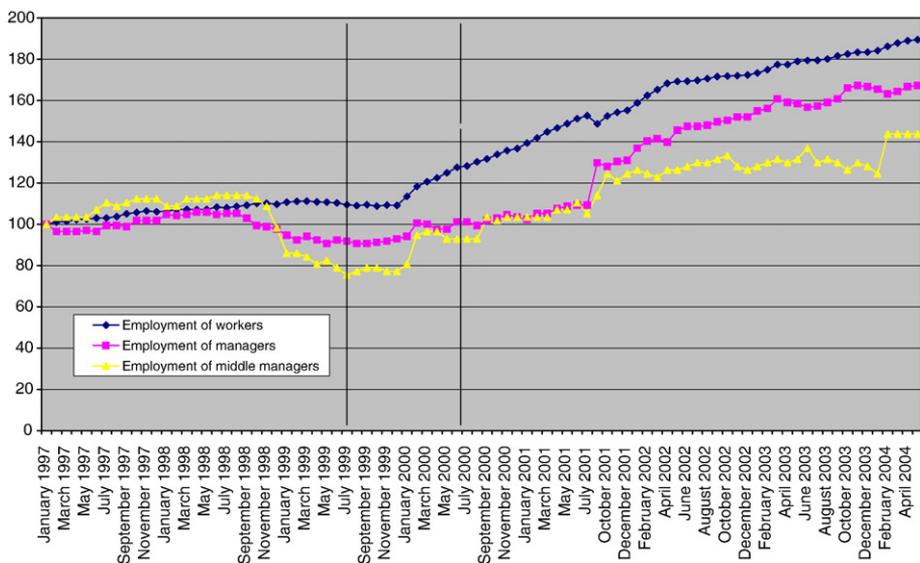


Fig. 2. Evolution of the index of employment, lower managerial employment and middle managerial employment (January 1997 = 100).

promoted to middle managers increased from 0.4 to 0.6 between the two periods. Promotions to upper management is infrequent and only concerns middle managers. Finally, we observed only one promotion to top management. Demotions are rare and are omitted from the figure. Entry and exit occur at all layers of the firm, although limited at the last two layers, which provides evidence against the importance of “ports of entry and exit” in this organization.

3.3. *Teams, Departments, and Span of Control*

An unusually rare feature of this dataset is that relationships within the hierarchy are reported, i.e. for each employee, we know precisely who is his manager, to whom the manager reports, and so on. This clear description of the chain of command allows a richer analysis of the internal economics of the firm and of the hierarchical relationships than in previous studies. On the basis of this information, we created our unit of analysis, a team, or a “cell”³, defined as a group of workers with the same supervisor and the same chain of command. This is the smallest unit in the chain of command.

Teams often coincide with the department, especially the smaller ones, while large teams sometimes include more than one department as some managers can be responsible for more than one department (for example, one administrative department and two production departments with closely related activities). The number of teams in our dataset has increased from 235 in May 2000 to 382 in May 2004, while the number of departments increased from 342 by name (344 by number) in January 1997 to 437 by name (420 by number) in July 2001, and then to 607 by name (415 by number, 800 including subdepartments) in May 2004. Departments are organized in five larger units, dividing financial, sales and marketing, R&D, administrative and production tasks.

The span of control is then simply constructed by combining information about job levels and the chain of command. We define the span of control of a manager as the number of subordinates who refer to him as the manager. It is also equal to the size of the team. This is probably the most precise measure available (as opposed to the proxies used in the previous empirical papers) and the exact translation of the theoretical notion of the span-number of agents under the responsibility of the manager. One small disadvantage is that it does not measure the difference between real and formal authority (Aghion and Tirole, 1997) and the amount of delegation, but this is a common issue when trying to capture these theoretical notions in personnel records.

Table 1 shows the evolution of the span of control for managers. We see that the manager’s span of control has increased on average over the whole period, as already shown in Fig. 2. Despite a temporary decline after 2001, the span started rising again thereafter.

The notion of the span of control becomes more complicated for middle managers. Middle managers are responsible for managers but also possess their own team, which is a group of workers who do not have any subordinates below them in the chain of command. Moreover, middle managers also command indirectly workers under a manager. Therefore, we define three different measures of the span: the direct span (number of managers), the team (direct subordinates who are not managers) and the indirect span (number of workers reporting through the managers). In our regressions, we use only the indirect span, in line with the theoretical idea that talent is spread through the hierarchy. Table 2 provides summary statistics on the evolution of these measures. We can see that the team managed by middle managers has remained relatively constant over the period, while the average number of managers as subordinates has increased.

³ By definition, our notion of the cell is intrinsically linked to the individual in charge of the cell. When the manager of the cell leaves her position (either because she is promoted, she is reallocated to another cell or she leaves the firm), the position becomes vacant. The cell dies and is replaced by another one, with a new individual in charge. Moreover, units are sometimes reorganized, leading to a process of creative destruction of cells. See Smeets and Warzynski (2007).

Table 1
Span as manager (in May of each year)

	1997	1998	1999	2000	2001	2002	2003	2004
Mean	24.43	25.09	28.63	29.86	32.62	29.01	29.25	29.98
Median	16	17	17	17	20	16	16	16
Std. dev.	28.47	27.04	32.28	32.52	37.42	37.04	38.59	38.33
Min	1	1	1	1	1	1	1	1
Max	214	164	171	187	211	259	272	286
Nr. of obs.	159	172	148	161	177	214	231	254

3.4. Individual Information

Besides information about job description, position in the chain of command, department and unit, we have information about wage, bonus, tenure in the firm, age, gender, nationality, and other variables that we do not use in our analysis.

Wage is the monthly wage before tax. Bonus is the monthly bonus before tax. Bonuses are usually concentrated around the end of the year, but may also occur during the year. Tenure is defined in years as the difference between the year of observation and the hiring year. Age is also defined in years. We have detailed information about the individual education level. We use a summary measure (EDU) where individuals are divided in five groups: those with basic education

Table 2
Direct and indirect span as middle manager (in May of each year)

Direct subordinates–Team								
	1997	1998	1999	2000	2001	2002	2003	2004
Mean	22.30	17.37	26.77	24.79	24.65	13.59	13.70	21.14
Median	13	10	18	11	10	8	7	6
Std. dev.	22.68	22.78	29.38	34.22	39.48	19.57	26.01	53.47
Min	0	0	1	0	0	2	1	1
Max	214	164	171	187	211	259	272	286
Nr. of obs.	56	60	43	48	57	71	71	76
Direct subordinates–Managers								
	1997	1998	1999	2000	2001	2002	2003	2004
Mean	2.79	2.90	3.42	3.04	3.09	3.10	3.52	3.39
Median	2	2	3	2	2	2	3	3
Std. dev.	3.56	3.58	3.74	3.51	3.96	3.27	3.57	3.73
Min	0	0	0	0	0	0	0	0
Max	18	17	12	13	17	13	13	20
Nr. of obs.	56	60	43	48	57	71	71	76
Indirect subordinates–Workers								
	1997	1998	1999	2000	2001	2002	2003	2004
Mean	90.33	88.52	125.05	119.71	127.63	106.42	109.54	118.85
Median	37	36	57	39	40	42	41	45
Std. dev.	125.35	126.09	163.16	170.73	195.42	167.55	177.11	180.78
Min	1	1	1	1	1	1	1	1
Max	615	640	784	691	871	821	875	975
Nr. of obs.	56	60	43	48	57	71	71	76

(EDU=0, the default category), those with some technical degree or vocational education (EDU=1), those with technical higher education (EDU=2), those with B.A. or B.Sc. level of education (EDU=3) and those with a M.Sc., M.A. or Ph.D. level of education (EDU=4).

4. Empirical Analysis

4.1. Evolution of the Wage Gap Between Levels

We first look at the evolution of wage inequality between job levels. We run a traditional Mincerian regression of monthly wage over human capital variables (firm tenure and age in a quadratic form) and job level variables for each month in the dataset. We also include education dummies and gender as control variables. The coefficients for each job level measure the wage difference between a worker (job 0, our control group) and the individuals in various managerial positions. We then plot the coefficients of the job levels in Fig. 4 to illustrate the evolution of wage differences between layers in our firm.

$$\log W_{it} = \alpha_0 + \alpha_1 TENURE_{it} + \alpha_2 (TENURE_{it})^2 + \alpha_3 AGE_{it} + \alpha_4 (AGE_{it})^2 + \sum_{JL} \alpha_{JL} (D_{JL})_{it} + controls + \varepsilon_{it} \forall t$$

We see that wage inequality has increased between levels: the wage difference between managers and workers has increased from 25% to 35%, while the wage difference between middle managers and workers increased from 45% to 65%. We also notice that the difference between traditional managers and professional managers has increased as well. We suspect that part of this difference might be explained by the fact that professional managers do not exert supervision tasks. We test this in the following subsections.

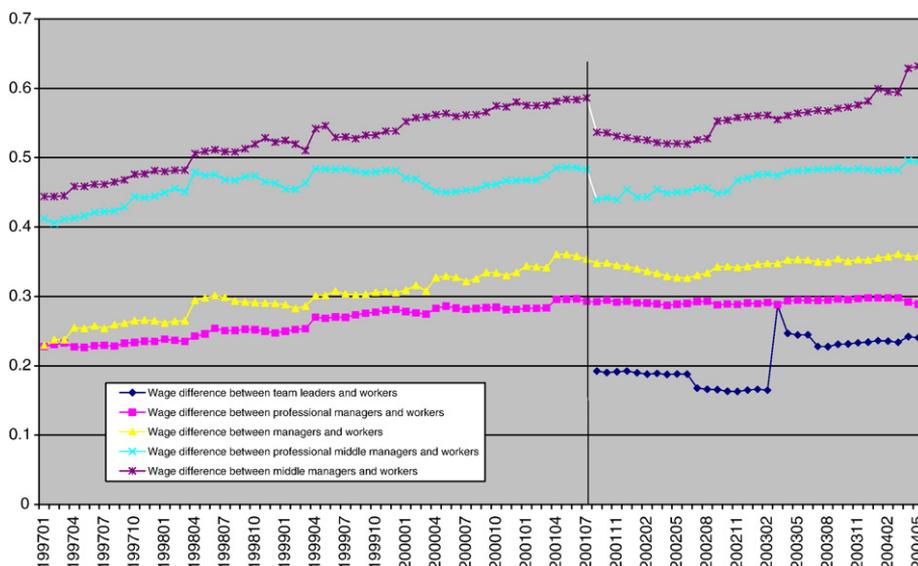


Fig. 4. Evolution of the wage gap between job levels.

4.2. Span of Control, Wages and Bonuses

We then test the effect of the span of control on wage. We run a Mincerian regression of monthly wage, adding the span of control as a manager and as a middle manager on top of the human capital variables and the job level controls.

$$\log W_{it} = \alpha_0 + \alpha_1 TENURE_{it} + \alpha_2 (TENURE)_{it}^2 + \alpha_3 AGE_{it}^2 + \alpha_4 (AGE)_{it}^2 \\ + \sum_{JL} \alpha_{JL} (D_{JL})_{it} + \alpha_{S,M} D_M SpanMan_{it} + \alpha_{S,MM} D_{MM} SpanMidMan_{it} \\ + controls + \varepsilon_{it}$$

Table 3 shows the results for the two periods of study. The first specification uses only human capital controls, the second specification includes job level controls, while the third specification

Table 3
Wage regression

	Jan 1997– July. 2001			Sept. 2001– May 2004		
Dependent variable: $\log W$						
Tenure	0.011*** (0.0001)	0.005*** (0.0001)	0.005*** (0.0001)	0.011*** (0.0001)	0.005*** (0.0001)	0.005*** (0.0001)
Tenure ² /100	-0.017*** (0.0005)	-0.005*** (0.0004)	0.003*** (0.0005)	-0.017*** (0.0004)	-0.003*** (0.0003)	-0.003*** (0.0003)
Age	0.038*** (0.0003)	0.037*** (0.0003)	0.037*** (0.0003)	0.031*** (0.0003)	0.029*** (0.0002)	0.029*** (0.0002)
Age ² / 100	-0.041*** (0.0004)	-0.041*** (0.0004)	-0.041*** (0.0004)	-0.033*** (0.0003)	-0.031*** (0.0003)	-0.031*** (0.0003)
Technical or vocational education	0.039*** (0.001)	0.043*** (0.001)	0.043*** (0.001)	0.051*** (0.001)	0.052*** (0.001)	0.052*** (0.001)
Technical higher education	0.059*** (0.001)	0.056*** (0.001)	0.055*** (0.001)	0.10*** (0.001)	0.093*** (0.001)	0.092*** (0.001)
BA, BS	0.25*** (0.001)	0.21*** (0.001)	0.21*** (0.001)	0.34*** (0.001)	0.284*** (0.001)	0.282*** (0.001)
MA, MSc, PhD	0.45*** (0.001)	0.34*** (0.001)	0.34*** (0.001)	0.52*** (0.001)	0.393*** (0.001)	0.393*** (0.001)
Female	YES			YES		
Job level: Assistant Manager	-	-	-	-	0.21*** (0.002)	0.21*** (0.002)
Job level: Prof. Manager	-	0.27*** (0.002)	0.27*** (0.002)	-	0.29*** (0.001)	0.29*** (0.001)
Job level: Manager	-	0.32*** (0.002)	0.30*** (0.002)	-	0.36*** (0.001)	0.35*** (0.001)
Job level: Prof. Mid. Manager	-	0.46*** (0.003)	0.46*** (0.003)	-	0.47*** (0.003)	0.47*** (0.003)
Job level: Mid. Manager	-	0.56*** (0.002)	0.53*** (0.002)	-	0.59*** (0.003)	0.56*** (0.003)
Span as Manager / 27.9	-	-	0.028*** (0.001)	-	-	0.019*** (0.001)
Span as Middle Manager / 107.3	-	-	0.041*** (0.002)	-	-	0.032*** (0.001)
Month dummies	YES			YES		
Adj. R ²	0.61	0.73	0.73	0.68	0.81	0.81
Nr. Obs.	256,707			241,949		

Note: standard errors in parentheses; *** indicates statistical significance at 1% confidence level.

adds the span of control of managers and middle managers. In the first specification, age and tenure have the usual effect. However, age appears to have a stronger effect on compensation than tenure. Once controlling for job level (specification 2), tenure has a remarkably small effect, a finding similar to Baker, Gibbs and Holmström (1994, Table 5 p. 907). Leaving aside potential problems of colinearity between tenure and job level (or endogeneity of the job level), this could indicate that the traditional human capital effect could be divided into two components: acquired responsibility and firm specific human capital. The coefficients of education also diminish once job levels are controlled for. The coefficients of job levels roughly correspond to an average of the plotted coefficients in Fig. 4. The wage difference between layers is slightly lower when we control for the span of managers and middle managers (specification 3). As such, it does not bring additional explanatory power but instead divides the job level effects in two components: one linked to the size of the team and another purely linked to the level. For ease of interpretation, we use a rescaled measure of the span, dividing the number of individuals supervised by the manager/middle manager by the average span of managers/middle managers over the period (respectively 27.9 for managers and 107.3 for middle managers). The span of control has a positive effect on compensation both for managers and middle managers. The effect is relatively large. For managers, supervising a team twice as large as the average implies a salary difference of 2.8%. For middle managers, being indirectly responsible for twice as many workers implies a wage difference of 4.1%. This shows that the firm rewards supervision tasks with higher salaries and uses wage differentiation within job level. Looking at the second period, we see that wages of managers and middle managers have become slightly less sensitive to the span but more sensitive to the level⁴.

We also want to test whether the span of control affects bonuses. It is very likely that firms may use bonuses rather than wages when they want to reward supervision. We therefore test the idea that, when individuals receive bonuses, the size depends on responsibility. We run the same estimation as before but using bonuses instead of wages as the dependent variable⁵.

$$\begin{aligned} \log BONUS_{it} = & \alpha_0 + \alpha_1 TENURE_{it} + \alpha_2 (TENURE)_{it}^2 + \alpha_3 AGE + \alpha_4 (AGE)_{it}^2 \\ & + \sum_{JL} \alpha_{JL} (D_{JL})_{it} + \alpha_{S,M} D_M SpanMan_{it} + \alpha_{S,MM} D_{MM} SpanMidMan_{it} \\ & + control + \varepsilon_{it} \end{aligned}$$

Results are shown in Table 4 for both periods. We find that bonuses are much more sensitive to job levels than wages. Looking at the effect of the span of managers on bonuses, we find a positive effect for the first period, in line with the previous wage estimation. However, the span as manager has a negative effect in the second period, in sharp contrast with our previous result of the effect of the span of managers on wages (see Table 3). One explanation might be that the firm now uses a more precise definition of the job. Another explanation could be that the determination of bonuses has changed dramatically, for example following negotiation with unions, leading to a lack of flexibility in a context of rising span of control. Yet another explanation is that the introduction of assistant managers has modified the logic of the bonus determination. Regarding the span of control as middle managers, we can see that the size of the bonus is positively related to the number of subordinates as middle manager in both periods, as it was the case in the

⁴ To further investigate the wage heterogeneity within job level, we ran a similar estimation by job level. We found that, within job level, supervising more workers also translates into higher wages, in line with previous estimations.

⁵ We do not test for the occurrence of bonus as a function of performance since the latter is unavailable in our dataset.

Table 4
Bonus regressions

Dependent variable: log Bonus	Jan 1997–July. 2001	Sept. 2001–May 2004
Tenure	0.005** (0.002)	-0.0003 (0.002)
Tenure ² /100	-0.020*** (0.008)	0.006 (0.007)
Age	0.014** (0.006)	0.023*** (0.005)
Age ² / 100	-0.018*** (0.007)	-0.030*** (0.006)
Education dummies	YES	
Female	YES	
Job level: Assistant Manager	-	0.31*** (0.031)
Job level: Prof. Manager	0.39*** (0.021)	0.56*** (0.021)
Job level: Manager	0.58*** (0.024)	0.76*** (0.024)
Job level: Prof. Mid. Manager	0.73*** (0.041)	0.84*** (0.046)
Job level: Mid. Manager	0.86*** (0.029)	1.13*** (0.034)
Adjusted Span as manager	0.042*** (0.016)	-0.050*** (0.012)
Adjusted Span as Middle Manager	0.056*** (0.018)	0.19*** (0.021)
Month dummies	YES	
Adj. R ²	0.59	0.48
Nr. Obs.	9646	12910

Note: see Table 3 20.

previous wage estimation. Note also that bonuses have become more sensitive to rank and to age over time, but less to seniority.

4.3. Probability of Promotion and Determinants of the Span

As a next step, we analyze the relationship between the span of control and the probability of promotion. We perform a probit regression where the dependent variable is a dummy variable equal to 1 if the individual is promoted and 0 otherwise. We first consider the promotion probability from manager to middle manager, and relate it to the span as manager in the previous period (in $t-1$). For the span of manager, we use as before a rescaled measure of the span, dividing the number of individuals supervised by the manager by the average span of managers. What we want to test is whether individuals who had more responsibilities in the previous layer have a higher probability of promotion. We include age and age squared to control for the accumulation of (general) human capital variables; tenure and tenure squared to control for the accumulation of firm specific human capital. The other controls include gender, education dummies (as additional general human capital variables), and large unit dummies.

$$\begin{aligned}
 PROM_{it}^* = & \beta_0 + \beta_1 TENURE_{it} + \beta_2 (TENURE_{it})^2 + \beta_3 AGE \\
 & + \beta_4 (AGE_{it})^2 + \beta_{S,M} D_{M} SpanMan_{i(t-1)} + controls + \varepsilon_{it}
 \end{aligned}$$

where

$$PROM_{it} = \begin{cases} 1 & \text{if } PROM_{it}^* > 0 \\ 0 & \text{if } PROM_{it}^* \leq 0 \end{cases}$$

Table 5 presents the marginal changes of the Probit estimation for the entire period. Since we use monthly data, promotions occur rarely in percentage. One has to compare our coefficient to

Table 5
Determinants of promotion to middle manager (marginal changes)

Dependent variable:	P ROM _{Man–MidMan}
Tenure	0.0001 (0.0002)
Tenure ² /100	–0.0005 (0.0008)
Age	0.0014** (0.0005)
Age ² /100	–0.0018** (0.0006)
Lagged adjusted span as manager	0.0007*** (0.0002)
Education Dummies	YES
Female	YES
Monthly dummies	YES
Pseudo–R ²	0.06
Nr. obs.	16572
Log likelihood	–265.13
Obs. Probability	0.0024
Predicted probability	0.0013

Note: see Table 3.

the observed probability of promotion. We find that the lagged adjusted span as manager has a significant and positive effect on the probability to be promoted middle manager. A manager with a span of control twice the size of the average is expected to experience an increase of around 30% of the observed probability of promotion to middle manager.

Finally, we try to better understand what determines the number of subordinates. We investigate whether the (adjusted) span as manager before promotion affects the (adjusted) span once the manager has been promoted to middle manager. In this regression, we only consider individuals who were promoted from manager to middle manager during the period of analysis.

$$AdjSpanMidMan = \gamma + \gamma_1 + TENURE_{it}^2 + \gamma_2(TENURE)_{it}^2 + \gamma_3 AGE + \gamma_4(AGE)_{it}^2 + \gamma_{S,M} D_M AdjSpanMidMan_{i(t-1)} + controls + \varepsilon_{it}$$

Our results indicate that having a high span as a manager positively affects the span of control as a middle manager. A manager with a span of control twice the size of the average is expected to end up after promotion with a span of control as a middle manager nearly 30% higher (see Table 6).

Table 6
Determinants of the number of subordinates as middle manager

Dep. var.: Adjusted (indirect) span as middle manager	
Adjusted span as manager before promotion	0.29*** (0.05)
Age	1.30*** (0.19)
Age ² /100	–1.58*** (0.21)
Seniority	–0.13*** (0.05)
Seniority ² /100	0.59*** (0.16)
Gender	YES
Unit dummies	YES
Education dummies	YES
Constant	YES
Adj. R ²	0.28
Nr. Obs:	1492

Note: see Table 3.

To sum up, the results in this section illustrate that human capital and learning affect the number of subordinates, and that the number of subordinates also has implications for wages, bonus and career dynamics.

5. Confronting Theory With the Facts

Our analysis has given rise to the following facts: (i) an increase in the wage gap between layers over time, (ii) an increase in the span of control over time, (iii) the span of control positively impacts wages, promotions and weakly bonuses and (iv) a positive relationship between the span as manager and the span once promoted to the next level. How we can interpret these new facts? We now confront each of these findings with the predictions of the alternative theories on hierarchies.

Our first finding is an increase in the wage gap between layers. More inequality between layers could be generated as a consequence of a change in incentives (hierarchies as incentives mechanisms), a change in the size of the firm (hierarchies as supervision technologies), or the adoption of a new technology reducing communications costs (knowledge based hierarchy). It could also be that the firm is hiring talented people from the outside and have to pay them a higher wage than what they pay to the previous or current managers (hierarchies as assignment mechanism). We have no indication that the firms sought to increase incentives through their wage structure. We observed that the firm hired a significant number of new managers from the outside, but their pay did not differ significantly from the incumbents'. On the other hand, the size of the firm has increased two-fold, and the firm switched to a more efficient ERP, facilitating communication and information sharing.

Second, we document an increase in the span of control. Improved communication could explain that managers can better leverage their knowledge, solve more problems and supervise larger teams, according to the knowledge based hierarchy model. The theory of hierarchies as information processors generates a similar prediction: agents can process more information. However, the nature of the work in this manufacturing company suggests that solving problems plays a more important role than information processing. Additionally, the introduction of a new informal layer suggests that knowledge can be partitioned more precisely, hence the relevance of an extra layer in the hierarchy to economize the time of the manager.

Third, our regression analysis confirms the existence of a positive link between span of control and wage. The most likely explanation is again provided by the knowledge based hierarchy theory: the more able managers supervise more workers and command higher wages because they can leverage their knowledge. An alternative explanation could be that firms increase the wage difference between levels to maintain incentives high and compensate for a lower probability to be promoted, due to the presence of more competitors (hierarchies as incentives mechanisms).

To summarize, the knowledge based hierarchy theory provides the most likely explanation for these three results in an environment with decreasing communication costs, what could have resulted from the introduction of a new ERP or more generally from the introduction of better communication technology over the period that we investigate. An additional implication of the model is that wages for workers should also be higher in larger teams as a consequence of positive sorting. We find indeed that wages increase with the size of the team, although the effect is rather small and varies according to department.

Finally, as already stated, none of the existing theories of hierarchies relates the span of control to career dynamics. Tournament theory or dynamic assignment theories explain promotions along

the hierarchical ladder but do not relate it to the span. Intuitively, if the span is related to the expected managerial ability of managers, it should then be a good predictor of future promotion. A simple model combining Rosen (1982) and Gibbons and Waldman (1999) would probably do a better job confronting this fact.

6. Conclusion

Our results appear to confirm empirical implications from various models of hierarchy, like Bolton and Dewatripont (1994), Rosen (1982) and Qian (1994), but the Garicano and Rossi–Hansberg (2006) model offers the most complete theoretical explanation of most of our results, at least when communication costs are decreasing: we observe an increase in the span, an increase in wage inequality between job levels, and the introduction of a new hierarchical level. We also find that higher spans are associated with higher wages and –in most cases– higher bonuses.

However, we also stress a different mechanism absent from the static models of hierarchies. We find that the span has implications for the future individual career and partly explains promotion decisions, what suggests that firms “learn through the span”, i.e. use the span of control as a way to learn about managerial ability. We interpret these results as evidence of learning and reallocation of talent within and across job levels, a finding that cannot be explained by a static model of knowledge based hierarchy but rather by dynamic models of careers in organizations (e.g. Gibbons and Waldman, 1999). We suggest a new model of hierarchies where individuals accumulate general and managerial human capital on the job, and firms learn gradually about individuals’ managerial ability and allocate managers to span according to their expected effective ability. Combining these two characteristics within a single theoretical framework opens new and exciting avenues for the study of careers in hierarchies.

Acknowledgments

We thank Nancy Beaulieu, Jeremy Fox, Guido Friebel, Mike Gibbs, Esteban Rossi–Hansberg, Michael Raith, Lan Shi, Michael Waldman, seminar participants at Aarhus School of Business, Cornell University, the CAED 2006 conference, the CAFE 2006 Conference, Universidad Carlos III de Madrid, and three anonymous referees for helpful comments and/or discussions on previous drafts.

References

- Aghion, Philippe, Tirole, Jean, 1997. Real and Formal Authority. *Journal of Political Economy* 105, 1–29.
- Baker, George, Gibbs, Michael, Holmström, Bengt, 1994. The Internal Economics of the Firm: Evidence from Personnel Data. *Quarterly Journal of Economics* 109, 881–919.
- Baker, George, Holmström, Bengt, 1995. Internal Labor Markets: Too Many Theories, Too Few Facts. *American Economic Review* 85, 255–259.
- Bolton, Patrick, Dewatripont, Mathias, 1994. The Firm as a Communication Network. *Quarterly Journal of Economics* 109, 809–839.
- Fox, Jeremy (2006), Explaining Firm Size Wage Gaps with Equilibrium Hierarchies, mimeo, University of Chicago.
- Garicano, Luis, 2000. Hierarchies and the Organization of Knowledge in Production. *Journal of Political Economy* 108, 874–904.
- Garicano, Luis and Hubbard, Thomas N. (2005a), Learning About the Nature of Production from Equilibrium Assignment Patterns, mimeo, Chicago GSB.
- Garicano, Luis, Hubbard, Thomas N., 2005b. Hierarchical Sorting and Learning Costs: Theory and Evidence from the Law. *Journal of Economic Behavior and Organization* 58, 349–369.
- Garicano, Luis and Hubbard, Thomas N. (2006), The Return to Knowledge Hierarchies, mimeo, Chicago GSB.

- Garicano, Luis, Rossi–Hansberg, Esteban, 2006. Organization and Inequality in a Knowledge Economy. *Quarterly Journal of Economics* 121, 1383–1435.
- Gibbons, Robert, Waldman, Michael, 1999. A Theory of Wage and Promotion Dynamics Inside Firms. *Quarterly Journal of Economics* 114, 1321–1358.
- Gibbs, Mike, Hendricks, Wallace, 2004. Do Formal Salary Systems Really Matter? *Industrial and Labor Relations Review* 58, 71–93.
- Holmström, Bengt, Tirole, Jean, 1989. The theory of the firm. In: Schmalensee, R., Willig, R. (Eds.), *Handbook of Industrial Organization*, vol. I. North Holland, pp. 61–133.
- Lazear, Edward P., 2004. “The Peter Principle: A Theory of Decline”. *Journal of Political Economy* 112, S141–S163.
- Lazear, Edward P., Rosen, Sherwin, 1981. Rank Order Tournaments as Optimal Labor Contracts. *Journal of Political Economy* 89, 841–864.
- Ortín–Ángel, Pedro, Salas–Fumás, Vicente, 2002. Compensation and Span of Control in Hierarchical Organizations. *Journal of Labor Economics* 20, 848–876.
- Prendergast, Canice, 1999. The Provision of Incentives in Firms. *Journal of Economic Literature* 37, 7–63.
- Qian, Yingyi, 1994. Incentives and Loss of Control in an Optimal Hierarchy. *Review of Economic Studies* 61, 527–544.
- Radner, Roy, 1992. Hierarchy: The Economics of Managing. *Journal of Economic Literature* 30, 1382–1415.
- Rajan, Raghuram G., Wulf, Julie, 2003. The Flattening of the Firm: Evidence from Panel Data on the Changing Nature of Corporate Hierarchies. NBER Working Paper Nr. 9633.
- Rosen, Sherwin, 1982. Authority, control and the distribution of earnings. *Bell Journal of Economics* 13, 311–323.
- Rosen, Sherwin, 1986. Prizes and Incentives in Elimination Tournaments. *American Economic Review* 76, 701–715.
- Smeets, Valérie, Warzynski, Frédéric, 2007. The Internal Biology of the Firm. Team Rotation and Learning about Managerial Ability in a Multinational Firm, work in progress.
- Van Zandt, Timothy, 1998. Organizations with an Endogenous Number of Information Processing Agents. In: Majumdar, Mukul (Ed.), *Organizations with Incomplete Information*. Cambridge University Press.