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HOW WORKER PRODUCTIVITY AND WAGES GROW WITH TENURE AND EXPERIENCE: THE FIRM PERSPECTIVE

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ABSTRACT

How worker productivity evolves with tenure and experience is central to economics, shaping, for example, life-cycle earnings and the losses from involuntary job separation. Yet, worker-level productivity is hard to identify from observational data. This paper introduces direct measurement of worker productivity in a firm survey designed to separate the role of on-the-job tenure from total experience in determining productivity growth. A key innovation is to elicit what managers know about the productivity of their workers. Several findings emerge concerning the initial period on the job. (1) On-the-job productivity growth exceeds wage growth, consistent with wages not being allocative period-by-period. (2) Previous experience is a substitute, but a far less than perfect one, for on-the-job tenure. (3) There is substantial heterogeneity across jobs in the extent to which previous experience substitutes for tenure. The survey makes use of administrative data to construct a representative sample of firms, check for selective non-response, validate survey measures with administrative measures, and calibrate parameters not measured in the survey.

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1 Introduction

Understanding how worker productivity develops with firm-specific experience (tenure) versus more general occupation-related experience is a key research question in labor economics. It is a pivotal mechanism behind many labor market outcomes, including job mobility, life-cycle patterns of employment and earnings, income inequality, and the costs of turnover in the labor market over the business cycles.

Quantifying the link among productivity, wage, tenure, and experience is difficult because worker-level productivity is rarely observable. Wages can be used as a proxy for productivity. But given the durability of the employment relationship, dynamics of productivity during the match, and indeterminacy in how the match surplus is distributed over time, the time path of wages is unlikely to match the time path of productivity. Therefore, for any study that steps away from a spot labor market assumption, it is important to identify separately productivity and wage dynamics (see, for example, Hall, 2005). The firm survey approach in this paper elicits productivity dynamics distinctly from wage dynamics. This approach complements existing methods that make use of quasi-experimental variation to quantify returns to employment relationships.

In this paper, we aim to measure directly how worker productivity evolves with tenure and experience from the perspective of firms by fielding a survey to managers or owners at a representative sample of firms in Denmark. Managers and owners, who supervise production, observe performance of many workers with varying tenure and experience, and make decisions regarding hiring and compensation, should be in a good position to tell how worker productivity changes with time spent at their firms and time spent in a similar occupation before joining their firms. The key contribution of our survey approach is to lever this knowledge of managers and owners to inform us about worker productivity. Yet, eliciting perceptions about worker productivity from a survey is challenging, in particular when tasks are multidimensional. Our approach is to design questions that should resonate with how managers and owners would think in actual business. In particular, their views on worker productivity—a complex and abstract object—are elicited in concrete and familiar dimensions: tenure needed to reach a certain productivity level and wages by tenure and productivity.

The key survey question first asks how many years of tenure would be needed, for a modal worker with no previous relevant experience, to reach maximal productivity. Maximal productivity is defined as the level of productivity where additional tenure no longer results in a meaningful increase in productivity. The survey repeats this question assuming varying numbers of years of previous relevant experience. A key advantage of this approach is that we can elicit the productivity trajectory without requiring any cardinal metric of output. The counterfactual nature of the questions makes it possible to directly inform how productivity changes with tenure and experience. In that sense, our survey builds on previous experience in using hypothetical questions designed to measure parameters that are not directly observable in behavioral data (e.g., Barsky et al., 1997, Ameriks et al., 2011, and Ameriks et al., 2020*a*). We apply this approach in a purpose-designed survey on firms. See Bachmann, Elstner and Sims, 2013, Bloom et al., 2019, Barrero, Bloom and Davis, 2021, and Altig et al., 2022 for related papers surveying firms to learn critical aspects of firm management that are not directly observable in market outcomes. Barron, Berger and Black (1999) surveys firms about worker productivity, using an alternative approach that asks employers to compare a new hire's productivity with that of a fully trained employee using a 100-point scale.

We use Danish registry data to design a representative sample and validate survey measures. Danish registry data covers the universe of firms and workers in Denmark. Invitations were sent to a randomly selected set of firms, stratified by industry and firm size. Since we know the identity of non-respondents, we can create survey weights to account for potential selection as well as over-sampling of certain firm characteristics. For the survey measures where the corresponding records are available in Danish registry data, we compare them to validate the survey responses. In particular, we show close alignment between survey questions and registry information on the most common occupation at each firm as well as the wages paid to employees with varying levels of tenure and previous relevant experience. We also use registry data to calibrate variables not measured in the survey.

We find the following key patterns in the evolution of worker productivity. First, there is significant heterogeneity across jobs in the amount of tenure needed to reach maximal productivity. About half of the firms report that, for their most common occupation, one year of tenure would be enough to bring the productivity of a worker with no previous relevant experience to maximal level. At the same time, about 40% of firms report that at least three years of tenure is needed, while 10% report that at least five years is needed. The amount of tenure required to reach maximal productivity varies with the occupation group. The variation within occupation groups is also substantial. Second, whether experience is a good substitute for tenure depends on the type of job as well as the experience the worker has already obtained. For the jobs that require many years of tenure before achieving maximal productivity, having one or two years of relevant experience reduces the amount of tenure needed to reach maximal productivity by the same length. Additional relevant experience beyond that, however, reduces the amount of tenure needed by a smaller amount. For jobs that require less tenure before achieving maximal productivity, relevant experience is not a good substitute for tenure. These patterns suggest that empirical studies aiming to estimate returns to tenure and experience should allow for variation in returns across jobs (within occupation groups) as well as the level of experience that workers have already gained.

Our survey also asks how much firms are willing to pay to hire a new worker with varying levels of previous relevant experience. This allows us to estimate wage returns to tenure and experience and compare the results to those from the literature that uses market outcomes. The wage returns we estimate fall into the range of the estimates from the literature. Additionally, consistent with Dustmann and Meghir (2005), we find that returns to tenure are more important for jobs that are more likely to be taken by unskilled workers while returns to experience are more important for jobs that are more likely to be taken by skilled workers.

These responses, combined with the key questions on productivity measurement, allow us to step away from the spot labor market assumption, and hence to identify separately dynamics of wage and productivity. The result shows that wage dynamics do not directly match productivity dynamics. In particular, productivity returns to tenure are estimated to be two to three times larger than wage returns to tenure.

The productivity as functions of tenure and experience that we estimate are central input to several lines of research within labor economics, including studies on wage dynamics and human capital (Becker, 1962, Bagger et al., 2014), life-cycle patterns of labor market outcomes (Menzio, Telyukova and Visschers, 2016, Jung and Kuhn, 2018), and labor market inequality (Blair, Debroy and Heck, 2021). Existing work on measuring worker-level productivity focuses on specific occupations.[1] There are also attempts to disentangle productivity and wage by focusing on occupations where self-employment is common (Lazear and Moore, 1984) and by comparing older employees with short and long tenure (Kotlikoff and Gokhale, 1992). The current paper provides direct measurement of the link between worker productivity, experience, tenure, and wages, perceived by firm managers, for the most common occupations at a representative sample of firms.[2]

Our survey approach to measuring productivity and wages complements a large and important literature on estimating wage returns to tenure and experience. To address the selection issue—workers who remain on the same job may have different characteristics than those who switch jobs—this literature applies various identification strategies, including

[1] See, for example, Dinerstein, Megalokonomou and Yannelis (2020) for teachers, Choudhury, Foroughi and Larson (2021) for patent workers, Bloom et al. (2015) and Emanuel and Harrington (2021) for call-center workers, Oettinger (2001) for stadium vendors, Lundborg et al. (2021) for physicians, and Kunn, Seel and Zegners (2020) for professional chess players.

[2] In other contexts, such as productivity changes due to working from home, the impact in question may be more salient to employees, and hence an employee survey can be useful. See Barrero, Bloom and Davis (2021) for such an example.

leveraging exogenous sources of variation such as firm closures or employing instrumental variables for tenure: See, for example, Altonji and Shakotko (1987), Topel (1991), Bronas and Famulari (1997), Bingley and Westergaard-Nielsen (2003), Williams (2009), Amann and Klein (2011), and Dustmann and Meghir (2005). Our survey instrument provides a new identification strategy based on counterfactual hiring scenarios that allow us to separate wage and productivity returns to tenure and experience for a general sample from the population of firms.

This paper also contributes to the literature that surveys firms to learn about factors that are central in their decision-making process but cannot be directly observed in market outcomes. Existing work in this literature includes surveys on firm management (Bloom et al., 2019), on business uncertainty (Guiso and Parigi, 1999; Bachmann, Elstner and Sims, 2013; Awano et al., 2018; Bachmann et al., 2020; Altig et al., 2022), on firm-level production function (Bloom et al., 2020), and on expectations about macroeconomic conditions such as inflation, stock market, and business conditions (Ben-David, Graham and Harvey, 2013; Bachmann and Elstner, 2015; Coibion and Gorodnichenko, 2015; Massenot and Pettinicchi, 2018; Coibion, Gorodnichenko and Ropele, 2020). We apply the approach that leverages strategic surveys questions, which has been successful in measuring preferences in household surveys (e.g., Barsky et al., 1997; Ameriks et al., 2011; Brown, Goda and McGarry, 2016; Fuster and Zafar, 2016; Wiswall and Zafar, 2018; Ameriks et al., 2020*a*; Ameriks et al., 2020*b*). The strategic survey questions help address confounding factors in behavioral data by explicitly controlling these factors in the hypothetical situations assumed in the question.

The structure of the rest of the paper is as follows. Section 2 introduces our survey design and describes the results. Section 3 estimates productivity returns to tenure and experience by combining the productivity and wage responses. Section 4 validates our survey responses by comparing them to the registry data.

2 Survey Design and Results

2.1 Overview of Design and Conceptual Framework

A key innovation of this paper is to quantify productivity dynamics by asking managers how long after an initial hire it takes an employee to reach a certain level of productivity. Time on the job to become productive is potentially more salient for managers than growth or level of productivity. Specifically, it is a metric for job performance that may be easier to elicit, especially for workers in complex production processes or working as part of team. Whether a worker is "up to speed" after a period of time is a conventional performance indicator that does not rely on measuring individual-level productivity.

In this subsection, we present prototypical versions of the key questions. The specific question wording and sequence are presented in detail in Section 2.3. For concreteness, the questions refer to the most common occupation at the firm. For parsimony, we ask about time to reach a the point where there is no substantial gain from additional tenure within the firm. We call this level of productivity the *maximal productivity*. The prototypical question is

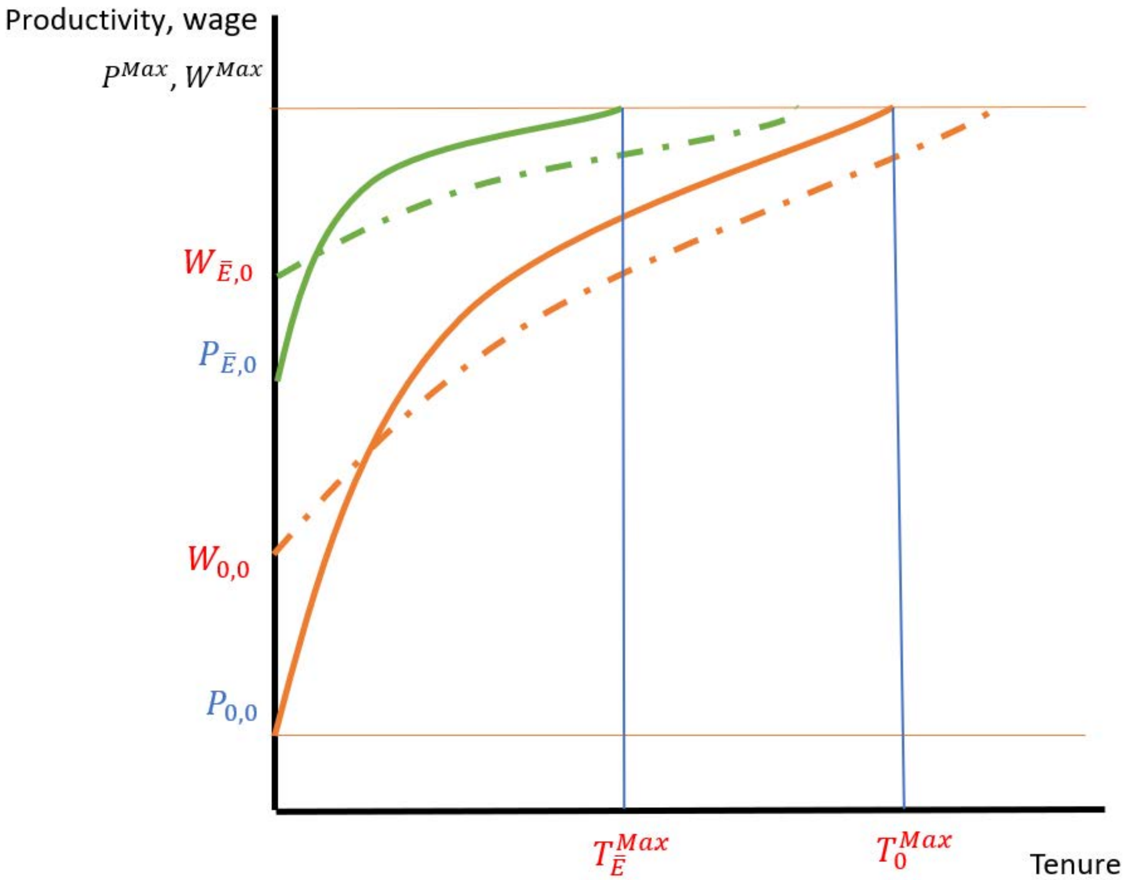
> *Consider workers with different levels of relevant experience prior to starting at your firm. Please state how many years of specific experience within your firm this worker would need to accumulate in order to reach maximal productivity.*

We also ask wages at entry and at the point when maximal productivity is reached. Assuming that the wage bill balances productivity over the expected duration of the contract, this information about the productivity trajectory and the levels of wages enables us to separately quantify the growth rates of productivity and wages.

In the rest of this subsection, we present a conceptual framework that allows us to analyze the trajectory of productivity and wages for the initial periods during which a new hire reaches maximal productivity. It is simply an accounting framework that permits a clear mapping of the responses to the above question into returns to tenure and experience. While the framework does not impose any restrictions on the paths of productivity and wages, we do present it in a way that anticipates the finding that the wage trajectory is flatter than the productivity trajectory.

Let $P_{\bar{E},T}$ be the productivity of an employee with $\bar{E}$ years of *previous relevant experience* and T years of *tenure*. So $\bar{E}$ is a constant after joining the firm. There are two key factors that anchor the trajectory of this productivity. The first is the productivity of newly hired employees with varying levels of previous relevant experience, $P_{\bar{E},0}$, relative to maximal productivity. The second is the amount of tenure needed to achieve maximal productivity, $T_{\bar{E}}^{Max}$, which also varies with the level of previous relevant experience. Figure 1 illustrates this conceptual framework using example productivity paths of two employees, one with no previous experience (solid orange curve) and the other with $\bar{E}$ years of previous relevant experience (solid green curve). The employee with no previous experience starts with a lower productivity ($P_{0,0}$) than the employee with $\bar{E}$ years of experience ($P_{\bar{E},0}$), reflecting the possibility of previous experience contributing to the productivity on the current job. For the same reason, it may also take shorter tenure for the one with previous experience to reach maximal productivity ($T_{\bar{E}}^{Max} < T_0^{Max}$). Combined, these factors anchor the productivity trajectory and allow us to infer the productivity returns to tenure and experience.[3]

Figure 1: Hypothetical trajectories of on-the-job productivity and wage, by tenure and previous experience



Notes: This figure illustrates how productivity and wage vary with tenure and previous experience. The orange lines correspond to an employee with no previous experience, while the green lines correspond to an employee with $\bar{E}$ years of previous experience. The solid lines are the productivity paths after joining the firm and the dash-dot lines are the wage paths. The variables in red—tenure needed to reach maximal productivity and wages at entry—are directly measured from the survey. The variables in blue—the productivity at entry—are inferred from the survey responses and a model of a durable employment relationship.

[3]We assume that maximal productivity, P^{Max}, does not vary with the level of previous relevant experience, $\bar{E}$. We made this choice to keep the survey structure simple, given the limited survey time. At the same time, we believe this assumption is realistic for the jobs considered in this paper. As explained in Section 2.3, the survey focuses on the most common occupation at the firm, which turns out to be entry-level jobs where tasks are likely to be relatively simple. For these jobs, we do not expect much variation in the eventual productivity level by the level of previous relevant experience.

Similarly, let $W_{\bar{E},T}$ be the wage of an employee with $\bar{E}$ years of previous relevant experience and T years of tenure. The dash-dot curves in Figure 1 illustrate the wage paths of the same two example employees. We allow for the possibility of the wage paths being different from the productivity paths, illustrated as the dash-dot curves being different from the solid curves. The wages of the newly hired employees with varying levels of previous relevant experience, $W_{\bar{E},0}$, relative to the wage at maximal productivity, combined with tenure needed to reach the latter wage level, anchor the wage trajectory and allow us to infer wage returns to tenure and experience.

Our survey directly measures the amount of tenure needed for maximal productivity ($T_{\bar{E}}^{Max}$, see Section 2.3) and wages to newly hired employees ($W_{\bar{E},0}$, normalized by the wages to employees with maximal productivity, see Section 2.4). These items are in red font in Figure 1. These are objects that are salient to the survey respondents who are in charge of hiring and assessing employees. Using these measurements we estimate the wage returns to tenure and experience and compare them with the estimates from the literature that uses the realized wage data. Identifying the productivity path (i.e., pinning down the productivity at hiring, $P_{\bar{E},0}$, in blue font in Figure 1), while allowing it to be different from the wage path, requires a model of a durable employment relationship. In Section 3, we estimate such a model with survey responses and calculate the implied productivity returns to tenure and experience.

2.2 Survey Sample

As our main data source, we use a survey purpose-designed by the authors. An external survey agency, Epinion, drew the sample from the universe of Danish firms and fielded the survey on behalf of the authors. For subsequent analysis, we link the responses to administrative data about the firms and their employees.

Through a contract with Epinion, we fielded the survey in November 2020. The survey agency has information on the number of employees and the industry for the universe of Danish firms. It sampled firms from the universe of 44,000 privately owned firms with at least 5 employees. It invited managers and owners of 15,000 Danish firms to participate. To have good coverage of different firm sizes and industries, the universe of Danish firms was stratified into 10 industries and 4 firm size strata (5-9, 10-49, 50-199, and 200 or more employees), which yields 40 cells. Table A1 in Appendix A shows the number of Danish firms in each cell. The firms in the cells with fewer firms (large firms and industries with few firms) were over-sampled. Table A2 shows how many firms were invited in each cell.

The survey agency sent out invitations to participate using the official email account called *e-boks*, which Danish firms use to receive official communications from the public sector, for example the tax authority. The invitation letter was addressed to the person responsible for personnel. Note that, as Appendix Table A1 shows, most Danish firms are small: About half of the firms have fewer than 10 employees and firms with more than 50 employees are very rare. In these firms, the survey respondent (could be the owner for very small firms) is likely to be in charge of both hiring and organization of work. Hence, the survey targets those in a good position to evaluate and report the level and trajectory of worker productivity. The respondents answered the survey on an online platform and it took approximately 15 minutes to complete on average. Reminder emails were sent out to non-respondent firms in December 2020 and again in February 2021. In addition, the survey agency contacted the non-respondent firms by telephone to further increase response rates. The final response rate is 18.3%, with 2,747 complete responses. The number of responses and the response rate by size and industry are shown in Tables A3 and A4 in Appendix A. The survey agency constructed sampling weights that account for both oversampling and differences in response rates across cells. Throughout the analysis we use the sampling weights to ensure that our results are representative.[4]

In addition to the information on the size and industry used by the survey agency in creating the sample frame, we have access to data on firms (both respondents and non-respondents) from two additional sources—both linked to the survey responses at the firm level. First, we use the Experian KOB database that includes annual information on key firm parameters, such as firm age, firm size, type of ownership, and industry. Second, we link our data to the official administrative data on the employees of the firms (both respondents and non-respondents). The individual level data on employees come from various administrative registries collected by Statistics Denmark from relevant public authorities. For example, the Danish Tax Agency collects monthly information about all employees directly from all employers in Denmark. In addition to earned income, we use information on hours worked, tenure at the current firm and relevant work experience, and occupation. For the survey responses where the corresponding variables exist in the administrative data—for example, the most common occupation at the firm and how the wage varies by tenure and experience—we use the the administrative data to validate the survey responses (see Section 4).

In Table A5 in Appendix A, we use the observed characteristics of both the firms and their employees from the administrative data to show that there appears to be little selection into completing the survey conditional on being invited. Firms that completed the survey

[4]Extreme weights are rare, with 95% of the weights being in the interval $[0.35, 1.93]$. Using the weights or not does not make noticeable differences in the main results of this paper.

are not noticeably different from those that did not, though the former tend to have a slightly higher age and employ more experienced employees.

Validating survey responses. A frequent concern with survey responses is whether respondents are able to provide valid responses to the variables the survey is designed to elicit. We make use of our ability to link survey responses to administrative data to validate the survey responses. Manager's responses are well aligned with measurements from the registry. In particular, there is a strong correlation across survey responses and registry data for (a) the most common occupation and (b) initial wages by previous relevant experience in this occupation. Section 4 presents the validation exercises.

2.3 Measuring Productivity Dynamics

We describe our survey strategy for separating the returns to tenure versus experience. Our strategy is to ask about the trajectory of on-the-job productivity for different levels of relevant previous experience. In this section, we describe the specific questions and summarize the findings. The full script of the survey can be found in Appendix B.

2.3.1 Survey Questions on Productivity Dynamics

Defining the Job. The aim of the survey is to elicit productivity dynamics for a specific job from the managers. To do so, the survey focuses on the productivity dynamics at the most common occupation at the respondent's firm. Hence, the survey first asks:

> *What is the most common occupation at your company among employees aged 35 years or older?*

The respondent can choose one out of ten categories that correspond to the first-digit level occupation classification in Denmark (Danish ISCO). The respondent can also provide the second-digit level occupation classification if applicable. In the analysis, we only use the first-digit level occupation classification to have enough observations for each category. The question asks respondents to think about employees not younger than 35 years because our focus is not on jobs that are taken by young, temporary and/or part-time employees. We use "occupation groups" to refer to the occupation groups at the first-digit level and "jobs" to refer to the specific positions reported by each firm.

The rows of Table 1 report the most common occupations from the survey. Across the firms, there is a wide variety in the most common occupations. The most prevalent occupation groups are occupations that require a high level of knowledge, followed by skilled manual labor and occupations that require a medium level of knowledge.[5] Therefore, we have a range of occupations that have different productivity profiles over tenure and experience. At the same time, the most common occupation is by construction unlikely to be a highly specialized position within each occupation group. For example, among those who report that the most common occupation belongs to the management category, according to the second-digit level classification, only 6% are in "top management" positions. Section 4.1 compares this survey response with the most common occupation in the registry data at the firm level and confirms that they are well aligned.

Table 1: Most common occupations

Occupation groups	N	%
Management	119	4.8
Require high knowledge	701	22.9
Require medium knowledge	404	13.5
Office & customer services	192	7.0
Sales & service	338	15.0
Farming	126	4.3
Manual labor, skilled	525	21.2
Operator and assembly	202	6.4
Manual labor, unskilled	138	4.9
Unknown	2	

Notes: This table reports the distribution of the most common occupation, at the first-digit level in Danish ISCO, based on the survey responses. Note that the "level of knowledge" occupation groups are official Danish terms for describing occupations. The percentages are calculated using the sampling weights.

Eliciting Productivity Dynamics. After identifying the most common occupation, the survey asks the core questions about productivity of new hires and trajectory of productivity with tenure. Specifically, to anchor the tenure-productivity trajectory, it asks the amount of tenure where there is no substantial gain from additional experience and learning within the firm. We call the level productivity at this tenure the "maximal productivity," cf., P^{Max} in Figure 1. The survey asks this required tenure for maximal productivity for different levels of previous relevant experience. The first part of the battery asks about the new hire with no relevant industry/occupation experience, but as noted above, is at least 35 years old, so

[5]Note that the "level of knowledge" occupations are official Danish terms for describing occupations, not characterizations by us.

is not likely a new entrant to the labor market in general. This counterfactual is designed to allow direct measurement of the effects of occupational experience versus tenure in the firm's most common occupation. Specifically, the survey first asks whether one year is enough to reach maximal productivity:

> *Think about a hiring a new employee in OCCUPATION.*[6] *This new hire is aged 35 or older and has no prior relevant industry and/or occupation experience.*
>
> *Suppose that this employee has worked in your firm for 1 year. Would this employee have reached close to his/her maximal productivity within your firm or would he/she have substantially more to gain in terms of productivity from additional experience and learning within you firm?*

If the answer is no, the survey repeats this question, asking whether 5 years of tenure is sufficient to reach maximal productivity. After this, the survey asks for the exact number of years of tenure needed, either in a range of 2-5 years or a range of more than 5 years, depending on the answers to the previous questions. Therefore, for the case of workers with no previous relevant experience, the respondent has given us the number of years of on-the-job tenure required to reach maximal productivity (T_0^{Max} in Figure 1). Rather than repeating the question battery for different levels of relevant experience, the survey then asks the respondent to fill out a table that indicates the tenure needed for this maximal productivity for different levels of relevant experience ($T_{\bar{E}}^{Max}$ in Figure 1). Specifically,

> *In the table below consider workers with different levels of relevant experience prior to starting at your firm. Please state how many years of specific experience within your firm this worker would need to accumulate in order to reach the same level of productivity as the worker with no previous relevant experience and [Fill in: Tenure needed for maximal productivity with no relevant experience] year(s) of specific experience within your firm.*

Relevant experience outside your firm	Experience within your firm
1-2 years	____ year(s)
3-4 years	____ year(s)
5-9 years	____ year(s)
10+ years	____ year(s)

[6] "OCCUPATION" is a string filled with each firm's response about the most common occupation.

The design of these questions allows the respondents to think about worker productivity—a complex and abstract object—in a concrete and familiar dimension (the amount of tenure needed).

2.3.2 Productivity Trajectories: Results

In this section we examine the tenure needed to reach maximal productivity. We start with the case for new employees with no previous relevant experience, exploring the heterogeneity across jobs. Then we examine the substitutability between relevant experience and tenure.

Productivity Trajectory with No Relevant Previous Experience. The tenure needed for a new employee with no experience to reach maximal productivity (T_0^{Max}) varies a lot across jobs. Table 2 presents the distribution. For about half of jobs, 1 year of tenure is enough to achieve maximal productivity. On the other hand, for more than 30% of the jobs it requires at least 3 years of tenure, while for more than 10% of the jobs it takes at least 5 years of tenure.[7]

Table 2: Tenure needed to reach maximal productivity (with no relevant previous experience, T_0^{Max})

Jobs By T_0^{Max}	Share (%)
1 year	48.5
2 years	13.9
3-4 years	27.4
5+ years	10.2

Notes: N = 2,747. Sampling weights are used in calculating the distribution.

Note that the survey question considers a situation where the hypothetical employee does not switch the occupation within the firm until she reaches maximal productivity. Using the registry data, we confirm that employees indeed rarely switch occupations within the firm before T_0^{Max} years of tenure. To be specific, among the new employees in the most common

[7] There is at least one precedent for asking about productivity in terms of time needed. In particular, in some waves the PSID asked employees how many years of training is needed for a new employee to be fully trained and qualified for their jobs. There are differences between our question and the PSID's. Our question is about maximal productivity while the PSID's is about qualifications; our question is asked of firms while the PSID's is asked of employees. Because of these differences, the elicited variables are not quantitatively comparable. Nonetheless, it is interesting to compare them. Brown (1989) documents that more than 80% of PSID employees report their jobs require no more than a year to be be fully qualified. Our survey finds time to maximal productivity to be higher.

occupation who stay at the firm for more than T_0^{Max} years, 86% of them stay in the same occupation (at the two-digit level, which is the highest granularity used in the survey) before reaching T_0^{Max} years of tenure.[8]

The tenure needed to reach maximal productivity varies by occupation group. Table 3 shows the average and median by the occupation group identified from the survey. The rows are sorted in descending order of the average tenure needed. Jobs that require "high-level knowledge" (Danish ISCO terminology) need the most tenure (an average of 2.9 years), followed by management (2.3 years) and farming (2.3 years). Unskilled manual work requires the least tenure (1.5 years), followed by operator and assembly work (1.6 years) and office and customer services (1.6 years). Overall, this ordering is consistent with our prior. Regressing tenure needed on the occupation-group dummies yields mostly statistically significant coefficients, with the adjusted R^2 of 0.059.[9] Therefore, while there is a considerable variation in the tenure needed across occupation groups that is consistent with our prior, there is also substantial across-firm heterogeneity within occupation groups.

Table 3: Tenure needed for maximal productivity by occupation group (with no relevant previous experience, T_0^{Max})

	T_0^{Max} **needed**		
Occupation group	**Average**	**Median**	**N**
Require high knowledge	2.9	3	701
Management	2.3	2	119
Farming	2.3	2	126
Manual labor, skilled	2.3	2	525
Require medium knowledge	2.2	2	404
Sales & service	2.0	1	338
Office & customer services	1.8	1	192
Operator and assembly	1.6	1	202
Manual work, unskilled	1.5	1	138
All	2.2	2	2,747

Notes: Tabulations use the sampling weights.

[8]In this analysis, we consider all the new employees who have joined since 2008. If we only consider the new employees with limited previous experience in the same occupation, the share of employees not switching occupations is slightly higher at 89%.

[9]The explanatory power of the industry dummies (using ten categories corresponding to the first-digit level classification in Danish ISCO) is smaller than that of the occupation-group dummies. Using the industry dummies alone yields the adjusted R^2 of 0.030, while using both the occupation-group dummies and the industry dummies yields 0.071. The coefficients on the industry dummies are mostly not statistically significant.

Given this occupation pattern, it is natural to ask how T_0^{Max} varies with the educational requirements for the jobs. Using the registry data, we examine the correlation between T_0^{Max} and the average education level among the employees in the occupation. To be specific, in the registry data, for each firm, we calculate the average years of education among the employees in the most common occupation identified in the survey. Then we regress T_0^{Max} to the average education level. The estimated coefficient is 0.13, statistically significant with the t-statistic of 6.8. For the jobs held by employees with four more years of education, on average, T_0^{Max} is 0.5 year longer. Hence, these findings support that the jobs requiring more tenure to reach maximal productivity tend to be jobs that are taken by more skilled employees. Once we control for the first-digit level occupation-group fixed effects, the estimate becomes smaller (0.03) and statistically insignificant. Therefore, the correlation between T_0^{Max} and education comes mainly through employees with higher education selecting into occupation groups with high T_0^{Max}.

Productivity Trajectory: Substitutability between Tenure and Experience How much does previous occupation-related experience reduce the amount of tenure needed to reach maximal productivity? Recall that the design of the survey is to ask the respondents how tenure needed to achieve maximal productivity ($T_{\bar{E}}^{Max}$) varies with the relevant previous experience of new employees ($\bar{E}$). Column 1 of Table 4 shows the average responses. Having relevant experience significantly reduces the required tenure to achieve maximal productivity, implying that tenure and experience are substitutes. At the same time, relevant experience is far from being a perfect substitute for tenure. Figure 2 visualizes this relationship shown in the "All" column of Table 4.[10] There are positive but diminishing returns from relevant previous experience. Moving from zero to one year of relevant experience reduces required tenure by about 0.6 year, which is a significant reduction but not close to perfect substitution (i.e., one year of reduction in required tenure, as specified in the red reference line). The slope reduces to negative 0.3 year between 4 and 6 years of relevant experience and to close to zero (negative 0.016 year) for above 7 years of relevant experience. As a result, even when a new employee has at least 10 years of experience, she still needs to be on this job for more than a half year to reach maximal productivity.

This unconditional analysis, however, masks key heterogeneity in the substitutability between tenure and experience across jobs. Subsequent columns in Table 4 and lines in Figure 3 group the jobs by tenure needed for maximal productivity with zero relevant previous experience (T_0^{Max}). For the jobs that require only one year of tenure with no previous

[10]Since previous relevant experience assumed in the question is in categories, we assign the following scalars to each category in the figure: 1.5 years for 1-2 years, 3.5 years for 2-4 years, 7 years for 5-9 years, and 13 years for 10+ years.

Table 4: Tenure needed for maximal productivity ($T_{\bar{E}}^{Max}$) by previous relevant experience ($\bar{E}$)

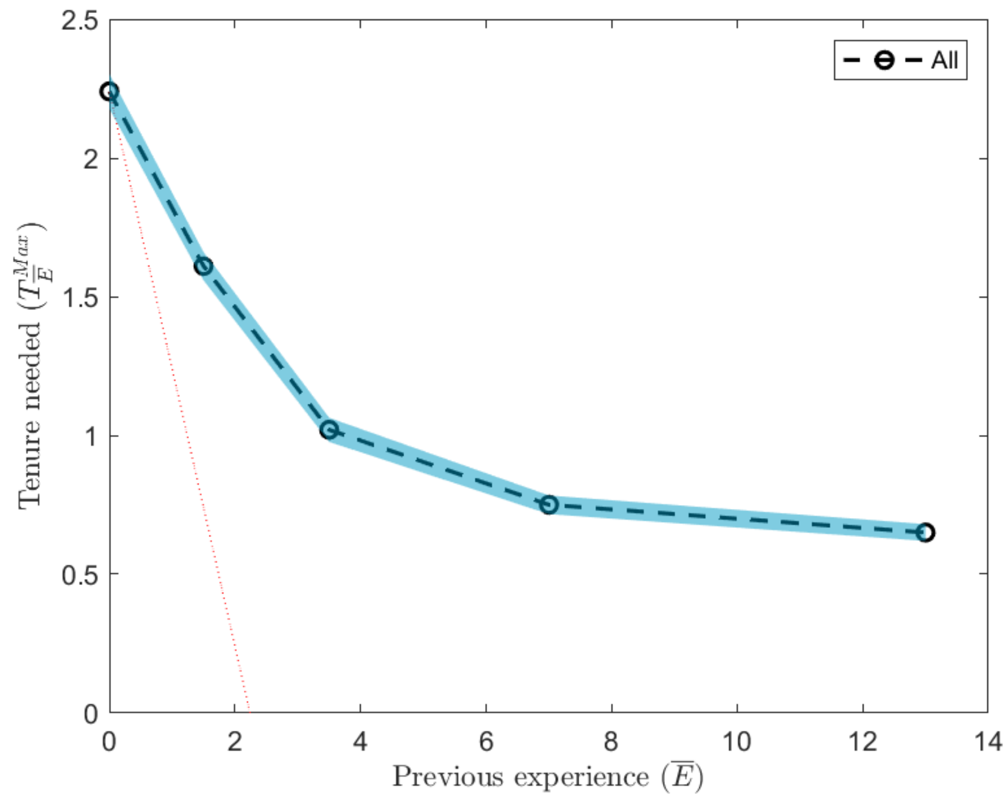
New employees' relevant experience ($\bar{E}$)	All	Jobs by T_0^{Max} 1 year	2 years	3-4 years	5+ years
0 year	2.2	1.0	2.0	3.2	5.9
1-2 years	1.6	0.8	1.5	2.1	4.1
3-4 years	1.0	0.5	0.9	1.3	2.7
5-9 years	0.8	0.5	0.7	0.9	1.6
10+ years	0.7	0.5	0.6	0.8	1.1
N	2,747	1,294	393	764	296

Notes: Tabulations use the sampling weights. Columns subset the jobs by the amount of tenure needed to reach maximal productivity with no relevant previous experience (T_0^{Max}).

relevant experience ($T_0^{Max} = 1$, second column in Table 4 and the bottom curve in Figure 3), relevant experience is not a good substitute for tenure, even at a low level of experience. The first year of experience only replaces 0.13 years of tenure, so the curve is already far from the red 45-degree reference line that implies perfect substitution. For these jobs, even a new employee with at least 10 years of experience still needs 0.5 years of tenure, or 50% of what is needed by someone with no relevant experience. At the opposite extreme are the jobs that require at least five years of tenure with no relevant experience ($T_0^{Max} \geq 5$, the last column in Table 4 and the top curve in Figure 3). For these jobs, the first several years of experience are indeed close to a perfect substitute for tenure. Having 3.5 years of experience, compared to no experience, reduces the amount of tenure needed by 3.2 years. Over this interval, the curve is not statistically significantly different from the reference line for perfect substitution. Additional experience beyond that level replaces less tenure. Overall, the key pattern we find from this analysis is that additional experience adds less to worker productivity when the worker is close to maximal productivity. Qualitatively, this is consistent with the findings from Dustmann and Meghir (2005) that returns to experience are significant among jobs taken by skilled workers (likely to be in the top curve in Figure 3) while they are not significant for jobs taken by unskilled workers (likely to be in the bottom curve in Figure 3). In addition to confirming these patterns, our results also show important dynamics in the substitutability between tenure and experience: The contribution of experience to productivity is comparable to that of tenure at lower levels of experience, but it diminishes significantly with additional experience within each group of jobs.

We also examine heterogeneity by occupation groups. Figure 4 shows the substitutability between tenure and experience for four selected occupation groups from Table 3: jobs that require high-level knowledge, skilled manual labor, sales and service, and unskilled manual

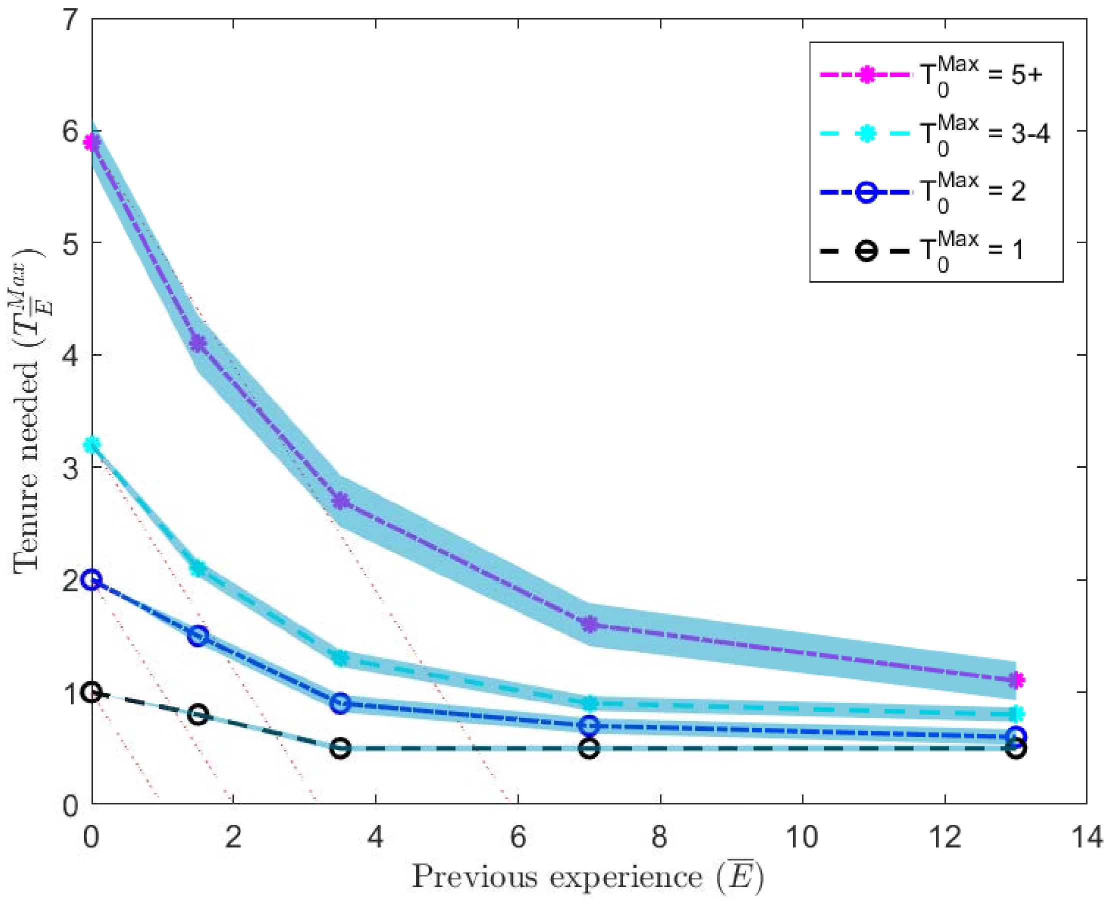
Figure 2: Tenure needed to reach maximal productivity by relevant previous experience: all jobs



Notes: N=2,747. This figure plots the average amount of tenure needed to reach maximal productivity ($T_{\bar{E}}^{Max}$) as a function of previous relevant experience ($\bar{E}$). Since previous relevant experience ($\bar{E}$) assumed in the question is in categories, we assign the following scalars to each category in the figure: 1.5 years for 1-2 years, 3.5 years for 2-4 years, 7 years for 5-9 years, and 13 years for 10+ years. The red line is a reference line for perfect substitution between tenure and previous experience. The shaded area is the 95-percent confidence interval.

labor. These are relatively common occupation groups in this sample. The first group requires the most tenure to reach maximal productivity, the last one requires the least, and the other two are in the middle of the range. We find a similar pattern as in Figure 3. For unskilled manual labor, which requires the least tenure, one year of previous relevant experience reduces required tenure only by 0.25 year even at a low level of experience (less than four years), and the slope becomes effectively zero at higher levels. For the job category that "require high-level knowledge," which is on the other extreme in terms of tenure needed, one year of experience replaces 0.41 year of tenure at a low level of experience (less than four years), and the slope does not become zero even at higher levels of experience. This illustrates

Figure 3: Tenure needed to reach maximal productivity ($T_{\bar{E}}^{Max}$) by relevant previous experience ($\bar{E}$), by tenure needed with no previous relevant experience (T_0^{Max})

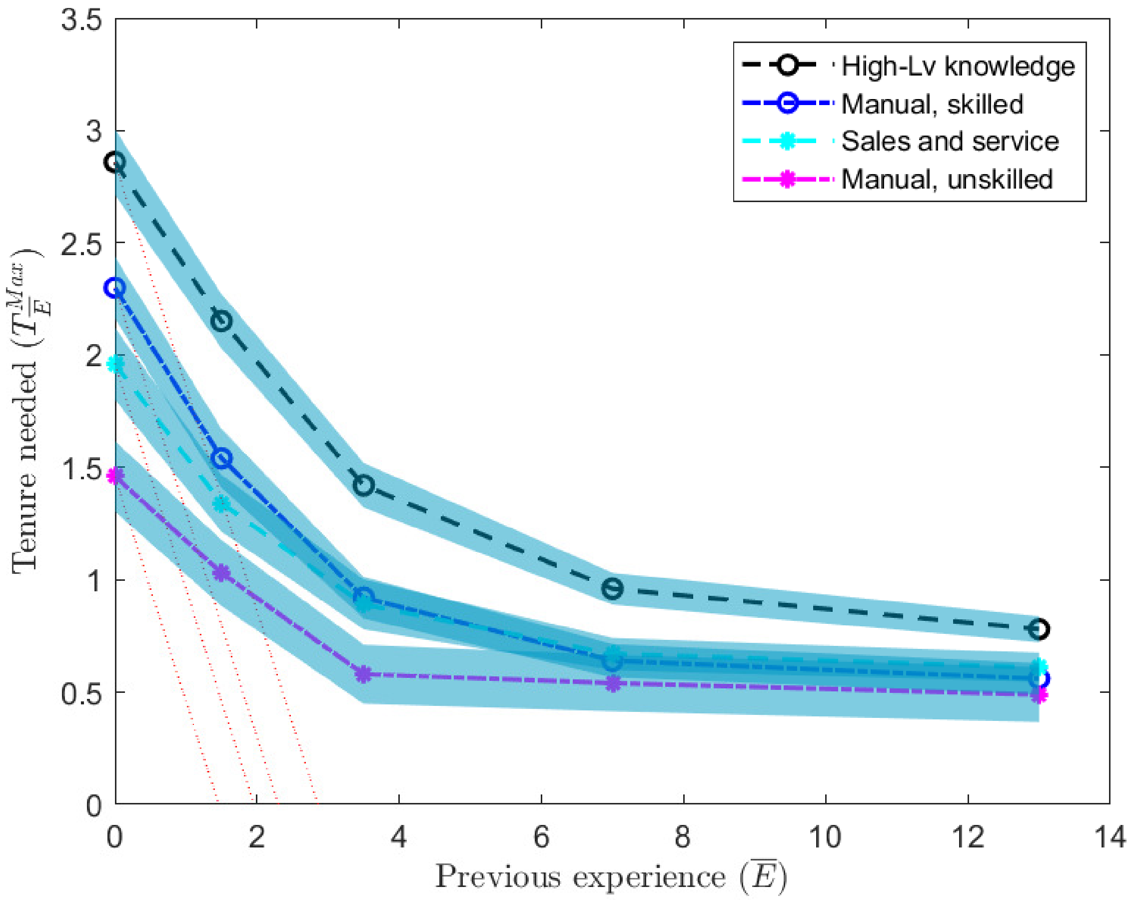


Notes: This figure plots the average amount of tenure needed to reach maximal productivity ($T_{\bar{E}}^{Max}$) as a function of previous relevant experience ($\bar{E}$), by groups of jobs based on the tenure needed with no relevant experience (T_0^{Max}). N = 1,294, 393, 764, and 296 from the bottom to the top curves. The red lines are reference lines for perfect substitution between tenure and general experience. The shaded areas are the 95-percent confidence intervals.

stark differences between occupation groups not only in terms of overall tenure needed but also in the substitutability between tenure and experience. At the same time, heterogeneity by occupation groups in Figure 4 does not fully account for the size of dispersion documented in Figure 3, implying the importance of the within-occupation-group heterogeneity as well.

To summarize our main findings in this section, our survey responses reveal that experience and tenure are substitutes, but there is diminishing returns to experience. The relative contribution of experience diminishes more quickly for the jobs that require less

Figure 4: Tenure needed to reach maximal productivity ($T_{\bar{E}}^{Max}$) by relevant previous experience ($\bar{E}$), by selected occupation groups



Notes: This figure plots the average amount of tenure needed to reach maximal productivity ($T_{\bar{E}}^{Max}$) as a function of previous relevant experience ($\bar{E}$), by selected occupation groups: jobs that require high-level knowledge, skilled manual labor, sales and service, and unskilled manual labor. N = 708, 525, 338, and 138 for each occupation group. The red lines are reference lines for perfect substitution between tenure and general experience. The shaded area is the 95-percent confidence interval.

tenure to reach maximal productivity. The difference across occupation groups can explain a large part of heterogeneity in substitutability, but we also find evidence for significant within-occupation-group heterogeneity. Our findings imply that empirical work on returns to tenure and experience should consider dynamics of the relative contribution of tenure and experience as well as the importance of capturing the across- and within-occupation-group heterogeneities in those dynamics.

2.4 Measuring Wage Dynamics

In addition to the questions on the required tenure to reach maximal productivity, the survey also asks about the wage that the firm is willing to pay to employees with varying levels of tenure and relevant experience. In this section, we present the measured wage trajectories and estimate the wage returns to tenure and experience.

2.4.1 Survey Questions on Wages

So far we have focused on the survey questions about the required amount of tenure for new employees to reach maximal productivity ($T_{\bar{E}}^{Max}$). The survey also asks the wages of the employees that reached maximal productivity as well as the entry wages with different levels of previous relevant experience ($W_{\bar{E},0}$). These questions allow us to quantify the tenure-wage trajectory for various levels of experience. See Appendix B for the question sequence. Note that the questions about wages are asked in parallel with the questions on productivity.

2.4.2 How Wages Vary with Tenure and Experience

We examine the wages that firms are willing to pay to a new employee with various levels of previous relevant experience ($W_{\bar{E},0}$), normalized by the wage of an employee with maximal productivity. Table 5 shows the median wages firms are willing to pay.[11] As expected, firms are willing to pay higher wages to more experienced employees. Also, a new employee with no relevant experience receives a relatively lower wage if the job requires more tenure to reach maximal productivity. In Section 4.2, we show that we find quantitatively similar results from the registry data. Now consider the trade-off between tenure and experience. Recall that T_0^{Max} is the amount of tenure an employee with no relevant experience needs to reach maximal productivity. The responses show that many firms are willing to pay a wage equivalent to what they pay to the employee with maximal productivity if the new employee comes with T_0^{Max} or more years of relevant experience. That is, along the approximate diagonal of Table 5, we find the normalized wage reaches one. Hence, experience is a close substitute for tenure in compensation. In the next section, we will reconcile the difference between wage returns and productivity returns.

[11] We present the medians instead of the averages because the former is less sensitive to outliers that are sometimes extreme in the ratio variables. The averages of the winsorized observations at the 5th and 95th percentiles are not noticeably different from the medians (not reported).

Table 5: Normalized wages by previous relevant experience ($W_{\bar{E},0}$)

New employees' relevant experience ($\bar{E}$)	Jobs by T_0^{Max} 1 year	2 years	3-4 years	5+ years
0 year	0.94	0.89	0.84	0.77
1-2 years	1.00	0.98	0.91	0.84
3-4 years	1.00	1.00	1.00	0.92
5-9 years	1.00	1.00	1.00	1.00
10+ years	1.00	1.00	1.00	1.00
N	1,277	385	754	293

Notes: Wages ($W_{\bar{E},0}$) are normalized relative to the wage of an employee with maximal productivity. Table reports the median wages. Columns subset the jobs by the amount of tenure needed to reach maximal productivity with no relevant previous experience (T_0^{Max}).

2.4.3 Wage Returns to Tenure and Experience

In this section, we use the survey responses about wages to decompose growth in wages into the returns to experience and tenure. This decomposition parallels the decomposition for productivity growth to be presented in the next section. The survey and our analysis focus on the initial years of tenure at the firm while the firm-worker match is building to maximal productivity.

There is, of course, a fundamental problem in separating returns to experience and returns to tenure within a job since they increase together. We now show how to use information collected from our strategic survey questions to separate the returns to experience and the returns to tenure. Recall our notation that $W_{\bar{E},T}$ is the wage to an employee with $\bar{E}$ years of previous experience and T years of tenure. The total experience of this employee is $E = \bar{E} + T$, combining experience from the previous jobs as well as from the current job. Now, consider a new employee with no previous relevant experience, so $\bar{E} = 0$ and $E = T$ will evolve on the job. The entry wage is $W_{0,0}$, while the wage after T_0^{Max}, i.e., after reaching maximal productivity, is $W_{0,T_0^{Max}}$. Then the average per-annum total wage return, R^W, is calculated as

$$R^W = (W_{0,T_0^{Max}} - W_{0,0})/T_0^{Max}. \quad (1)$$

The total wage return, R^W, reflects both returns to general occupation-related experience, R_E^W, and returns to tenure, R_T^W. We can decompose R^W into R_E^W and R_T^W using the following identity. We add and subtract the entry wage $W_{T_0^{Max},0}$ of an employee with relevant experience of T_0^{Max} years, that is, the number of years of tenure it takes for the employee with no relevant previous experience to reach maximal productivity. Specifically,

$$\begin{aligned} R^W &= (W_{0,T_0^{Max}} - W_{0,0})/T_0^{Max}, \\ &= (W_{0,T_0^{Max}} - W_{T_0^{Max},0})/T_0^{Max} + (W_{T_0^{Max},0} - W_{0,0})/T_0^{Max}, \\ &= R_T^W + R_E^W. \end{aligned} \tag{2}$$

Hence, R_T^W is identified by comparing the wage of an employee with no previous experience and T_0^{Max} years of tenure and that of an employee with T_0^{Max} years of previous experience and zero tenure. Both employees have T_0^{Max} years of occupation-related experience; the difference is that it is only the former that has T_0^{Max} years of firm-specific experience. Hence, the wage difference between these two employees measures the wage returns to tenure. On the other hand, R_E^W is identified by comparing the initial wages of an employee with no previous experience and an employee with T_0^{Max} years of previous experience. $W_{T_0^{Max},0}$, $W_{0,0}$, and T_0^{Max} are directly measured from the survey, while $W_{0,T_0^{Max}}$ is normalized to be one. Hence, we can estimate R_T^W and R_E^W for each job.

Table 6 presents the estimates of wage returns across jobs with different T_0^{Max}. Panel A reports the average returns (after winsorizing estimated returns at the 5th and 95th percentiles) while Panel B reports the median returns. In terms of the overall size of the estimates, our results fall in the range of the estimates from the literature. For example, Williams (2009) estimates the return to experience to be about 2% per year while the return to tenure to be less than 1% per year. On the other hand, Dustmann and Meghir (2005) estimates them to be larger, in particular in the earlier part of workers' career: 6-10% per year for the return to experience and 2-4% per year for the return to tenure. Our estimates, both the winsorized average and the median, fall into this range. Our results also reproduce key qualitative patterns found in the literature. Williams (2009) finds that returns to experience dominate returns to tenure. We find the same pattern for almost all the groups considered, except for the average estimate for the jobs that require one year of tenure to reach maximal productivity. Dustmann and Meghir (2005) finds that tenure is relatively more important for unskilled workers while the relative importance of experience is larger for skilled workers. Given that the jobs that require more tenure to reach maximal productivity are likely to be taken by skilled workers (as suggested by Table 3), our estimates show the exactly the same pattern.

Overall, the fact that we find similar patterns in wage returns compared to the literature using a different measurement and identification strategy is reassuring. At the same time, tenure and experience appearing to be much more substitutable in compensation (Table

Table 6: Wage returns to tenure and experience

	Jobs by T_0^{Max}			
	1 year	2 years	3-4 years	5+ years
A. Average estimates				
Total return ($R^W = R_T^W + R_E^W$)	8.9	7.0	5.4	4.6
Return to tenure (R_T^W)	4.8	2.7	1.6	1.1
Return to experience (R_E^W)	4.1	4.3	3.8	3.5
B. Median estimates				
Total return ($R^W = R_T^W + R_E^W$)	4.8	4.4	4.0	3.5
Return to tenure (R_T^W)	2.0	0.7	0.7	0.5
Return to experience (R_E^W)	2.8	3.7	3.3	3.0
N	1,277	385	754	293

Notes: All the numbers presented are in percentages. Wage returns to tenure and experience are estimated based on equation (2). The estimated returns are for the initial period of work at the firm, before reaching maximal productivity, and per annum. The average estimates in Panel A are calculated after winsorizing outliers at 5 and 95 percentiles. Columns subset the jobs by the amount of tenure needed to reach maximal productivity with no relevant previous experience (T_0^{Max}).

5) than in productivity (Figure 3) makes us suspect that wages are not proportional to worker productivity. To investigate this issue, we construct a stylized model of dynamic wage contracts and estimate it using the survey responses in the next section.

3 Productivity Returns to Tenure and Experience

3.1 Model Specification

In this section, we combine responses about wage and productivity trajectories in order to quantify the returns to tenure versus experience. As is well understood, and is stressed in introduction, in firms with long-term employment arrangements, the time path of wages does not necessarily equal the time path of productivity. In this section, we compare the time path of both, based on the survey responses. We also impose the constraint that the expected discounted present value of productivity equals that of wages. These calculations allow us to compare the productivity returns with wage returns to tenure and experience. To preview our results, the productivity returns to tenure are about two to three times larger the wage returns to tenure.

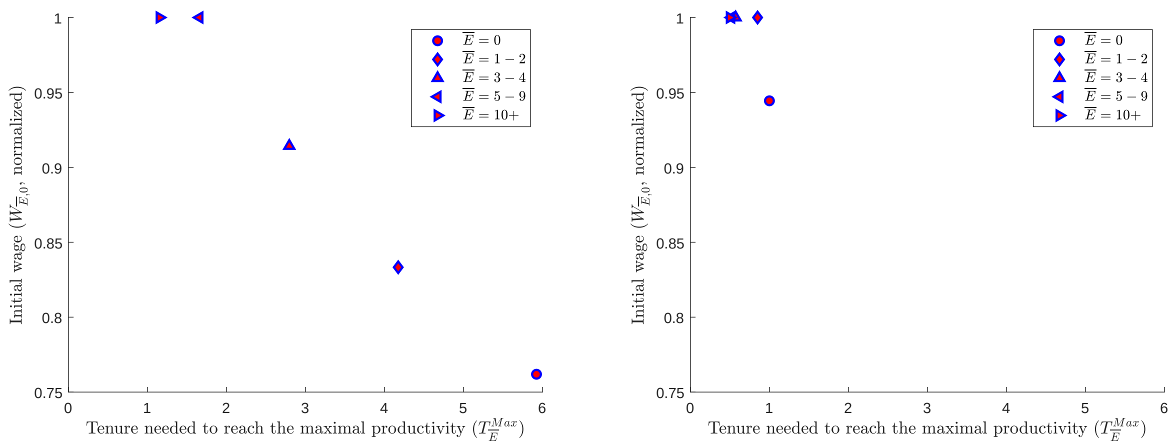
To illustrate that wages may not be proportional to productivity, in Figure 5, we show the scatter plots between the average tenure needed to reach maximal productivity ($T_{\bar{E}}^{Max}$, the horizontal axis) and the median initial wage for new employees ($W_{\bar{E},0}$, normalized by the wage to an employee with maximal productivity, the vertical axis) with varying levels of previous relevant experience ($\bar{E}$). In each panel, the right-most marker corresponds to those with no relevant experience ($\bar{E} = 0$), followed by those with 1-2 years, 3-4 years, 5-9 years, and at least 10 years of experience. Panel (a) shows this relationship for the jobs that require at least 5 years of tenure to reach maximal productivity for new employees with no relevant experience (i.e., $T_0^{Max} \geq 5$). The normalized wage firms are willing to pay increases with the level of relevant experience, and it is overall negatively correlated with the amount of tenure needed to reach maximal productivity. At the same time, when new employees have significant previous relevant experience, they still need a non-negligible amount of tenure to reach maximal productivity but firms are willing to pay the same wage as what they pay to the employees with maximal productivity. For example, new employees with 5 to 9 years of experience still need about 2 years of tenure to reach maximal productivity, but their initial wage is already the same as that of an employee with maximal productivity (second from the left). This clearly indicates that wages are not spot prices and therefore not proportional to the current productivity. One possible explanation could be that firms anticipate these employees staying for a number of years and front-load some of the productivity gains in the initial wage.[12] In Panel (b), we find the same pattern for the jobs that require the least amount of tenure to reach maximal productivity (i.e., $T_0^{Max} = 1$). Though experienced new employees still need some tenure to reach maximal productivity, at the median they receive the same wage.

To allow for distinctive paths of productivity and wages, we set up a stylized model of dynamic wage contracts. This stylized model is a general conceptual framework presented in Figure 1 embedded with the following restrictions that are useful for parameterizing the survey responses: (i) productivity curves are log-linear with a slope that is common across $\bar{E}$; (ii) maximal productivity does not vary with $\bar{E}$; (iii) the expected present value of productivity equals that of wage, where both of them are normalized with respect to their maximal levels.

[12] While our findings are consistent with a wage trajectory that is flatter than the productivity trajectory, there are theories that imply the opposite including Lazear's prominent theory that low initial wages serve as a bond (Lazear, 1979). On the other hand, most theories where employers bear the costs of on-the-job training suggest that productivity should rise more rapidly than wages (e.g., Becker, 1964, Acemoglu and Pischke, 1998, 1999, and Barron, Berger and Black, 1999). As discussed in Section 2, our framework does not impose that wages are flatter than productivity, so our finding is a result, not an assumption.

Figure 5: Wage not proportional to productivity

(a) 5+ years of tenure needed ($T_0^{Max} \geq 5$) (b) 1 year of tenure needed ($T_0^{Max} = 1$)



Note: The scatter plots show the average tenure required to reach maximal productivity ($T_{\bar{E}}^{Max}$, the horizontal axis) and the median initial wage ($W_{\bar{E},0}$, normalized by the wage for an employee with maximal productivity, the vertical axis) for new employees with varying levels of previous relevant experience ($\bar{E}$). For each panel, the right-most marker corresponds to those with no relevant experience, followed by those with 1-2 years, 3-4 years, 5-9 years, and at least 10 years of experience. Panel (a) is for the jobs that require at least 5 years of tenure to reach maximal productivity for those with no relevant experience (i.e., $T_0^{Max} \geq 5$). Panel (b) is for the jobs that require 1 year of tenure (i.e., $T_0^{Max} = 1$).

To be specific, recall that we define $P_{\bar{E},T}$ and $W_{\bar{E},T}$ as the productivity and wage of an employee with T years of tenure and $\bar{E}$ years of previous relevant experience. Throughout, both $P_{\bar{E},T}$ and $W_{\bar{E},T}$ are normalized by setting the respective maximal level to one. Hence, though productivity and wage are in different units, our measures of them are comparable. Productivity reaches maximal level after $T_{\bar{E}}^{Max}$ years of tenure by definition. Wages reach that level later in the model. This is similar to the example illustrated in Figure 1. We assume that the normalized productivity and wage paths satisfy the following break-even condition

$$\int_0^{\infty} [P_{\bar{E},T} - W_{\bar{E},T}] e^{-(\lambda_T^O + r)T} dT = 0, \tag{3}$$

where λ_T^O is the separation rate by occupation group (O) and tenure (T) and r is the discount rate. This condition disciplines the timing of compensation compared to that of productivity.[13] For example, the condition implies that if compensation is front-loaded compared to

[13] Bils, Kudlyak and Lins (forthcoming) also impose a long-run restriction to discipline the relationship between wage and productivity.

productivity, as indicated in Figure 5, the growth rate of wage should be smaller than the growth rate of productivity. Note that since the condition is based on normalized variables, it does not impose any restrictions on the level of total compensation compared to that of productivity.[14]

We assume that productivity increases log-linearly until it reaches maximal productivity:

$$log(P_{\bar{E},T}) = -R^P \times Max(T_{\bar{E}}^{Max} - T, 0), \tag{4}$$

where R^P is the total productivity return (i.e., the annual growth rate in productivity). Note that maximal productivity is normalized to be one.

The wage path is also assumed to be log-linear:

$$log(W_{\bar{E},T}) = log(W_{\bar{E},0}) \times \frac{Max(T_{\bar{E}}^{Max,W} - T, 0)}{T_{\bar{E}}^{Max,W}}, \tag{5}$$

where the highest level of wage is the same as maximal productivity (one) and $T_{\bar{E}}^{Max,W}$ is the tenure needed for a new employee with $\bar{E}$ years of previous relevant experience to reach the that level of wage. Note that $T_{\bar{E}}^{Max,W}$ can be different from $T_{\bar{E}}^{Max}$ as the productivity and wage paths are allowed to be distinct. Given the productivity path, and given the initial level of wage, $W_{\bar{E},0}$, the break-even condition (3) will endogenously determine $T_{\bar{E}}^{Max,W}$, and hence the entire wage path. Recall that the survey asks initial wages in Danish Kroner (DKK). To convert wages into units comparable to productivity, we normalize these wage responses by the reference wage (i.e., the wage associated with maximal productivity for an employee with no experience, see Section 2.4) adjusted for the front-loading implied by the model. To be specific, initial wages in the survey are converted to model units as

$$W_{\bar{E},0} = W_{\bar{E},0}^{DKK} \times \frac{W_{0,T_0^{Max}}}{W_{0,T_0^{Max}}^{DKK}}, \tag{6}$$

where $W_{\bar{E},0}^{DKK}$ and $W_{0,T_0^{Max}}^{DKK}$ are initial and reference wages in DKK and $W_{0,T_0^{Max}}$ is the reference wage in the model unit. With front-loading, $W_{0,T_0^{Max}}$ can be less than one.

We express the initial wage, $W_{\bar{E},0}$, as

$$W_{\bar{E},0} = (1 + x)P_{\bar{E},0}. \tag{7}$$

[14]For example, allowing for rent-sharing by adjusting the entire wage path by the same factor will not affect our model as it does not change normalized wages.

We call x the front-loading factor: If it is positive, then the initial wage is above initial productivity, while that will result in slowly-increasing wage compared to productivity to satisfy the break-even condition (3). Note that we do not constrain x to be positive, so the model allows for the possibility of back-loaded wages as well.

The equations of the model specified in this section map directly into the hypothetical wage and productivity trajectories introduced in Figure 1. The solid line correspond to productivity trajectories and the dashed lines to wage trajectories for two different employee-job matches. In the next subsection, we discuss how we estimate productivity returns based on survey moments, calibrated parameters, and the model.

3.2 Model Calibration and Estimation

We set the firm discount rate, r, to be 4 percent per year.[15] We calibrate the occupation group and tenure specific separation rates λ_T^0 from the registry data.[16] The years of tenure needed to reach maximal productivity ($T_{\bar{E}}^{Max}$) and the initial wages ($W_{\bar{E},0}$) are from the survey.

The value of x is not uniquely identified. To explain the cases where new employees receiving the same wage as those with maximal productivity while not currently having maximal productivity (Figure 5), we need a certain level of front-loading in the wage, putting a lower bound on x. We choose the smallest value of x that is consistent with this pattern for all the job groups. This value of x is 7%.[17]

Then we estimate R^P, the total productivity return, conditional on this calibrated value of r, λ_T^0, and x. The estimation of R^P is separately done for jobs grouped by tenure needed to reach maximal productivity with no previous relevant experience (T_0^{Max}). We estimate R^P

[15]Because the separation rate dominates, the calculations are not sensitive to reasonable alternative discount rates.

[16]We used employees with age 35-54 to be consistent with what we assume in the survey and abstract from weaker labor market attachment at the beginning and the end of employees' career. See Appendix D for the estimated separation rates. The estimated separation rates are decreasing functions of tenure. The separation rates are particularly higher for employees with less than one year of tenure, which may partly reflect screening that is not the focus of this paper. Hence, for $T < 1$, we replace the estimated separation rates with the extrapolation based on those with $T \in [1, 3]$. Using the original estimates for the separation rates with $T < 1$ does not make a noticeable change in the result.

[17]Beyond the calibrated level, any value of x can be consistent with the survey observations of the wages, with a corresponding adjustment in R^P (given the observed wages, the larger x is, the lower the initial productivity should be, i.e., the larger R^P should be).

by minimizing the squared residuals summed over the firms and levels of previous relevant experience

$$D = \sum_{i=1}^{N} \sum_{\bar{E} \in 0,1.5,3.5,7,13} (W^{s,i}_{\bar{E},0} - W^{m,i}_{\bar{E},0})^2 \times (1/Var_{\bar{E}}), \tag{8}$$

where N is the number of the firms, $W^{s,i}_{\bar{E},0}$ is the initial wage reported in the survey by the firm i for $\bar{E}$ years of relevant experience, $W^{m,i}_{\bar{E},0}$ is the corresponding initial wage generated by the model, and $Var_{\bar{E}} \equiv Var(W^{s,i}_{\bar{E},0})$ is the variance of the initial wage in the survey conditional on $\bar{E}$ years of relevant experience.

Table 7 (Panel A) presents the estimates of the productivity return over each year of tenure before reaching maximal productivity, R^P. It varies between 7%-12% per year, with greater annual (though less cumulative) productivity growth for jobs that take fewer years to achieve maximal productivity on the job.[18]

Figure 6 illustrates the estimated productivity and wage paths with median survey responses by jobs grouped by T_0^{Max}. In each panel, the yellow circle is the reference wage ($W_{0,T_0^{Max}}$) from the model.[19] The red circles represent median wages paid to new employees with varying levels of relevant experience from the survey, converted to unit comparable to productivity by equation (6) ($W_{\bar{E},0}$). The bottom red circle in each figure represents those with no relevant experience, followed by more experienced ones in order. The red triangles represent productivity after those new employees gain the required tenure to reach maximal productivity. For these triangles, the horizontal axis presents the required tenure needed to reach maximal productivity ($T_{\bar{E}}^{Max}$, from Table 2), while the vertical axis presents maximal productivity normalized to be one. The curves are the productivity and wage paths implied by the estimated model. The solid curves are the productivity paths over tenure, illustrating how new employees eventually arrive at those red triangles. The dashed curves are the wage paths.

Let us take an example of jobs that require at least five years of tenure to reach maximal productivity for new employees with no previous relevant experience ($T_0^{Max} \geq 5$, Panel (d)). Imagine that there is no front-loading, i.e., $x = 0$, so that wages are proportional to productivity. Then the wage paths should be identical to the productivity curves, meaning that each productivity/wage path should start close to the corresponding red circle when tenure is zero and end at the corresponding red triangle when it reaches the required tenure.

[18]Under a larger value of x, the estimated R^P will be larger.

[19]Recall that this wage level is different from the highest wage in the model. Given the front-loading of wage, wage grows slower than productivity, so it takes longer for the wage than for the productivity to reach its highest level (i.e., $T_{\bar{E}}^{Max,W} > T_{\bar{E}}^{Max}$).

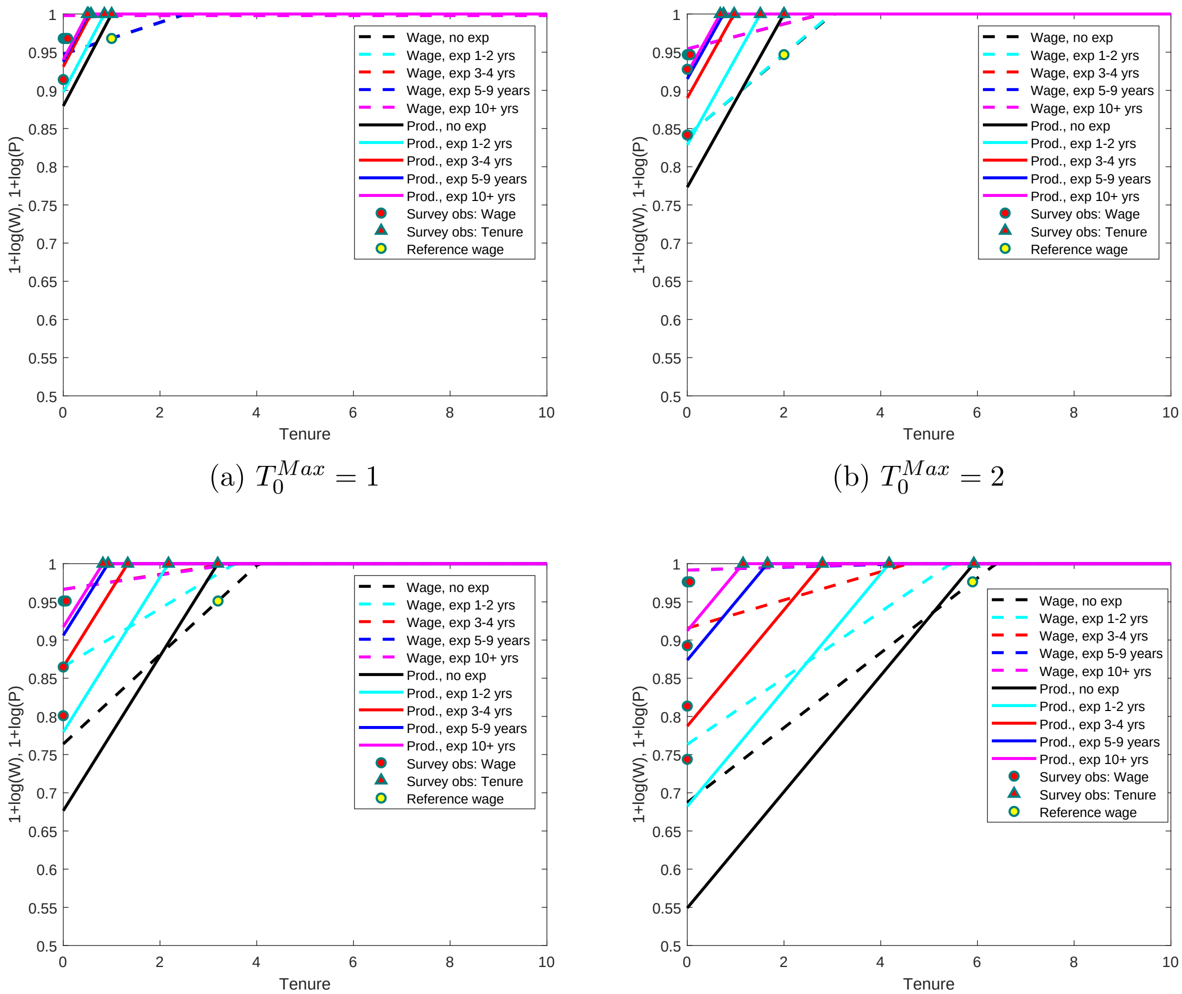
Table 7: Model estimates and decomposition into returns to tenure and experience

	Jobs by T_0^{Max}			
	1 year	2 years	3-4 years	5+ years
A. Total productivity return (GMM estimate)				
$R^P = R^P_T + R^P_E$	12.0	11.3	10.1	7.6
	(3.4)	(2.6)	(1.1)	(1.3)
B. Decomposing productivity return				
To tenure (R^P_T)	10.8	7.8	4.8	3.0
To experience (R^P_E)	1.2	3.5	5.4	4.6
C. Decomposing wage return (from Table 6)				
To tenure (R^W_T)	4.8	2.7	1.6	1.1
To experience (R^W_E)	4.1	4.3	3.8	3.5
N	1,277	385	754	293

Notes: All the numbers presented are in percentages. Returns to tenure and experience are for the initial period of work at the firm, before reaching maximal productivity, and per annum. Columns group the jobs by the amount of tenure needed to reach maximal productivity with no relevant previous experience (T_0^{Max}).
Panel A reports the estimates from the model of dynamic wage contracts ((3) - (7)) that allows for the wage path being different from the productivity path while imposing that the expected present-value of the two should be the same. The front-loading factor (x) is calibrated to be 7%, the smallest value that creates the front-loading patterns observed in Figure 5. The productivity slope is estimated conditional on the calibrated value of x as well as the estimated job separation rate from the registry data (Appendix D). The estimates are obtained by minimizing (8), with the standard errors reported in the parentheses.
Panel B decomposes the estimated productivity slope (R^P) into the productivity returns to tenure (R^P_T) and experience (R^P_E) using equation (9).
Panel C reproduces the wage returns estimated using the wage responses alone, reported in Table 6 Panel A, for comparison.

But under the assumption that R^P is constant with respect to tenure and experience, i.e., the productivity paths are parallel, it is not possible to draw such five parallel lines. In particular, we cannot produce productivity paths that explain the top two red circles, where firms are paying the almost full wage to new employees that need one or two years of tenure to reach maximal productivity. With $x > 0$, however, the starting point of the wage path becomes higher than the starting point of the productivity path, allowing us to bring the former close to the red circles. As a result of front-loading, the initial productivity of new employees is lower than what is implied by the initial wages. We also find the same pattern in all the other panels.

Figure 6: Estimated paths of productivity and wage across jobs



(a) $T_0^{Max} = 1$

(b) $T_0^{Max} = 2$

(c) $T_0^{Max} = 3, 4$

(d) $T_0^{Max} = 5+$

Notes: Each panel represents the estimated productivity and wage paths by jobs grouped by the amount of tenure needed to reach maximal productivity with no previous experience (T_0^{Max}). The yellow circle is the reference wage ($W_{0,T_0^{Max}}$). The red circles are median initial wages from the survey normalized as in equation (6) ($W_{\bar{E},0}$). They are ordered with the least previous experience ($\bar{E} = 0$) at the bottom. The red triangles are the tenure needed to reach maximal productivity ($T_{\bar{E}}^{Max}$). They are ordered with the least previous experience ($\bar{E} = 0$) in the most right. The curves are the implied paths of productivity (solid) and wage (dashed) from the estimated model.

Given that we have estimated the productivity path that is distinct from the wage path, we can now calculate the productivity returns to tenure and experience and compare them to the wage returns, for the initial period of work at the firm before reaching maximal productivity. In parallel to our wage return estimation, we decompose productivity growth rate per each year of tenure into the productivity returns to tenure (R_T^P) and experience (R_E^P) using the following identity:

$$\begin{aligned} R^P &= (P_{0,T_0^{Max}} - P_{0,0})/T_0^{Max}, \\ &= (P_{0,T_0^{Max}} - P_{T_0^{Max},0})/T_0^{Max} + (P_{T_0^{Max},0} - P_{0,0})/T_0^{Max}, \\ &= R_T^P + R_E^P. \end{aligned} \tag{9}$$

Our estimated model pins down the productivity of new employees with varying previous experience, $P_{0,0}$ and $P_{T_0^{Max},0}$, while $P_{0,T_0^{Max}}$ is normalized to be one, allowing for the estimation of R_T^P and R_E^P.

Table 7 (Panel B) reports the estimated productivity returns to tenure and experience. Panel C of Table 7 reproduces the wage returns to tenure and experience reported in Table 6 for ease of comparison. As expected from the front-loading of wage and the steeper slope of the productivity path (compared to the wage path), the estimated productivity return to tenure is much larger than the wage return to tenure, while the returns to experience are similar. The difference between the productivity and wage returns to tenure is substantial. The productivity return to tenure is about two to three times larger than the wage return to tenure across the job groups. Overall, the weighted average of the productivity return to tenure (across job groups) is 7.9% per year, while that of the wage return to tenure is 3.2% per year.

The larger productivity return, compared to the wage return, to tenure implies that using observed wage alone may underestimate the loss of productivity due to turnover in the labor market. For example, imagine a firm which had to replace an employee who has worked for five years (with no previous relevant experience) with another employee who has five years of relevant experience, for a job with $T_0^{Max} \geq 5$ (the last column in Table 7). The productivity loss from this transition, at the moment of the replacement, is 15.0% (3.0% per year times 5 years) according to the productivity returns. But it is only 5.5% (1.1% per year times 5 years) if one infers it from the observed wages.

This section demonstrated how one can use a firm survey to measure worker productivity, an object that is distinctive from the observed wages and cannot be typically inferred directly from market outcomes. Though the estimates of the parametric model require auxiliary assumptions (e.g., assuming the productivity return to tenure being constant and common for all levels of relevant experience), it is readily apparent in the raw survey responses (Figure 5) that productivity returns to tenure are substantially greater than wages returns.

4 Comparing Survey Responses with the Registry Data

We validate the survey responses by comparing them to the corresponding records in the registry data. For the most common occupation at each firm as well as the wages paid to the employees with varying levels of tenure and previous relevant experience, the registry data have corresponding records, allowing for this comparison.

4.1 Most common occupation

Survey responses on the most common occupation are well aligned with the most common occupations in the registry data. The columns of Table 8 show the distributions of the most common occupations from the registry data matched at the firm level. The modal most common occupation in the registry data (shaded) is the one reported in the survey (i.e., on the diagonal line), except for the management category that has the least observations. In addition, for the cases that are not on the diagonal line, many of them are in categories that are similar. For example, the most common off-diagonal entry for the occupation category "require a high level of knowledge" (row 2) is the category "require a medium level of knowledge," and vice versa. The last column shows the percent of responses for each row where there is exact alignment between the survey response and registry data. The broad alignment of survey and registry occupations is initial confirmation that survey respondents understand the target of the survey at a high level.

Table 9 revisits the relationship between the tenure needed for maximal productivity with no previous experience (T_0^{Max}) and occupation groups, this time also considering the occupation groups identified in the registry data. Panel A is the reproduction of Table 3, which uses the most common occupation reported in the survey. Panel B uses the most common occupation from the registry data. We use the same ordering of the rows as in Panel A. We find a similar pattern between the two panels. The occupation group that demands the most tenure (jobs requiring high-level knowledge) and that demands the least tenure (unskilled manual work) are identical between the two panels. The only differences are that the ranking between management and jobs that require medium-level knowledge as well as that between sales and service and office and customer services are flipped.[20]

[20]Overall dispersion in the average tenure needed is smaller in Panel B. The adjusted R^2 from the regressions is also smaller when the occupation-group dummies from the registry data are used (0.031) than that based on the occupation-group dummies from the survey (0.059). Overall, these results show that the occupation group identified from the registry data is a noisier measure—than what is reported in the survey—of the occupation that the respondent had in mind during the survey.

Table 8: Most common occupations

Survey	N	Registry 1	2	3	4	5	6	7	8	9	unknown	% exactly aligned
1. Management	119	5	16	11	7	26	6	13	2	16	17	4.2
2. Require high knowledge	701	12	308	133	65	36	6	50	15	17	59	43.9
3. Require medium knowledge	404	12	78	100	56	35	6	45	16	22	34	24.8
4. Office & customer services	192	3	20	42	54	21	0	5	6	29	12	28.1
5. Sales & service	338	5	14	49	32	105	1	31	15	44	42	31.1
6. Farming	126	1	5	1	4	9	43	6	4	15	38	34.1
7. Manual labor, skilled	525	1	8	14	10	29	9	320	22	57	55	61.0
8. Operator and assembly	202	1	1	8	16	6	0	39	100	23	8	49.5
9. Manual labor, unskilled	138	1	5	5	15	14	10	12	17	44	15	31.9
Unknown	2							1		1		

Notes: The first two columns in this table report the distribution of the most common occupation, at the first-digit level in Danish ISCO, based on the survey responses. The next ten columns are cross-tabulations between the most common occupations from the survey and the registry data, with the cell with the most observations in each row shaded. The last column reports the fraction of firms in each row where the most common occupation from the registry data belongs to the same occupation group as the most common occupation from the survey (using the sampling weights).

4.2 Wages to new employees

To validate the wage measures from the survey, we show that there is a strong correlation between the normalized wages to new employees with limited previous relevant experience from the survey ($W_{0,0}$, the first line of Table 5) and the corresponding measure from the registry data.

Figure 7 is a binned scatter plot of wages from survey versus registry data, both normalized relative to the wage of an employee with maximal productivity. Each dot in the figure corresponds to a group of jobs by tenure needed to reach the maximum productivity with no relevant experience (T_0^{Max}, corresponding to columns in Table 5). The horizontal axis shows the averages of normalized wages for each group from the survey, winsorized at the 5th and 95th percentiles. The normalized wages to new employees in the registry data, on the vertical axis, are constructed in the following way. We use the employees in the same first-digit level occupation as the most common occupation reported in the survey. We use the observations from 2018, which is the most recent wave available in the registry data, and we use the averages from up to 12 monthly observations for each firm-employee pair. We include those with ages between 25 and 55 who have little experience (less than 2 years) in the first-digit level occupation before joining the current firm to make it comparable to the

Table 9: Tenure (T_0^{Max}) needed for maximal productivity by occupation group

A. Occupation group (survey)	**Avg T_0^{Max} needed**	**Median T_0^{Max} needed**	**N**
Require high knowledge	2.9	3	701
Management	2.3	2	119
Farming	2.3	2	126
Manual labor, skilled	2.3	2	525
Require medium knowledge	2.2	2	404
Sales & service	2.0	1	338
Office & customer services	1.8	1	192
Operator and assembly	1.6	1	202
Manual work, unskilled	1.5	1	138

B. Occupation group (registry)	**Avg T_0^{Max} needed**	**Median T_0^{Max} needed**	**N**
Require high knowledge	2.7	3	455
Management	2.1	2	41
Farming	2.3	2	81
Manual labor, skilled	2.3	2	522
Require medium knowledge	2.6	2	363
Sales & service	1.9	1	281
Office & customer services	2.0	2	259
Operator and assembly	1.9	1	197
Manual work, unskilled	1.9	1	268

Notes: Tabulations use the sampling weights.

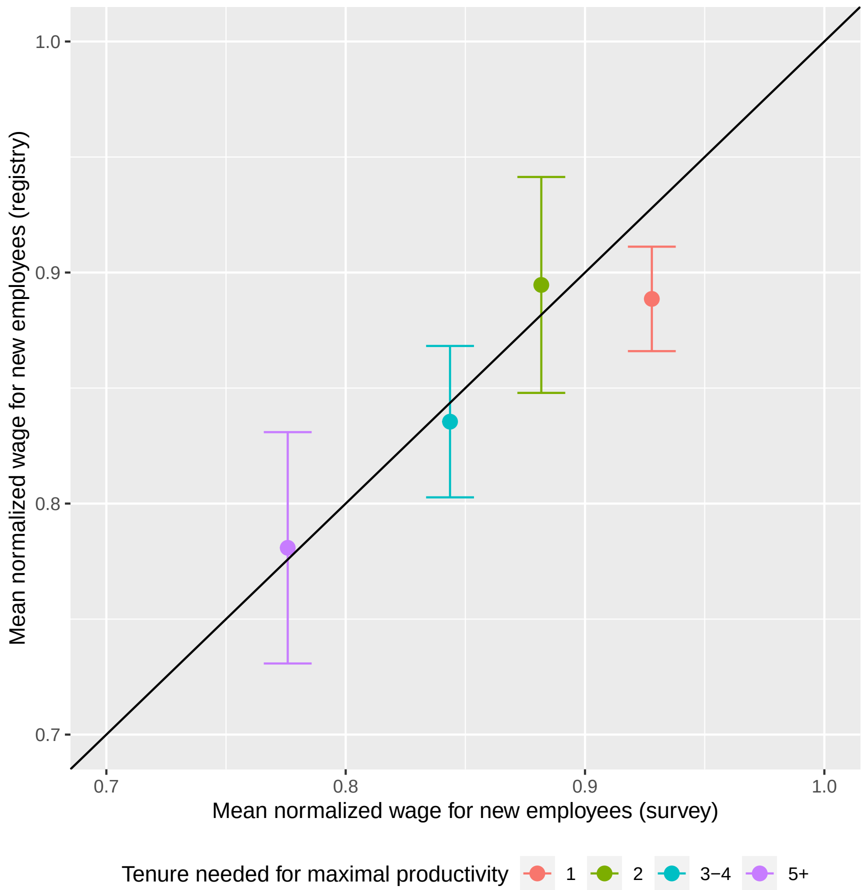
situation assumed for the first line in Table 5.[21] Then within each firm, we calculate the ratio between the average wages paid to new employees, defined as having tenure less than two years, to that paid to employees with high tenures, defined as having more than four years of tenure.[22] The vertical axis in the figure shows the averages of these ratios across firms within each group, again winsorized at the 5th and 95th percentiles. The bars around the points are the 95% confidence intervals of the mean estimates. Note that, for reliable measurement of the normalized wage in the registry data, we include only those firms with at least five employees with low tenure and at least five employees with high tenure who also satisfy the age condition (between 25 and 55) and have little relevant experience in the

[21] We condition on having little relevant experience instead of having zero as assumed for the first line in Table 5 to keep enough observations in the analysis.

[22] Note that we apply the same threshold for high tenure for all the groups. If we define it as having more than T_M years of tenure, which varies across the groups, we may capture the mechanical relationship coming from seniority payment. The observed patterns are robust to using larger than four years as a common threshold and to using T_M as the threshold for each group (Appendix C).

same occupation. As a result, 494 out of 2,747 firms that are surveyed are included in this analysis. The confidence intervals nonetheless indicate that the sample size is large enough to yield precise inferences.

Figure 7: Normalized wages for new employees ($W_{0,0}$): survey versus registry data



Notes: This figure compares the normalized wage to new employees ($W_{0,0}$) from the survey (horizontal axis) and that from the registry data (vertical axis) by groups of jobs by tenure needed to reach maximal productivity with no previous relevant experience (T_0^{Max}). The normalized wage in the survey is the wage of a new employee with no relevant experience normalized relative to the wage of an employee with maximal productivity. The normalized wage in the registry data is the average wage of new employees (those with less than 2 years of tenure) normalized relative to the average wage of employees with high tenure (more than 4 years). We only use employees that are between 25 and 55 years old, in the same first-digit occupation as the most common occupation reported in the survey, and have less than 2 years of relevant experience. The position of each dot shows the average for each group, winsorized at the 5th and 95th percentiles. The bars indicate the 95%-level confidence intervals of the mean estimates from the registry data. 494 firms are included in the analysis.

There is a strong correlation between the survey measures and the observations from the registry. The averages of both measures are almost identical, as they are very close to the 45-degree line. Only for the group with $T_0^{Max} = 1$, the null of the averages of the two measure being identical is rejected, but the magnitude of the deviation from the 45-degree line is small at around 2 percentage points. Also, the pattern that the new employees receive a relatively lower wage with a higher T_0^{Max} is clearly visible in both measures. In fact, the average normalized wage to new employees is statistically significantly lower for groups of jobs that need more tenure to reach maximal productivity, except for between the groups with $T_0^{Max} = 1$ and $T_0^{Max} = 2$. These findings render support to the credibility of the survey responses on both the tenure needed to reach maximal productivity and how the wages firms are willing to pay vary by tenure and experience.

5 Conclusion

This paper quantifies how worker productivity evolves with general experience and on-the-job tenure in a representative sample of occupations and firms. Measuring productivity trajectories at the worker level is difficult for several reasons. First, worker-level productivity is rarely directly measured in observational data. Second, marginal product need not equal wages period-by-period in long-term employment relationships. Third, an extra year of tenure also provides an extra year of general experience.

The paper addresses these issues by eliciting how productivity and wages grow with on-the-job tenure and occupation-related experience in a survey of managers in a representative sample of firms. Managers are asked how long it takes a new hire to become maximally productive and how that time is affected by the hire's previous experience. The paper uses administrative data in tandem with the survey to support the analysis—for assuring that the sample is representative, for validating the survey responses, and for measuring variables that are combined with survey responses to estimate a simple model linking the trajectory of productivity and wages.

The paper thus advances a method for estimating parameters critical for understanding the value of firm-worker matches. Several salient findings emerge from our analysis. Previous experience is a substitute, though an imperfect one, for experience on the job. For jobs that require a long time to reach maximal productivity, previous experience is a good substitute for on-the-job experience. Additionally, the trajectory of wages is much flatter than the trajectory of productivity on the job. Specifically, during the initial period of employment before a new hire reaches maximal productivity, the productive return to tenure is three times the wage return to tenure. These results are therefore useful for understanding, among other things, the costs of job turnover resulting from both exogenous separations and endogenous response to business cycle and other shocks.

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A Appendix: Sampling and Response Analysis

Table A1: Population of Danish firm with 5+ employees by size and industry

Industry	5-9	10-49	50-199	200+	Total
Agriculture, forestry and fishing	1,557	705	44	4	2,310
Business service	2,952	2,526	506	132	6,116
Construction	3,329	2,698	347	51	6,425
Culture and sports	1,220	942	147	28	2,337
Finance and insurance	352	337	103	67	859
Information and communication	1,109	1,099	238	52	2,498
Manufacturing, raw materials	1,935	2,563	748	239	5,485
Public, teaching and health	844	369	13	4	1,230
Real estate and rental	627	287	35	9	958
Trade and transport	8,085	6,525	963	250	15,823

Table A2: Number of invited firms by size and industry

Industry	5-9	10-49	50-199	200+	Total
Agriculture, forestry and fishing	500	250	25	0	775
Business service	851	799	353	79	2,082
Construction	1,050	850	222	32	2,154
Culture and sports	452	348	101	21	922
Finance and insurance	150	150	82	52	434
Information and communication	453	398	154	39	1,044
Manufacturing, raw materials	632	799	500	150	2,081
Public, teaching and health	400	150	10	0	560
Real estate and rental	250	138	25	2	415
Trade and transport	2,001	1,801	572	159	4,533

Table A3: Number of complete responses by size and industry

Industry	5-9	10-49	50-199	200+	Total
Agriculture, forestry and fishing	99	49	5	0	153
Business service	159	184	63	12	418
Construction	137	138	45	6	326
Culture and sports	90	119	22	6	237
Finance and insurance	17	44	25	10	96
Information and communication	73	82	30	2	187
Manufacturing, raw materials	121	173	114	34	442
Public, teaching and health	63	21	4	0	88
Real estate and rental	34	28	8	0	70
Trade and transport	281	307	115	27	730

Table A4: Response rate (in percent) by size and industry

Industry	5-9	10-49	50-199	200+	Total
Agriculture, forestry and fishing	19.8	19.6	20.0	0.0	19.7
Business service	18.7	23.0	17.8	15.2	20.1
Construction	13.0	16.2	20.3	18.8	15.1
Culture and sports	19.9	34.2	21.8	28.6	25.7
Finance and insurance	11.3	29.3	30.5	19.2	22.1
Information and communication	16.1	20.6	19.5	5.1	17.9
Manufacturing, raw materials	19.1	21.7	22.8	22.7	21.2
Public, teaching and health	15.8	14.0	40.0	0.0	15.7
Real estate and rental	13.6	20.3	32.0	0.0	16.9
Trade and transport	14.0	17.0	20.1	17.0	16.1

Table A5: Balance table by survey participation

	Participants	**Non-participants**	**Difference**
Number of observations	2,747	12,253	
A. Firm age in years (average)			
Firm age	28.491 (31.958)	22.54 (26.991)	5.951 (0.657)
B. Firm size (shares)			
5-9	0.391 (0.488)	0.462 (0.499)	-0.071 (0.010)
10-49	0.417 (0.493)	0.370 (0.483)	0.046 (0.010)
50-199	0.157 (0.364)	0.132 (0.338)	0.0250 (0.008)
200+	0.035 (0.185)	0.036 (0.185)	0.000 (0.004)
C. Industry (shares)			
Trade and transport	0.266 (0.442)	0.310 (0.463)	-0.045 (0.009)
Agriculture, forestry and fishing	0.056 (0.229)	0.051 (0.220)	0.005 (0.005)
Construction	0.119 (0.323)	0.149 (0.356)	-0.031 (0.007)
Culture and sports	0.086 (0.281)	0.056 (0.230)	0.030 (0.006)
Manufacturing, raw materials	0.161 (0.368)	0.134 (0.340)	0.027 (0.008)
Finance and insurance	0.035 (0.184)	0.028 (0.164)	0.007 (0.004)
Business service	0.152 (0.359)	0.136 (0.343)	0.016 (0.008)
Information and communication	0.068 (0.252)	0.070 (0.255)	-0.002 (0.005)
Public, teaching and health	0.032 (0.176)	0.039 (0.192)	-0.006 (0.004)
Real estate and rental	0.025 (0.158)	0.028 (0.165)	-0.003 (0.003)
D. Region (shares)			
Midtjylland	0.242 (0.429)	0.229 (0.420)	0.014 (0.009)
Syddanmark	0.217 (0.412)	0.205 (0.404)	0.012 (0.009)
Hovedstaden	0.326 (0.469)	0.356 (0.479)	-0.031 (0.010)
Nordjylland	0.098 (0.297)	0.100 (0.299)	-0.002 (0.006)
Sjælland	0.117 (0.321)	0.110 (0.313)	0.007 (0.007)
E. Firm type (shares)			
Sole proprietorship	0.105 (0.306)	0.100 (0.300)	0.005 (0.006)
Stock-based corporation	0.417 (0.493)	0.361 (0.480)	0.056 (0.010)
Private limited company	0.312 (0.463)	0.432 (0.495)	-0.120 (0.010)
Other	0.166 (0.372)	0.107 (0.309)	0.059 (0.008)
F. Employee characteristics (average)			
Wage	36,959.16 (12,147.58)	36,669.18 (38,036.11)	289.98 (431.72)
Tenure	5.332 (3.641)	4.479 (3.503)	0.852 (0.079)
Experience	12.171 (5.496)	10.946 (5.690)	1.225 (0.121)

Notes: 15,000 firms were invited to participate in the survey. Columns "Participants" and "Non-participants" show summary statistics for those who completed the survey and those who did not, respectively, with standard deviations in parenthesis. The "Difference" column shows the first column minus the second column, with the standard errors of a Welch two-sample t-test in parentheses. Panels B, C, D, and E report shares of firms in each category. Panel F reports employee averages from the matched employer-employee data set.

B Appendix: Survey Questions

In this Appendix, we presents the full script of the sections of the survey used in this paper (translated to English).

> *We will now turn to ask questions to learn about how valuable good employee matches are to your firm in terms of productivity, i.e. the part of productivity of an employee in your firm that rests on the employee having worked in your firm for some time.*
>
> *To do this we would first like you to identify the most common occupation in your firm when the firm is in full operation.*
>
> ***Q7.*** *What is the most common occupation at your company among employees aged 35 years or older?*
>
> ***Q8.*** *If relevant, please provide a finer classification of that occupation.*

We use a standard ISCO classification system and the respondents specify a 2-digit occupation, stored in the `OCCUPATION` variable.

> *Next we will ask you a series of hypothetical questions about hiring new employees in the occupation:*
>
> `OCCUPATION`
>
> *For this purpose, please imagine that you will be hiring employees in a situation, say 2-3 years from now, where there is herd immunity for COVID-19, a cure, or a vaccine which is widely available.*
>
> *Think about a hiring a new employee in* `OCCUPATION`*. This new hire is aged 35 or older and has no prior relevant industry and/or occupation experience.*
>
> ***Q9a.*** *Suppose that this employee has worked in your firm for 1 year. Would this employee have reached close to his/her maximum productivity within your firm or would he/she have substantially more to gain in terms of productivity from additional experience and learning within you firm?*
>
> ☐ *Yes, the employee should have reached close to his/her maximum productivity by working for 1 year.*
>
> ☐ *No, the employee should have substantially more to learn from additional experience after working for 1 year.*

`[If Q9a==Yes, define TENURE=1, and skip to Q10.]`

Q9b. *`[IF Q9a==No]` Suppose that this employee has worked in your firm for 5 years. Would this worker have reached close to his/her maximum productivity within your firm or would he/she have substantially more to gain in terms of productivity from additional experience and learning within you firm?*

☐ *Yes, the employee should have reached close to his/her maximum productivity by working for 5 years.*

☐ *No, the employee should have substantially more to learn from additional experience after working for 5 years.*

`[If Q9b==Yes, then go to Q9c.  If Q9b==No, then go to Q9d.]`

Q9c. *Between 2 and 5 years, how much experience at your firm do you think this employee would need to reach close to his/her maximum productivity within your firm?*

______ *years*

`[Accept a whole number in 2-5.  Define TENURE = Q9c.  Go to Q10.]`

Q9d. *Suppose that this employee has worked in your firm for 10 years. Would this worker have reached close to his/her maximum productivity within your firm or would he/she have substantially more to gain in terms of productivity from additional experience and learning within you firm?*

☐ *Yes, the employee should have reached close to his/her maximum productivity by working for 10 years.*

☐ *No, the employee should have substantially more to learn from additional experience after working for 10 years.*

`[If Q9d==Yes, then go to Q9e.  If Q9d==No, then go to Q9f.]`

Q9e. *Between 6 and 10 years, how much experience at your firm do you think this employee would need to reach close to his/her maximum productivity within your firm?*

______ *years*

`[Accept a whole number in 6-10.  Define TENURE = Q9e.  Go to Q10.]`

Q9f. *How much experience at your firm do you think this employee would need to reach close to his/her maximum productivity within your firm?*

_______ *years*

`[Accept a whole number in 11-40.  Define TENURE = Q9f.]`

Q10. *Would this employee be paid a monthly salary, paid by the hour, or other?*

☐ *Paid a monthly salary*

☐ *Paid an hourly wage*

☐ *Other arrangements (Specify)*

`[Define a string variable WAGE, as:  WAGE="monthly salary" if Q10==Paid a monthly salary; WAGE="hourly wage" if Q10==Paid an hourly wage; WAGE ="total monthly compensatio if Q10==Other arrangements.]`

Q10a*. What would be the* `WAGE` *for this employee, with* `TENURE` *year(s) of experience within your firm?*

DKK _______

`[Accept a whole number in 1-1,000,000.]`

Now please consider the extent to which relevant experience outside your firm can compensate for lack of experience within your specific firm.

Please consider a combination of relevant experience outside your firm and experience within your specific firm that would give rise to an employee which is equally productive or valuable to you as the employee with no prior relevant experience outside your firm and `TENURE` *year(s) of experience within your specific firm.*

Q11. *In the table below consider workers with different levels of relevant experience prior to starting at your firm. Please state how many years of specific experience within your firm this worker would need to accumulate in order to reach the same level of productivity as the worker with no prior relevant experience and* `TENURE` *year(s) of specific experience within your firm.*

Relevant experience outside your firm	Tenure	
1-2 years	______	year(s)
3-4 years	______	year(s)
5-9 years	______	year(s)
10+ years	______	year(s)

```
[ Activate only the first line when the table is first presented.
Activate the second line when the first line is answered, etc.
Accept a whole number in 0-TENURE in the first line.  Define TENURE2 based on
this response.
Accept a whole number in 0-min(TENURE, TENURE2) in the second line.  Define TENURE4
based on this response.
Accept a whole number in 0-min(TENURE, TENURE4) in the third line.  Define TENURE9
based on this response.
Accept a whole number in 0-min(TENURE, TENURE9) in the fourth line.  Define TENURE10
based on this response.]
```

Q12. *We would now like to quantify your willingness to pay for new employees, i.e. employees who have never worked for you before, but who have some general relevant experience. How much* `WAGE` *would you pay such an employee depending on how much general relevant experience he/she has?*

For comparison, you reported that your firm would pay the `WAGE` *of DKK* `Q10` *to an employee with* `TENURE` *year(s) of experience within your firm.*

Relevant experience outside your firm	WAGE
0 year	DKK ______
1-2 years	DKK ______
3-4 years	DKK ______
5-9 years	DKK ______
10+ years	DKK ______

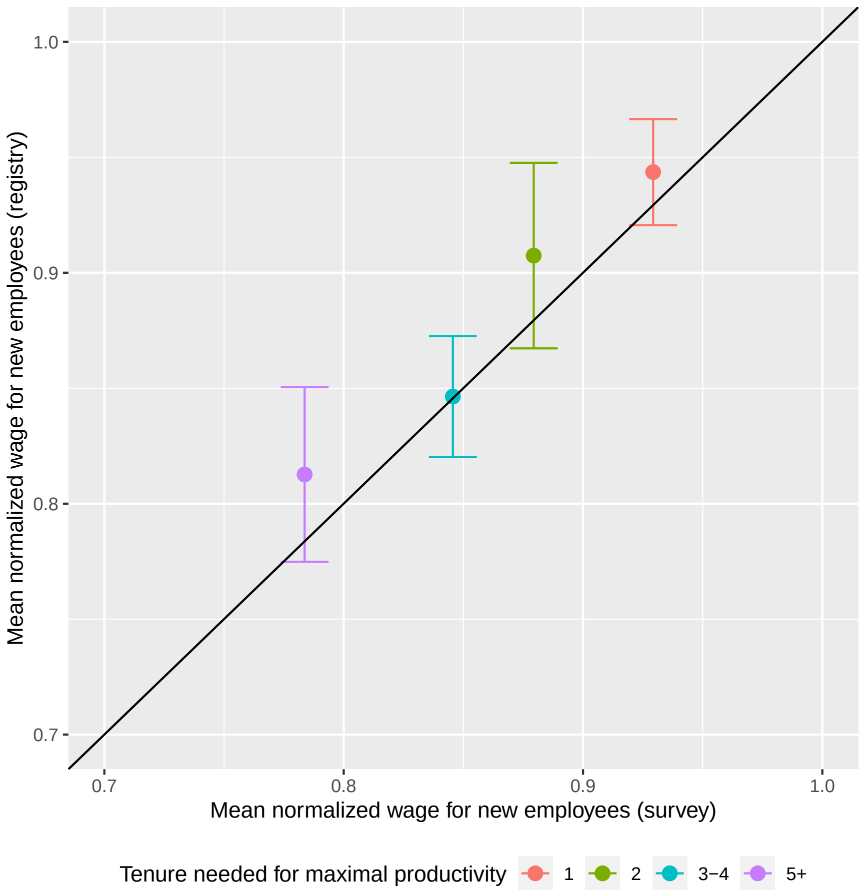
[Accept a whole number in 1-1,000,000 for each line. Do not present lines that correspond to the lines where the respondent put 0 in Q11. For example, if the respondent put 0 in ‘‘5-9 years’’ and ‘‘10+ years’’ while she put a positive number in ‘‘1-2 years" and ‘‘3-4 years’’, the lines to be presented in this table is the first three (‘‘0 year’’, ‘‘1-2 years’’, and ‘‘3-4 years’’).]

C Appendix: Comparisons of Normalized Wages to New Employees between the Survey and Registry data under Alternative Specifications

Figure 7 in the main text presents the comparisons of normalized wages to new employees between the survey and registry data under specific definitions of low tenure, high tenure, and little previous experience. To be specific, low tenure is defined as having lower than two years of tenure, high tenure is defined as having more than four years of tenure, and having little previous experienced is defined as having less than two years of experience in the same one-digit level occupation before joining the current firm.

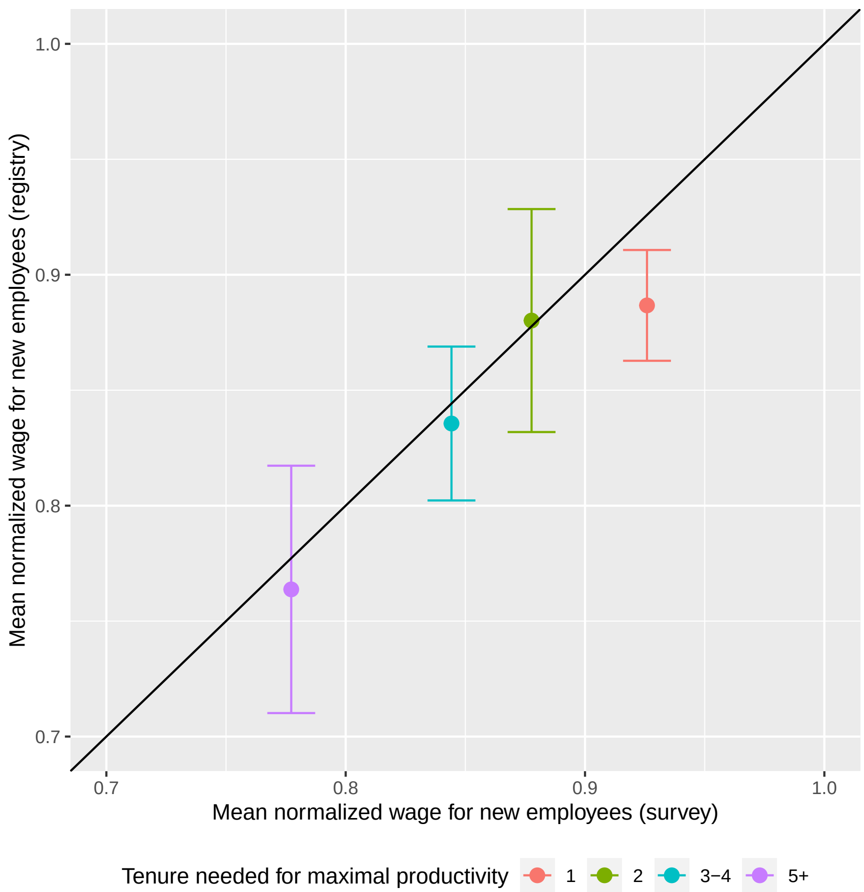
This appendix presents the same comparison under alternative definitions of these concepts. In Figure C1, we define high tenure as having more than T_M years of tenure, which varies across the groups considered. In Figure C2, we define high tenure as having more than 6 years of tenure. In Figure C3, we define the low tenure as having less than one year of tenure. Lastly, in Figure C4, we define having little previous experience as having less than four years of previous experience. All the other specifications are the same as Figure 7 in each figure. Under all these alternative specifications, it remains true that the survey measures line up very close with the administrative measures.

Figure C1: Normalized wages for new employees in the survey versus that in the registry data, with high tenure threshold = T_M



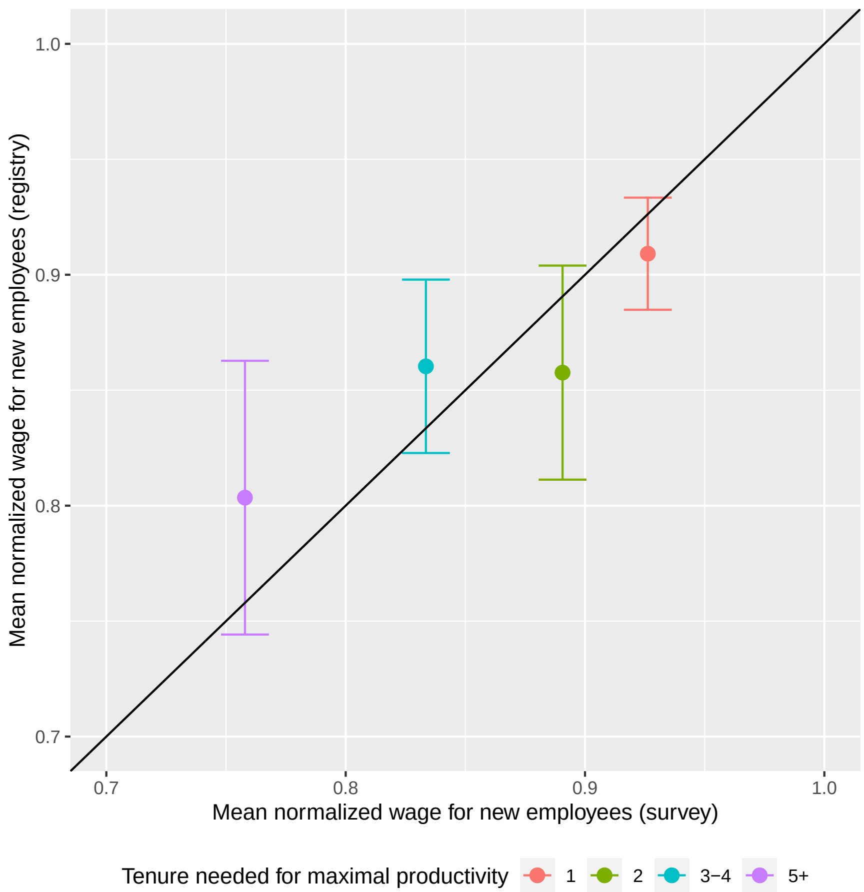
Notes: Same as Figure 7 but with high tenure defined as having more than T_M years of tenure. 534 firms are included in the analysis.

Figure C2: Normalized wages for new employees in the survey versus that in the registry data, high tenure = more than 6 years



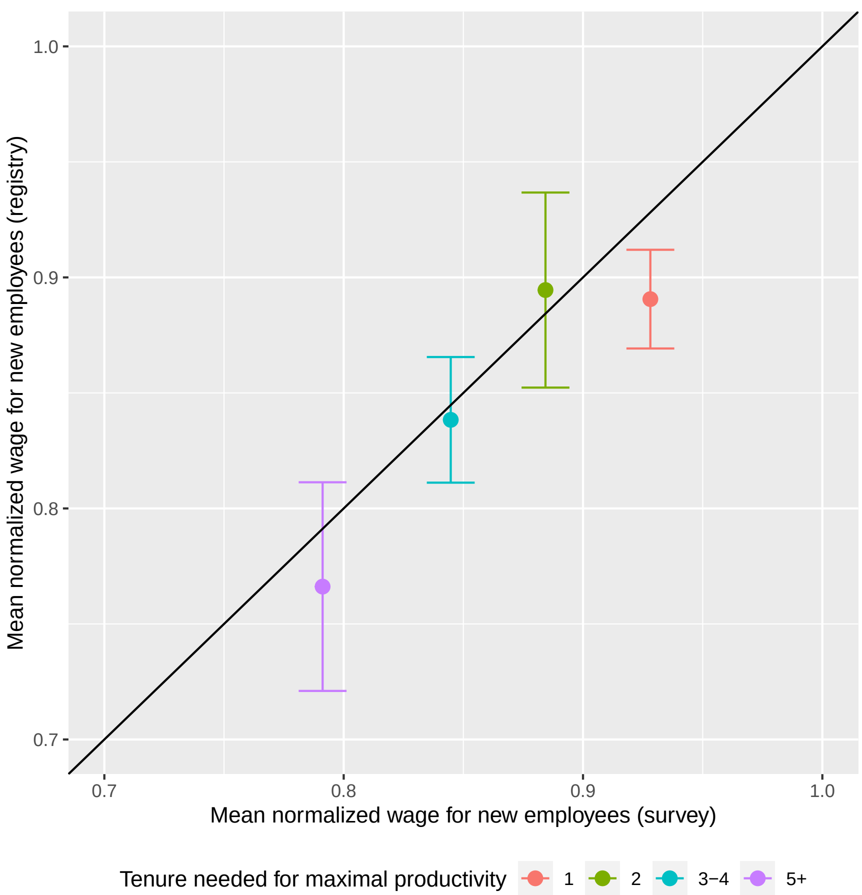
Notes: Same as Figure 7 but with high tenure defined as having more than 6 years of tenure. 445 firms are included in the analysis.

Figure C3: Normalized wages for new employees in the survey versus that in the registry data, low tenure = less than 1 year



Notes: Same as Figure 7 but with low tenure defined as having less 1 year of tenure. 411 firms are included in the analysis.

Figure C4: Normalized wages for new employees in the survey versus that in the registry data, less than 4 years of previous experience



Notes: Same as Figure 7 but with less than 4 years of previous experience. 549 firms are included in the analysis.

D Appendix: Separation Rates Estimated from the Registry Data

This Appendix reports the separation rates by occupation group and tenure estimated from the registry data. We use employees between 35 and 54 years old to be consistent with hypothetical employees used in the survey. Separation rates are typically decreasing with tenure. Initial separation rates are lower for management occupations and also for occupations that require a high or medium level of knowledge.

Table D1: Separation rates (λ_T^0, %) by occupation and tenure

	Tenure									
Occupation	1	2	3	4	5	6	7	8	9	10+
Management	24.4	22.0	21.4	19.4	16.1	14.7	15.1	12.1	10.6	7.3
Require high knowledge	26.6	20.9	17.8	16.2	15.3	14.5	13.2	10.9	9.0	6.3
Require medium knowledge	27.7	22.3	20.0	17.8	16.1	14.7	13.2	11.1	9.9	6.3
Office & customer services	31.7	22.6	19.3	16.4	14.4	13.8	11.7	11.0	9.8	7.1
Sales & service	37.3	28.4	23.7	17.9	16.2	14.6	14.2	11.3	9.6	5.8
Farming	37.4	27.8	24.0	17.6	17.9	9.7	26.0	15.4	11.6	7.5
Manual labor, skilled	37.6	25.3	20.4	17.9	15.8	12.5	10.7	12.1	10.3	7.0
Operator and assembly	36.1	23.4	19.0	17.8	15.4	13.8	10.5	14.1	11.5	7.0
Manual labor, unskilled	41.8	27.1	21.6	17.7	15.1	15.6	13.4	11.1	10.4	6.6