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Job tenure and unskilled workers before the Industrial Revolution: St Paul's Cathedral 1672-1748

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Abstract

How were unskilled workers selected and hired in preindustrial labour markets? We exploit records from the rebuilding of St. Paul's Cathedral, London (1672–1748) to analyze the hiring and employment history of over one thousand general building labourers, the benchmark category of 'unskilled' workers in long-run wage series. Despite volatile demand, St. Paul's created a stable workforce by rewarding the tenure of long-standing workers. More senior workers received more days of work each month, preference when jobs were scarce, and the opportunity to earn additional income. We find the cathedral's strategy consistent with reducing hiring frictions and turnover costs.

Introduction

Just over 350 years ago, St. Paul's Cathedral was destroyed in the Great Fire of London. Under the guidance of Sir Christopher Wren, the Cathedral was entirely rebuilt between 1672 and 1711. This pre-industrial mega-project left not only a legacy on the London skyline, but also detailed individual-level records of the employment and remuneration of building labourers. With these records,

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unparalleled in continuity and scope for this period, we reconstruct and analyse the employment histories of over one thousand workers employed as general labourers during a seventy-year period. We find that St. Paul's hiring practices encouraged retention and reduced turnover, giving a core group of labourers more work, priority in rehiring after slowdowns, and access to additional ways to earn. Despite the volatility that characterized pre-industrial labour demand, St. Paul's was able to establish a stable workforce by incentivizing tenure and rewarding long-standing labourers. These patterns of organizing worker hiring and retention have not been recognized in earlier studies of early modern labour markets.

Preindustrial urban unskilled labourers are often believed to have been casual workers employed on transient, short-term contracts, usually by the day, with wage rates that responded to supply and demand (Woodward 1995, pp. 96, 100-06; Ashton 1964, pp. 77-87; Grantham 1994, pp. 12-15; Williamson 1987; Rule 1981, pp. 49-73; Wallis 2014, pp. 189-43; Allen 2009, pp. 113-15).[2] As Elizabeth Gilboy noted "The rule of employment was over-work for a few days and then no work at all" (1934, p. 5). Urban labouring work was never regulated by craft guilds, nor organized in annual service contracts as some agricultural labour was (Boulton 1996, p. 271; Kussmaul 1981). The implication is that urban unskilled workers were assumed to be essentially indistinguishable to employers who simply drew the numbers they needed each day from the pool gathering at the gate of any site.[3] It was in this vein that the seventeenth-century political economist, William Petyt, spoke of labour as a "capital material …raw and undigested…committed into the hands of supreme authority, in whose prudence and disposition it is to improve, manage, and fashion it to more or less

[2] Our data is for urban labourers, as discussed in this literature. In agriculture, annual contracts were agreed on the spot at large hiring fairs during which mobility between employers was the norm (Kussmaul 1981). See Bowley (1900, pp. 59-60) for the fundamental assumptions of a competitive market which underpin the law of one wage and wage series. Clark and van der Werf (1998) take the assumption of spot market conditions through to labour market arbitrage between these markets. See Humphries and Weisdorf (2019) for the application of labour market arbitrage to real wage series. Skilled labour markets were sometimes regulated by guild or corporative systems that set different norms, as discussed in Wallis (2014).

[3] See Boulton (2017, pp. 310-13) for a summary of the questions of intermittency, seasonality and by-employment.

advantage."[4] Unskilled labourers have featured more prominently in literature on mobs, unrest and disputes in pre-industrial London than in economic analysis (George 1925, p. 124; Harrison 1986; Landes 1987; Gilboy 1934). Although some studies suggest labourers might have more complex relationships with their employers (Woodward 1995; Yamamoto 2004; Schwarz 2007), economic historians have generally agreed that more structured approaches to hiring arose later (Clark 1984, 1994), when firms eventually "rejected the market…to secure a reliable and productive labor force" (Huberman 1996, p. 6).

Our study offers the first in-depth econometric analysis of pre-industrial hiring practices for labourers in construction work in England. We examine the characteristics of unskilled hiring and employment at St. Paul's Cathedral through the main period of construction, 1672–1711, and up to 1748 when labourers were used for maintenance. The Cathedral's employment records encompass almost every day of work that general labourers supplied over these 76 years.[5] They are unusual because they list each labourer by name in each period they were active, allowing us to reconstruct the individual employment histories including days worked, earnings, absences, and the overall duration of employment of the 1,011 general labourers hired during these years.

The literature indicates construction work is notoriously volatile, and at St. Paul's many labourers appeared briefly on the site and never returned. However, as we show, the recruitment and retention of labourers during the rebuilding did not fit a pattern of casual, transient, short-term employment. Over the period we observe, we find that the workforce stabilized, hiring and separation rates fell, and the average length of employment increased. These changes occurred without labourers gaining contracts, and most still faced periods when they were laid off temporarily. Nonetheless, a core of long-serving labourers developed, and it was this group who supplied most of the general labouring work during the rebuilding of St Pauls.

[4] Quoted in Furniss 1965, p. 41.
[5] Recorded in monthly or quarterly accounting periods

To explore how this happened, we examine econometrically the relationship between labourers' tenure and the number of days of work awarded, the consistency of employment, and access to additional income earning opportunities. Our results indicate that St. Paul's incentivized and rewarded tenure. The Cathedral privileged a core group of workers whose access to additional and more consistent income increased with the length of time they were employed there. These core labourers were given more days of work each month than others—workers with the most tenure were more than three times as likely as those with the least to be fully employed within a month. These effects do not diminish as tenure increases, suggesting that this is not explained by on-the-job learning or the employer discovering worker productivity, as one might expect.

Tenure was rewarded in several additional ways. Tenured labourers had more consistent access to employment. Long-standing labourers were less likely to have periods in the year in which they were not hired at all and were more likely to be rehired after seasonal breaks in construction. Finally, the labourers with the most tenure were twice as likely as newer labourers to be given the benefit of additional shifts as watchmen, which increased earnings in a month by up to 15 percent.

While the day wage at St. Pauls remained the same for 70 years, we find that long-standing labourers at the Cathedral received an income premium through tenure-related opportunities. At the largest building site in early-modern England, these results indicate that tenure was incentivized and rewarded, leading to a stabilization of the workforce despite volatile labour markets. Long-standing relationships and seniority appear to define how the employer distributed opportunities to labourers.

Our findings for unskilled labourers complement an emerging body of work identifying institutional adaptability in the economy and organizational innovation in skilled labour markets in the centuries before the industrial

revolution (de La Croix et al. 2018; Kelly et al. 2014). Recent studies have argued that large organizations operating in a pre-industrial context were capable of creating internal labour markets for skilled workers (García-Zúñiga and López-Losa 2019; Murphy 2010, 2015; Rosenband 2016). In a related vein, studies have revealed strong performance-related incentives in eighteenth century navies (D. W. Allen 2002). That a major building project should introduce similar mechanisms is consistent with arguments about the creative potential of early-modern administrative elites in the face of shocks (Dittmar and Meisenzahl 2020) and novel challenges in scale and scope (Harris 2020). Our findings also contribute to an emergent theme in the economic history of real wages and labour markets which examines varying types of employment contract and duration of employment and working days per year (Humphries and Weisdorf 2019; Gary 2019; Stephenson 2020b; Ridolfi 2021).

The paper proceeds as follows. In the next section, we provide historical background on the reconstruction of St. Paul's and describe the data set sourced from the project. Then we describe employment churn and turnover the Cathedral, demonstrating the stabilization of St. Paul's workforce over the construction phase. Next, we analyse the relationship between tenure and the number of days worked each month, the consistency of employment, and access to watchmen shifts. We then discuss explanations for the patterns identified and conclude.

Historical Context and Data

St Paul's was the largest construction site in London from 1675 to 1711. The Cathedral had been destroyed by the Great Fire of 1666, and, after several years of planning and demolition work, Sir Christopher Wren's design for the new Cathedral was finally approved in 1675. The project took place against the backdrop of a rapidly expanding rebuilt city that was experiencing substantial long-term growth and high labour demand (Boulton 1996), driven by trade and services (Broadberry et al. 2015), and a prolonged construction boom (Barras

2009). As Surveyor to the Crown, Wren was also responsible for the management of many other projects around London: the City Churches, Greenwich Hospital, and, later, Westminster Abbey.

The Cathedral's accounts are exceptionally detailed and well maintained, largely because of its funding model.[6] The project was paid for by a new tax on coal imported into the city. Parliament and the City expected strict oversight and auditing. The formal accounts were compiled from journals and call books that recorded weekly pay. These were counter-signed as an accurate record of payments and were subject to audit, giving some reassurance about their quality. The records from 1672–1748 that we use cover the main period of construction from 1674 to 1711, the period to 1720 when some masonry and other work were still being carried out, and nearly three decades to 1748 when a small group of labourers were hired for general maintenance.

In each account book, the labourers who were hired directly by the Cathedral's clerk-of-works were listed by name, with the number of days they worked and the rate they were paid. The records give the number of days that each man worked per accounting period (month or quarter) but do not indicate who was working on each day of the week. They describe labourers carrying out general tasks such as moving stone, dragging goods, and sorting and carrying rubbish, as well as demolition work; mixing mortar; watching doors; ramming and cutting walls; stripping tiles; plumbing; and assisting specialist contractors. The accounts do not give details of the most skilled craftsmen on the site. Most specialized tasks such as brickwork, masonry, and plastering were supplied by skilled subcontractors who hired their own workers directly and kept separate, private accounts for wages.[7] This system, where general labourers paid on day rates worked alongside skilled subcontractors, was common in the building industry in this period, as it still is.[8]

[6] Full records of the series in London Metropolitan Archives, CLC/313/I/B/25473
[7] See Stephenson 2020b for the most detailed descriptions of these.
[8] See Woodward 1995; Stephenson 2020b. Trade-specific labourers hired by specialist sub-contractors worked alongside general labourers employed centrally at Westminster Abbey 1712-

St. Paul's was operational every week of the year, and the normal working week was six full days, as at other sites in London. However, not all active labourers worked every day. The number of days worked and labourers hired varied with project intensity and with the seasons. The number of labourers employed in January was about 60% of the number employed in July.

Decisions about who to hire to meet these rapidly changing demands for labour, and other aspects of the organization of employment, were in the hands of the clerk-of-the-works, a position held by John Tilson until 1685 and by Lawrence Spencer thereafter. The clerk was responsible for the day-to-day co-ordination of materials, contractors and workers on site, cost management, and record-keeping. He hired at will from an available pool of potential labourers. Employment seems to have been agreed verbally on a weekly or daily basis—there are no surviving contracts for labourers, and probably none ever existed. Labourers thus had no contractual expectation about ongoing employment, but there is ample evidence that they freely entered the employment relationship.[9]

Our dataset contains all 402 surviving sets of accounts from 1 October 1672 to 24 June 1748. There are full accounts for all periods from 1672 to 1748 with the exception of two short breaks, lasting for two years in the construction period and three years in the maintenance period.[10] The dataset ends with the cessation of accounts containing nominal data. The majority of accounts (73%) cover periods of one month. The rest run over longer periods, with 5% covering full years.[11] The shorter duration accounts are all from the construction period, giving us finer grained information for that time.

1719 and Greenwich Hospital 1696-1706. There are not comparable named records at either site, however. Labour organization was similar in private housebuilding (McKellar 1999). For studies of similar employment records in other parts of Europe see Rota and Weisdorf (2020), and García-Zúñiga and López-Losa (2019).

[9] Some men signed for task work (see below), indicating they had the opportunity to contract independently and work for others. Campbell 2007 pp.35-39 describes various types of work undertaken by labourers even before the rebuilding began.

[10] October 1674 – October 1675 and June 1710 – June 1714

[11] Unfortunately, the books do not run neatly in yearly runs. Accounts were kept quarterly at first, monthly from 1674 to January 1683, quarterly from January 1683 to April 1686, monthly

We extracted the labourers' names, number of days worked per period, and pay for all 402 accounting periods. We identify 1,033 unique labourers whose employment histories on the project appear in 21,793 entries.[12] 4.69% of entries lacked names or were excluded because two active labourers share the same name.[13] 69 labourers are identified as disabled, and there are no female names in the dataset. Most entries report days of labouring work, but 14% are for shifts as night watchmen on the site, a common practice intended to prevent trespass and theft and a useful supplement to day wages for those who were given them.

Labourers were paid a day rate that was almost entirely uniform across workers and did not change during the 76 years we observe. During the winter months (late October through early March), labourers earned 16d. per day. During the spring, summer, and early autumn (March to early September), they earned 18d. per day. These rates were similar to those recorded at a number of sites around the city at this time, including for labourers working directly for independent sub-contractors at St Paul's.[14] A labourer's income was a simple function of how many days he worked. The Cathedral spent nothing on beer, food, or other perks or provisions for labourers. Whilst labourers used the Cathedral's drogues, ramps, barrows, scaffold and rope, we do not know whether the tools they dug with were their own or the Cathedral's. Nominal day wages at the Cathedral were rigid for three-quarters of a century despite moderate price inflation, sustained growth in GDP per capita, and sharp economic shocks (see Online Appendix 2.3, also Allen 2009; Broadberry et al. 2015, pp. 239-42; Hatcher 1998, pp. 70, 74; Boulton 2000).

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for a decade from April 1686 to 1696, quarterly from October 1696 to June 1701, monthly from June 1701 to June 1710, bi-annually from June 1710 to December 1726, and then annually.

[12] The small sample and consistent format allowed us to manually identify repeat appearances based on unique forename and surname combinations with a high degree of confidence. We restrict linkage to allow individuals a maximum period of absence of five years, after which we assume we are observing two same-named individuals.

[13] 14 entries were unnamed; 1,022 entries are ambiguous, in that two individuals may have been active simultaneously, based on the repetition of names within an account. These ambiguous entries relate to 19 distinct names, and almost half (537) are from one, John Scott.

[14] One contractor paid 18d. per day all year round to most of his labourers and 16d. per day to a smaller number of men assisting layers (Stephenson 2020a, chapter 6.)

We might imagine this rigidity was tolerated as the price of accessing better opportunities, but labouring work offered limited progression. A very small number of labourers worked as foremen, receiving higher wages (20 to 24d.).[15] They seem to have been used during periods in which the greatest amount of work was being carried out. Forty-four labourers also acted as sub-contractors for labouring task work that required more skill or was more dangerous during the demolition phase.[16]

Evidence on the external labour market is limited. We know the period under investigation saw a great deal of construction across the city and high labour mobility (Brett James 1935; Barras 2009, pp. 6-14; Wrigley 1967).[17] It is likely that labourers were able to find work at any number of building sites, albeit none that equalled the scale and duration of St. Paul's.[18] Construction accounted for about 10% of male employment in the city.[19] The share of labourers within that is unclear, but if they made up a quarter of the male workforce in the sector that would be just over 4,000 men.[20] Although it was the largest construction project in the city, St. Paul's was not a dominant employer—the Cathedral never employed more than 200 men in a month, and rarely more than 50. In this period, skilled and unskilled construction work was not subject to guild

[15] Only 10 men over the 35 years of the main construction period earned above 18d. per day and all for short periods, associated with specialist or supervisory work.
[16] These labourers agreed task contracts worth between £1 and £150 between 1676 and 1690, acting as petty entrepreneurs. The contracts specified the length or volume of material to be removed, without the difficulty of the work being known, offering a chance for profit if it could be done in fewer days work than estimated, or loss or lower pay per day if not. Many of them signed their contracts, indicating relatively high human capital in a period where male literacy was still low.
[17] Whilst the Great Fire created a rebuilding boom to, initially, 1675, there is evidence that activity was maintained until the late 1720s. Between 1670 and 1686 expenditure at the Office of King's Works increased from £20,000 to £45,000 per annum (Colvin 1976, p. 32). Data for the 1690s are not available, but the Middlesex land registry shows a sharp increase in building from 1706 to 1721 and a steady rate 1721- 1730 , after which there was a sustained decline until after the late 1740s. See Barras 2009, p. 7; Stephenson 2020a, pp. 41-49.
[18] The surviving records of other major sites, such as Westminster Abbey and Greenwich, indicate a maximum of 10 labourers hired per week paid on day rates. More were presumably hired on task contracts.
[19] See Beier, A. L, (1986); also see Schwarz. (1992, 12, 13, 15). Keibek, S. A. J. (2017, p. 175).
[20] This back of the envelope calculation assumes a London population of 575,000, in which 57.5% were aged 15-59, and half were male, in line with standard estimates. See Allen 'Reply' 2019 p.743.

restrictions on access (Beier 1986), and even at the Cathedral itself, labourers were able to work directly for specialist contractors and suppliers.[21] Labourers thus had many options, and we cannot observe, or exclude, the effect that their preferences played a role in the hiring patterns we observe at St. Paul's. However, the scale and longevity of the Cathedral project offered the potential for more continuous work than on other projects. Therefore, a higher position in the queue for work at the Cathedral was a potentially important incentive.

The St. Paul's workforce

How many general labourers were employed at St Paul's and how long were they employed for? The employment records reveal that, over time, the Cathedral stabilized its workforce, despite the generally precarious nature of pre-industrial employment relations. Although there was significant variation in demand for labourers, monthly hiring and separation rates trended downward over the construction period and the share of labourers new to the project each year declined through to 1710. When we explore the data on an individual level, large differences in the total length of time that labourers worked at the Cathedral emerge—some workers were employed only briefly at St. Paul's, while other workers served for many years.

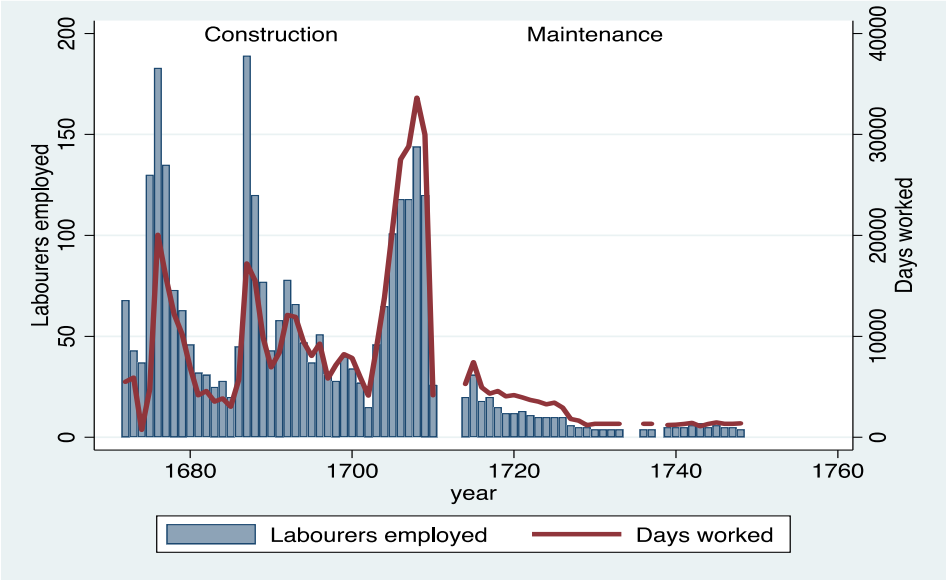
a) Variation in demand for labour at St. Paul's

The amount of labouring work available at the Cathedral varied greatly throughout the construction period with multi-year peaks and troughs of labour demand in addition to regular seasonal patterns. This high level of demand volatility is consistent with what we know of construction on other similar sites.[22] This was a period of sharp economic cycles, but they are only weakly associated with the pattern observed here (see Online Appendix 2.3), and the

[21] For example, 11 of the 68 men working for the specialist mason William Kempster from 1708 to 1709 also worked as labourers at the Cathedral (Stephenson 2018, pp.120-121).
[22] See Stephenson 2020a pp. 50-62; 173-92.

main driver of demand appears to be project centred. [23] Figure 1 plots the total number of labourers on site and the number of days of work they provided during the rebuilding from 1674 to 1711. Labourers' work peaked in the late 1670s; between 1687 and 1693; and most notably between 1705 and 1709, when several years saw around 30,000 days of work by labourers costing the Cathedral more than £2,000 each year. By contrast the demand for labourers in the early 1680s was low, with annual employment on-site at about one quarter of the level seen in 1676. Because construction work is stage dependant, and subject to the vagaries of supply chains, weather and finance, such peaks and troughs of demand are typical of any building site or large project.

Figure 1. Total numbers of labourers on site and total number of days worked, per annum, 1676 to 1748 (see text for source).



b) Stabilization of the workforce at St. Paul's

Despite this volatility in the amount of labour needed to rebuild the Cathedral, the workforce became more stable over time. Hiring and separation rates

[23] Broadly speaking from 1667 to the late 1670s the foundations of the old cathedral were cleared, and new foundations laid (Campbell, 2007). From the 1680s onwards, the walls were raised and the west front and towers were added from 1694 to 1705. The Dome was erected and plastered between 1705 and 1709. See note 18 above for the references to literature on patterns of activity elsewhere. Time dummies in our model absorb these project changes and broader trends in the construction industry.

declined over the construction period, and the share of labourers who were new to the project each year fell.

To measure worker turnover, we calculate monthly hiring and separation rates at the Cathedral, following Davis et al. (2006).[24] Our 'all transition' figures include all labourers who worked in an accounting period, no matter how long they stayed at the Cathedral. This means that workers who were only hired for a few days on one occasion count as a hire and a separation in these calculations. These figures also include temporary separations, as separated workers may have returned in later months.

Table 1: Monthly hiring and separation rates at the Cathedral

	Hiring Rate			Separation Rate				
	Mean	Std. Dev.	Max	Mean	Std. Dev.	Max	Months Observed (n)	Share of Months Observed (%)
1675-1679	14.23	13.42	51.43	16.77	14.75	48.78	51	85.00
1680-1684	9.79	14.83	74.19	12.34	13.32	52.83	33	55.00
1685-1689	11.04	13.13	57.94	12.96	14.05	54.95	43	71.67
1690-1694	8.03	6.35	34.78	5.5	7.6	38.6	50	83.33
1695-1699	3.68	4.22	13.33	6.96	10.09	28.57	17	28.33
1700-1704	6.41	9.48	42.11	4.69	10.55	60	42	70.00
1705-1709	9.42	21.46	120.61	8.06	21.61	134.18	60	100.00
Overall	9.58	14.26	120.61	9.83	15.19	134.18	295	70.24

Source: See text. Notes: Only for 295 periods with two sequential one-month accounts. Hiring rate is the percent of laborers who were brought on each month, and the separation rate is the percent who departed. Details in Appendix A.

Table 1 reports the average hiring and separation rates for the quinquennia that cover the construction of the Cathedral. The hiring and separation rates can be interpreted as the percent of labourers who were brought on or who departed each month. Over the whole period, an average of about ten percent of labourers

[24] Further details are in Online Appendix 1. These calculations are restricted to periods for which two sequential accounts are of one-month duration, representing 295 account books in the construction period. Quarterly and quarterly quasi-census calculations are included in Online Appendix 1.

arrived or departed each month. Peak turnover was much higher—in some months, half or more of the workforce had not worked in the previous month, and in other months, a third of labourers were not employed in the following month.

Today, construction is a high turnover industry, with worker flows three times higher than manufacturing firms (Davis et al. 2006, pp.7-8; US Bureau of Labor Statistics 2020). Even without the effect of firms opening and closing, the monthly job flows for St. Pauls are roughly twice the level seen in modern US data, where the hiring and separation rates are about 4 to 5 per cent on average (US Bureau of Labor Statistics 2020).[25] Turnover trended downward over the construction of St. Paul's. From 1675 to 1680, the average hiring rate was 14%, whereas from 1705–1709, the average hiring rate was only 9%. Likewise, the average separation rate decreased from 17% in 1675-1680 to 8% in 1705-1709.

Because these hiring and separation rates include labourers who many have been temporarily separated from the Cathedral, we also examine the share of labourers who joined the St. Paul's workforce for the first time each year. The share of newcomers among labourers at the Cathedral declined over time. Table 2 presents decadal averages (after the initial five years) showing the gradual decline in the share of new labourers to the project each year. This extended even to peaks of demand. For instance, in 1687, an early period of high activity, more than 80 per cent of labourers were new to the project. Twenty years later in 1708, which was the year with the largest single amount of work, only a quarter of labourers were new.

The increasing stability of the workforce was not just a function of the number of workers who had previously worked at St. Paul's expanding as time passed. Given the short tenure of the great majority of labourers, there was no lack of labourers to rehire after the earliest years of the 1670s, which we exclude in the

[25] The quarterly hiring and separation rates at St. Pauls, presenting in Online Appendix 1, are about 17 per cent, compared to about 14 per cent in modern US data (Davis et al. 2006, p. 8).

calculations in Table 2. Further, the size of the pool of labourers who had previously worked at St. Paul's had no effect on the hiring and separation rates in Table 1, which show the same general trend of stabilization.

Table 2. Labourers new to the project each year

Decade	New labourers per year (% of total)			Mean number of labourers employed per year (n)
	Mean	Min	Max	
1675-9	40.75	12.70	79.23	116.80
1680-9	28.88	6.25	84.66	61.30
1690-9	27.98	13.51	46.15	47.90
1700-9	25.40	0.00	47.83	78.80
1710-9	10.42	0.00	29.03	20.29
1720-9	4.44	0.00	20.00	9.20
1730-9	10.00	0.00	25.00	4.14
1740-9	12.96	0.00	40.00	5.11

Source: See text. Notes: For the 1670s, we exclude the initial 2 years of data, where the entire workforce is new.

c) Tenure at St. Paul's

How did this affect the employment of individual labourers? Our individual-level reconstructions of the employment histories of labourers at St. Paul's allow us to examine differences in the length of time which individuals worked at the Cathedral. These differences are given in Figure 2, which includes all labourers who worked during the construction phase at St. Paul's. Tenure is calculated as the amount of time between a labourer's first and last appearance in the Cathedral's account books.

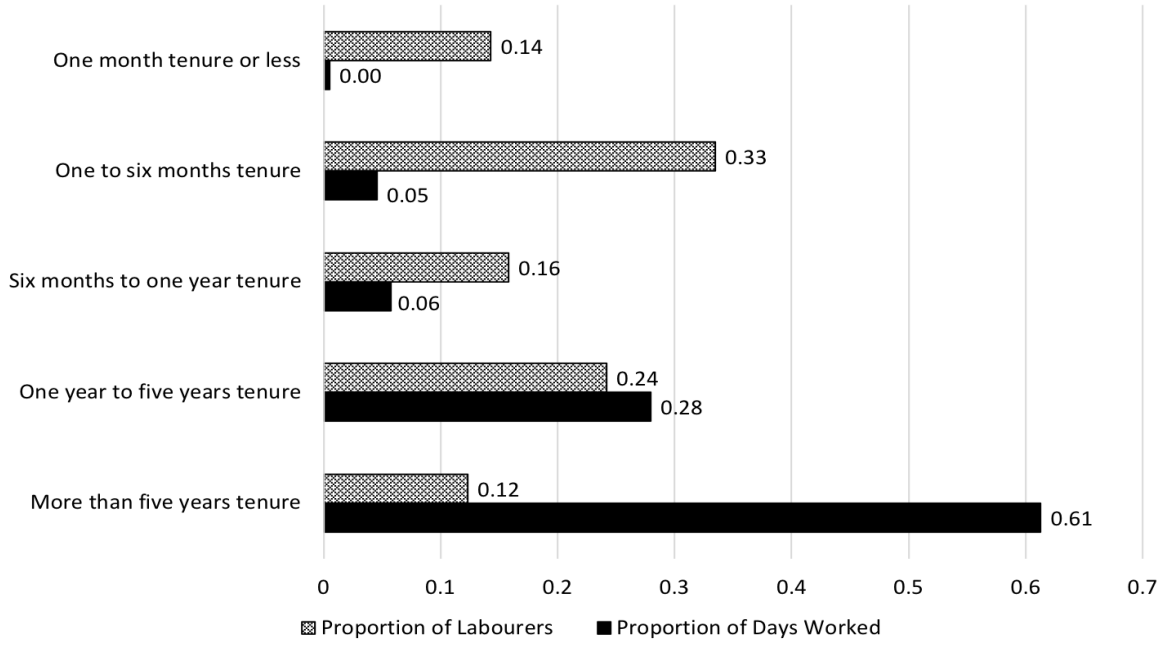
The patterned bars in Figure 2 give the proportion of all labourers with each length of tenure. 14% of all labourers stayed for less than one month, and almost half of all labourers (47%) stayed for six months or less. This accords with historical perceptions of fleeting, precarious employment relations.

However, at the other end of the distribution, some labourers were involved over much longer periods. Almost one quarter of labourers (24%) were associated with St. Paul's for between one and five years. A further 12% of labourers worked at

the site for over five years. Overall, twelve men appear in the accounts for a period of thirty or more years, with one, Simon Satchell, active for 43 years in total. Thus, for some workers, labouring at St. Paul's was fleeting, while for others, it was a long-standing arrangement.

The vast majority of labouring days were supplied by the group of longer-lasting workers. The black bars in Figure 2 indicate that the 12% of labourers who worked at St. Paul's for more than five years provided over 60% of all labouring days at the Cathedral during the construction period. The labourers who appeared most briefly at the Cathedral accounted for less than one per cent of all labouring days at St. Paul's. [26]

Figure 2. Proportion of labourers and days worked according to length of tenure



Source: See text

[26] We treat labourers as having been engaged in a month based on any number of days within a month (1 to 31) or any number of months within a year (so they could be employed in March and not appear again until February but would be considered as active for 1 year in that case). These extremes are not patterns we observe in reality. The discussion here is based on this approach, as we see it as the best option. But these ambiguities in work patterns are why we use two different measures of tenure in the econometric analysis.

Evidence that these longer-term workers were deliberately prioritized by the clerk exists in the accounts. The order in which labourers were literally listed on the page indicates that hiring occurred in a sequence. Long-term labourers were taken on first and are listed higher in the accounts than less tenured or new labourers. Often the exact sequence of the upper section of the list of hires was repeated between months. Table 3 gives the position in the accounts for new labourers, those who had worked at the Cathedral for a number of months, and those who had worked at the Cathedral over a year. Two-thirds of new labourers were listed in the bottom quartile of the accounts. If they remained on site for the next few months, they shifted up the order, but almost half were still in the last quartile for the rest of their first trimester on the site.[27] By the time labourers had accrued nine to twelve months of experience at the Cathedral, most were in the middle of the list. Those labourers who stayed for over a year were most often found in the top quarter of the clerk's list. These patterns suggest that the clerk possessed a clear idea about who was to be hired and in what order, with a well-defined preference for those labourers who had accrued more tenure at the site.[28]

Table 3: Share of labourers in each quartile of the clerk's list by elapsed time since entry to workforce

Position in Account (quartile)	New	2-3 months	4-6 months	7-9 months	10-12 months	>1 year
0-25	3.38	3.15	7.80	12.50	14.64	31.10
26-50	10.41	20.40	29.93	37.50	37.38	25.27
51-75	46.27	55.19	43.84	34.34	30.37	18.20
76-100	39.94	21.26	18.44	15.66	17.60	25.43
Total	100	100	100	100	100	100
N	3.38	3.15	7.80	12.50	14.64	31.10

Source: See text.
Notes: Calculations only include labourers recorded in non-alphabetical accounts produced during the period of construction, from January 1675. Details in Appendix E.

[27] That their position in the accounts was still low after their first appearance makes it clear that these patterns were not just contingent on the time within the month that a labourer was first taken on.
[28] See Online Appendix 6 for more analysis of the ordering of labourer's names in the account book, including evidence that gang labour was not present here.

The distribution of work at St. Paul's was polarized. Much of the labouring workforce faced enormous instability of employment, with highly variable demand and high turnover rates. This is what is generally expected of labouring in the pre-industrial period. However, some labourers were attached to the site for periods of several years or more, and it was this group that provided most of the labour needed for the reconstruction. This does not appear to be a pre-existing feature of general labouring in London that was present from the start of the project, but rather a pattern that emerged over time. Taken with the downward trend in the hiring and separation rate at the Cathedral and the decline in the share of new workers in the Cathedral's workforce, it appears that St. Paul's was able to stabilize its workforce over the forty-year construction period.

Results on hiring, retention, and tenure

How was St. Paul's able to stabilize its workforce? In this section, we explore econometrically the hypothesis that stability was achieved by the employer incentivizing and rewarding tenure. We analyse the relationship between tenure and the number of days of work awarded, the consistency of employment, and access to additional income earning opportunities. Our results indicate that the Cathedral privileged a core group of workers who were given priority in access to work as their tenure increased.

a) Method

How did a labourer's prior tenure affect the amount of work they received, the consistency of this work, and their access to additional earning opportunities? Our individual-level data allows us to explore these questions using a series of logit and conditional logit models.

We capture prior tenure in these models in two ways. Our first measure is based on the cumulative number of days a labourer had worked at the site before the date of the account in question. The absolute number of days previously worked

strictly increases with time, so we model each labourer's tenure relative to that of the rest of the St. Paul's workforce who were active in each period. This gives a measure of a labourer's tenure relative to the other workers who may have been available within the pool of workers the clerk was hiring from. Specifically, we calculate the percentile rank according to cumulative days worked up to that point for all workers who were active at the Cathedral during the accounting period. This standardizes our measurement of relative prior tenure across time and over accounting periods of differing lengths. Our second measure is constructed in the same way, as a percentile rank, but is based on the elapsed time in days since the labourer first began working at the site. The percentile rank of elapsed time in days differs from the cumulative days worked because many workers had gaps in employment (seasonal or otherwise) or did not work the maximum number of days in prior account books.[29]

Throughout the analysis, we exclude the first three years of the accounts, before January 1675, to remove the attenuating effect that the earliest periods, when all workers had little experience, would otherwise have produced. We also limit our main analysis to the construction period, that ended in 1711, which saw the majority of employment. Finally, we rely on a full panel construction of the dataset where all active workers are represented in each accounting period, including those given no days of work. We consider labourers to be active at St. Paul's during an accounting period if that period was between the first and final dates, inclusive, that the labourer appeared in the Cathedral accounts over their career.

The dependent variable in our models is always a binary indicator. Our basic model is a logit model

$$y_{it} = \beta_0 + \beta_1 x_{it} + \beta_3 M_t + \beta_4 T_t + \epsilon,$$

[29] Alternative measures of tenure that are cardinal, rather than ordinal, and continuous are considered in Online Appendix 7. The main results are robust to these alternative measures of tenure.

*w*here y_{it} is a binary variable which equals 1 if a labourer worked over 85% of possible days in a period (subsection b), if a labourer was given any work in an accounting period (subsection d), or if a labourer was given a watchman shift (subsection e). x_{it} is the labourer's tenure as a percentile rank of all active labourers in an accounting period, measured either by cumulative days previously worked or by elapsed time since beginning to work at St. Paul's. T_t are year dummies and M_t are month dummies to control for seasonality. Labourer fixed effects are also included in some specifications to ensure that potential unobservable differences between labourers are not driving our results.

b) Work allocation between labourers

The clerk of works hired labourers for different numbers of days in each accounting period. For example, in May 1687, a peak month of construction in which 71 labourers worked for 1,037 days, William Nelson was hired for just seven days and Anthony Minshaw for five days. This was the first of only two months Nelson was hired, while it was Minshaw's last appearance after eight months of consistent work on site. Conversely, four labourers each worked for 23 days, the maximum in the month: two of them, John Hudson and Dan Northam, would be active for more than twenty years. Only three of the 71 labourers who were active in the Cathedral labour force did not work at all during the month.

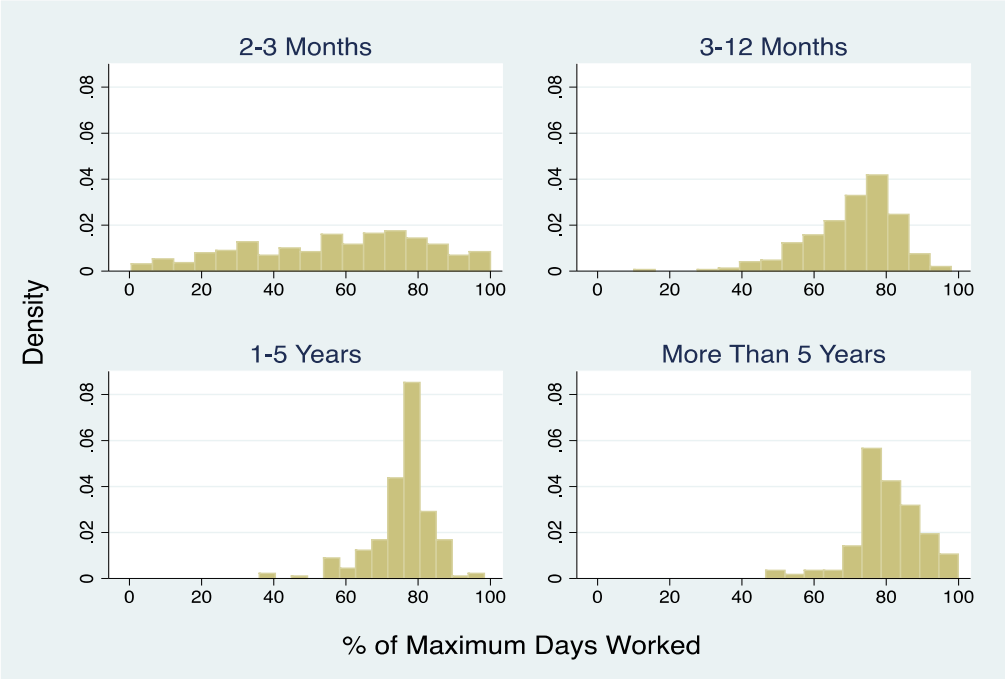
This inequality in the amount of work that labourers received gives us a simple and important test of the structure of employment at the Cathedral: were long-standing labourers given the most work? If labourers were undifferentiated (differentiated) in the eyes of the clerk, then the amount of work they were given should be uncorrelated (correlated) with prior experience. A strong visual indication that the clerk favoured long-serving labourers when choosing who to hire can be found in Figure 3, which shows how the share of available work given to labourers varied according to the time they had worked on the site. The share of work is the ratio between the number of days each labourer worked and the

maximum possible in the entire period they were active at St. Paul's.[30] The labourers who were on site for the shortest periods, between two and three months, were given the least work. Some of these labourers were only on site for a few days each month; they were truly casual labour. In contrast, labourers who were present on the site for longer periods, especially those for a year or more, generally worked more intensely, with a convergence to a mode of around 80 percent of the maximum available days. Among the longest-serving labourers, those who stayed more than five years, many worked at the Cathedral on most if not all of the possible days during their tenure.

For analytical simplicity, we estimate the effect of prior tenure on work allocation by examining the probability that labourers worked "full time" during a given accounting period. We define full time generously to include anyone working between 85% and 100% of the maximum days any labourer was reported to have worked during an accounting period. In a few cases where the clerk recorded paying wages for more days than existed in the calendar period covered by an accounting period, we capped the maximum number of days at the number of days in the calendar period.

[30] To calculate this, we sum the total number of days that each labourer worked from their first to last appearance. We then divide this by the sum of the maximum number of labouring days worked by a labourer in each accounting period in which the labourer was active. Note that this analysis is conducted only for labourers in the construction period of the Cathedral who worked for more than one accounting period.

Figure 3. Share of maximum work given to labourers by length of tenure at separation



Source: See text

A limitation of our data is that we cannot see which day in an accounting period a labourer began work at the Cathedral. The first time a worker is hired, the number of days they worked may be censored if they started after the beginning of the accounting period, so we drop the first observation of each worker. Unfortunately, this also means that we lose in this part of the analysis 160 individuals who only worked at the Cathedral for one accounting period.

The three models in Table 4 estimate the effect of a labourer's prior tenure, in terms of days worked and elapsed time at the Cathedral, on the probability of the labourer working full time during the accounting period. All of the models have year fixed effects to account for time trends and month fixed effects for seasonality, with standard errors clustered at the labourer level.

Columns (1) and (2) give our primary results for tenure percentile in terms of cumulative days worked. The estimates indicate that long-standing workers were significantly more likely to be given full time work during each accounting

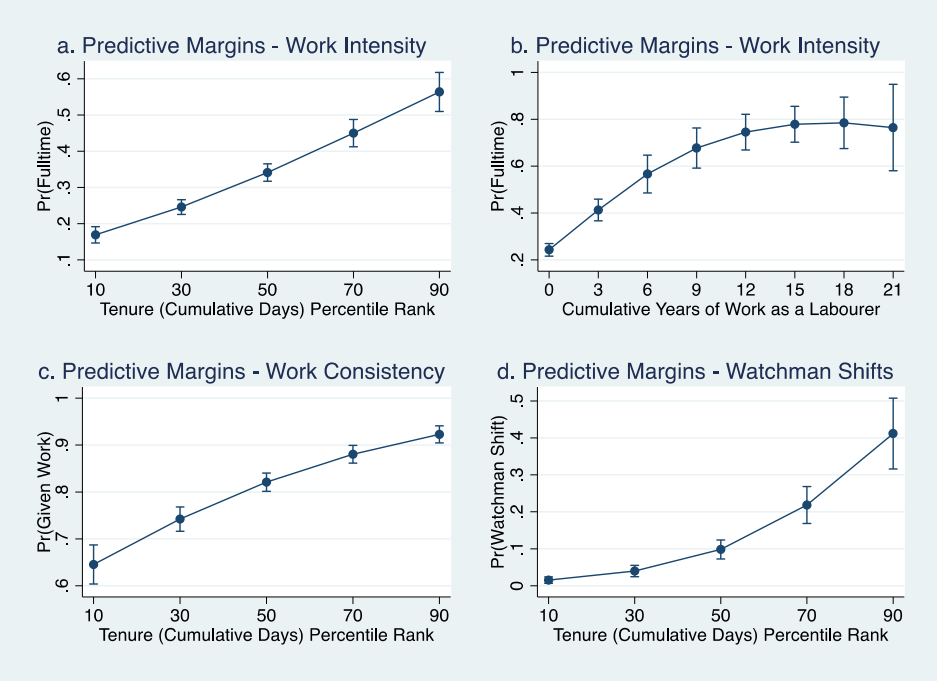
period. The marginal effects in column (2) imply that a one quartile increase in the percentile rank of a labourer's tenure increases their probability of working full time by 12 percentage points ($p < 0.001$, $25 * 0.0049 = 0.1225$). Figure 4a shows that a worker in the 10th percentile in terms of cumulative days worked has only a 17% chance of working full time in a given period, while a worker in the 90th percentile has a 56% chance. Column (3) shows that these results are robust to the incorporation of labourer fixed effects, though the effect size is smaller. Columns (4) and (5) explore this further by estimating linear probability models with and without labourer fixed effects, which indicate that the within-labourer effect accounts for about 20% of the overall effect but is still strongly significant. Columns (6) and (7) present the results with the labourer's elapsed time percentile rank as the independent variable of interest. The results for the logit model are significant and again slightly smaller, but they are not robust to the inclusion of labourer fixed effects in the conditional logit in Column (8).

Table 4: Logit models for the probability of a labourer working fulltime

	Cumulative Days Tenure					Elapsed Time Tenure		
	Logit Coeff.	Logit Margins	Cond. Logit Coeff. (FE)	Linear Prob.	Linear Prob. (FE)	Logit Coeff.	Logit Margins	Cond. Logit Coeff. (FE)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Tenure	0.0267***	0.0049***	0.0117*	0.0050***	0.0010***	0.0180***	0.0035***	0.0092
	(0.0023)	(0.0004)	(0.0059)	(0.0004)	(0.0003)	(0.0026)	(0.0005)	(0.0068)
Constant	-3.7217***			-0.1814***	-0.0681*	-2.8929***		
	(0.2213)			(0.0353)	(0.0343)	(0.2206)		
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Labourer FE	No	No	Yes	No	Yes	No	No	Yes
N	19861	19861	18921	19861	19861	19861	19861	18921
# Labourers	798			798		798		
(Pseudo) R2	0.172		0.156	0.204	0.136	0.131		0.155

Source: See text. Notes: * p<0.05, ** p<0.01, *** p<0.001. Robust standard errors in parentheses. Tenure given in percentile rank of all active labourers at the site in an accounting period. The outcome variable is whether the labourer worked 85% or more of the maximum days worked in the accounting period.

Figure 4. Predictive margins



Source: See text

The results in Table 4 strongly support the hypothesis that the Cathedral favoured longer-standing labourers when allocating employment. This relationship is robust to alternative measures of allocation, including varying the threshold for 'full time' and continuous measures of the share of work given to each labourer (Online Appendix 2.1 and 2.2). It is also robust to the inclusion of controls for external shocks which could have affected hiring at St. Paul's, including wars, variation in temperature, mortality, and financial volatility (Online Appendix 2.3).

The relationship grew stronger in periods where the project was at a more critical and potentially risky stage, as with the construction of the Dome, involving flying scaffolds (Campbell 2007, p. 151), when labourers with greater experience and reliability may have been more important to the success of the project (Online Appendix 3). The same pattern of preferential treatment, albeit weaker, persisted in the period from 1714 to 1748 among labourers hired for maintenance work (Online Appendix 4).

c) Marginal returns to tenure over time

The results in Table 4 suggest that St. Paul's favoured long-standing workers when allocating days of work each accounting period. There is a strong and significant relationship between tenure and the number of days of work a labourer was allocated in a month even when individual productivity is accounted for, albeit imperfectly, with labourer fixed effects. How does this relationship change as a labourer's tenure increases?

We expect the marginal returns to tenure to diminish if the employment patterns we observe at St. Paul's are explained by two of the standard models in labour economics: worker's on-the-job learning (Lazear 2009), or the employer's discovery of a worker's true productivity, as in the Jovanovic (1979) model. If on-the-job learning is driving our results, the marginal effect of tenure should diminish to zero after a short period of learning. Because labouring at St. Paul's was relatively unskilled, we would expect this learning to take a year or less. Likewise, it would not take more than a year for employers to recognize which workers are most productive and adjust their hiring accordingly, especially as no explicit contracts were involved. If the returns to tenure do not diminish shortly after a labourer is hired, this suggests that tenure was incentivized and rewarded for other reasons.

We capture whether the relationship between tenure and whether a labourer worked full time diminished after one year by interacting the labourer's tenure percentile rank measured in cumulative days with an indicator for whether their cumulative years of tenure was greater than one year. The results for the logit specification are given in Table 5 column (1). For robustness, we also estimate this model as conditional logit with labourer fixed effects in column (2), and as a linear probability model with and without fixed effects in column (3) and (4). We also examine different thresholds for learning/discovery with an indicator for whether tenure was greater than six months, two years, or three years, in columns (5), (6), and (7) respectively.

In all seven models in Table 5, the interaction of the tenure rank percentile with the indicator for cumulative years of tenure greater than k is insignificant. The marginal effects of tenure on the probability of a labourer working full time are similar for labourers who were just beginning their careers at St. Paul's and for labourers who had been associated with the Cathedral for longer. This suggests that on-the-job learning and employer learning do not drive the relationship between tenure and number of days worked.

Table 5: Marginal returns to tenure as tenure increases: learning models

	1 Year Indicator, $k = 1$				6 Month Indicator, $k = 0.5$	2 Year Indicator, $k = 2$	3 Year Indicator, $k = 3$
	Logit	Cond. Logit	Linear Prob.	Linear Prob. (FE)	Logit	Logit	Logit
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Tenure Percentile Rank	0.0272***	0.0144**	0.0048***	0.0014***	0.0369***	0.0232***	0.0246***
	(0.0029)	(0.0049)	(0.0005)	(0.0003)	(0.0038)	(0.0024)	(0.0022)
Indicator for k tenure years	-0.5856*	0.0099	-0.1223**	0.0130	-0.4374	-0.5981	-0.3758
	(0.2600)	(0.3357)	(0.0419)	(0.0210)	(0.2315)	(0.3689)	(0.5927)
Tenure * Indicator for k tenure years	0.0056	-0.0030	0.0015	-0.0006	-0.0052	0.0100	0.0065
	(0.0042)	(0.0062)	(0.0008)	(0.0004)	(0.0047)	(0.0053)	(0.0078)
Constant	-3.7571***		-0.1728***	-0.0975*	-4.0713***	-3.4779***	-3.5771***
	(0.2402)		(0.0365)	(0.0380)	(0.2489)	(0.2331)	(0.2258)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Labourer FE	No	Yes	No	Yes	No	No	No
Avg. Marginal Effects							
Tenure years indicator							
$k = 0$	0.0051***		0.0048***	0.0014***	0.0067***	0.0042***	0.0045***
$k = 1$	0.0056***		0.0062***	0.0008***	0.0055***	0.0057***	0.0055***
N	19861	18921	19861	19861	19861	19861	19861
# Labourers	798		798		798	798	798
(Pseudo) R2	0.173	0.156	0.206	0.136	0.176	0.173	0.172

Source: See text. Notes: * p<0.05, ** p<0.01, *** p<0.001. Robust standard errors in parentheses. Tenure in cumulative days given in percentile rank of all active labourers at the site in an accounting period. The outcome variable is whether the labourer worked 85% or more of the maximum days worked in the accounting period.

Table 5 indicates that the marginal effects of tenure did not diminish early in the employment relationship. Is there any change in the importance of tenure over a labourer's career? We can estimate how long it takes for the marginal returns to tenure to diminish by allowing the relationship of tenure to the probability of working full time to vary non-linearly. We estimate a logit model with tenure and tenure squared where we measure tenure using raw cumulative years worked at St. Paul's. Using this logit model, Figure 4b shows that the probability of working full time only begins diminishing after a labourer's eighteenth year of work at St. Paul's.[31]

The employment patterns we observe at St. Paul's were not apparently driven primarily by on-the-job learning or by the clerk learning labourers' true productivity in the first months or years of a labourer's employment. This is further evidence that long-standing labourers were rewarded for their tenure and seniority at St. Paul's.

d) Persistence of employment

As well as deciding how many days of work to give to labourers in each week, the clerk chose who would be hired again the next week. As the estimates of churn in Table 1 indicate, the Cathedral saw high levels of hiring and separation from month-to-month. This offers us a second, critical test of the structure of employment: were long-standing labourers more likely to be retained month-by-month at St. Paul's? If the clerk saw labourers as undifferentiated (differentiated), then the amount of time they had spent on the site should be uncorrelated (correlated) with the probability they would be hired in the future.

The consistency of employment would have been a pressing concern for labourers. The peaks and troughs of labour demand on the site (Figure 1) left few untouched. Breaks in employment at the Cathedral were commonplace: we can identify 840 periods of temporary separation in our panel, when a labourer was absent for one or more accounting period before reappearing in a later period.

[31] The full estimation results are given in Appendix 7 Table 7.3.

Because we do not observe separations of less than a month, this is likely to be an under-estimate. Almost all absences (89%) were for less than a year, and the median absence was two months (62 days). Long-serving workers did not escape periods without work—four-fifths of labourers employed for more than a year had at least one break in employment.

Given the frequency of breaks in employment, we model how prior tenure affected whether labourers were hired in each accounting period. In each time period, as in subsections b and c, we focus on the supply of possible labourers from among those individuals who were existing active workers at the Cathedral—those who had worked one shift at the Cathedral previously and who had not yet made their final appearance in the records. However, in this part of the analysis, we can also include the 160 workers dropped from the analysis in the previous sections who appeared in the accounts only once. These estimates do not speak to the choice of whom to hire from outside the pool of active laborers, and we cannot examine the determinants of a labourers' final exit from the site. In effect, this analysis can be interpreted as how tenure affected the chance that workers had periods in which they were not hired from among the general pool of labourers.

In the three models in Table 6, the dependent variable is a binary indicator equal to 1 if the worker was given work in an accounting period, and 0 otherwise. Our independent variable of interest is the worker's prior tenure relative to all active workers in that period, again given as a percentile rank of cumulative days worked or elapsed time at the Cathedral. As above, all of the models have year and month fixed effects with clustered standard errors.

Our main results in columns (1) and (2) demonstrate that long-standing workers were more likely to be given work in each accounting period. Column (1) gives the coefficient estimates from a logit model. The marginal effects in column (2) indicate that a one quartile increase in a labourer's tenure percentile rank increases their probability of being given employment by 9 percentage points

($p<0.001$, $25 * 0.0035 = 0.0875$). As Figure 4c indicates, these estimates indicate that a worker in the 90th percentile of cumulative days worked prior to a given accounting period had a 92% chance of be hired, while a worker in the 10th percentile had only a 65% chance. This effect is robust to the inclusion of labourer fixed effects in a conditional logit model in column (3), and the effect size is similar between a linear probability model with and without labourer fixed effects in columns (4) and (5).

Table 6: Logit models for the probability of a labourer being given work

	Cumulative Days Tenure					Elapsed Time Tenure		
	Logit Coeff.	Logit Margins	Cond. Logit Coeff. (FE)	Linear Prob.	Linear Prob. (FE)	Logit Coeff.	Logit Margins	Cond. Logit Coeff. (FE)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Tenure	0.0260***	0.0035***	0.0275***	0.0035***	0.0036***	0.0184***	0.0026***	0.0440***
	(0.0025)	(0.0003)	(0.0084)	(0.0003)	(0.0002)	(0.0027)	(0.0004)	(0.0084)
Constant	-1.0639***			0.4073***	0.4220***	-0.3757		
	(0.2196)			(0.0357)	(0.0268)	(0.2043)		
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Labourer FE	No	No	Yes	No	Yes	No	No	Yes
N	20780	20780	17839	20780	20780	20780	20780	17839
# Labourers	955			955		955		
(Pseudo) R2	0.154		0.151	0.148	0.105	0.119		0.185

Source: See text: Notes: * p<0.05, ** p<0.01, *** p<0.001. Robust standard errors in parentheses. Tenure given in percentile rank of all active labourers at the site in an accounting period. The outcome variable is whether an active labourer was given work during the accounting period.

Columns (6) and (7) give the coefficients and marginal effects of a logit model using our alternative measure of tenure percentile based on elapsed time. The effect size is significant but slightly smaller: a one quartile increase in the labourer's elapsed time percentile rank increases the probability of being hired by 7 percentage points ($p<0.001$, $25*0.0026 = 0.065$). Column (8) indicates that these results are also robust to the inclusion of labourer fixed effects.

The models in Table 6 indicate that long-standing workers were given more consistent employment at St. Paul's. Of all active labourers, it was those with the least tenure who were most likely to face periods in which they were not hired. Longer standing labourers, in contrast, were the last to be stood down. Moreover, as Online Appendix 5 shows, the seasonality of building work strongly suggests that labourers were not absenting themselves for better offers on other sites. Less-tenured workers were laid off in periods when low demand would be widespread across the sector, making a seamless transition to another site unlikely.

e) Additional income earning opportunities

Finally, how did the clerk distribute the chance to earn additional income at the Cathedral? One lucrative perk in his gift was shifts as night watchmen, given to labourers in addition to their regular labouring days. A night's watch paid 8d. until 1700 and 12d. thereafter, equivalent to half to two-thirds of the daily wage.[32] The most shifts any labourer was allotted was two per week or ten per month, limiting the monthly income premium to about 15%. Our test is the same as that in the previous sections: were long-standing labourers more likely to be given watchman shifts at St. Paul's?

[32] Since not all long-standing labourers were offered shifts as watchmen, we infer watch work was a desirable opportunity, not an obligation accepted as the price for additional day. Lang (1956, p. 87) describes men who serviced the watch as being furnished with 'warm cloaks' for their comfort. The watch was a privileged position of trust at other city and crown institutions (see Sainty 1975). We have not been able to establish why the rate of pay per shift increased in 1700 in the minutes of the commission or otherwise.

Overall, just 8% of all labourers served as watchmen.[33] Watch shifts were associated with longer tenure—the median tenure at the Cathedral for workers given watch shifts was nine years, whereas the median tenure for workers who were not given watch shifts was only six months. Two-thirds of watchmen had been active as labourers for more than a year before their first night shift. However, even among long-standing labourers the majority were not hired as watchmen—only 32% of labourers who were employed as labourers for longer than two years in the construction period were given watch shifts.

In general, being hired as a watchman seems to have been a valuable privilege that possibly reflected information about trustworthiness: shifts were given to a small and relatively stable group among the labourers.[34] This trustworthiness mostly appears to have arisen from a worker's tenure at the Cathedral, but relationships and kinship may also have had an effect. Four labourers (Charles Lepton, Thomas Tillison, Thomas Bugby, and Richard Hart) were given a watchman's shift in their first period working at the site, and at least two of them may have had relatives who already worked at the site.[35] Watch shifts thus appear to be a lucrative reward for labourers who were considered trustworthy enough to manage the site overnight.

We estimate the extent to which long-standing labourers at the Cathedral were more likely to be allocated shifts as watchmen. In the four models in Table 7, the dependent variable is whether or not a labourer was also hired as a watchman during an accounting period. Tenure is measured as before. The final years of

[33] The exception was the quiet years of the 1690s; in these slump years just under half of labourers took work as watchmen. In years when construction peaked, this fell to as low as 7% of labourers.
[34] Over 90% of those with watch shifts in one period were given shifts in the next period, and the majority (60%) of those serving as watchmen would do so for every month of a year in which they were active.
[35] Charles Lepton, who became a watchman in his first account (March 1703), may have been related to Christopher Lepton, who had worked between October 1697 and September 1698, and who himself reappeared in November 1703 (with a watch shift at his reappearance). Thomas Tillison was possibly related to John Tillison, who had worked for a year from March 1676 to June 1677.

the construction phase (1708-1711) are excluded because watchman shifts are not recorded in these years.

Table 7: Logit models for the probability of a labourer having a watchman shift in an accounting period

	Cumulative Days Tenure				Elapsed Time Tenure	
	Logit Coeff.	Logit Margins	Linear Prob.	Linear Prob. (FE)	Logit Coeff.	Logit Margins
	(1)	(2)	(3)	(4)	(5)	(6)
Tenure	0.0497***	0.0053***	0.0050***	0.0046***	0.0431***	0.0048***
	(0.0054)	(0.0006)	(0.0007)	(0.0002)	(0.0055)	(0.0007)
Constant	-5.6099***		-0.1838***	-0.0046	-4.7720***	
	(0.5309)		(0.0506)	(0.0233)	(0.5134)	
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Labourer FE	No	No	No	Yes	No	No
N	16903	16903	16903	16903	16903	16903
# Labourers	746		746		746	
(Pseudo) R2	0.228		0.178	0.110	0.188	

Source: See text. Notes: * p<0.05, ** p<0.01, *** p<0.001. Robust standard errors in parentheses. Tenure given in percentile rank of all active labourers at the site in an accounting period. The outcome variable is whether the labourer was given a watchman shift in an accounting period.

Our main results in columns (1) and (2) show that more tenured labourers were more likely to be hired as watchmen. The marginal effects in column (2) indicate that a one quartile increase in the percentile rank of a labourer's tenure increases the probability that they were hired as a watchman by 13 percentage points (25*0.0053 = 0.1325). Figure 4d plots how the probability of being awarded a watchman shift changes with a labourer's tenure percentile. New labourers in the 10th percentile in terms of tenure had only a 15% chance of being given a watchman shift, while those in the 90th percentile had a 41% chance. Columns (3) and (4) give linear probability models with and without labourer

fixed effects, demonstrating that the within-labourer effect of tenure on getting a watchman shift is very large and significant. Columns (5) and (6) in Table 7 show that this effect is robust to our alternative measure of tenure and is of a similar magnitude. Watch shifts were thus largely given to labourers with longer tenure and added an important additional reward for labouring at the Cathedral.

f) Implications for labourer income

Long-term labourers were advantaged in the number of days of work they were allocated each month and the persistence of their work over the seasons. The impact of this on annual employment and income was substantial.[36] The median number of days worked per year on this site for all labourers in any year was just 145, but for those who were active at the Cathedral for more than two years, the median was 200 days.[37] With longer tenure, labourers could achieve something like full-time work from a single employer, avoiding the costs of searching for other work. Because wages were nominally rigid, this differential in hiring determined the level of income that labourers could achieve through work at the Cathedral.

[36] We acknowledge that we can only calculate income from the Cathedral here, with income from other external sources unknown. That income will depend on the day or task rate paid for such work, the amount of external work, and the cost of time and effort spent searching for it. There is unfortunately not enough information about other sites to calculate labourer's incomes more comprehensively.

[37] Calculations for the construction phase, excluding watch shifts.

Table 8. Average annual income (£) for labouring and watch at St. Paul's, by tenure

	Tenure Percentile			
	1st-24th	25th-49th	50th-74th	75th-99th
Construction				
1675-9	£3.61	£7.73	£11.16	£10.31
1680-4	£6.31	£9.79	£13.38	£13.53
1685-9	£4.11	£9.63	£11.33	£14.84
1690-4	£4.95	£11.32	£14.08	£17.98
1695-9	£8.72	£15.47	£15.86	£20.56
1700-4	£11.56	£16.21	£19.79	£22.85
1705-9	£9.78	£16.42	£18.71	£22.34
Maintenance 1711-1748	£15.75	£19.09	£18.57	£19.25

Source: See text. Notes: Tenure percentile rank is calculated each year relative to all labourers who worked in that year based on the elapsed time since the labourer began working at St. Paul's. These calculations only include income from the Cathedral, labouring or watch shifts, with any other income from other external sources unknown.

The dispersion in labourers' income from St Paul's is apparent in Table 8, which summarises the average income of labourers according to their tenure for each half decade of the construction period, 1675–1709, and for the maintenance period, 1711–1748. These calculations include pay for days worked as a labourer and any additional income from watch shifts. In each period, labourers who had worked at the Cathedral the longest had higher annual incomes from the Cathedral than those who were relatively new to the project. Their access to more days of work, more consistent working patterns, and watchman shifts gave them substantially higher average annual incomes than those in the bottom half of the tenure distribution.

During the early years of construction, even the most tenured workers earned less than £20 per year in nominal terms.[38] If they were to earn enough to support themselves and a family, these workers would have needed to find work on multiple sites or in a variety of by-employments each year, although the seasonality of construction work will have made this difficult. In later years,

[38] For comparison, the standard estimates of annual income for this period are generally based on day rates of 20d to 24d for a standard 250 days a year (Allen 2009; Broadberry 2015). This implies an average labourer earned £20 -£25 per annum.

with the stabilization in hiring at the Cathedral, labourers' incomes from employment there grew markedly. By 1700–1709, the majority of labourers were employed for enough days each year on this site to earn over £18. As work moved towards maintenance after 1711, and the labouring workforce dwindled to a few men in each month, the average labourer at the Cathedral was employed for over 300 days a year, and even labourers in the lowest quartile of tenure were earning £16 or more. In real terms this would have fluctuated considerably, as this was a period of highly volatile price inflation and deflation.[39]

Discussion

To summarize, despite enormous volatility in labour demand during the construction of St. Paul's, the hiring of general labourers gradually stabilized, turnover fell, and average tenure increased. Employment became highly polarised, even though all the general labourers were doing similar work requiring a similar skill level. A core set of workers achieved relative job stability and access to additional work, and a periphery of temporary workers experienced short tenure. This core of long-lasting workers supplied a large share of the project's needs.

The day wage rate was almost identical for all workers in both groups, and did not change over eight decades. However, as we have shown, longer-standing labourers received preferential treatment in four ways that increased their earnings. First, they were given more days of work in each period in which they were present. Second, they were more likely to be retained. Third, they were more likely to be rehired after being laid off. Finally, they were given access to lucrative watchman shifts. That this was a deliberate strategy developed by the Cathedral is apparent from the accounts. Core workers were hired first by the site each month, with peripheral workers added later as needed. Evidently,

[39] See price series in the Bank of England's, "A millennium of macroeconomic data," Thomas and Dimsdale (2017)

workers had to choose to return, and were rewarded for doing so, but their chance of selection rested on the clerk's view of their place in his system.

An intuitive explanation for the clerk's hiring decisions is that they simply reflected productivity differences between labourers: it was those workers who were the most productive, or expected to be the most productive, who were being hired first and for the most days. In a competitive market, we would usually expect productivity differences to be reflected in wages.[40] With wages nominally fixed, offering extra work could have been a form of additional incentive. Perhaps the clerk was able to learn about which workers were innately more suitable or productive, as in Javonovic (1979)'s screening model, or workers were building up firm-specific human capital through on-the-job learning (Lazear 2009).[41] The greater returns to tenure during the construction of the Dome (Online Appendix 6) offer some support for this interpretation.[42] The absence of declining marginal returns to tenure, however, indicate that neither on-the-job learning or employer learning can fully explain how hiring operated at the Cathedral .

A second explanation is that the early modern labour market in construction in London had more frictions than has been previously assumed. St. Paul's may have pursued strategies in order to address principal-agent problems (Shapiro and Stiglitz 1984), to minimize turnover costs (Stiglitz 1974), or to overcome information asymmetries with adverse selection (Weiss 1980). The efficacy of these strategies varies with workers' tenure, possibly explaining the different experiences of tenured and non-tenured workers at the Cathedral.

Among explanations focusing on frictions, our results are most obviously consistent with a model in which St. Paul's faced high costs of hiring and

[40] That wage differentials are expected for workers with heterogenous expected marginal products is a typical feature of neoclassical labour market models.
[41] Note that Javonovic (1979) implies wage differentials, which are not found at St. Paul's.
[42] In a sense by hiring the most experienced or safest workers on the Dome the clerk was avoiding "mistake costs", where the employer's strategy was designed to avoid moral hazard in scaffolding safely.

training workers, and so 'tenure mattered'.[43] If turnover costs were significant, there would be an incentive for the clerk to create long-term bonds such as implicit contracts that could provide this form of job security (Okun 1982). To reduce the costs of turnover, whilst posting fixed wages, some workers were given access to additional income though more consistent work and a higher probability of being rehired after seasonal breaks. This ensured enough worker retention to minimize these costs. The clerk's adherence to seniority in hiring across the duration of employment at the site fits well with this. The risk that weather, finance, or project factors might stop work at any time, however, precluded longer-term contracts.

Our results reveal how employers could use the organisation of work rather than wages to manage supply and demand in pre-industrial unskilled labour markets. The Cathedral optimized the structure of its pool of general labourers by rewarding and incentivizing tenure, reducing turnover costs in the face of substantial shifts in supply and demand for labour.

Given the difference between our findings and earlier assumptions, the question arises of how much we can surmise about the market for and employment of unskilled labour more generally from St. Paul's. The very existence of the records we study, and the argument we pursue, suggests employment patterns may have been different at this site because its scale and duration offered the opportunity for longer-term working relationships than other projects. However, recent results from a similar eighteenth century project in Madrid imply returns to tenure for skilled and unskilled workers elsewhere.[44]

The Cathedral certainly was an unusually large project. Although it was publicly funded in a possibly bureaucratic manner, the operation of its hiring and contracting were broadly representative of the market. Other aspects of building work on the Cathedral operated in the same way as on other large sites in the

[43] As per Manning (2003, p. 3) that jobs have rents.
[44] García-Zúñiga and López Losa (2021)

city (Stephenson 2020a, pp. 35-64, 79-106). The wharving of the Fleet ditch in the early 1670s reputedly used hundreds of labourers contracted by Thomas Fitch during the two to three years that the project took; unfortunately, no named records survive (Skempton and Chrimes 2002, p. 228). General labourers were also hired at Westminster Abbey, 1712–1713, and Greenwich, 1696–1706, two of the largest contemporaneous sites, although in smaller numbers.[45] Similarly, Woodward (1995, pp. 100-06) offers evidence of some labourers' long-term association with sites. Other places such as the dockyards may have developed similar systems of hiring to St. Paul's, but it is impossible to test whether the same trends in tenure and hiring occurred. However, the records of the contractors who operated such sites also tentatively indicate a positive relationship between tenure and the annual numbers of days worked (Stephenson 2020b, p. 424). Those contractors worked across private and publicly funded projects.

The relationship we document between a worker's length of tenure with an employer and the number of days for which they were hired has obvious implications for living standards. Wage labourers' income has conventionally been estimated by multiplying day rates with a standard number of days worked.[46] Changes to the number of days worked have been linked to general shifts in industriousness and immiseration. If the days of work available to labourers were not randomly distributed, as this case strongly suggests they were not, then flat nominal day wage rates may conceal considerable inequality between workers.

Conclusion

Workers on London's largest building site in the later seventeenth-century faced high levels of uncertainty about whether or not they would be given work in the

[45] Westminster Abbey Muniments cat. no.34513; The National Archives, Greenwich Hospital ADM 68/4

[46] Clark 2005; Clark 2007; Allen 2001. But see Allen and Weisdorf (2011), and Humphries and Weisdorf (2019) for a consumption-led variation to this.

next week or month. The needs of the project varied dramatically, and with it the chance of being hired. However, work was not allocated in a pure spot market. Instead, the Cathedral developed and prioritized a core group of long-term workers, who were put at the head of the queue in hiring, offered additional work as watchmen, and allotted a larger share of the available work than their less-experienced peers, who received short and insecure periods of work. Tenure—as we might generously term what remained a tenuous and intermittent relationship—was rewarded by the Cathedral with access to larger amounts of work, and so a higher and more reliable income. Building labourers' incomes were thus more varied than their day-rates imply.

These patterns are explicable if St. Paul's was using its hiring strategy to deal with the volatility of labour markets. Wages did not adjust to shifts in demand in the short- or long-term; rather, nominal rates persisted despite eight decades of urban expansion, persistent GDP growth, and structural change. Labourers were incentivized to return by the prospect of more work, not more money per day: higher incomes not higher wages. This strategy may have reduced turnover costs for the Cathedral, contributing to the stabilization of their workforce which we have observed.

To be clear: no direct record of the management strategy of the Cathedral exists, even if one was ever articulated explicitly by those involved. But the Cathedral's hiring choices indicate an employer deliberately favouring their long-term workers. St. Paul's thus presents a phenomenon that is, in the context of the existing literature, unexpected for a pre-industrial unskilled labour market. This distinctive mechanism used to reward and retain workers seems to have emerged endogenously as a response to the standard challenge of supplying large numbers of workers of a suitable quality in a volatile labour market.

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Online Appendix 1: Worker Churn at St. Paul's

This appendix explains our approach to churn at St Paul's Cathedral. Worker churn has three main components. Firms add or cut jobs, as demand increases or falls. Firms fire some workers while other workers quit, and replacements are hired. And firms are established or fail. Measures of turnover depends on how many of these channels of hiring and separation are observed, and the basis for measuring worker churn varies in important ways between studies.

Measures of turnover also depend on how employment is captured. Where employment is measured via a quasi-census at intervals, some types of churn are omitted. For example, present day measures for Germany and other settings utilize data that capture employment at sequential cross sections: Bachmann et al (2020) consider a labourer to be working for an establishment if she is employed at the end of the quarter. The number of jobs at the end of the quarter follows from this (J_{it}); the number of hires (H_{it}) is the number of workers who were not working at the end of the previous quarter; and the number of separations (S_{it}) is the number who had been working at the end of the previous quarter and who have now left (Bachman et al:5, 25-28). Turnover *within* a quarter is not observable in this approach. Alternatively, some sources, such as the LEHD dataset studied by Davis et al (2006), include all worker transitions of whatever duration. Measures of this kind produce much higher rates of hiring and separation than those that focus on 'full quarters' (Davis et al 2006:6).

Our dataset is organized into periods of one or more month's duration and reports all workers employed in an accounting period (month, quarter or longer) as labourers and watchmen, including short employment spells. We construct measures of job and worker flow within St Paul's based on the available accounting periods. Where the duration of the accounts is a month, we define the number of jobs, $J_{it,}$ as the number of workers employed as day labourers within that month (excluding workers employed solely as watchmen). The number of labourers who appear in the records in that month but not in the previous month gives us our count of hires, H_{it}. The number of labourers who were not retained from the previous month is our count of separations, S_{it}. We compute net monthly job flow as $JF_{it} = J_{it} - J_{it-1}$. Job creation JC_{it} occurs where employment increases ($JF_{it}>0$) and job destruction JD_{it} occurs when it falls ($JF_{it}<0$). Because more workers may be hired or separated in a period than jobs (i.e. $H_{it}>JC_{it}>0$), we also report the churn (Ch_{it}), as defined by Burgess et al (2000).

$$Ch_{it}=(H_{it}-JC_{it})+(S_{it}-JD_{it})$$

We follow the normal convention (Davis et al 1996) in converting hiring and separation flows into rates by dividing totals by the average of employment in the previous and current period, so the hiring rate is defined as:

$$HR_{it}=H_{it}/(J_{it}+J_{it-1})*1/2$$

Other rates (separation, job creation, job destruction and churn) are defined in the same manner. This approach constrains growth rates to between -200 and +200 percent. We report rates based on monthly accounts which survive for much of the construction phase. These calculations are restricted to periods for which two sequential accounts are of one-month duration. For quarterly estimates, the period commonly found in the modern literature, we carry out the same calculation using three-month windows and taking the first quarter as January to March, to align with general practice.

The measures we report are the equivalent to 'all transition' figures, because they count every person employed, no matter how long they stayed. Workers who were only hired for a few days on one occasion still count as a hire and a separation, even though they just appeared in a single month or quarter, respectively. Workers who had been employed previously, but had been absent for a period, are also counted as new hires.

For comparison, we also compute 'full quarter' figures. We report two variants on the quarterly data. First, in our 'quarterly (any)' calculations we treat workers as employed if they are hired at any point within a quarter. From this definition, follows the number of jobs at the cathedral, the number of hires (workers who had not been active in the previous quarter), and separations (workers who were no longer active from the previous quarter). These figures have the advantage of observing all transitions of any period.

Second, in our 'quarterly, (quasi-census)' calculations we treat workers as employed if they are employed in the final month of a quarter (March, June, September, December). This is the closest we can come to the approach taken by Bachmann et al (2020) who define employment based on a worker being employed at the end of a quarter. These figures neglect short-term employment in other months and are oriented towards identifying longer-term hiring. These figures are useful for comparison, but should be treated with caution, given that short periods of work were the norm and they will be particularly shaped by the specifics of hiring in the final month of each the quarter.

The number of months falling into observation in the monthly series is reported in the main text. The number of quarters in observation is given in Table 1.1. To estimate churn, we require a quarter to be part of a continuous sequence of accounts, ensuring we observe the previous and the next quarter in order to work out hiring and separations.

Table 1.1: Quarters in observation for churn estimates by quinquennia.

Period	Quarters observed (n)	Share of quarters observed (%)
1675-	17	85
1680-	11	55
1685-	15	75
1690-	20	100
1695-	7	35
1700-	14	70
1705-	20	100
Total	97	69

Our data allow us to distinguish permanent from temporary separation and hiring. Permanent hiring and separation are defined as occurring on a workers' first and last appearance in the Cathedral records. Because temporary absences where workers appear in one period and then return to work after a period of absence are common in the St Pauls records, the permanent hiring and separation rates are substantially below the job creation and job destruction rate.

Where the numbers employed increased, this is job creation. Where the numbers decrease this is job destruction. When there is no creation/destruction, the figure is set to zero. The closest modern equivalent would be the flow of workers into and out of zero-hours contracts with highly unstable monthly labour demand. Aggregate rates in the literature are calculated using seasonally adjusted series. We do not adjust for seasonality, given that we are dealing with a single site with highly volatile employment.

Table 1.2: Churn Estimates, Monthly

Job Creation Rate (monthly)

	mean	sd	min	max	count
1675-	7.78	12.21	0	51.43	50
1680-	6.86	14.14	0	70.97	33
1685-	7.50	12.55	0	54.21	43
1690-	5.53	6.38	0	34.78	50
1695-	3.03	4.49	0	13.33	17
1700-	5.46	9.90	0	43.90	42
1705-	7.24	21.75	0	120.61	60
Total	6.54	13.68	0	120.61	295

Job Destruction Rate (monthly)

	mean	sd	min	max	count
1675-	10.28	15.35	0	48.78	50

1680-	8.91	13.28	0	49.06	33
1685-	8.45	14.16	0	54.95	43
1690-	2.89	7.28	0	38.60	50
1695-	5.08	9.35	0	28.57	17
1700-	2.74	9.83	0	60.00	42
1705-	5.88	21.60	0	134.18	60
Total	6.34	14.69	0	134.18	295

Hiring Rate, first starts (monthly)

	mean	sd	min	max	count
1675-	4.96	6.52	0	30.86	50
1680-	1.40	3.68	0	16.13	33
1685-	8.69	12.26	0	54.21	43
1690-	4.30	4.30	0	15.73	50
1695-	1.49	2.33	0	6.90	17
1700-	3.89	6.47	0	27.59	42
1705-	3.45	5.37	0	35.90	60
Total	4.34	7.04	0	54.21	295

Hiring Rate, starts & returns (monthly)

	mean	sd	min	max	count
1675-	14.23	13.42	0	51.43	50
1680-	10.06	14.68	0	74.19	33
1685-	11.67	13.42	0	57.94	43
1690-	8.57	7.38	0	34.78	50
1695-	4.09	4.49	0	13.33	17
1700-	7.30	11.01	0	43.90	42
1705-	9.42	21.46	0	120.61	60
Total	9.88	14.34	0	120.61	295

Separation Rate, final (monthly)

	mean	sd	min	max	count
1675-	7.66	8.01	0	32.89	50
1680-	3.73	5.52	0	23.53	33
1685-	8.23	8.53	0	35.56	43
1690-	3.67	5.27	0	22.86	50
1695-	4.83	7.39	0	22.64	17
1700-	1.97	3.71	0	20.00	42
1705-	2.26	4.94	0	35.44	60
Total	4.56	6.68	0	35.56	295

Separation Rate, temporary & final (monthly)

	mean	sd	min	max	count
1675-	16.77	14.75	0	48.78	50
1680-	12.11	13.18	0	52.83	33

1685-	12.75	13.75	0	54.95	43
1690-	5.93	7.77	0	38.60	50
1695-	6.14	9.72	0	28.57	17
1700-	4.58	10.44	0	60.00	42
1705-	8.06	21.61	0	134.18	60
Total	9.70	14.97	0	134.18	295

Table 1.3: Churn Estimates, Quarterly, Any

Note: these figures report rates based on any appearance by a worker in each quarter.

Creation Rate (quarterly, any)

	mean	sd	min	max	count
1675-	5.97	9.36	0	27.45	16
1680-	5.01	8.90	0	33.33	20
1685-	14.53	26.45	0	90.00	20
1690-	10.35	11.56	0	41.67	20
1695-	9.64	14.41	0	51.43	20
1700-	15.92	24.71	0	88.37	20
1705-	7.80	9.03	0	30.05	20
Total	10.00	16.72	0	90.00	136

Job Destruction Rate (quarterly, any)

	mean	sd	min	max	count
1675-	13.49	12.47	0	31.93	16
1680-	8.86	10.23	0	26.09	20
1685-	13.06	17.50	0	71.60	20
1690-	7.78	15.82	0	52.38	20
1695-	10.37	19.85	0	73.17	20
1700-	13.74	29.89	0	100.00	20
1705-	3.87	9.21	0	30.93	20
Total	10.07	17.75	0	100.00	136

Hiring Rate, first starts (quarterly, any)

	mean	sd	min	max	count
1675-	11.23	12.81	0	49.11	16
1680-	4.63	5.98	0	21.28	20
1685-	18.86	25.20	0	86.67	20
1690-	11.29	8.31	0	28.26	20
1695-	7.34	8.40	0	34.57	20
1700-	8.57	11.01	0	32.32	20
1705-	9.15	8.05	0	27.12	20
Total	10.12	13.27	0	86.67	136

Hiring Rate, starts & returns (quarterly, any)

	mean	sd	min	max	count
1675-	17.70	14.94	0	51.25	16
1680-	11.41	11.02	0	34.62	20
1685-	23.19	26.91	0	91.67	20
1690-	17.07	12.08	0	45.83	20
1695-	14.04	15.15	0	57.14	20
1700-	18.42	25.30	0	88.37	20
1705-	12.18	9.89	2	33.16	20
Total	16.25	17.76	0	91.67	136

Separation Rate, final (quarterly, any)

	mean	sd	min	max	count
1675-	18.62	11.15	0	37.45	16
1680-	9.23	6.58	0	23.08	20
1685-	16.50	14.18	0	49.38	20
1690-	10.96	10.94	0	38.10	20
1695-	8.79	8.76	0	28.99	20
1700-	6.02	8.25	0	25.53	20
1705-	5.58	6.49	0	27.16	20
Total	10.59	10.57	0	49.38	136

Separation Rate, temporary & final (quarterly, any)

	mean	sd	min	max	count
1675-	25.22	12.81	2	42.70	16
1680-	15.27	9.70	0	34.78	20
1685-	21.73	18.41	2	74.07	20
1690-	14.51	15.54	0	61.90	20
1695-	14.77	19.33	0	73.17	20
1700-	16.23	29.38	0	100.00	20
1705-	8.26	10.63	0	37.11	20
Total	16.31	18.10	0	100.00	136

Table 1.4: Churn Estimates, Quarterly, Quasi-Census

Note: these figures report rates based on any appearance by a worker in the final monthly account of a quarter, replicating the 'end of quarter' approach.

Job Creation Rate (quarterly, quasi-census)

	mean	sd	min	max	count
1675-	11.73	19.48	0	72.82	16
1680-	5.59	10.38	0	24.00	8
1685-	17.93	30.03	0	85.71	14

1690-	10.35	12.41	0	46.81	20
1695-	11.28	18.06	0	41.03	6
1700-	10.46	18.68	0	63.83	13
1705-	8.29	10.72	0	32.50	20
Total	10.93	17.73	0	85.71	97

Job Destruction Rate (quarterly, quasi-census)

	mean	sd	min	max	count
1675-	15.65	20.93	0	59.83	16
1680-	11.66	13.60	0	30.77	8
1685-	19.99	26.33	0	75.47	14
1690-	7.37	11.30	0	40.00	20
1695-	16.74	22.49	0	47.06	6
1700-	5.43	18.43	0	66.67	13
1705-	4.29	8.34	0	23.20	20
Total	10.59	17.81	0	75.47	97

Hiring Rate, first starts (quarterly, quasi-census)

	mean	sd	min	max	count
1675-	4.81	8.28	0	32.82	16
1680-	0.42	1.20	0	3.39	8
1685-	7.84	10.52	0	30.36	14
1690-	3.32	4.01	0	15.91	20
1695-	1.98	1.55	0	3.33	6
1700-	3.71	7.95	0	27.59	13
1705-	2.66	2.33	0	8.62	20
Total	3.81	6.49	0	32.82	97

Hiring Rate, starts & returns (quarterly, quasi-census)

	mean	sd	min	max	count
1675-	17.60	12.54	0	42.67	16
1680-	10.70	8.80	0	24.00	8
1685-	14.68	17.42	0	56.00	14
1690-	10.44	10.36	0	38.30	20
1695-	7.25	9.83	0	26.67	6
1700-	6.93	12.26	0	38.30	13
1705-	7.24	6.23	0	25.53	20
Total	10.93	11.81	0	56.00	97

Separation Rate, final (quarterly, quasi-census)

	mean	sd	min	max	count
1675-	6.68	8.91	0	34.91	16
1680-	6.94	6.16	0	16.33	8
1685-	8.13	8.24	0	26.59	14
1690-	4.63	6.07	0	21.54	20

1695-	8.90	10.78	0	26.47	6
1700-	2.75	5.66	0	20.51	13
1705-	3.61	5.33	0	23.63	20
Total	5.47	7.17	0	34.91	97

Separation Rate, temporary & final (quarterly, quasi-census)

	mean	sd	min	max	count
1675-	29.93	18.84	6	67.92	16
1680-	19.58	13.34	7	40.68	8
1685-	29.97	24.41	2	79.25	14
1690-	15.57	13.90	0	52.31	20
1695-	20.09	23.21	0	50.00	6
1700-	10.68	17.37	0	66.67	13
1705-	9.87	9.33	1	29.83	20
Total	18.80	18.36	0	79.25	97

Online Appendix 2: Robustness Checks and Alternative Specifications

This appendix considers whether the results for the intensity of work are robust to changes in how "full-time" is defined, to the use of a fractional logit model, to the inclusion of external shocks that may have affected hiring at St. Paul's, and to the exclusion of possible foremen.

2.1. Are our main results robust to changes in the "full time" boundary?
The 85% of max days worked in a period boundary includes 7,189 of 19,861 (36.18%) observations for the construction period excluding the first few years and those working their first shift. Table 2.1 shows that lowering or raising the boundary causes the percent of observations considered full-time to increase or decrease. At an 80% boundary, over half of observations are included as full-time workers. At a 95% boundary, less than one quarter of observations are included as full-time.

Table 2.1: Percent of workers full time and not full time at different boundaries

	% Full time	% Not full time
Full time > 75	57.99	42.01
Full time > 80	50.86	49.14
Full time > 85	36.18	63.82
Full time > 90	26.03	73.97
Full time > 95	18.40	81.60

Figure 2.1 gives the density of observations across 5-year buckets of the percent of maximum days worked by any labourer in the period. Over half of observations are past 80% of maximum days worked. The 85% boundary excludes the clusters of observations around 80% to capture the top end of the distribution in terms of days worked. Figure 2.2 gives this histogram by decade. The 80% breakpoint is noticeable in each decade, especially after 1700.

Figure 2.1: 5-year bucket density observations with percentage of maximum days worked by any labourer in the period

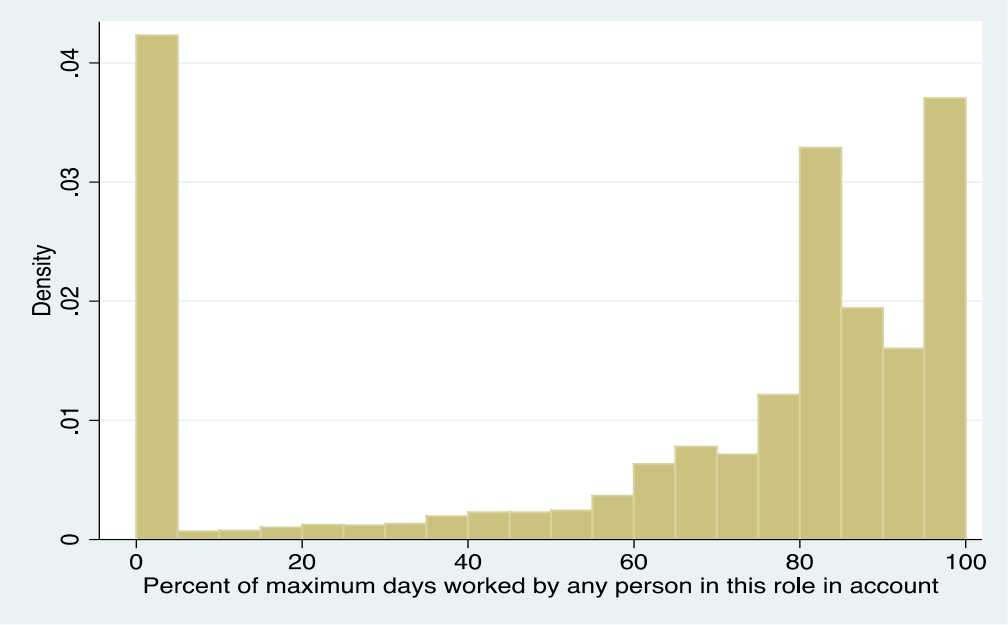


Figure 2.2: 5-year bucket density observations with percentage of maximum days worked by any labourer in the period by decade.

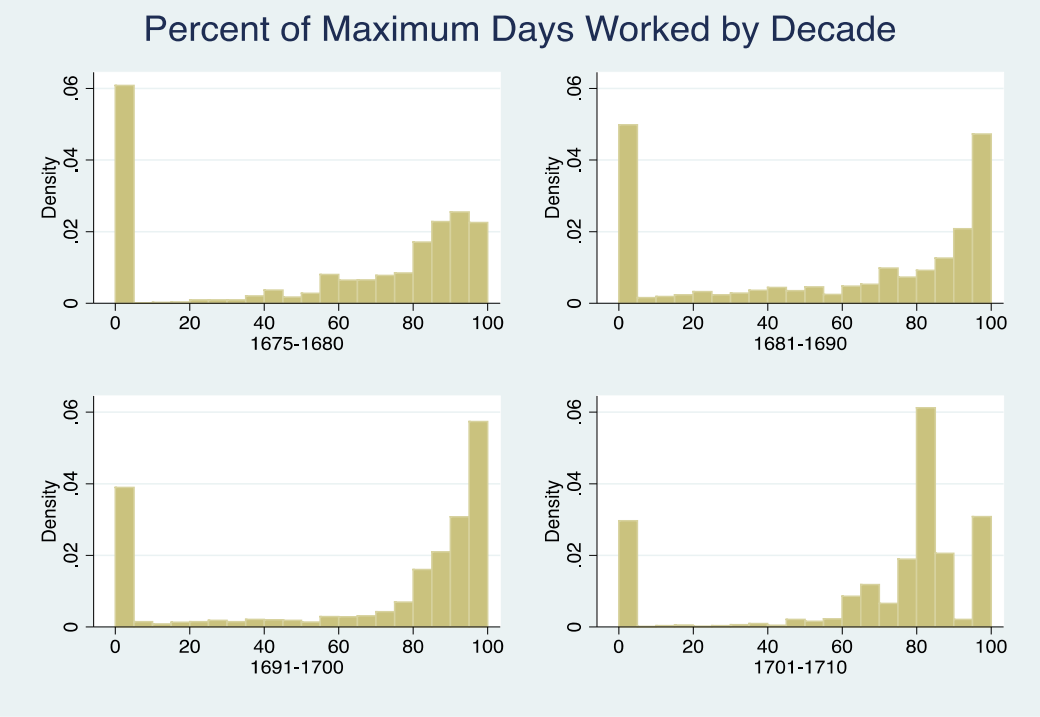


Table 2.2 gives the coefficients and marginal effects from a logit model for the probability of a labourer working full time during an accounting period. The independent variable of interest is tenure in terms of the percentile rank of cumulative days worked previously. Columns (1) and (2) are the results where a worker is considered full time at more that 80% of the maximum days worked during the accounting period. (3) and (4) give the results for the assumed full-

time boundary of 85%. (5) and (6) use a full-time boundary of over 90%, and (7) and (8) use a full time boundary of over 95%.

Table 2.3 is structured the same way, capturing tenure through the percentile rank of elapsed time since the worker began at the cathedral.

Both Table 2.2 and Table 2.3 indicate that the relationship of tenure to the intensity of work during an accounting period is robust to changing the boundary for when a worker is considered full time. In all models in Table 2.2, the marginal effects indicate that a one quartile increase in a labourer's percentile rank of tenure in terms of cumulative days corresponds to over a 10 percentage point increase in the probability that the labourer worked full time during an accounting period, even as the boundary for full time is adjusted ($p < 0.001$, $25 * 0.0040 = 0.10$). Likewise, the models in Table 2.3 indicate that a one quartile increase in a labourer's percentile rank of tenure in terms of elapsed time corresponds to over a 7.5 percentage point increase in the probability that the labourer worked full time during an accounting period, even as the boundary for full time is adjusted ($p < 0.001$, $25 * 0.0030 = 0.075$).

Table 2.2: Probability of a labourer working full time at different full time boundaries

	FT 80 - Coef	FT 80 - Margins	FT 85 - Coef	FT 85 - Margins	FT 90 - Coef	FT 90 - Margins	FT 95 - Coef	FT 95 - Margins
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Tenure - Cum. Days	0.0235***	0.0047***	0.0267***	0.0049***	0.0295***	0.0045***	0.0329***	0.0040***
	(0.0020)	(0.0004)	(0.0023)	(0.0004)	(0.0027)	(0.0004)	(0.0030)	(0.0005)
Constant	-3.5724***		-3.7217***		-6.6361***		-7.4575***	
	(0.2160)		(0.2213)		(0.5982)		(0.9737)	
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Num. of observations	19861	19861	19861	19861	19861	19861	19861	19861
Num. of individuals	798		798		798		798	
Pseudo R2	0.163		0.172		0.189		0.184	

Robust standard errors, adjusted for clustering by individual, are presented in parentheses.
Tenure given in percentile.
* p<0.05, ** p<0.01, *** p<0.001

Table 2.3: Logit models for the probability of a labourer working full time at different full time boundaries

	FT 80 - Coef (1)	FT 80 - Margins (2)	FT 85 - Coef (3)	FT 85 - Margins (4)	FT 90 - Coef (5)	FT 90 - Margins (6)	FT 95 - Coef (7)	FT 95 - Margins (8)
Tenure - Elap. Time	0.0148***	0.0031***	0.0180***	0.0035***	0.0205***	0.0033***	0.0235***	0.0030***
	(0.0023)	(0.0005)	(0.0026)	(0.0005)	(0.0030)	(0.0005)	(0.0033)	(0.0005)
Constant	-2.7713***		-2.8929***		-5.7406***		-6.5117***	
	(0.2051)		(0.2206)		(0.6447)		(1.0644)	
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Num. of observations	19861	19861	19861	19861	19861	19861	19861	19861
Num. of individuals	798		798		798		798	
Pseudo R2	0.126		0.131		0.146		0.139	

Robust standard errors, adjusted for clustering by individual, are presented in parentheses.
Tenure given in percentile.
* p<0.05, ** p<0.01, *** p<0.001

2.2: Are our main results robust to a non-binary dependent variable?

We can also check the robustness of our results by using a fractional dependent variable for the raw percentage of maximum days worked in a period. The model specification is a fractional logit model with year and month fixed effects. These results are given in Table 2.4.

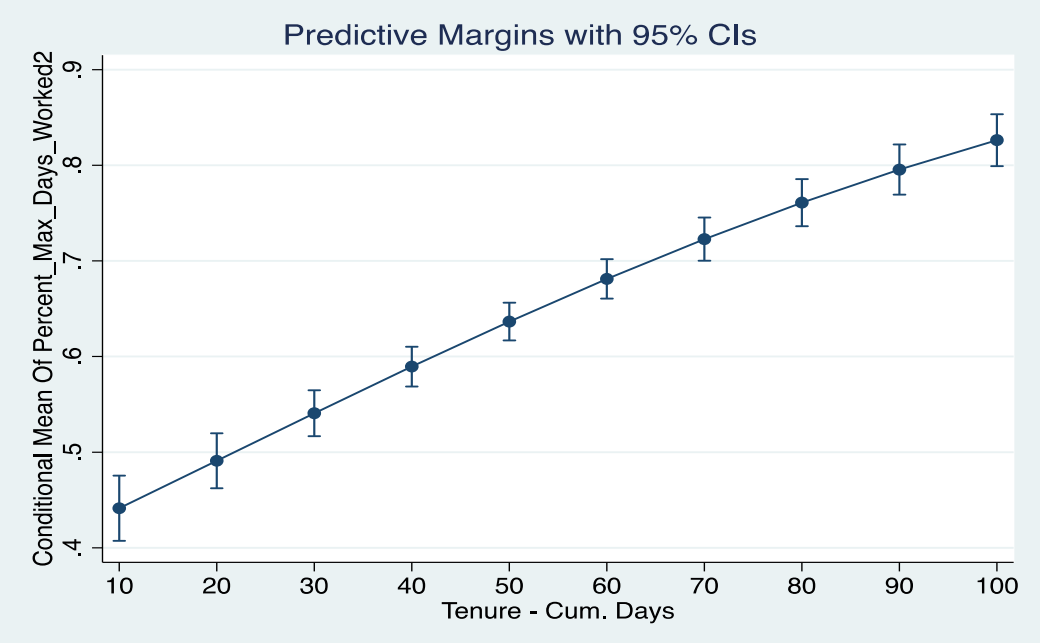
Columns (1) and (2) use the percentile rank of cumulative days previously worked as the measure of tenure. The marginal effect indicates that a one quartile increase in percentile rank of tenure corresponds to a 10.75 percentage point increase in the percent of maximum days worked in an accounting period (p<0.001, 25*0.0043 = 10.75). Columns (3) and (4), using elapsed time percentile rank as the measure of tenure, indicate that a one quartile increase in percentile rank of tenure corresponds to a 7.8 percentage point increase in the percent of maximum days worked in an accounting period (p<0.001, 25*0.0031 = 7.8). Figure 2.3 graphs the marginal effects for the model in (1) and (2). As the percentile rank increases, the percent of maximum days worked increases.

Table 2.4: Fractional logit models for percent of maximum days worked in the accounting period

	Cum. Days Tenure - Coefficients	Cum. Days Tenure - Margins	Elap. Time Tenure - Coefficients	Elap. Time Tenure - Margins
	(1)	(2)	(3)	(4)
Tenure	0.0215***	0.0043***	0.0150***	0.0031***
	(0.0017)	(0.0003)	(0.0019)	(0.0004)
Constant	-2.5237***		-1.9146***	
	(0.1677)		(0.1575)	
Year Fixed Effects	Yes	Yes	Yes	Yes
Month Fixed Effects	Yes	Yes	Yes	Yes
Num. of observations	19861	19861	19861	19861
Num. of individuals	798		798	
Pseudo R2	0.107		0.078	

* p<0.05, ** p<0.01, *** p<0.001. Robust standard errors, adjusted for clustering by individual, are presented in parentheses. Tenure given in percentile.

Figure 2.3: Marginal effects for the model (1) and (2) in Table 2.4, showing percentile rank and percent of maximum days worked.



2.3: Are our main results robust to the inclusion of external shocks which may have affected St. Paul's?

Over the period of the reconstruction of St. Paul's, there were numerous external shocks which could have shaped the tightness of the construction labor force. In this Appendix, we briefly examine whether some of the major shocks of the period affect our main results on the relationship of tenure to the amount of days worked in each accounting period. We control for four types of historical shocks in our analysis in this Appendix: temperature, wars, mortality, and financial volatility (after 1688).

Because construction is an extremely seasonal industry, variations in the weather patterns across years could affect the intensity of work in a given month. We control for these variations by including the mean monthly temperature of Central England in our analysis. This monthly time series is taken from Manley (1974).[47]

Wars are disruptive to general economic activity and can draw young male labourers out of the workforce. As this population might overlap the labourers we observe at St. Paul's, we include a dummy variable in our analysis indicating whether England was engaged in a war during each accounting period. This variable is based on Peter Brecke's Conflict Catalog, which gives the start and end dates of international conflicts during this period.[48]

We also include a measure of general mortality in London to capture the effects of pestilence and disease on the labour force. The data we use is the number of burials each month in London. These data were kindly shared with us by John Landers, who developed the monthly series based on the London Bills of Mortality from 1675-1825.[49]

Finally, we include a measure of the number of bankruptcies in London throughout the period as a proxy for general financial volatility. The Cathedral was a large project that relied heavily on borrowing, and thus employment and hiring at the Cathedral could have been shaped by the state of financial markets. Our annual series of bankruptcies in London is from Julian Hoppitt's 1987 study of English business, used for the eighteenth century by Schwarz (1992) .[50]

The results of our robustness checks incorporating these additional variables are given in Table 1 and Table 2. Our time series on bankruptcies in London begins only in 1688, so we first present the models without this variable for the entire construction period, and then including this variable but only for the period after 1688.

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[47] Manley, G. 1974. "Central England Temperatures: Monthly Means 1659 to 1973," Quarterly Journal of the Royal Meteorological Society, pp. 389-405

[48] Brecke, Peter. 2012. Dataset: Conflict Catalogue (Violent Conflicts 1400 A.D. to the Present in Different Regions of the World). Available at http://www.cgeh.nl/data.

[49] Landers, John. 1987. "Mortality and Metropolis: the Case of London 1675-1825." *Population Studies* 41/1, pp. 59-76.

[50] Hoppit 1987, p. 45; Schwarz 1992, p. 90-91 n.24.

Table 2.5 indicates that our main results are robust to the inclusion of these additional controls. The marginal effects in column (2) imply that a one quartile increase in the percentile rank of a labourer's tenure in terms of cumulative days worked increases their probability of working full time by 12.25 percentage points ($p < 0.001$, $25 * 0.0049 = 0.1225$). This is identical to the main results in the paper. Likewise, the marginal effect for tenure in terms of elapsed time, given in column (5), is also identical. However, the within-labourer effects are not significant with either of these measures of tenure. All of the additional controls we include have the sign that is expected, with work intensity increasing with higher average temperatures, decreasing with wars, and decreasing, though not significantly, with mortality.

Table 2.5: Logit models for the probability of a labourer working fulltime with controls for historical shocks

	Cum. Days Tenure - Coefficients	Cum. Days Tenure - Margins	Cum. Days Tenure - Coefficients (FE)	Elap. Time Tenure - Coefficients	Elap. Time Tenure - Margins	Elap. Time Tenure - Coefficients (FE)
	(1)	(2)	(3)	(4)	(5)	(6)
Tenure	0.0269***	0.0049***	0.0109	0.0181***	0.0035***	0.0085
	(0.0023)	(0.0004)	(0.0059)	(0.0026)	(0.0005)	(0.0069)
Monthly Burials	-0.0001	-0.0000	-0.0003*	-0.0001	-0.0000	-0.0003*
	(0.0001)	(0.0000)	(0.0001)	(0.0001)	(0.0000)	(0.0001)
Monthly Avg. Temp	0.0827***	0.0150***	0.1069***	0.0791***	0.0152***	0.1067***
	(0.0140)	(0.0025)	(0.0174)	(0.0134)	(0.0025)	(0.0174)
Conflict Indicator	-0.9211***	-0.1671***	-1.2571***	-0.8857***	-0.1702***	-1.2625***
	(0.1162)	(0.0209)	(0.1416)	(0.1106)	(0.0209)	(0.1409)
Constant	-2.8397***			-2.0094***		
	(0.2884)			(0.2778)		
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Month Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Labourer Fixed Effects	No	No	Yes	No	No	Yes
Num. of observations	19861	19861	18921	19861	19861	18921
Num. of individuals	798			798		
Pseudo R2	0.175		0.163	0.135		0.162

* p<0.05, ** p<0.01, *** p<0.001. Robust standard errors, adjusted for clustering by individual, are presented in parentheses. Tenure given in percentile.

Table 2.6 incorporates the London bankruptcy data into the analysis, which restricts the years of the analysis to 1688-1710. Our results are robust to the inclusion of this variable. The marginal effect of tenure in terms of cumulative days worked increases from 0.0049 to 0.0051 ($p<0.001$), and the marginal effect in terms of elapsed time also increases from 0.0035 to 0.0041 ($p<0.001$). As in Table 2.5, the within-labourer effects are not significant. Somewhat surprisingly, the effect of bankruptcies is to increase the intensity of labour at St. Paul's Cathedral.

Table 2.6: Logit models for the probability of a labourer working fulltime with controls for historical shocks and bankruptcies, 1688-1710

	Cum. Days Tenure - Coefficients	Cum. Days Tenure - Margins	Cum. Days Tenure - Coefficients (FE)	Elap. Time Tenure - Coefficients	Elap. Time Tenure - Margins	Elap. Time Tenure - Coefficients (FE)
	(1)	(2)	(3)	(4)	(5)	(6)
Tenure	0.0289***	0.0051***	0.0042	0.0223***	0.0041***	0.0085
	(0.0030)	(0.0005)	(0.0080)	(0.0031)	(0.0006)	(0.0069)
Monthly Burials	-0.0003*	-0.0001*	-0.0005**	-0.0003*	-0.0001*	-0.0003*
	(0.0001)	(0.0000)	(0.0002)	(0.0001)	(0.0000)	(0.0001)
Monthly Avg. Temp	0.0042	0.0007	0.0130	0.0036	0.0007	0.1067***
	(0.0145)	(0.0026)	(0.0200)	(0.0139)	(0.0026)	(0.0174)
Conflict Indicator	-0.7379***	-0.1304***	-1.1376***	-0.7243***	-0.1338***	-1.2625***
	(0.1436)	(0.0251)	(0.1833)	(0.1361)	(0.0248)	(0.1409)
Annual Bankruptcies	0.0147***	0.0026***	0.0167	0.0136***	0.0025**	
	(0.0041)	(0.0008)	(0.0099)	(0.0041)	(0.0008)	
Constant	-2.0320***			-1.5860***		
	(0.3284)			(0.3189)		
Year Fixed Effects	Yes	No	Yes	Yes	No	Yes
Month Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Labourer Fixed Effects	No	No	Yes	No	No	Year
Num. of observations	13401	13401	12733	13401	13401	18921
Num. of individuals	473			473		
Pseudo R2	0.198		0.168	0.167		0.162

* p<0.05, ** p<0.01, *** p<0.001. Robust standard errors, adjusted for clustering by individual, are presented in parentheses. Tenure given in percentile.

2.4: Are our main results robust to the exclusion of labourers that might have been foremen?

During the period of construction, fewer than ten men were paid more than the standard day rates of 16d and 18d. Historical records suggest that these men were foremen, acting in a managerial role.[51] As foremen, they would have worked most days in an accounting period and had significant tenure. It is thus possible that they impacted the relationship we find between tenure and intensity of work.

To check whether this is the case, as a robustness check we run the main models excluding any labourer who earned over 18 pence per day during their time working for St. Paul's. This results in dropping 548 observations representing the work of 7 out of 797 labourers. The results are almost identical to those from the main model, presented in Table 2.7.

[51] See Campbell (2007) pp.42-44.

Table 2.7 Logit models for the probability of a labourer working fulltime, with foremen excluded from sample

	Cum. Days Tenure - Coefficients (1)	Cum. Days Tenure - Margins (2)	Cum. Days Tenure - Coefficients (FE) (3)	Elap. Time Tenure - Coefficients (4)	Elap. Time Tenure - Margins (5)	Elap. Time Tenure - Coefficients (FE) (6)
Tenure	0.0256***	0.0046***	0.0114	0.0179***	0.0034***	0.0093
	(0.0023)	(0.0004)	(0.0059)	(0.0027)	(0.0005)	(0.0068)
Constant	-3.7124***			-2.9761***		
	(0.2295)			(0.2220)		
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Month Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Labourer Fixed Effects	No	No	Yes	No	No	Yes
Num. of observations	19313	19313	18447	19313	19313	18447
Num. of individuals	790			790		
Pseudo R2	0.173		0.155	0.140		0.154

* p<0.05, ** p<0.01, *** p<0.001. Robust standard errors, adjusted for clustering by individual, are presented in parentheses. Tenure given in percentile.

Online Appendix 3: Change Over Time

The results presented in Table 4 in the main text indicate that long-standing labourers were given more days of work in each accounting period than labourers with less tenure. How did the relationship between tenure and days worked change over time?

First, St. Paul's was built in stages (Campbell, 2007:102-3). From the late 1660s demolition work was carried out and this was not finally completed until the late 1680s even as the lower walls of the new cathedral were raised, and the masonry walls of the choir were up by 1690. Roofing was carried out throughout the first decade of the new century. One stage of building which challenged the skills of all on site was the construction of the dome from 1705 through completion in 1711. This building phase was experimental and required bricklayers, carpenters and plasterers to work alongside masons with innovations in scaffoldings and materials (Campbell 2007:121-137) which may have required more experience than other general labouring jobs. Without raising wage rates, it is possible that St. Paul's awarded more working days per month, and more consistent working days, to secure experienced labourers to complete the construction of the dome.

Table 3.1 presents three models exploring whether the relationship between tenure and days worked in a month changed during the period of dome construction at the cathedral. The dependent variable is the probability of working full time during the accounting period, defined as in Table 4 in the main text. Prior tenure is measured by cumulative days worked in previous accounting periods in columns (1) and (2), and by elapsed time since the labourer began working at St. Paul's in columns (3) and (4). All models have year and month fixed effects with clustered standard errors.

Column (1), our primary results, give the coefficients and marginal effects of a logit model using the cumulative days measure of tenure. The significant interaction term indicates that the relationship between tenure and whether labourers worked fulltime did change during the period of dome construction. The marginal effects, given in the third panel of Table 3.1, imply that a one quartile increase in a labourer's tenure percentile rank increases the probability of working full time by 8.5 percentage points in the period prior to dome construction ($p < 0.05$, $25*0.0034 = 0.085$), and by 13.5 percentage points during the period of dome construction ($p < 0.05$, $25*0.0054 = 0.135$). Figure 3.1 shows that in both periods, labourers with more tenure were more likely to work full time, but that the returns to tenure were steeper during the period of dome construction.

Table 3.1: Logit models for the probability of a labourer working full time, dome building vs. rest of building

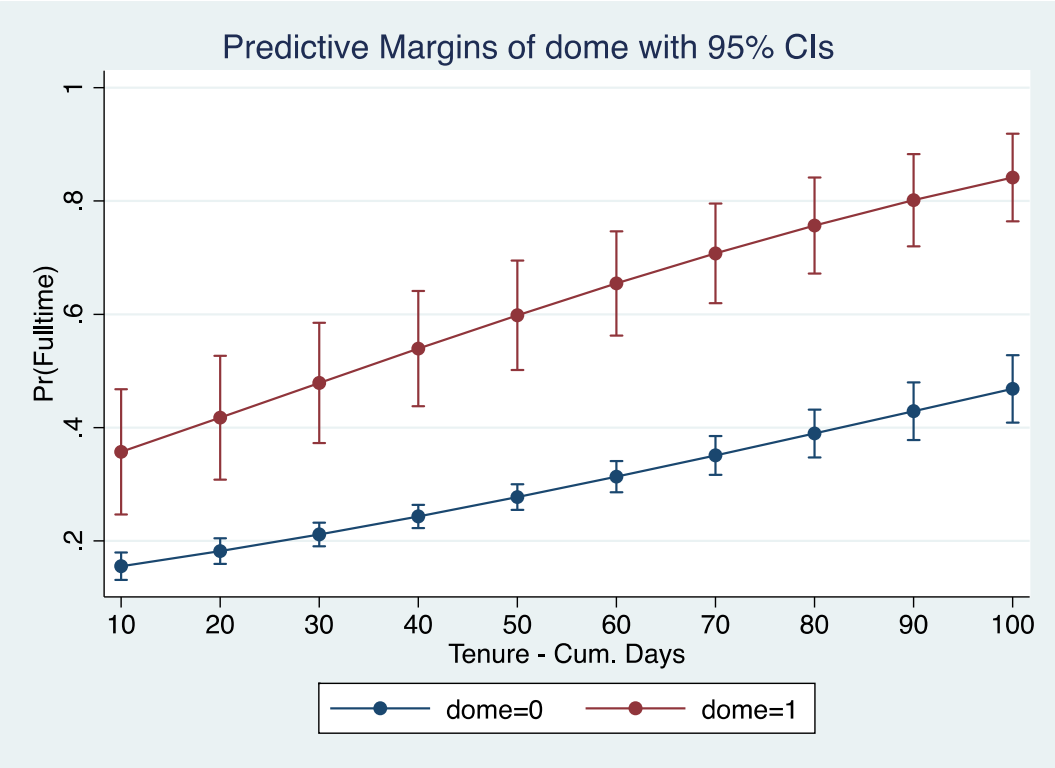
	Cum. Days Logit - Coef	Cum. Days Cond. Logit (FE) - Coef	Elap. Time Logit - Coef	Elap. Time Cond. Logit (FE) - Coef
	(1)	(2)	(3)	(4)
	b/se	b/se	b/se	b/se
Tenure - Cum. Days	0.0232***	0.0094		
	(0.0027)	(0.0060)		
Dome = 1	1.3000*	-0.1795	0.8801*	-0.0696
	(0.4087)	(0.9003)	(0.4287)	(1.0492)
Dome * Tenure - Cum. Days	0.0128*	0.0313**		
	(0.0057)	(0.0083)		
Tenure - Elap. Time			0.0136***	0.0079
			(0.0032)	(0.0068)
Dome * Tenure - Elap. Time			0.0144**	0.0280**
			(0.0058)	(0.0087)
Constant	-3.4701***		-2.6447***	
	(0.2360)		(0.2318)	
Year Fixed Effects	Yes	Yes	Yes	Yes
Month Fixed Effects	Yes	Yes	Yes	Yes
Labourer Fixed Effects	No	Yes	No	Yes
Average marginal effects				
Tenure – Cum. Days				
Dome = 0	0.0034***			
Dome = 1	0.0054***			
Tenure – Elap. Time				
Dome = 0			0.0022***	
Dome = 1			0.0047***	
Num. of observations	19861	18921	19861	18921
Num. of individuals	798		798	
Pseudo R2	0.175	0.158	0.136	0.157

Robust standard errors, adjusted for clustering by individual, are presented in parentheses.
Tenure given in percentile.
* p<0.05, ** p<0.01, *** p<0.001

Column (2) presents estimates from a conditional logit specification with labourer fixed effects. The results are robust to the inclusion of individual fixed effects, as the interaction effect increases in both magnitude and significance.

Column (3) gives the results from a logit specification using the percentile rank of elapsed time as the measure of prior tenure. The results are similarly striking. A one quartile increase in a labourer's tenure percentile rank in terms of elapsed time increases the probability of working full time by 5.5 percentage points in before the dome construction ($p < 0.01$, $25*0.0022 = 0.055$) and by 11.75 percentage points during dome construction ($p < 0.01$, $25*0.0047 = 0.1175$). These results are robust to the inclusion of labourer fixed effects in column (4).

Figure 3.1 Returns to tenure through construction phase.



Online Appendix 4: Results for the Maintenance Period

Most of the data collected represents the construction period of St. Paul's through 1711. Less than 3% of the data in our panel is from the maintenance period. This appendix explores whether there was a change in the relationship between tenure and intensity of work during the maintenance period.

Columns (1) and (2) of Table 4.1 indicate that there was a significant relationship between tenure in terms of cumulative days worked and whether a labourer worked full time during the maintenance period. The marginal effects in (2) indicate that a one quartile increase in the labourer's percentile rank increases the probability of working full time by 8.5 percentage points ($p<0.05$, $25*0.0033 = 0.0825$). However, this result is not robust to the inclusion of labourer fixed effects in column (3), or to the elapsed time measure of tenure in columns (4)-(6).

The relationship between tenure and whether a labourer worked more than 85% of the maximum days in an accounting period thus was weaker and possibly insignificant during the maintenance period.

Table 4.1: Logit models for the probability of a labourer working full time during maintenance period

	Cum. Days Tenure - Coefficients	Cum. Days Tenure - Margins	Cum. Days Tenure - Coefficients (FE)	Elap. Time Tenure - Coefficients	Elap. Time Tenure - Margins	Elap. Time Tenure - Coefficients (FE)
	(1)	(2)	(3)	(4)	(5)	(6)
Tenure	0.0178*	0.0033**	0.0042	0.0130	0.0025*	0.0057
	(0.0079)	(0.0013)	(0.0263)	(0.0071)	(0.0012)	(0.0211)
Constant	-0.9479			-0.6937		
	(0.5250)			(0.4775)		
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Month Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Labourer Fixed Effects	No	No	Yes	No	No	Yes
Num. of observations	545	545	456	545	545	456
Num. of individuals	54			54		
Pseudo R2	0.200		0.258	0.187		0.258

* $p<0.05$, ** $p<0.01$, *** $p<0.001$. Robust standard errors, adjusted for clustering by individual, are presented in parentheses. Tenure given in percentile.

Online Appendix 5: Tenure and Seasonal Hiring Patterns

Many breaks in employment at St Paul's were a by-product of the seasonal volatility of demand for construction work. Most absences began when the arrival of winter brought the peak building period to a close. Almost 40 per cent began in January; another 10 per cent began in December. Those labourers who reappeared did so between February and June, as the weather improved and work intensified. In the peak month of July, there was on average 1,466 days of general labouring work conducted by 49 labourers. In the January dip, there was about half as much labour, averaging 784 days of work conducted by 32 labourers.

Using these seasonal patterns, we can probe deeper into whether the clerk hired more tenured labourers more consistently over the year. We explore whether long-standing labourers were more likely to be kept on during the winter months and, if they were let go, whether they were more likely to be rehired in the spring. Winter work was particularly valuable, as the seasonal slowdown affected construction across the city. We consider specifically the month of March, which is when labour typically picked up again after the steep seasonal decline in January and February.

In Table 5.1, we present two models using a sample of labourers active in the month of March in any year during the construction period. The first model in columns (1) and (2) explores whether workers with longer tenure were more likely to have worked over the seasonal downturn. The dependent variable is an indicator for whether the labourer had worked at the Cathedral in the preceding January and February. The estimates in column (1) indicate that tenure was positively related to the probability of working in these months. The size of this effect is substantial—the marginal effect in column (2) indicates that a one quartile increase in the labourer's tenure percentile rank increases the probability of working in January and February by 19 percentage points ($p<0.001$, $25 * 0.0075 = 0.1875$). Longer-standing labourers at the Cathedral were much more likely to be kept on when work slowed over the winter months.

Table 5.1: Tenure and seasonal hiring patterns for active workers in the month of March

	Prob. of Working in Jan and Feb - Coefficients (1)	Prob. of Working in Jan and Feb - Margins (2)	Prob. of Rehiring in March - Coefficients (3)	Prob. of Rehiring in March - Margins (4)
Tenure	0.0467***	0.0075***	0.0341***	0.0053***
	(0.0032)	(0.0003)	(0.0051)	(0.0006)
Constant	-2.9451***		-1.2371*	
	(0.2546)		(0.4814)	
Year Fixed Effects	Yes	Yes	Yes	Yes
Num. of observations	1613	1613	565	565
Num. of individuals	533		282	
Pseudo R2	0.298		0.323	

Source: See text.
Notes: * p<0.05, ** p<0.01, *** p<0.001. Robust standard errors in parentheses. Tenure given in cumulative days percentile. The sample contains labourers who were active at the Cathedral in the month of March in any year of the construction phase. The dependent variable in columns (1) and (2) is an indicator for whether the labourer had worked at the Cathedral in the preceding January and February. Columns (3) and (4) restrict the sample to those who did not work in January and February, and the dependent variable is an indicator for whether these workers were rehired in March. Tenure given in percentile rank and is calculated according to cumulative days worked as a labourer.

What about labourers who did *not* work in either January or February of a year? Were more tenured workers more likely to be rehired in March than less tenured workers? In the second model in columns (3) and (4), we look exclusively those active labourers not hired over the winter. The dependent variable is an indicator for whether these workers were rehired in March. The estimate in column (3) and marginal effects in column (4) suggest that more tenured labourers who did not work over the winter were more likely to be rehired in the spring. Among workers who were not hired in January or February, a one quartile increase in the labourer's tenure percentile rank increases the probability of being hired in March by 13 percentage points ($p<0.001$, $25 * 0.0053 = 0.1325$).

Long-standing labourers at the Cathedral thus had more stable employment, with an increased chance of being rehired after seasonal downturns in hiring. The seasonality of building work strongly suggests that labourers were not absenting themselves for better offers on other sites. They were laid off in periods when low demand would be widespread across the sector, making a seamless transition to another site unlikely.

Online Appendix 6: The Ranking of Labourers in the Accounts

The organization of the accounts suggests that the clerk possessed a clear idea about who was to be hired and what they were entrusted with. In each period, hiring occurred in a sequence, with preferred workers taken on first. In this appendix, we expand on several points that we can only cover briefly in the paper: (1) that the sequence suggests that the clerk deliberately hired labourers in a specific and persistent order; (2) that the pattern of entry and exit argues against labourers being organized into gangs Long-term labourers were allotted a higher place in the queue for whatever work was available. The structure of the account also argues against the idea that labourers were being hired as gangs.

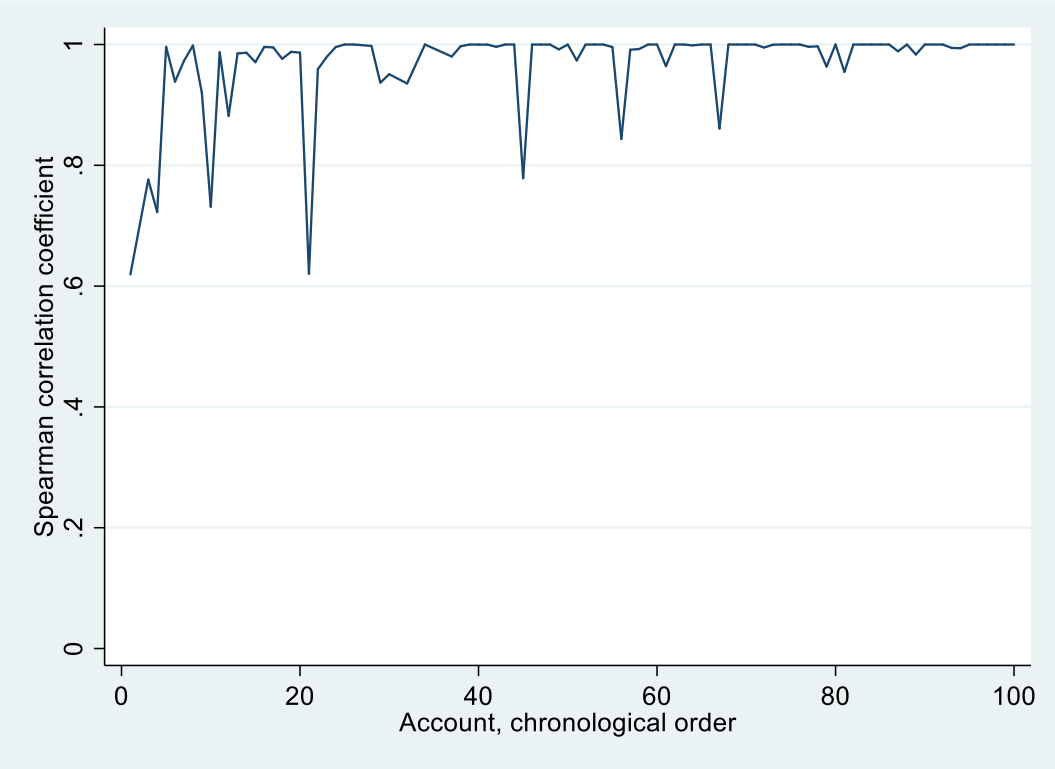
We are able to observe this process because of how the clerk kept the accounts for the majority of the period. For seven years from 1675-1682, the accounts were organized alphabetically; this affects 21% of the series. Before and after this, however, the order of labourers' names seems to reflect the order of hiring.[52] The only exception to this is that first and last positions were sometimes determined by status, and were at times occupied by the foreman and clerk of works.

6.1. Ranking & Labourer Status

The ranking of labourers' appearances in the accounts was strongly persistent between accounts. Figure 6.1 plots the Spearman correlation coefficient between the order of workers in sequential pairs of accounts with at most a gap of one month between them. There is very little change in the order.

[52] Some of the longer accounting records seem to contain several sequential lists of work, which can be identified by the repeated appearance of the labourer who appears to be acting as foreman and then the set of workers that follow. These have been treated as separate accounts for this analysis. The watchmen's shifts are listed separately after the labourers is finished, so those individuals appear twice in the account

Figure 6.1 Correlation between the order of workers in pairs of accounts



Note: sample restricted to accounts with more than 50 unique observations of labourers which are separated from the next account by a gap of less than 33 days. Spearman correlations were run on pairs of accounts. All coefficients were significant at the 0.001% level or better. Accounts organized alphabetically are excluded. Only accounts from the construction phase can be formally analysed in this way. The earliest pair of accounts in the discussion are 1672-3, the last are 1709-10

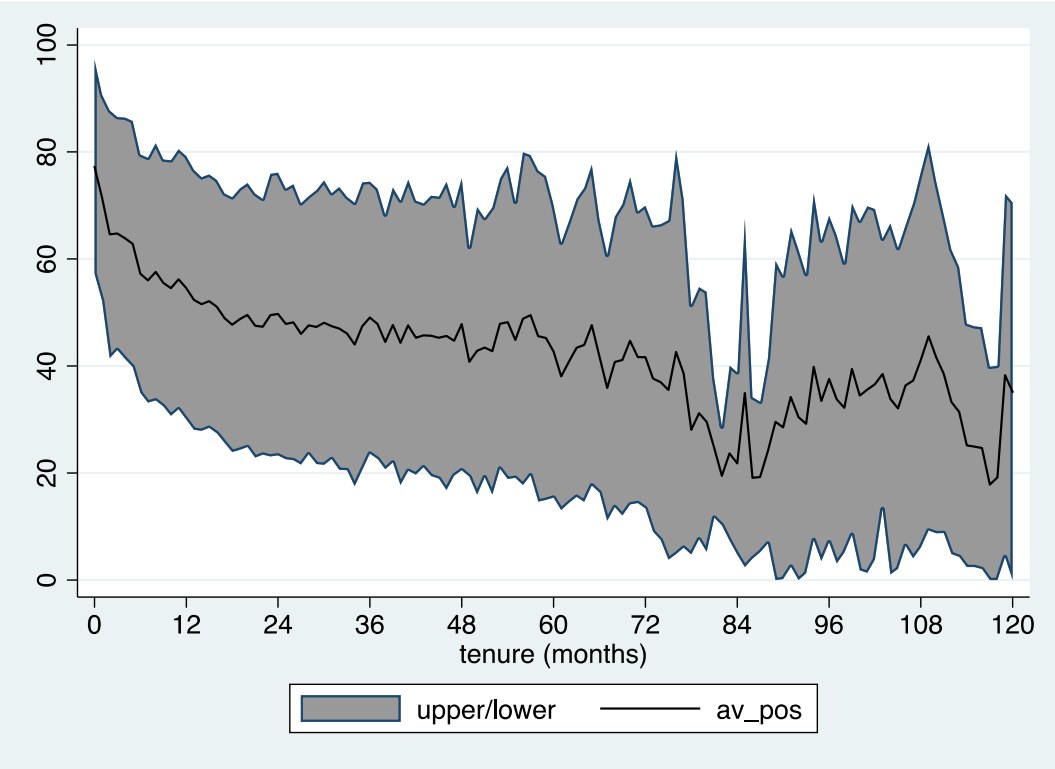
The persistence of the order in which labourers were named in the accounts – when not alphabetical – suggests that the clerk who hired them had a clear view of which workers to prioritize and take on first.

The factor that appears to explain the clerk's decision was the labourer's tenure – their experience on the site. This has a strongly determining effect on the order of hiring. There is a strong negative relationship between this at an individual and grouped effect. Workers who have worked for longer are positioned towards the top of the list.[53] We can also see this occurring dynamically over time: workers move up the order of the listing as their tenure increases. This is conveyed clearly if we graph the average position workers have in the account by the number of months that have elapsed since they began work. As Figure 6.2 shows, workers in their first month are – on average – listed around the 80th percentile of the account, but this declines consistently until they are – again on average – positioned around 30th out of 100. As the time since starting work

[53] Regressing position on time since the worker first appeared gives a coefficient of -0.0035*** (SE 0.0000802) and an R2 of 0.48 with account-level FE.

increases, volatility grows as the number of labourers shrinks. But for the first five years, we have at least 27 labourers active in every month observed, and in the initial few years the sample is based on the position of several hundred laborers.

Figure 6.2 Ranking in the accounts and tenure



Note: position is calculated for accounts with over 50 individuals observed

The relationship that this generated between tenure and access to work is discussed in depth in the text. Table 6.1 complements Table 5 in the main text, and shows how the different quartiles of the clerk's list were composed of labourers with widely differing degrees of experience on the Cathedral. Only 0.3% of labourers listed in the top quarter were new entrants to the workforce; 14% of those listed in the fourth quartile of people were new that period. At the other extreme, 93% of those listed in the top quartile of each account had been active for more than a year, as were 74% of those in the second quartile.

Table 6.1: placement of workers in the clerk's list and time since entry

	Time since entry to workforce							
Place in account (quartile)	New	2-3 months	4-6 months	7-9 months	10-12 months	>1 year	%	N
Share of each quartile made up by labourers from each category (row)								
0-25	0.22	0.94	1.92	2.39	2.44	92.09	100.00	3,603
26-50	1.53	7.17	7.28	6.85	6.14	71.03	100.00	3,793
51-75	8.02	19.73	10.54	6.17	4.95	50.59	100.00	3,841
76-100	7.05	7.85	4.64	2.99	2.99	74.49	100.00	3,645
Total	4.24	9.07	6.18	4.65	4.17	71.7	100.00	14,882

Note: table reports labourers recorded in non-alphabetical accounts produced during the period of construction

We can explore this relationship econometrically by constructing a measure of the relative ranking of labourers in the accounts. We treat each account (for the month) as the "employment pool" and then construct an index of the relative position of the laborers by dividing the rank by the number of possible positions in the pool. In order to match common notions of rankings, we construct the index such that a lower score (closer to 0) represents a better ranking, and a higher score (closer to 1) represents a lower ranking.

We then a regression where the dependent variable is the labourer's relative position within the account constructed in this way. The independent variable is our normal measures of tenure. This helps us explore to what extent tenure affects the employer's hiring preferences, as measured by their relative ranking. The analysis is conducted only for those accounts in which the ranking is not alphabetical.

Table 6.2: Fractional logit models for the effect of tenure on the labourer's position in the ordering of names in the account book

	Cum. Days Tenure - Coefficients (1)	Cum. Days Logit - Margins (2)	Elap. Time Tenure - Coef (3)	Elap. Time Tenure - Margins (4)
Tenure	-0.0215***	-0.0049***	-0.0199***	-0.0046***
	(0.0031)	(0.0006)	(0.0029)	(0.0006)
Constant	1.4572***		1.2014***	
	(0.3727)		(0.3347)	
Year Fixed Effects	Yes	Yes	Yes	Yes
Month Fixed Effects	Yes	Yes	Yes	Yes
Num. of observations	12303	12303	12303	12303
Num. of individuals	798		798	
Pseudo R2	0.058		0.053	

Robust standard errors, adjusted for clustering by individual, are presented in parentheses. Tenure given in percentile. The dependent variable is the relative position of the labourer in the account book, where a small value (closer to 0) is the best/higher ranking, and a larger value (closer to 1) is the worst/lower ranking.
* p<0.05, ** p<0.01, *** p<0.001

Table 6.1 demonstrates a strong relationship between a labourer's tenure and their ranking in the account book. Columns (1) and (2) give the estimates with tenure measured in cumulative days. The marginal effects in (2) imply that a one quartile increase in the percentile rank of a labourer's tenure adjusts their ranking index by -0.1225 ($p<0.001$, 25*-0.0049 Labourers with greater tenure thus are more likely to be named near the top of the lists in the account books and have a more privileged position in the hiring order. Our assumption that these rankings reflect a hiring preference for more tenured workers is thus corroborated.

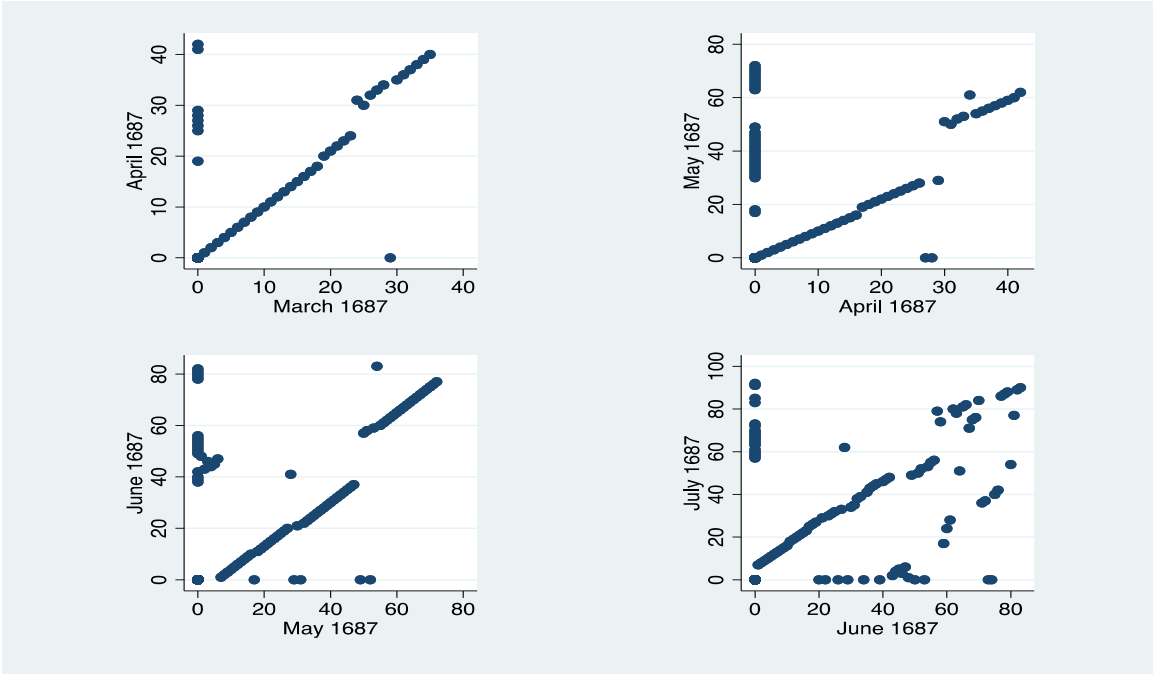
6.2 Ranking and Gang Labour

Might labourers have been organized in gangs and supplied by agents who managed them? Gang labour is important in some areas of unskilled labour. However, it does not seem to have been occurring in this part of the London building sector. We can use the order in which the labourers' names were given in the accounts to demonstrate this.

The order was usually repeated consistently from month to month, as we have seen. This was not wholly mechanical. Labourers did change position. Figure 6.3 illustrates this by showing the relationship between positions of labourers in the sequence of accounts in the four months between March 1687 and July 1687. Each sub-plot shows the position of an individual labourer in two sequential months. The labourers' position in the first month is plotted along the x-axis. Their position in the second month is plotted on the y-axis. Each month saw some labourers arrive and some leave. The lines of points on the y-axis show groups of labourers being taken on, while labourers left individually – and so are

scattered along the x-axis, as they have a position in the first month, but not the second.

Figure 6.3: Rank of labourers name in the sequence of accounts between March 1687 and July 1687.



The contrast between the two stages of arrival and departure provides good reason to reject the idea that labourers were being employed as gangs, with an internal management structure separate to their employer. While the hiring of gangs would be compatible with the pattern of clusters of labourers entering the account in a group. That separations were scattered across the list of labourers indicates that no group structure was maintained between workers within the site. We would expect workers to arrive and separate collectively if they were part of a gang. There is no sign of this.

Online Appendix 7: Measures of Tenure

In the analysis in the main text, we construct two variables to capture labourers' prior tenure at the Cathedral. Both measures are relative, comparing the labourer's tenure to the tenure of all other active labourers in the St. Paul's workforce at each point in time. The first measure is based on the cumulative days the labourer had worked at the Cathedral before the observation, and the second measure is based on the elapsed time they had worked at the Cathedral. We construct a percentile rank of these measures for all workers who were active at the Cathedral in each accounting period. This method of capturing tenure has the benefit of standardizing across time and across accounting periods of differing lengths. However, a valid concern may be that this purely relative, ordinal measure of tenure misses out on relationships that might be captured by a cardinal, continuous measure of tenure.

In this Appendix, we consider alternative measures of tenure as a robustness check for our central results. Table 7.1 columns (1) and (2) replicate our key analysis on the intensive margin using a simple continuous measure of tenure. Tenure is defined as the number of years the labourer had previously worked at St. Paul's before each accounting period. The coefficient given in column (1) and marginal effects in column (2) indicate a strong relationship between tenure and whether a labourer works fulltime at the Cathedral. Specifically, a one-year increase in a worker's tenure at the Cathedral increases their probability of working fulltime by 3.97 percentage points ($p < 0.001$). This is a strong confirmation of the results in the main text in Table 4. This simple continuous measure of tenure is also used in Table 6 in the main text to explore non-linear returns to tenure.

Table 7.1: Logit models for the probability of a labourer working fulltime - robustness to continuous measure of tenure

	Tenure Years - Coefficients	Tenure Years - Margins
	(1)	(2)
Tenure in Years (continuous)	0.2101***	0.0397***
	(0.0268)	(0.0049)
Constant	-2.0492***	
	(0.1848)	
Year Fixed Effects	Yes	Yes
Month Fixed Effects	Yes	Yes
Num. of observations	19861	19861
Num. of individuals	798	
Pseudo R2	0.147	

* p<0.05, ** p<0.01, *** p<0.001. Robust standard errors, adjusted for clustering by individual, are presented in parentheses. Tenure given continuously in years.

Table 7.2 Columns (1) and (2) check whether our results are robust to interacting the continuous measure of tenure with indicators for each decade in the period. The results indicate that the effect of tenure on the probability of a labourer working fulltime lessens later in the time period. However, it is impossible to distinguish whether this is represents a true relationship or just an effect of using a continuous measure of tenure. The absolute number of days worked increases strictly with time, confounding any analysis with a time component when a measure that is not relative is used. For example, the maximum tenure in 1679 is around seven years, while the maximum tenure in 1701 is around twenty-nine years. This is borne out in the data – from 1675 to 1680, less than 1% of laborers have more than six years of tenure, whereas from 1701-1710, 14.5% of laborers have more than six years of tenure. This pattern could be driving the small trend shown in Table 7.2 Columns (1) and (2). This is one of the primary strengths of the measure of tenure used in the main text, which standardizes across time and across accounting periods of differing lengths. (Note also that in Appendix C, we find that there are greater returns to tenure during the period of dome construction 1705-1711.)

Columns (3) and (4) in Table 7.2 conduct a robustness check with a different continuous measure of tenure that is scaled by the possible years of tenure available in each year period to address this issue. Columns (3) and (4) give the coefficients and margins of a model when the raw years of tenure are scaled by the number of previous years in which the site was active in our data. Letting y represent the year of the observation and T_R the raw years of tenure, the scaled tenure years T_S are given by,

$$T_S = (T_R / (y-1672))*100$$

The marginal effects in column (4) are difficult to interpret, but some examples can be illustrative. In 1690, $T_S = 55.55$ for a worker who had 10 raw years of tenure, while $Ts = 61.11$ for a worker who had 11 raw years of tenure. This one year increase in tenure thus results in a 4.8 percentage point increase in the probability of a labourer working fulltime at the Cathedral ($0.0087*(61.11-5.55) = 0.048$), confirming our main results.

Table 7.2: Probability of a labourer working fulltime – robustness to year interaction

	Tenure Years Continuous - Coefficients	Tenure Years Continuous - Margins	Tenure Years Scaled - Coefficients	Tenure Years Scaled - Margins
	(1)	(2)	(3)	(4)
Tenure in Years (continuous)	0.5783***	0.0554***		
	(0.1241)	(0.0075)		
Tenure in Years (scaled)			0.0458***	0.0087***
			(0.0052)	(0.0009)
Tenure in Years (continuous) * 1681-1690	-0.3550**			
	(0.1140)			
Tenure in Years (continuous) * 1691-1700	-0.3671**			
	(0.1287)			
Tenure in Years (continuous) * 1701-1710	-0.3836**			
	(0.1231)			
1681-1690		-0.1282***		
		(0.0340)		
1691-1700		-0.1334***		
		(0.0392)		
1701-1710		-0.1407***		
		(0.0361)		
Constant	-2.1763***		-2.5919***	
	(0.1848)		(0.2009)	
Year Fixed Effects	Yes	Yes	Yes	Yes
Month Fixed Effects	Yes	Yes	Yes	Yes
Num. of observations	19861	19861	19861	19861
Num. of individuals	798		798	
Pseudo R2	0.150		0.146	

Robust standard errors, adjusted for clustering by individual, are presented in parentheses.
Tenure given continuously in years.
* p<0.05, ** p<0.01, *** p<0.001

Table 7.3 gives the full estimation results for Figure 4b in the main text, estimating how long it takes for the marginal returns to tenure to diminish by allowing the relationship of tenure to the probability of working full time to vary non-linearly. This model uses raw cumulative years worked at St. Paul's as a percentile rank so that the turning point in the relationship can be observed. The results for tenure in raw cumulative years of work at St. Paul's given in Table 7.3 columns (1) and (2) indicate that the returns to tenure in terms of the probability of working full time only diminish very slowly as tenure increases. When tenure is measured in elapsed time associated with St. Paul's in Table 6.3 columns (3) and (4), there is no significant nonlinear effect.

Table 7.3: Nonlinear returns to tenure: learning models

	Cum. Days Tenure - Coefficients	Cum. Days Tenure - Margins	Elap. Time Tenure - Coefficients	Elap. Time Tenure - Margins
	(1)	(2)	(3)	(4)
Tenure	0.3356***	0.0539***	0.1215***	0.0202***
	(0.0638)	(0.0087)	(0.0363)	(0.0050)
$Tenure^2$	-0.0098*		-0.0021	
	(0.0038)		(0.0014)	
Constant	-2.0951***		-2.0807***	
	(0.1839)		(0.1788)	
Year Fixed Effects	Yes	Yes	Yes	Yes
Month Fixed Effects	Yes	Yes	Yes	Yes
Num. of observations	19861	19861	19861	19861
Num. of individuals	798		798	
Pseudo R2	0.151		0.120	

* p<0.05, ** p<0.01, *** p<0.001. Robust standard errors, adjusted for clustering by individual, are presented in parentheses. Tenure given in percentile rank of all active labourers at the site in an accounting period. Tenure percentile rank is calculated according to cumulative days worked as a labourer in columns (1) and 2 and according to elapsed time at the Cathedral in columns (3) and (4). The outcome variable is whether the labourer worked full time during an accounting period, measured as 85% or more of the maximum days worked in the period.