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Vacancies, Employment Outcomes and Firm Growth: Evidence from Denmark*

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Abstract

We use a comprehensive dataset from Denmark that combines online job advertisements with a matched employer-employee dataset and a firm-level dataset with value added and revenue information to study the relationship between vacancy-posting and various firm outcomes. We find that posting a vacancy significantly increases a firm's hiring rate, and that two-third of the additional hiring occurs in the same quarter while one-third occurs with one quarter lag. The majority of the effect is accounted for by hiring from employment. Small and slow-growth firms show greater hiring responses and the hiring response of high-productivity firms takes longer to materialize. We find that separations that are likely associated with quits predict vacancy posting, consistent with replacement hiring and vacancy chains. Growth in value added and revenue has a strong positive effect on vacancy posting but only when shocks are permanent; transitory shocks do not affect vacancy posting.

Keywords: Vacancies, hiring, separations, employment growth, firm growth, value added, revenue
JEL Classification: J23, J63

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1 Introduction

The starting point of the search-and-matching approach to labor market analysis is that it takes time and effort for workers to find desirable employers and firms to find suitable employees. A key outcome of this process is the time it takes to find a match on the other side of the market and the determinants of who searches and for how long. While the empirical literature has documented a large set of facts about workers' job-search process, including the typical characteristics of job-searchers, the speed of job-finding, and its dependence on personal characteristics or labor market conditions, the firm side of the market has been studied much less, largely due to a lack of appropriate data. A deeper understanding of when and how firms recruit, however, is essential for attaining a more complete picture of the workings of labor markets both at the micro and the macro levels.

This paper uses a unique dataset from Denmark to document a novel set of empirical facts about the effect of vacancy posting on many dimensions of hiring and about the determinants of vacancy-posting. The main strength of our data lies in its comprehensiveness: we merge a large dataset of online job advertisements with a matched employer-employee dataset, which provides very detailed information about labor market spells and transitions, and a firm-level VAT account dataset, which provides high frequency information on firm revenue, purchases and value added. The vacancy data is a comprehensive dataset of online job advertisements and the latter two datasets include, essentially, the population of business-sector firms and workers in Denmark. Furthermore, we observe the posting date of job advertisements, which allows the study of the time-lag between the beginning of the (formal) search process by the firm and, for example, hiring outcomes. While it is not our purpose to provide theoretical models for the facts that we document, we provide a short discussion of their implications and hope that they will be useful for motivating theoretical features and parametrizing quantitative aspects of labor markets models.

We first study the effect of vacancy-posting on various employment-related outcomes. We find that vacancy-posting has a significant effect on the hiring rate, leading to a 50 percent increase overall. We find that two-thirds of this effect occurs in the quarter when the vacancy is posted and one-third occurs with one quarter lag. These findings suggest that the magnitudes are significant and that the hiring process can be quite time-consuming.

When we consider the newly-hired workers' previous labor market status (employed or non-employed) separately, we find that vacancy-posting has a much stronger effect on hires from employment than non-employment: more than 60 percent of the total effect comes from hires from employment, as opposed to slightly more than 50 percent in the unconditional data. We view this as evidence that posting a vacancy reflects more intense search effort by the firm. With respect to heterogeneity, we find that vacancy-posting's effect on the hiring rate is monotonically decreasing in firm size (measured by employment or value added) and growth (growth in employment or value added). Furthermore, the effect on the hiring rate occurs later (i.e. is tilted towards the one-quarter lag) for the high-productivity firms (measured by value added per worker or average wage). This finding suggests that high-productivity firms screen more intensely than low-productivity firms.

Turning to the determinants of vacancy-posting, we explore the effect of separations on the probability of posting a vacancy and find evidence in favor of replacement-hiring. Specifically, engaging in any separations increases the probability of posting a vacancy by approximately 4 percentage points, on a baseline probability of 21.5 percent, and that magnitude declines if the separation rate was very high, which might be associated with downsizing. Furthermore, this effect is stronger for separations into employment, probably related to poaching, while separations to non-employment have a negligible effect on the probability of posting a vacancy. Overall, this evidence supports the replacement hiring hypothesis, and combined with the earlier results, the vacancy-chains hypothesis.

Finally, we explore the relationship between growth in value added and revenue, which might be associated to demand shocks, and the probability of vacancy-posting. We find that increasing value added and revenue growth by one standard deviation increases the probability of posting a vacancy by 7.5 and 9.7 percentage points, respectively, which corresponds to 35 and 45 percent of the unconditional probability, respectively. The contemporaneous effect, however, is negligible and almost all of the effect occurs several quarters later, which might appear somewhat counter-intuitive. We explore this finding further by estimating a permanent-transitory shock process for value added and revenue and estimating the effect of permanent and transitory shocks separately on the vacancy-posting probability, using the techniques developed by Guiso, Pistaferri, and Schivardi (2005). We find that the effects of permanent shocks are sizeable and a one-standard-deviation positive shock in value added and revenue increases the probability of vacancy-posting by 43 and 37 percent of the baseline, respectively. Transitory shocks, on the other hand, do not have a sizeable effect.

Our paper contributes to the existing empirical literature on vacancy posting and recruitment behaviour of firms. Most micro studies on vacancies predominately use firm-level survey data, including but limited to Davis, Faberman, and Haltiwanger (2013), Barron and Bishop (1985), Burdett and Cunningham (1998) and Faberman and Menzio (2018) for the US, van Ours and Ridder (1991), van Ours and Ridder (1993), van Ommeren and Russo (2014) for the Netherlands, Carrillo-Tudela, Gartner, and Kaas (2020) for Germany. Our paper is also related to empirical work on vacancies using online job board data (Marinescu and Wolthoff (2020), Davis and Samaniego de la Parra (2017), Modestino, Shoag, and Ballance (2019), Hershbein and Kahn (2018) and Banfi and Villena-Roldan (2019) among others) and more recent papers that match vacancy data with the administrative matched employer-employee data (e.g. Carrillo-Tudela, Gartner, and Kaas (2020) and Kettemann, Mueller, and Zweimüller (2018)). While most of the literature mentioned above have data on establishment size, employment growth and industry, and in some case also wages, these studies lack direct measures of firm outcomes, such as sales and value added.

The paper is organized as follows. Section 2 describes the data, section 3 presents some descriptive statistics, section 4 documents the relationship between vacancy-posting and employment outcomes (hiring, separations and employment growth), section 5 explores the relationship between value added, revenues and vacancy-posting and section 6 concludes.

2 Data

In this section we present the sources underlying our data, describe the construction of the data that we use in the empirical analysis and discuss several features of the vacancy data.

2.1 Data sources

Our data originates from Denmark and we combine information from four distinct sources: a matched employer-employee dataset with labor market spells, a firm-level panel with information about firms' characteristics and activities, a firm-level panel with firms' quarterly revenue and purchases, and a firm-level dataset with real-time job advertisements. We describe each data source in turn.

Labor market spells dataset. This dataset contains rich information on employment spells for all legal residents in Denmark aged 15-70 between January 1st, 1985 and December 31st, 2013. It is constructed from income tax reports obtained from the administrative registers CONS/RAS (Registerbaseret Arbejdsstyrke Statistik, covering 1985-2007) and BFL (Beskæftigelse For Lønmodtagere, covering 2008 onwards), and data on employer contributions to the employee pension fund Arbejdsmarkedets Tillægs Pension which covers the universe of workers.[1] The unit of observation is a worker-spell-year and an observation contains unique identifiers for the worker and the firm, start- and end-dates of the job spell, the annual worker earnings pertaining to the job and an estimate of the annual number of hours worked in the job, from which we compute (an estimate of) a worker's average annual wage rate in every job. Workers are identified via their social security number (CPR-number), a number that is unique to the individual, does not change over time and is issued to every legal resident of Denmark. Firms are identified via their registration number in the Danish Central Business Registry (the CVR).[2] A job spell is defined as a period of continuous primary employment at a given firm.[3] Annual hours are estimated using workers' mandatory pension contributions.[4] Periods when no job spells are recorded for a worker are non-employment spells; we do not observe whether the worker is unemployed or out of the labor force during a nonemployment spell.[5]

IDA data. Integreret Database for Arbejdsmarkedforskning (IDA) is a comprehensive matched employer-employee panel which covers the entire Danish population and all firms with economic activity and links workers and firms via their employment relationships in the last week of November. IDA is constructed, updated and maintained by Statistics Denmark using administrative records and is organized in three main components: IDA-P, IDA-N, and IDA-S. IDA-P contains person-information (e.g. age, gender, education, labor market experience), IDA-N contains information on all last-week-of-November employment relationships (e.g. earnings and hours information), and IDA-S contains

[1]Henning Bunzel at Aarhus University has been instrumental in constructing the labor market spells dataset. Hejlesen (2016) provides a technical description of the construction of the labor market spell data from the raw administrative records.

[2]The Central Business Registry was established in 1999 and contains primary data on all businesses with economic activity in Denmark, regardless of economic and organizational structure. Prior to 1999, firms were identified by the registration number in the SE-registry (Stamregistret for Erhvervsdrivende), which was established in 1985 to identify businesses vis-a-vis the tax authorities.

[3]In a given month a worker has "primary employment" at the firm where he works the greatest number of hours for that month and the next two calendar months. A worker's firm of primary employment is determined every calendar month.

[4]Lund and Vejlin (2016) develop and implement a procedure for computing annual hours at a job for the period 1980-2007, primarily using information on mandatory pension contributions. This procedure, with minor modifications, is used to construct the hours measure in the labor market spells dataset.

[5]Although the dataset consists overwhelmingly of employees, some job spells might refer to self-employed who take compensation that is reported as labor income for tax purposes.

information on every physical workplace in Denmark (e.g. physical location, nature of operations). We use the IDA-S industry classification of workplaces. The unit of observation in the aggregated IDA-S panel is a workplace-year.

VAT accounts. All firms operating in Denmark with expected revenues that exceed 50,000 DKK (approximately USD 7,500) over a 12-month period are legally obliged to obtain a Value Added Tax (VAT) account with the tax authorities and to settle their VAT accounts on a monthly, quarterly or semi-annual frequency, depending on the level of revenues.[6] The VAT accounts dataset contains a firm panel which starts in January, 2001 with monthly information on revenues and purchases at the firm level, where firms are identified by their CVR-number. The monthly information is imputed by Statistics Denmark for the firms that settle VAT accounts at a quarterly or semi-annual frequency and contains an indicator for the frequency at which each firm settles their VAT accounts. We have access to the data between January, 2001 and December, 2012.

Vacancies. The data source is Jobindex A/S, a major private online job board in Denmark. Jobindex features job advertisements that are either posted directly on its job board or are originally posted elsewhere on the internet. Jobindex scans daily the Danish part of the World Wide Web to locate job advertisements (e.g. on individual firms' web pages, other job boards, public job centers, etc.), operates an algorithm to detect identical advertisements posted at multiple online outlets and re-posts all unique job advertisements on its job-board, to attract traffic from job-seekers.[7] It covers up to 90% of the job advertisements posted online in Denmark during the relevant period.[8]

We have access to job advertisement data from June 1st, 2002 to March 31st ,2009 and use the period Jan 1st, 2003 to June 30th, 2009.[9] The job advertisements that we use were less than three weeks old when located by Jobindex and are, hence, categorized as "new" job advertisements. The unit of observation is a job advertisement which contains the date of posting, the job's occupation (recorded according to the job board's own detailed occupation classification) and, approximately two-thirds of the time, the advertising firm's CVR-number.[10] The dataset contains 1,918,966 observations. One feature worth noting is that it includes a wide variety of jobs, as documented by the occupation information of each observation. We map the occupation information of JobIndex to the 10 major

[6] Firms with expected annual revenues of more than 50 mill. DKK (approximately USD 7.5 mill.) must settle VAT accounts at monthly frequency, firms with expected revenues in the range 5 mill. (approximately USD 750,000) to 50 mill. DKK must settle accounts at a quarterly frequency, and firms that expect annual revenues below 5 mill. DKK must settle at a semi-annual frequency. Firms may apply to settle at a higher frequency than required by their expected revenues, and the tax authorities may on a case-by-case basis require a firm to settle at a higher frequency than the revenue would otherwise stipulate. Firms in their first year of existence must settle VAT accounts quarterly for at least 6 quarters, independently of expected annual revenues.

[7] Brodersen, Dimova, and Rosholm (2016) report the sources of job advertisements on Jobindex as: 35% direct posting on Jobindex, 35% other job databases, 25% public job centers and 5% firm websites. This is for a slightly different time period.

[8] Source: Personal communication with the director of Jobindex.

[9] Jobindex began collecting the data we have access to in June, 2002 and the data is considered reliable since the beginning of 2003.

[10] The CVR-number is a firm's main administrative identifier vis-a-vis its stakeholders and routinely appears on invoices and company websites. The CVR number is either directly provided to JobIndex or is otherwise included in the job advertisement.

Table 1: Occupational distribution of job advertisements

	2006 Workforce	Job advert data	With CVR-number
Managers	0.03	0.04	0.05
Professionals	0.16	0.25	0.26
Technicians and associate professionals	0.21	0.15	0.15
Clerical support workers	0.11	0.06	0.06
Service and sales workers	0.17	0.27	0.26
Skilled agricultural, forestry and fishery workers	0.02	0.01	0.01
Craft and related trades workers	0.12	0.06	0.06
Plant and machine operators, and assemblers	0.07	0.05	0.05
Elementary occupations	0.12	0.11	0.11
Unclassified	0.00	0.01	0.01
Observations		1,918,966	1,237,333

Notes: Occupational distribution (ISCO-08) in Danish workforce, vacancy data and data used for empirical analysis. The 2006 Danish workforce occupational distribution is computed from IDA-P.

groups in ILO's ISCO-08 (International Standard Classification of Occupations) system and present the outcome in Table 1.

2.2 Cleaning and merging the data

This section describes how we clean the data, merge the four data sources and construct our variables of interest.

Time period. We select the period 2003Q1-2009Q2 for analysis. This is the period for which reliable vacancy data is available.

Firm panel with employment. We use the labor market spells data to construct a firm panel that contains each firm's workforce in every quarter. We first modify our data in two ways to avoid some very short non-employment spells: we overwrite any nonemployment spells shorter than 31 days between two job spells with different employers by back-dating the start-date of the second job spell to the day after the end-date of the first job spell; and we overwrite any nonemployment spells shorter than 92 days when the worker returns to the same employer and instead record a single continuous job spell.[11] We measure the employment of each firm on January 1st, April 1st, July 1st, and October 1st of every year, which corresponds to employment in the first, second, third and fourth quarter of that year, respectively, and we denote it by N_{jt} where j is the firm and t is the observational period.[12] We use observations between 2003Q1 and 2009Q2. The resulting quarterly firm panel covers the universe of Danish firms with employment and contains 3,823,188 observations on 267,176 firms and 26 quarters.

Hires and separations. We create quarterly series on firms' hires and separations. A worker who is on firm-j's payroll at the beginning of quarter $t+1$ but is not at the beginning of quarter t is counted

[11] Earnings are adjusted so that hourly wages are not affected by these modifications.

[12] By construction, job spells that start and end within the same calendar quarter are counted neither in firm employment nor in hires and separations, described below.

as a hire by firm j in quarter t; we denote the number of hires of firm j in quarter t by H_{jt}. Similarly, a worker who is on firm-j's payroll at the beginning of quarter t but is not at the beginning of quarter $t+1$ is counted as a separator from firm j in quarter t; we denote the number of separations of firm j in quarter t by S_{jt}. The law of motion for the employment of firm j is:

$$N_{jt+1} = N_{jt} + H_{jt} - S_{jt}. \tag{1}$$

A firm that enters in period t has $N_{jt} = 0$, $N_{jt+1} = H_{jt}$ and $S_{jt} = 0$. A firm that exits in period t has $S_{jt} = N_{jt}$, $H_{jt} = 0$ and $N_{jt+1} = 0$.

We split the total hires of firm j in quarter t (H_{jt}) into hires from employment (H_{jt}^{EE}) and hires from non-employment (H_{jt}^{NE}) depending on the newly-hired employees' employment status in quarter $t-1$; by construction $H_{jt} = H_{jt}^{EE} + H_{jt}^{NE}$. Similarly, we split the total separations of firm j in quarter t (S_{jt}) into separations to employment (S_{jt}^{EE}) and separations to non-employment (S_{jt}^{EN}) depending on the separating employees' employment status in quarter $t+1$; by construction $S_{jt} = S_{jt}^{EE} + S_{jt}^{EN}$.

Finally, we normalize all variables described above by firm employment, averaged over two quarters, to define them as *rates*. Specifically, the hiring rate of firm j in quarter t is

$$h_{jt} = \frac{H_{jt}}{(N_{jt} + N_{jt-1})/2}, \tag{2}$$

and similarly for the EE- and NE-hiring rates (h_{jt}^{EE} and h_{jt}^{NE}), the separation rate (s_{jt}) and the EE- and EN-separation rates (s_{jt}^{EE} and s_{jt}^{EN}).

Non-financial business sector firms. We aggregate IDA-S to the firm-level by combining all workplaces that belong to the same firm and assign them the industry affiliation of the workplace with the highest employment as recorded in IDA-S. Industry codes are measured using NACE codes.[13] The unit of observation in the aggregated IDA-S panel is a firm-year. We merge the firm panel with the IDA-S data to obtain firms' NACE 2.0 industry affiliation. IDA-S is available at an annual frequency and we therefore merge it to the quarterly employment panel by firm ID (CVR-number) and calendar year. We match 92 percent of the firm-years in the firm panel with industry affiliation from IDA-S. We focus our analysis on firms belonging to the NACE 2.0 business sector and we discard data on firms from the financial sector and the non-business sector, which mostly includes employment in the public sector.[14] This leads to the exclusion of 71,166 firms, approximately a quarter of the total.

[13] Our data period is long enough to stretch across several versions of the NACE taxonomy and we recode earlier NACE 1.0 and NACE 1.1 codes to the newer NACE 2.0 codes using their empirical correspondence, as follows. New NACE classifications appear in 2003, when NACE 1.1 replaced NACE 1.0, and in 2007, when NACE 2.0 replaced NACE 1.1. In the first year after each new NACE classification is introduced, Statistics Denmark classify the IDA-S workplaces according to both the new and the old NACE-scheme which allows us to construct an empirical correspondence table that tallies the number of workplaces of a given old NACE classification that belongs to a given new NACE classification. We use the 2003 correspondence table to assign NACE 1.1 codes to the pre-2003 workplace-years based on the most frequently occurring 2003-correspondence. In the same way, we use the 2007 correspondence table to assign NACE 2.0 codes to the pre-2007 workplace years.

[14] Using NACE 2.0 section labels, the business sector consists of the following industries: Mining and quarrying; Manufacturing; Electricity, gas, steam and airconditioning supply; Water supply, sewerage contractors, waste management, and remediation activities; Construction; Wholesale and retail trade, repair of motor vehicles and motorcycles; Transport and storage; Accommodation and food service activities; Information and communication; Real estate activities; Professional, scientific, and technical activities; and Administrative and support service activities. The non-business sector consists of the following industries: Agriculture, forestry and fishing; Public administration and Defence and compulsory social

Revenues, purchases and value added. We aggregate the monthly VAT account information to a quarterly frequency and discard the firms that settle their accounts at a semi-annual frequency, thereby creating a quarterly panel for 2001Q1-2012Q4 of firm revenues and purchases which is not contaminated by imputation.[15] We merge the firm employment panel with the firm-level administrative VAT accounts using the firm CVR codes. We discard 15,957 firms that contain missing revenues and purchases data in some quarter. We discard 9,670 firms with multiple entries and exits during the observation window. We do not balance the panel; that is, we allow a firm to enter once and exit once. We discard observations pertaining to the entry and exit quarter for firms entering and exiting, respectively, during the observation window. We discard 12,339 firms that exist in our firm panel for one quarter only. These operations leave us with 142,087 firms observed for a total of 2,010,755 firm-quarters. We create a quarterly value added variable by subtracting purchases from sales.

Vacancies. We use the job advertisement observations to create a quarterly firm vacancy variable. We discard the job advertisement observations that do not include a firm CVR number, which are approximately one-third of the total (681,633 out of 1,918,966). We create a binary vacancy posting indicator as

$$v_{jt} = \begin{cases} 1 & \text{if firm } j \text{ posts at least one job advertisement in quarter } t, \\ 0 & \text{otherwise.} \end{cases}$$

The vacancy posting indicator captures whether a firm takes an action to recruit. The firm CVR identifiers allow us to merge the quarterly vacancy posting indicator with the firm panel; we match 82% of the CVR numbers in the vacancy dataset with a firm in the panel, which we view as a high success rate given that the source of the vacancy data is a private company, and not a public register.

Firm vacancy panel. We have constructed a firm panel for 2003Q1-2009Q2 that includes the following variables at a quarterly frequency: employment, average wage, total hires, hires from employment, hires from non-employment, total separations, separations to employment, separations to non-employment, vacancies, revenues, purchases and value added. We split the full firm panel in two: a firm vacancy panel which includes all firms where $v_{jt} = 1$ for some t; a firm non-vacancy panel where $v_{jt} = 0$ for all t. We use the firm vacancy panel in our empirical analysis and we compare it to the non-vacancy panel along various dimensions in the section below.

2.3 Coverage and representativeness

In our empirical exercises the population of interest is the set of firms that hire and, particularly, use formal methods to advertise their job availability. Our combined firm vacancy and non-vacancy panel contains, essentially, the universe of Danish business-sector firms (outside of finance). The firm vacancy panel that we will use in our empirical analysis contains the firms of the combined panel that post an online job advertisement which includes a CVR number and is, furthermore, matched to the firm panel. In this section we discuss selection into our firm vacancy panel.

security; Education; Human health and social work activities; Arts, entertainment and recreation; Other service activities; Activities of households as employers; Activities of extraterritorial organizations and bodies. Financial firms are in the sector Financial and insurance activities.

[15]Firms that settle they VAT accounts semi-annually have negligible employment.

Table 2: Share of firm-quarters included in vacancy panel by industry

	Firm-quarters	% in vacancy firm panel
Mining and quarrying	2,649	38%
Manufacturing	250,055	43%
Electricity, gas, steam	10,695	34%
Water, sewerage, waste	12,326	23%
Construction	361,071	26%
Wholesale and retail trade	654,461	30%
Transport and storage	120,697	25%
Accommodation and food service	152,503	24%
Information and communication	88,368	35%
Real estate activities	55,887	20%
Professional activities	206,710	27%
Administrative activities	95,333	29%
Total	2,010,755	30%

Table 3: Characteristics of firms in vacancy and non-vacancy panels

	Vacancy panel	Non-vacancy panel
Number of firms	28,526 (20%)	113,561 (80%)
Number of observations	598,092 (30%)	1,412,663 (70%)
Value added per firm (annual, 1,000 DKK)	22,599	2,695
Value added per worker (annual, 1,000 DKK)	529	428
Share of total value added	69%	31%
Employment per firm	35	6
Share of total employment	59%	41%
Share of hires	79%	21%
Net job creation 2003Q1-2009Q2	141,683	−78,737

Notes: In January, 2020 the exchange rate of the Danish Krone to the US Dollar was approximately 1 USD = 6 DKK.

Table 2 reports the number of firm quarters separately by one-digit industry in the combined vacancy and non-vacancy panels and, also, the share of these observations that is included in the vacancy panel. Overall, the firm vacancy panel comprises 30 % of firm-quarters in the combined firm panel. There is no significant variation in the proportion of observations that is included in the vacancy panel by industry, though Manufacturing firms are somewhat more likely to be included.

Table 3 reports that the vacancy panel contains 20% of the firms and 30% of the firm-quarters (observations) of the combined panel. The value added of the average firm in the vacancy panel is almost ten times larger than that of the average firm in the non-vacancy panel and the vacancy panel accounts for almost 70% of the value added in the combined panel. Furthermore, the average firm in the vacancy panel has almost six times more workers and these firms account for almost 60% of total employment. Finally, and more importantly for the purposes of this study, firms in the vacancy panel account for almost 80% of hires and more than 200% of net job growth in the combined panel, i.e. the average firm in the non-vacancy panel shrank during the observation period.

Table 4 reports how observable heterogeneity affects a firm's rate of inclusion in the firm vacancy

Table 4: Share of firms included in vacancy panel by firm characteristics

Quintile	Employment		Value added /1,000 DKK		VA/worker /1,000 DKK		Average wage /1,000 DKK	
	Value	% vac.	Value	% vac.	Value	% vac.	Value	% vac.
1st	1	2%	24	6%	12	9%	104	4%
2nd	2	7%	376	6%	147	15%	209	13%
3rd	3	15%	871	13%	268	22%	277	21%
4th	7	27%	1,856	24%	389	28%	344	30%
5th	18	49%	6,519	51%	657	26%	479	32%

Notes: For each variable, we compute the firm average over time, bin firms according to variable-specific quintiles and report for every bin the median value (columns labeled "Value") and the share of firms that belongs to the vacancy firm panel (columns labeled "% Vac.").

panel. We focus on two variables that relate to firm size (employment and value added) and two variables that relate to firm productivity (value added per worker and average wage). For each of the four variables, we compute the average value for every firm in the combined vacancy and non-vacancy firm panels (142,087 firms) over the observation period. For each variable, we allocate the firms in quintiles and compute the quintile-specific median value and the quintile-specific proportion of firms that are included in the firm vacancy panel. We observe that the share of firms included in the vacancy panel is monotonically increasing in all measures of firm size and productivity.

Overall, the firm vacancy panel, while not representative of the average Danish firm, contains the firms that account for most of the economic activity, employment and, most importantly, hires in Denmark.

2.4 Discussion of data sources for vacancies

In this subsection we discuss (in broad terms) the existing firm-level vacancy data and place our own dataset in that context. It is useful to keep in mind the US Bureau of Labor Statistics' (BLS) definition of a vacancy: a position exists, work can begin within 30 days and the firm/establishment is recruiting from outside to fill the position.

There are two broad types of data sources for vacancies: firm surveys, where vacancy information is self-reported by the firm,[16] and sources related to a particular search method, such as online job boards or public employment agencies, where vacancy information is inferred from firms' actions, typically the posting of job advertisements.[17]

Survey-based datasets are typically representative of a well-defined firm- or vacancy-population of general interest, for example the US non-farm business sector in the case of JOLTS. Usually they apply a broad definition of vacancies which, importantly, does not depend on a specific action taken by the firm, unlike in search-method related datasets. The JOLTS, for example, uses the BLS's very broad definition of a vacancy. Furthermore, survey-based vacancy data might contain additional information about vacancies, firms' worker flows (typically distinguishing quits and layoffs in the case of separations),

[16]Examples include the US Job Openings and Labor Turnover Survey (JOLTS) and the Employer Opportunity Pilot Project (EOPP) and the German Job Vacancy Survey (JVS) survey.

[17]Examples include the Job Centres in the UK, the Austrian Public Employment Office ("Arbeitsmarktservice", AMS) and several market-based job board websites, such as CareerBuilder and Burning Glass Technologies.

and often include quantitative or qualitative questions designed to measure or elicit the firm's recruiting policies (wages, methods of advertisement etc.), the difficulty encountered in recruiting, the number of applicants per position, etc.

Vacancy survey data have some common disadvantages. They usually report the stock of vacancies at a point in time, which may not be representative of the flow of new vacancies. Furthermore, firm surveys typically provide much less information, if any at all, on worker-flows *into* the firm, which might be relevant when evaluating the implications of a vacancy posting. More generally, firm surveys usually have little information on individual workers in the firms' labor force. Finally, many vacancy surveys have relatively small sample sizes and short (if any) panel dimension.[18]

Search-method based datasets typically contain a much larger number of observations than vacancy surveys, but draw a narrower set of vacancies, since firms need to use a particular method in order to be included. This might create severe selection problems. First, they might contain the in- and outflow of new advertisements to a site or agency that might not be representative of any vacancy- or firm-population of interest to an analyst. Second, public employment agencies usually cater to lower-skill jobs and workers and, unless this is the population of interest, this might be a significant restriction.[19] Selection issues, however, also loom large for online job board data, unless the particular job board from which the data originates has a very high market share.[20] A further disadvantage of this data source is that it typically includes very rudimentary information on the posting firms.

It has recently become possible to link vacancy datasets from the above sources with administrative matched employer-employee datasets. This greatly expands the available information on posting (and non-posting) firms and the workers that flow between the firms. Examples include Kettemann, Mueller, and Zweimüller (2018), who link vacancy data from the Austrian AMS vacancy data (a search-method based public employment agency dataset) to social security records, and Carrillo-Tudela, Gartner, and Kaas, 2020, who link the German JVS (an establishment survey) to administrative employment histories of workers.

Our vacancy data originates from Jobindex, a Danish market-based online job board and is, hence, search-method based dataset. As described above, we link this vacancy data to Danish matched employer-employee data. Compared to Kettemann, Mueller, and Zweimüller (2018) and Carrillo-Tudela, Gartner, and Kaas (2020), our data is particularly rich on information on the posting firms, including quarterly value added and revenue observations, as well as containing detailed labor market histories of workers. This allows us to conduct a comprehensive firm-level evaluation of vacancy posting, employment outcomes and growth and answer questions that has hitherto eluded the literature. In particular, we can consider the composition of worker flow into the firm following a vacancy posting, and estimate the association between firm output shocks and vacancy postings. In relation to our vacancy data, we further note that we observe the flow of new vacancies, and that Jobindex's advertisement harvesting algorithm makes the data less susceptible to concerns about coverage and representativeness

[18]JOLTS, in this respect is an exception, covering 16,000 establishments with some establishments sampled for up to 24 months and others continuously sampled.

[19]The Austrian public employment agency AMS appears to be an exception in that it posts advertisements for a variety of positions.

[20]The fact that the vacancy data is obtained from online job advertisements is likely less of a concern, as online search has become ubiquitous.

Table 5: Within- and between-firm variation in vacancy posting

	Quarterly vacancy posting
Vacancy posting indicator	0.215
Within-firm variance	0.127
Between-firm variance	0.051
Fraction, within-firm variance	0.714

of the Danish vacancy population.

Finally, our binary vacancy-posting indicator (defined above) captures the BLS definition of having some position and looking externally for workers to fill that position. It does not, however, include information about the intensive margin, i.e. the potential number of positions available. This means that we will interpret the magnitude of the response to vacancy-posting with some care, since vacancies might be heterogeneous in the number of positions they refer to. However, the timing of the response to vacancy posting need not be affected by this feature.

3 Descriptive statistics

We present descriptive statistics of the firm vacancy panel.

3.1 Vacancies

We begin with the vacancy variable, v_{jt}. This is an indicator variable which takes value 1 if firm j posts a job advertisement in period t and 0 otherwise. Table 5 presents simple summary statistics. Approximately 22 percent of the panel's firm-quarters include a vacancy posting (a number that rises to 57 percent when employment-weighted). Furthermore, a within-/between-firm decomposition of the variation in v_{jt} shows that most of the is within-firm (70 percent), rather than between-firm.

Davis, Faberman, and Haltiwanger (2013) report that 88% of establishments post no vacancies in a month (45% when employment-weighed) and that 82% of them also post no vacancies in the next month. Extending a further month leads to 60% of establishments posting no vacancies in a quarter (30% when employment-weighed). These figures are lower than what we observe in our dataset (78% and 43%, respectively) which might be due to our more restrictive vacancy definition (requires an online job advertisement) or to other differences in the two economies.

Table 6 presents estimates of the residual autocovariance function of the vacancy posting indicator. We have residualized with respect to quarter effects, industry effects and their interactions and the residualized vacancy-posting variable is denoted $\widehat{v}_{jt}$. Table 6 shows autocovariances for $\widehat{v}_{jt}$ and $\Delta\widehat{v}_{jt}$, where Δ is the difference operator. In levels, vacancy posting exhibits significant positive autocovariances and the magnitude does not decline with the lag length. The first differenced vacancy posting residuals has quantitatively significant negative order 1 autocovariance, while higher order autocovariances are quantitatively negligible. This pattern is consistent with a persistent firm-specific component in $\widehat{v}_{jt}$, either a firm fixed effect or a random walk component, and a low order Moving Average component.

Table 6: Autocovariance structure of vacancy posting

	$\widehat{v}_{jt}$	$\Delta\widehat{v}_{jt}$
Lag 0	0.164***	0.219***
	(0.001)	(0.001)
Lag 1	0.056***	−0.105***
	(0.001)	(0.001)
Lag 2	0.051***	−0.003***
	(0.001)	(0.000)
Lag 3	0.050***	−0.001***
	(0.001)	(0.000)
Lag 4	0.049***	0.003***
	(0.001)	(0.000)
Lag 5	0.046***	−0.001**
	(0.001)	(0.000)
Lag 6	0.043***	−0.002***
	(0.001)	(0.000)
Firms	28,526	28,279
Observatinos	598,092	568,397

Notes: Asymptotic standard errors in parentheses. ***, **, and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. The vacancy posting indicator is residualized with respect to quarter effects, industry effects and their interactions.

3.2 Job and worker flows

Table 7 provides statistics about the magnitude and volatility of employment growth and its decomposition into the various worker-flow components. These variables are calculated at the firm level and also employment-weighted. The column labeled "Zero" reports the share of firm-quarters where the relevant rate is identically zero.

Quarterly employment growth is 1.2 percent, extremely volatile and only one third of firm-quarters feature no change in employment. Employment-weighting reduces all of these magnitudes considerably. Employment growth, though itself volatile, itself consists of even more volatile worker flows: the average firm hires 14 percent of its workforce and separates from a further 13 percent every quarter, figures that are only modestly reduced by employment-weighing. Slightly more than half of hires and separations involve employment-to-employment transitions. We shall return to this even split between hiring from employment and hiring from non-employment when interpreting some of the results of our analysis.

Job and worker reallocation in the Danish labor market is similar in magnitude to that in the US. Elsby and Michaels (2013) find that the standard deviation of annual employment growth in US establishments is 0.416, while the equivalent figure for Denmark is 0.344 (Table 7 reports the quarterly standard deviation). Davis, Faberman, and Haltiwanger (2012) report quarterly employment-weighted hiring and separation rates of 14-15 percent for the US, only slightly higher than the 11-12 percent reported for our data in Table 7. Fallick and Fleischman (2004) find that two-fifths of hires between 1994 and 2003 involved Employment-to-Employment transitions. Moscarini and Postel-Vinay (2016) report an average monthly Employment-to-Employment transition probability of 2 percent, which is not dissimilar to our quarterly EE-hazard rate of 6 percent. Davis, Faberman, and Haltiwanger (2012) report an even split between quits and layoffs as sources of separations, which is consistent with the split in our data into EE-separations and EN-separations, interpreting the former as likely quits and

Table 7: Quarterly hiring, separation, and employment growth rate distributions

	Non-weighted			Empl.-weighted		
	Avg.	SD	Zero	Avg.	SD	Zero
Quarterly employment growth rate	0.012	0.250	0.338	0.006	0.180	0.096
Quarterly hiring rate	0.137	0.206	0.363	0.117	0.155	0.078
Quarterly EE-hiring rate	0.072	0.129	0.506	0.061	0.082	0.131
Quarterly NE-hiring rate	0.065	0.143	0.560	0.056	0.109	0.165
Quarterly separation rate	0.125	0.184	0.371	0.111	0.136	0.074
Quarterly EE-separation rate	0.067	0.122	0.516	0.059	0.079	0.130
Quarterly EN-separation rate	0.058	0.124	0.567	0.052	0.089	0.158

Notes: The rates are computed by pooling all firm-quarters in our analysis data. Employment-weighting is done by $\overline{N}_{jt} = (N_{jt} + N_{jt-1})/2$. The column labeled "Zero" contains the share of firm-quarters where the relevant rate is zero.

the latter as likely layoffs.

3.3 Value added and revenues

Table 8 reports descriptive statistics on the distributions of annual value added and revenues, as well as their quarterly growth rates for the firms in our vacancy panel. The upper panel presents statistics at the firm-level, whereas the lower panel reports employment weighted growth rates.

Annual value added and revenues have highly skewed distributions with very long right tails.

The quarterly value added growth rate among the vacancy panel firms is 0.015, which is reduced to 0.011 when employment-weighted, and is highly dispersed with a standard deviation of 0.94; indeed, value added growth is almost four times as volatile as the employment growth rate, see Table 7.[21] This ratio is maintained when comparing employment weighted statistics.

Revenues grow at an average quarterly rate of 0.011, and is also highly dispersed, although its standard deviation of 0.55 is only a little more than half of the standard deviation of quarterly value added growth. The employment weighted statistics for quarterly revenue growth rates follow the same pattern as the unweighted ones.

This concludes our basic descriptive analysis of the key variables. We now turn our attention to estimating and quantifying the relationships between vacancy posting, hiring, separations, and value added and revenue growth.

4 Vacancies, hiring and separations

In this section we investigate the relationship between vacancy posting and various measures of employment dynamics.

We begin by examining the effect of vacancy posting on the hiring rate and, also, disaggregate

[21] The standard deviation of the unweighted annual value added growth is 0.739, while the weighted growth rate is 0.622. The annual value added growth rate are computed on the sum of the quarterly value added observations for each firm-year, and the reported standard deviation refers to the distribution of annual value added across firm-years. To employment-weigh, we use average employment over the year.

Table 8: Value added and revenue

	Unweighted				
	Avg.	SD	P25	P50	P75
Annual value added/1,000 DKK	22,599	577,579	1,198	3,220	9,013
Annual revenue/1,000 DKK	65,383	737,201	3,475	9,074	27,476
Quarterly value added growth rate	0.015	0.940	−0.369	0.017	0.403
Quarterly sales growth rate	0.011	0.548	−0.190	0.012	0.220
	Employment-weighted				
	Avg.	SD	P25	P50	P75
Quarterly value added growth rate	0.011	0.792	−0.257	0.009	0.294
Quarterly revenue growth rate	0.008	0.410	−0.121	0.006	0.141

Notes: Annual statistics are computed on annual value added and revenue observations on 167,847 firm-years in the vacancy panel. Growth rates of variable X is computed as $\Delta \log X$. The quarterly value added growth rate is computed on 484,859 firm-quarters, and the quarterly revenue growth rate is computed on 598,092 firm-quarters. Employment-weighting is done by $\overline{N}_{jt} = (N_{jt} + N_{jt-1})/2$.

that rate into hiring from employment and non-employment.[22] We then study the effect of vacancy posting on employment growth. Finally, we examine the effect of separations on vacancy-posting, i.e. use vacancies as an outcome variable, in order to examine the prevalence of replacement hiring and vacancy chains.

4.1 Vacancy posting and the hiring rate

We have data on firms' vacancy postings and on their worker and job flows and we investigate the dynamic effect of vacancy-posting on the hiring rate.

We estimate several variations of the following Distributed Lag panel data model,

$$z_{jt} = \sum_{k=0}^{K} \pi_k v_{jt-k} + \mathbf{x}'_{jt}\boldsymbol{\delta} + \rho_j + \epsilon_{jt}, \tag{3}$$

where $\mathbf{x}_{jt}$ is a vector of industry-dummies, quarter-dummies and quarter-dummies interacted with industry-dummies, ρ_j is a firm fixed effect, and ϵ_{jt} is the error term. The variable v_{jt} is the vacancy-posting variable that takes the value 1 if firm j posts a vacancy in quarter t and 0 otherwise. The vacancy-posting variable is included with a truncated lag distribution, where the lag-k weight is π_k. We refer to the maximum π_k in the lag distribution as the *peak response* and to $\sum_{k=0}^{K} \pi_k$ as the *cumulative response* of a vacancy posting.

We begin our analysis with the effect of posting vacancies on firms' hiring rate ($z_{jt} = h_{jt}$) and will consider alternative dependent variables later in this section. Table 9 presents estimates of four specifications of (3) for $z_{jt} = h_{jt}$, with and without firm fixed effects and with and without lagged responses. We keep the estimation sample fixed across the different specifications to facilitate comparisons. That is, we use the firm-panel for which we can estimate the richest parameterized version of (3), which includes five lags of the quarterly vacancy-posting variable v_{jt}. This sample contains 454,144 firm-quarters for 26,335 firms.

[22] Appendix A further disaggregates hiring into intensive and extensive margins.

Table 9: Vacancy posting and the hiring rate

DEPENDENT VARIABLE: h_{jt}	(1)	(2)	(3)	(4)
v_{jt}	0.045^{***} (0.001)	0.048^{**} (0.001)	0.043^{***} (0.001)	0.046^{***} (0.001)
v_{jt-1}			0.020^{***} (0.001)	0.024^{***} (0.001)
v_{jt-2}			-0.007^{***} (0.001)	-0.004^{***} (0.001)
v_{jt-3}			-0.009^{***} (0.001)	-0.005^{***} (0.001)
v_{jt-4}			-0.004^{***} (0.001)	0.001^{*} (0.001)
CUMULATIVE RESPONSE			0.044^{***} (0.001)	0.063^{***} (0.002)
FIRM FE	NO	YES	NO	YES
FIRMS	26,335	26,335	26,335	26,335
OBSERVATIONS	454,144	454,144	454,144	454,144

Notes: Robust standard errors in parentheses. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. All regressions include controls for quarter effects, industry effects and their interactions. The mean and standard deviation of h_{jt} in the estimation sample is 0.124 and 0.174, respectively.

Columns (1) and (2) regress the hiring rate h_{jt} on the vacancy-posting variable of the contemporaneous quarter v_{jt}, without and with firm fixed effects, respectively. Column (1) reports that, without controlling for firm fixed effects, vacancy posting is associated with a statistically significant increase in the contemporaneous quarterly hiring rate of 0.045. This corresponds to a 35 percent increase on the mean (unconditional) hiring rate and to 25 percent of a standard deviation. Controlling for firm fixed effects (column (2)), where the estimate is driven by within-firm variation only, yields a similar, if somewhat higher, estimated response.

Columns (3) and (4) expand the lag distribution of v_{jt} to include lags 0 through 4 quarters, without and with firm fixed effects, respectively. For both specifications the peak response occurs in the contemporaneous quarter, and is quantitatively very close to those reported in columns (1) and (2). The one-quarter lagged response, however, is also statistically and quantitatively significant, at approximately half the magnitude of the peak response. Further lagged vacancy postings yield quantitatively negligible effects, especially in our preferred specification with firm fixed effects in column (4). In that preferred specification, the estimated lag distribution implies a cumulative response of a vacancy posting of 0.063, which represents a 50 percent increase on the baseline hiring rate, and 35 percent of a standard deviation.

The main points of this analysis are the following. First, there is a strong hiring response to vacancy-posting. Second, there is significant variation in the timing of the response, since one-third of the increase occurs with one quarter lag. Appendix A disaggregates the response to the extensive and intensive margins of hiring and finds that both margins respond to vacancy-posting, with a similar timing structure.

Table 10: Vacancy posting and EE- and NE-hiring

Dependent varriable:	h_{jt}	h_{jt}^{EE}	h_{jt}^{NE}
v_{jt}	0.046*** (0.001)	0.027*** (0.000)	0.019*** (0.000)
v_{jt-1}	0.024*** (0.001)	0.016*** (0.000)	0.008*** (0.000)
v_{jt-2}	−0.004*** (0.001)	−0.002*** (0.000)	−0.002*** (0.000)
v_{jt-3}	−0.005*** (0.001)	−0.003*** (0.000)	−0.002*** (0.000)
v_{jt-4}	0.001* (0.001)	0.000*** (0.000)	0.001*** (0.000)
Cumulative response	0.063*** (0.002)	0.038*** (0.001)	0.023*** (0.001)
Firms	26,335	26,335	26,335
Observations	454,144	454,144	454,144

Notes: Robust standard errors in parentheses. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. All regressions include controls for quarter effects, industry effects and their interactions, and firm fixed effects. The average h_{jt}^{EE} and h_{jt}^{NE} in the estimation sample are 0.067 and 0.057. The standard deviations of h_{jt}^{EE} and h_{jt}^{NE} in the estimation sample are 0.113 and 0.118.

4.2 Hiring from employment and non-employment

We examine the responses to vacancy-posting of hiring from employment and non-employment by estimating (3) separately using the hiring rate from employment ($z_{jt} = h_{jt}^{EE}$) and the hiring rate from non-employment ($z_{jt} = h_{jt}^{NE}$) as dependent variables. Since $h_{jt} = h_{jt}^{EE} + h_{jt}^{NE}$ these regressions decompose the total hiring response to vacancy-posting presented above into the hiring-from-employment response and the hiring-from-nonemployment response.

The estimated models are tabulated in Table 10, where all specifications include firm fixed effects; that is, the estimated effects are identified from within-firm variation in hiring rates and vacancy posting. For ease of reference, the first column in Table 10 reproduces column (4) from Table 9, our preferred estimates of the effect of a vacancy posting on the hiring rate.

The timing of the vacancy posting responses in hiring from employment and nonemployment are similar, and thus coincide with the timing of responses in all hiring: The peak response is the contemporaneous effects, with statistically and quantitatively significant responses at a one-quarter lag and quantitatively insignificant responses thereafter. The cumulative hiring-from-employment response (0.038) accounts for 60 percent of the cumulative response on all hiring (0.063), which is higher by a non-trivial amount than the average share of such hires in the data (53 percent, see Table 7). Furthermore, the hiring-from-employment response materializes somewhat slower than the hiring-from-nonemployment response: the weight on contemporaneous hiring from employment is 1.7 times larger the weight on one-quarter lagged hiring (0.027 vs. 0.016) for hiring from employment while it is 2.4 times larger in the case of hiring from non-employment (0.019 vs. 0.008).

These findings are informative about the nature of heterogeneity in the recruitment process. The finding that vacancy-posting increases hiring from employment more than hiring from non-employment is consistent with greater effort requirements for recruiting employed workers (recall that this effect is identified from within-firm variation). The finding that firms take longer to hire from employment than from non-employment after posting a vacancy is consistent with facing greater difficulties in recruiting employed workers.

4.3 Firm heterogeneity

We explore heterogeneous hiring responses to vacancy-posting for firms that differ across two size measures (employment and value added), two productivity measures (value added per worker and average wage), and two firm growth measures (value added growth and employment growth). To illustrate the procedure, consider employment. For each firm in the data, we compute the average size over the observation period and split the firms in employment size quintiles (firm entry to and exit from our sample implies that the number of firm-quarters might differ slightly across quintiles). We then estimate (3) with $z_{jt} = h_{jt}$ in each subsample and report the resulting lag distributions. This procedure is repeated for each of the six variables along which we assess heterogenous hiring responses.

Tables 11, 12 and 13 present a rich picture of the heterogeneous responses for the size, productivity and firm growth measures, respectively. We organize our discussion around the cross-quintile variation of two outcomes: the magnitude of the cumulative response of hiring to vacancy-posting and the timing structure of the response, particularly comparing the contemporaneous and one-quarter lagged responses. The cumulative effect of vacancy posting on the hiring rate can be related to the vacancy yield (the number of hires per vacancy), though our vacancy measure is coarser since we use a binary variable. The dynamic aspect of vacancy-posting on the hiring rate (i.e. the lag structure of the effect) can be related to vacancy durations.[23] While we will not compare the exact magnitudes of our estimates with the literature, we can compare the relative magnitudes across different types of firms in our findings and the literature.

We begin by noting that the timing pattern that we observed in the general hiring rate regressions (table 9) holds across all quintiles of all variables and, therefore, appears to be a very robust feature of the data: peak responses are contemporaneous, one-quarter lagged responses are quantitatively and statistically significant and further lagged responses are quantitatively insignificant.

The cumulative hiring response to vacancy-posting is large for firms in the lower size quintiles (greater than their unconditional hiring rate) and it decreases monotonically in firm size, becoming an order of magnitude smaller than the unconditional hiring rate for the largest quintile. It appears, therefore, that the cumulative response of the overall hiring rate (which corresponds to half the unconditional hiring rate as shown in section 4.1) hides significantly heterogeneous responses across firms of different sizes.[24] This finding is consistent with the decline of the vacancy yield in firm size, as documented by Davis, Faberman, and Haltiwanger (2013).

For firms of different productivity, the cumulative hiring response decreases roughly monotonically with firm productivity, following the pattern of the unconditional hiring rate. This finding suggests either that higher-wage and higher-productivity firms find it harder to recruit or, more plausibly, that

[23]Note, however, that we cannot directly connect a particular hire is associated with a specific job advertisement and will, hence, be unable to explicitly compute vacancy durations.

[24]Note that the unconditional hiring rate does not vary much across employment size quintiles and, therefore, the heterogeneous responses are unlikely to be a mechanical feature of different employment sizes.

Table 11: Hiring responses to vacancy posting by two firm size measures

Quintile	1st	2nd	3rd	4th	5th
	Average employment				
v_{jt}	0.097***	0.067***	0.048***	0.030***	0.017***
	(0.003)	(0.002)	(0.001)	(0.001)	(0.001)
v_{jt-1}	0.057***	0.034***	0.022***	0.015***	0.008***
	(0.003)	(0.002)	(0.001)	(0.001)	(0.001)
v_{jt-2}	0.000	−0.003	−0.004***	−0.002**	−0.004***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
v_{jt-3}	−0.004*	−0.003*	−0.005***	−0.002**	−0.005***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
v_{jt-4}	0.000	0.005***	0.003**	0.000	0.001
	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
Cumulative response	0.150***	0.101***	0.064***	0.042***	0.016***
	(0.006)	(0.004)	(0.003)	(0.002)	(0.002)
Average hiring rate	0.127	0.130	0.127	0.121	0.118
Average employment	3.296	6.776	11.708	22.978	162.412
Firms	6,256	5,272	5,176	4,930	4,701
Observations	92,663	89,024	90,808	90,913	90,736
	Average value added				
v_{jt}	0.087***	0.071***	0.046***	0.032***	0.017***
	(0.003)	(0.002)	(0.001)	(0.001)	(0.001)
v_{jt-1}	0.043***	0.033***	0.024***	0.017***	0.012***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
v_{jt-2}	−0.004*	−0.004**	−0.002**	−0.001*	−0.004***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
v_{jt-3}	−0.008***	−0.002	−0.002	−0.004***	−0.005***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
v_{jt-4}	0.003	0.005***	0.002	0.000	0.000
	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
Cumulative response	0.121***	0.103***	0.068***	0.044***	0.021***
	(0.006)	(0.004)	(0.003)	(0.003)	(0.002)
Average hiring rate	0.148	0.134	0.119	0.112	0.106
Average value added/1,000 DKK	−477.132	569.697	1,121.806	2,390.174	31,152.140
Median value added/1,000 DKK	190.000	543.000	1,066.000	2,223.000	7,724.000
Firms	5,987	5,335	5,059	4,836	4,660
Observations	84,145	85,246	85,606	85,910	86,090

Notes: The dependent variable is h_{jt}. Robust standard errors in parentheses. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. All regressions include controls for quarter effects, industry effects, their interactions, and firm fixed effects.

Table 12: Hiring responses to vacancy posting by two firm productivity measures

Quintile	1st	2nd	3rd	4th	5th
	Average value adder per worker				
v_{jt}	0.054***	0.053***	0.048***	0.042***	0.035***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)
v_{jt-1}	0.020***	0.021***	0.023***	0.023***	0.031***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
v_{jt-2}	−0.009***	−0.003*	−0.002**	−0.002**	−0.002
	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
v_{jt-3}	−0.005**	−0.004***	−0.004***	−0.005***	−0.005***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
v_{jt-4}	0.008***	−0.001	0.002**	−0.001	−0.002
	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
Cumulative response	0.067***	0.064***	0.066***	0.057***	0.057***
	(0.004)	(0.003)	(0.003)	(0.003)	(0.004)
Average hiring rate	0.177	0.128	0.109	0.104	0.105
Average VA per worker/1,000 DKK	7.613	75.012	99.180	131.540	483.260
Median VA per worker/1,000 DKK	34.625	73,250	96.250	125.385	212.000
Firms	5,841	5,228	5,056	5,061	5,149
Observations	90,839	90,831	90,830	90,831	90,813
	Average wage				
v_{jt}	0.069***	0.056***	0.043***	0.038***	0.028***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
v_{jt-1}	0.024***	0.020***	0.021***	0.023***	0.030***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
v_{jt-2}	−0.005**	−0.003**	−0.004***	−0.003**	−0.004***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
v_{jt-3}	−0.004**	−0.005***	−0.005***	−0.004***	−0.006***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
v_{jt-4}	0.006***	0.001	0.003**	0.001	−0.004***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Cumulative response	0.090***	0.070***	0.059***	0.053***	0.044***
	(0.005)	(0.003)	(0.003)	(0.003)	(0.003)
Average hiring rate	0.185	0.125	0.111	0.102	0.098
Average wage/1,000 DKK	62.009	81.391	94.220	109.666	162.194
Median wage/1,000 DKK	62.773	80.715	92.949	107.529	135.542
Firms	5,524	5,194	5,191	5,108	5,318
Observations	90,849	90,813	90,842	90,832	90,808

Notes: The dependent variable is h_{jt}. Robust standard errors in parentheses. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. All regressions include controls for quarter effects, industry effects, their interactions, and firm fixed effects.

Table 13: Hiring responses to vacancy posting by two firm growth measures

Quintile	1st	2nd	3rd	4th	5th
			Average employment growth		
v_{jt}	0.061***	0.047***	0.037***	0.038***	0.049***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
v_{jt-1}	0.026***	0.026***	0.018***	0.022***	0.027***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
v_{jt-2}	−0.001	−0.002	0.000	−0.003**	−0.010***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
v_{jt-3}	−0.003**	−0.002***	−0.003**	−0.005***	−0.009***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
v_{jt-4}	0.008***	0.003***	0.003	−0.001	−0.004
	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
Cumulative response	0.090***	0.072***	0.054***	0.052***	0.053***
	(0.004)	(0.003)	(0.003)	(0.003)	(0.004)
Average hiring rate	0.127	0.101	0.109	0.121	0.164
Average employment growth	−0.042	−0.005	0.005	0.018	0.057
Firms	5,755	5,813	3,971	4,770	6,026
Observations	90,837	103,693	77,963	90,833	90,818
			Average value added growth		
v_{jt}	0.055***	0.046***	0.040***	0.042***	0.047***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
v_{jt-1}	0.026***	0.023***	0.022***	0.021***	0.025***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
v_{jt-2}	−0.004***	−0.001	−0.001	−0.002	−0.008***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
v_{jt-3}	−0.006***	−0.004***	0.000	−0.004***	−0.009***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
v_{jt-4}	0.004***	0.001	−0.001	0.001	0.001
	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
Cumulative response	0.074***	0.064***	0.061***	0.059***	0.056***
	(0.004)	(0.003)	(0.003)	(0.003)	(0.004)
Average hiring rate	0.123	0.112	0.119	0.128	0.135
Average value added growth	−0.126	−0.017	0.004	0.027	0.139
Firms	5,716	4,792	4,688	4,784	5,462
Observations	83,591	84,948	85,097	84,949	89,804

Notes: The dependent variable is h_{jt}. Robust standard errors in parentheses. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. All regressions include controls for quarter effects, industry effects, their interactions, and firm fixed effects. Note that the analysis that conditions on the value added growth rate is based on 428,389 firm quarters (and 25,442 firms) with positive value added for which we can compute the value added growth rate as $\Delta \log Y_{jt}$.

they are significantly more selective in who they hire; therefore, worker heterogeneity and the associated firm selectivity are an important features of the recruitment process. Finally, the cumulative response declines monotonically in firms' growth rate (both growth measures) both in absolute magnitude and as a ratio of the unconditional hiring rate, which, in general, increases in firm growth. This finding is surprising, especially since Davis, Faberman, and Haltiwanger (2013) find that fast-growing firms have higher vacancy yields, i.e. generate more hires per vacancy.

The timing composition of the cumulative hiring response does not appear to vary much across size quintiles: contemporaneous responses are approximately twice the size of one-lag responses, the higher value added firms being an exception. The timing of the response does vary in a very pronounced way, however, across firms of different productivity: for lower-productivity firms the contemporaneous response is three times larger than the one-quarter lagged response, and that ratio monotonically declines in productivity, reaching parity at the higher-productivity firms. This feature suggests that it takes longer to complete a hire for high-productivity firms which is consistent with such firms spending more time and effort screening their potential employees. The relative importance of later hires is also modestly increasing in firms' growth rate.

Overall, we find significant heterogeneity in firms' hiring responses, some of which is consistent with differential selectivity of workers and some of which seems puzzling, especially that of high-growth firms.

4.4 Vacancy posting and employment growth

We supplement the preceding analysis by examining the effect of vacancy posting on employment growth. We do this by estimating (3) taking z_{jt} to be the employment growth rate. Strictly speaking, the posting of a vacancy affects hiring rather than employment growth. This regression is informative to the extent that it allows the comparison with datasets which might only include job flows.

Table 14 reports the results. We only comment on our preferred specification in column (4) which includes lagged responses and firm fixed effect. Consistent with our analysis of the hiring rate response, the peak response in employment growth to vacancy-posting occurs contemporaneously, with quantitatively significant one-quarter lagged responses. In absolute terms, the cumulative response is smaller than for hiring, by almost two-thirds.[25] This is not surprising, given that hiring might occur to replace departing workers rather than to grow the firm's employment, a subject we turn to next.

4.5 Separations and vacancies

In this subsection, we explore the importance of replacement hiring and, by extension, the quantitative relevance of vacancy chains. The basic idea behind vacancy chains is that firms post vacancies to replace departing workers, as well as to grow in size, which might create volatility in aggregate labor markets.[26] Separations give a measure of departing workers and we investigate whether it predicts

[25]Because the quarterly employment growth rate is, on average, small, the cumulative vacancy response represent a quadrupling of the average growth rate; note, however, that it represents only 10 percent of a standard deviation of the quarterly employment growth rate.

[26]See Elsby, Michaels, and Ratner (2019) and Mercan and Schoefer (2020) for a full exposition. These studies infer the presence of replacement hiring by observing that firms that face quits often report stable employment, i.e. simultaneously hire to exactly offset departing workers.

Table 14: Vacancy posting and the employment growth rate

DEPENDENT VARIABLE: g_{jt}	(1)	(2)	(3)	(4)
v_{jt}	0.022***	0.025	0.025***	0.025***
	(0.001)	(0.001)	(0.001)	(0.001)
v_{jt-1}			0.012***	0.013***
			(0.001)	(0.001)
v_{jt-2}			−0.012***	−0.010***
			(0.001)	(0.001)
v_{jt-3}			−0.010***	−0.007***
			(0.001)	(0.001)
v_{jt-4}			−0.002**	0.002**
			(0.001)	(0.001)
CUMULATIVE RESPONSE			0.013***	0.023***
			(0.001)	(0.002)
FIRM FE	NO	YES	NO	YES
FIRMS	26,335	26,335	26,335	26,335
OBSERVATIONS	454,144	454,144	454,144	454,144

Notes: Robust standard errors in parentheses. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. All regressions include controls for quarter effects, industry effects and their interactions. The mean and standard deviation of g_{jt} in the estimation sample is 0.006 and 0.221, respectively.

vacancy-posting, which will now be a dependent variable in our regressions. We note that this is the first study to explicitly model the effect of separations on vacancy-posting.

A challenge to this exercise is that firms might not want to replace all separating workers and we have no direct indication of the type of separation. We address heterogeneity in the nature of separations (replaceable or not) in two ways: first, we control for large separation events, defined as events when 20% or more of a firm's employment separates in a quarter (i.e. where $s_{jt} > 0.20$) since such events are likely to be associated with down-sizing and, hence, unlikely to require replacing; second, by examining separations where the worker moved to a different firm as distinct from those where the worker moved to non-employment, the logic being that poached workers are more likely to be replaced.

We begin by documenting the relationship between the contemporaneous and past separation rate and vacancy-posting using the following Distributed Lag panel data model for v_{jt}, the vacancy-posting variable,

$$v_{jt} = \sum_{k=0}^{K} \pi_k^0 \mathbb{1}(s_{jt-k} > 0) + \sum_{k=0}^{K} \pi_k^+ s_{jt-k} \mathbb{1}(s_{jt-k} > 0) + \sum_{k=0}^{K} \pi_k^{++} (s_{jt-k} - 0.20) \mathbb{1}(s_{jt-k} > 0.20) + \mathbf{x}'_{jt}\boldsymbol{\delta} + \rho_j + \epsilon_{jt}, \quad (4)$$

where $\mathbf{x}_{jt}$ is a vector of quarter-dummies, industry-dummies and interactions, ρ_j is a firm fixed effect and ϵ_{jt} is the error term. Since v_{jt} is a binary variable, (4) is a linear probability model for vacancy posting event.

The regression (4) captures the effect of (contemporaneous and lagged) separation events on vacancy posting via linear spline functions. The regression includes a dummy (and its lagged values) for any separations, $\mathbb{1}(s_{jt-k} > 0)$, to capture the large inaction that we observe in the data, where 36 percent of firm-quarters feature $s_{jt} = 0$; moreover, it allows for large separation events to have nonlinear effects

Table 15: Vacancy posting and the separation rates

DEPENDENT VARIABLE: v_{jt}	(1)	(2)	(3)
$\mathbb{1}(s_{jt} > 0)$	0.069***	0.061***	0.027***
	(0.001)	(0.002)	(0.003)
$\mathbb{1}(s_{jt-1} > 0)$	0.019***	0.017***	0.012***
	(0.001)	(0.002)	(0.003)
$s_{jt}\mathbb{1}(s_{jt} > 0)$		0.034***	0.297***
		(0.004)	(0.016)
$s_{jt-1}\mathbb{1}(s_{jt-1} > 0)$		0.006	0.052***
		(0.004)	(0.016)
$(s_{jt} - 0.20)\mathbb{1}(s_{jt} > 0.20)$			−0.319***
			(0.019)
$(s_{jt-1} - 0.20)\mathbb{1}(s_{jt-1} > 0.20)$			−0.057***
			(0.019)
FIRMS	26,335	26,335	26,335
OBSERVATIONS	454,144	454,144	454,144

Notes: Robust standard errors in parentheses. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. All regressions include controls for quarter effects, industry effects, their interactions and firm fixed effects.

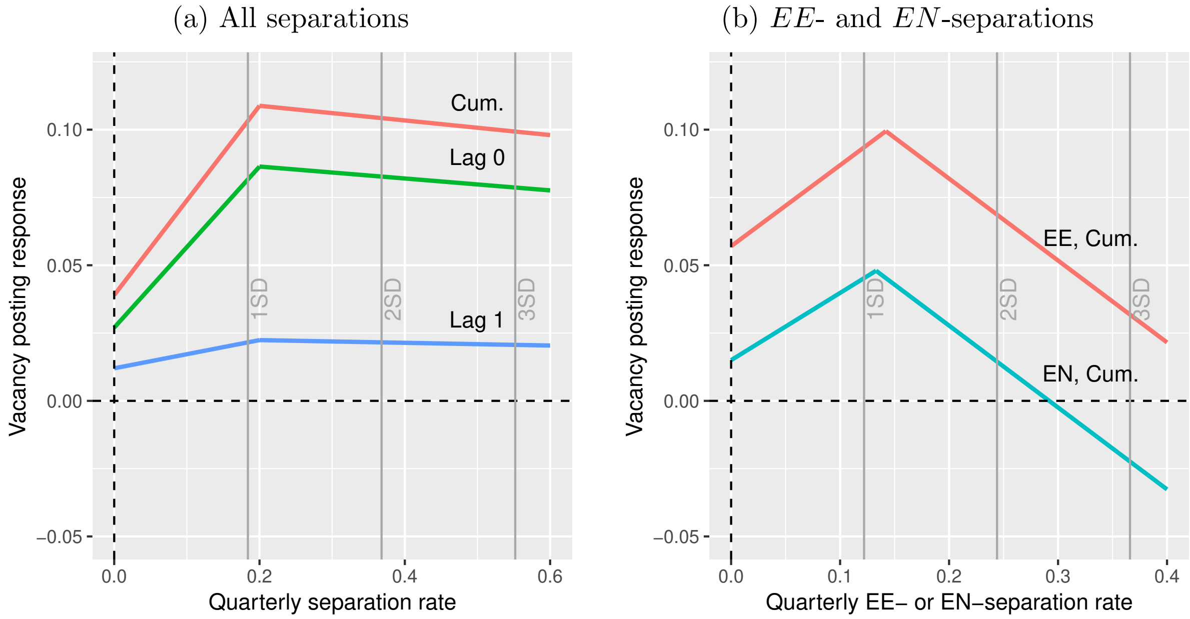
on vacancy posting by including a kink at a quarterly separation rate of 0.20, represented by the $(s_{jt-k} - 0.20)\mathbb{1}(s_{jt-k} > 0.20)$-terms. The slopes of the separation rate profiles implied by (4) in the intervals $s_{jt-k} \in (0, 0.20)$ and $s_{jt-k} \in (0.20, 2.00)$ are π_k^+ and $\pi_k^+ + \pi_k^{++}$, respectively, at the kth lag.

Table 15 shows parameter estimates for three different specifications of (4); the parameters are precisely estimated, and all bar one are statistically significant. Our preferred specification is in column (3), and Figure 1, panel (a) renders graphically the implied response profiles for this specification, including the cumulative response that adds the contemporaneous and one-quarter lagged responses. Engaging in any separations shifts the profile of the vacancy response up by 2.7 percentage points. Accounting for the effect of from one-quarter lagged separations (1.2 percentage points) yields a shift of the cumulative response of 3.9 percentage points. The vacancy posting probability increases relatively steeply with the magnitude of contemporaneous separations, so long as they are below 20 percent of the firm's workforce. The vacancy posting probability also increases in the magnitude of one-quarter lagged separations, but less so. The estimates implies that a "modest" 10 percent separation event (the standard deviation of the quarterly separation rate is 0.184), raises the vacancy probability by about 6.5 percentage point, a 30 percent increase on a baseline vacancy posting probability of 21.5 percent.[27] Finally, the estimated kink at a separation rate of 0.20 implies that "large" separation events have smaller, yet still positive, effects on the vacancy posting probability. Overall, we take these results as (indirect) evidence that replacement hiring, and thus, vacancy chains, is an empirically relevant phenomenon.

To document the relationship between vacancy-posting and separations to employment and non-employment, we extend equation (4) in a straightforward way by replacing the separation rate (s_{jt})

[27] A 20 percent separation event, close to the standard deviation of the separation rate, is associated with an almost 10 percentage increase in the vacancy posting probability, close a 50 percent increase in the baseline vacancy posting probability.

Figure 1: Vacancy posting response profiles to separation events



Notes: Vacancy posting responses to all separation events in panel(a) are constructed from the lag distributions reported in columns (3) in Table 15. The vertical lines in panel (a) delineate standard deviations of the quarterly all separation rate (0.184). Vacancy posting responses to EE- and EN-separation events in panel(b) are constructed from the lag distributions reported in columns (3) in Table 16. The vertical lines in panel (a) delineate standard deviations of the quarterly EE-separation rate (0.122, the standard deviation of the EN-separation rate is 0.124). The response profile related to EE-separations in panel (b) fixes EN-separations at their average value 0.058. The response profile related to EN-separations in panel (b) fixes EE-separations at their average value 0.067.

Table 16: Vacancy posting and the EE- and EN-separation rates

DEPENDENT VARIABLE: v_{jt}	(1)	(2)	(3)
$\mathbb{1}(s_{jt}^{EE} > 0)$	0.071***	0.063***	0.047***
	(0.001)	(0.002)	(0.002)
$\mathbb{1}(s_{jt-1}^{EE} > 0)$	0.016***	0.014***	0.010***
	(0.001)	(0.002)	(0.002)
$s_{jt}^{EE}\mathbb{1}(s_{jt}^{EE} > 0)$		0.048***	0.236***
		(0.007)	(0.015)
$s_{jt-1}^{EE}\mathbb{1}(s_{jt-1}^{EE} > 0)$		0.013***	0.063***
		(0.007)	(0.015)
$\mathbb{1}(s_{jt}^{EN} > 0)$	0.026***	0.027***	0.012***
	(0.001)	(0.002)	(0.002)
$\mathbb{1}(s_{jt-1}^{EN} > 0)$	0.008***	0.008***	0.003*
	(0.001)	(0.002)	(0.002)
$s_{jt}^{EN}\mathbb{1}(s_{jt}^{EN} > 0)$		−0.009	0.191***
		(0.006)	(0.015)
$s_{jt-1}^{EN}\mathbb{1}(s_{jt-1}^{EN} > 0)$		0.003	0.057***
		(0.006)	(0.015)
$(s_{jt} - 0.20)\mathbb{1}(s_{jt} > 0.20)$			−0.237***
			(0.016)
$(s_{jt-1} - 0.20)\mathbb{1}(s_{jt-1} > 0.20)$			−0.065***
			(0.016)
FIRMS	26,335	26,335	26,335
OBSERVATIONS	454,144	454,144	454,144

Notes: Robust standard errors in parentheses. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. All regressions include controls for quarter and industry effects, as well as their interactions.

with separations into employment (s_{jt}^{EE}) and non-employment (s_{jt}^{EN}):

$$v_{jt} = \sum_{k=0}^{K} \pi_s^{0,EE}\mathbb{1}(s_{jt-k}^{EE} > 0) + \sum_{k=0}^{K} \pi_k^{0,EN}\mathbb{1}(s_{jt-k}^{EN} > 0) + \sum_{k=0}^{K} \pi_k^{+,EE} s_{jt-k}^{EE}\mathbb{1}(s_{jt-k}^{EE} > 0) + \sum_{k=0}^{K} \pi_k^{+,EN} s_{jt-k}^{EN}\mathbb{1}(s_{jt-k}^{EN} > 0) + \sum_{k=0}^{K} \pi_k^{++}(s_{jt-k} - 0.20)\mathbb{1}(s_{jt-k} > 0.20) + \mathbf{x}_{jt}'\boldsymbol{\delta} + \rho_j + \epsilon_{jt}, \quad (5)$$

The right-hand side variables are defined analogously to the earlier specification. Note that (5) does not decompose (4).

Table 16 reports parameter estimates for three specifications of (5); the parameters are precisely estimated, and only two are statistically insignificant. Our preferred specification is listed in column (3). We focus our comments on the profiles of the cumulative responses which are plotted in panel (b) in Figure 1; there are two response profiles, one for EE-separation events, and one for EN-separation events. First, we note that EE- and EN-separation profiles are broadly similar to the cumulative all separation response in panel (a): engaging in separations is correlated with an increase in the probability of posting a vacancy, with a kink at a 0.20 separation rate, after which responses begin to decline. Indeed, events where a firm separates with more than 30 percent of its workforce via EN-separations (a little more than 2 standard deviations of the EN-separation rate), has a negative effect on vacancy-posting. Comparing the EE- and EN-separation profiles in panel (b), we note that the cumulative effect of separations to employment on vacancy-posting is almost 50 percent larger than the effect of separations to non-employment. This finding suggests that firms are considerably more likely to spend effort replacing workers who separate to join other firms, and lends some empirical support to the notions replacement hiring. The peak effect, which occurs after a separation shock to employment of one standard deviation, is associated with a 10 percentage point increase in the vacancy-posting probability, a 45% increase over the unconditional probability.

The general picture regarding the association between separations and firms' recruiting effort, as measured by vacancy posting, is that there is considerable heterogeneity and non-linearity: in general, engaging in separations increases the probability that a firm posts a vacancy. This effect is quantitatively much stronger in the case of separations to employment, many of which are likely due to poaching by other firms; finally, the effects of separations tapers off when we consider large separation events. Overall, we view this as supportive evidence for the presence of replacement hiring and vacancy chains.

5 Revenues, value added and vacancies

In this section we examine the relationship between firm growth in revenue or value added and the posting of vacancies and, therefore, whether realized revenue or value added growth leads to an increase in recruiting effort.

We take a two-pronged approach. First, we characterize the empirical relationship between revenue, value added, and vacancy-posting by way of Distributed Lag regressions, in line with our analysis of the association between vacancy-posting and hiring or separations in section 4. This can be viewed as a reduced form of a one-shock model where all dynamics in value added or revenue stem from a single shock process, and allow us to investigate possible dynamic and non-linear vacancy posting responses to value added and revenue growth.

Second, we use an empirical model with a richer process for value added and revenue processes that includes both permanent and transitory shocks and estimate separate vacancy-posting responses to permanent and transitory shocks.

5.1 Evidence from Distributed Lag regressions

We document the relationship between vacancy-posting, measured by the vacancy-posting variable v_{jt}, and contemporaneous and past growth in revenue or value added with the following linear probability model

$$\begin{aligned} v_{jt} = \sum_{k=0}^{K} \pi_k^{+} \Delta z_{jt-k} \mathbb{1}(\Delta z_{jt-k} \geq 0) + \sum_{k=0}^{K} \pi_k^{-} \Delta z_{jt-k} \mathbb{1}(\Delta z_{jt-k} < 0) \\ + \sum_{k=0}^{K} \pi_k^{++} (\Delta z_{jt-k} - \tau^z) \mathbb{1}(\Delta z_{jt-k} > \tau^z) + \sum_{k=0}^{K} \pi_k^{--} (\Delta z_{jt-k} + \tau^z) \mathbb{1}(\Delta z_{jt-k} < -\tau^z) \\ + \mathbf{x}_{jt}' \boldsymbol{\delta} + \rho_j + \epsilon_{jt}, \quad (6) \end{aligned}$$

where $z \in \{y, r\}$ (i.e. z denotes value added or revenue), $\mathbf{x}_{jt}$ is a vector of quarter-dummies, and quarter-dummies interacted with industry-dummies, ρ_j is a firm fixed effect and ϵ_{jt} is the error term.

In (6), we capture the effect of value added or revenue growth on vacancy-posting in a flexible manner using linear splines. First, we allow for asymmetric responses to negative and positive growth events. Second, we allow for separate nonlinear responses to large positive and negative growth events, by including a spline-knot at $\Delta z_{jt} = \tau^z$. When applying (6) to value added growth, we set $\tau^y = 0.40$, which is close to one half of a standard deviation in the cross section distribution of value added growth. For revenue growth, we set $\tau^r = 0.20$, close to one half of a standard deviation in the cross section distribution of revenue growth. Third, we allow for contemporaneous and lagged growth events to impact vacancy posting by including lag distributions of the spline functions truncated at lag $K = 5$. Fourth, we allow for firm fixed effects ρ_j.

Table 17 reports the estimates. Columns (1) and (4) include as regressors only contemporaneous growth in value added and revenue, respectively, and estimate linear effects. Columns (2) and (5) introduce non-linear effects, as discussed above. Columns (3) and (6) include lags and non-linear effects for all lags; (3) and (6) represent our preferred specifications. Figure 2 presents a graphical illustration of the estimates from (3) and (6), where the cumulative effect is added over time.

We note the following features: The contemporaneous linear effects are relatively small quantitatively. The contemporaneous non-linear effects are slightly larger but still not particularly impactful. The dynamic effects are considerably larger and, when cumulated over time, yield a strong response. Increasing value added and revenue growth by one standard deviation is associated with an increase in the probability of posting a vacancy of 7.5 and 9.7 percentage points, respectively, which corresponds to 35 and 45 percent of the unconditional probability. Reducing value added and revenue growth by one standard deviation is associated with a reduction in the probability of posting a vacancy of 6.2 and 8.7 percentage points, respectively, which corresponds to 29 and 40 percent of the unconditional probability. Overall, the cumulative response of vacancy-posting to value added growth and revenue growth is not far from linear, as can be seen in Figure 2.

Overall, these findings suggest that growth in value added and revenues have significant predictive power regarding firms' recruiting efforts. However, the significant effects of very long quarterly lags of value added or revenue growth on vacancy posting implied by (6) are not easy to interpret or rationalize. The next subsection presents an alternative analysis that avoids this feature.

5.2 Evidence from a permanent-transitory shock model

In this subsection we consider the association between vacancy posting and growth in value added or revenue by modeling the evolution of the latter series as resulting from a permanent-transitory shock processes. The main motivation for exploring this specification is the previous section's finding that value added growth and revenue growth are significantly related to vacancy posting even with very long lags. A more palatable interpretation of the data is that some shocks are permanent in nature.

Our analysis proceeds in the following steps. We residualize value added growth and revenue growth rates with respect to calendar quarter, industry and their interactions and compute their autocovariances. Based on the recovered residual autocovariance patterns, we argue that it is more appropriate for our purposes to focus on four-quarter, or year-on-year, growth, rather than quarter-on-quarter growth (i.e. to compare the value added or revenue of a certain quarter in a year with the same quarter of the previous year rather than with the previous quarter). We then posit a parametric $ARIMA$-process that features permanent and transitory shocks and fit the processes to the empirical autocovariances of (residual) log value added and log revenue growth. This exercise confirms the presence of a permanent and transitory components in both series.

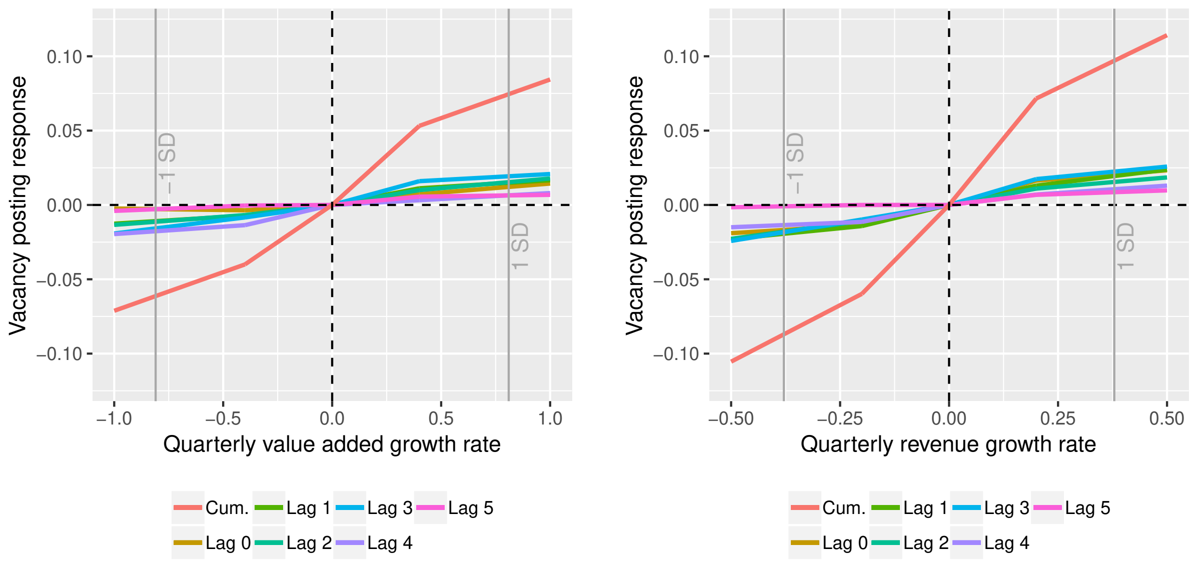
Table 17: Distributed Lag regressions of vacancy posting on value added and revenue growth

	Value added			Revenue		
Dependent variable: v_{jt}	(1)	(2)	(3)	(4)	(5)	(6)
Δz_{jt}	0.001* (0.001)			0.017*** (0.002)		
$\Delta z_{jt}\mathbb{1}(\Delta z_{jt} < 0)$		0.003 (0.006)	0.009 (0.007)		0.042*** (0.013)	0.068*** (0.013)
$\Delta z_{jt-1}\mathbb{1}(\Delta z_{jt-1} < 0)$			0.018*** (0.007)			0.071*** (0.014)
$\Delta z_{jt-2}\mathbb{1}(\Delta z_{jt-2} < 0)$			0.017** (0.007)			0.054*** (0.014)
$\Delta z_{jt-3}\mathbb{1}(\Delta z_{jt-3} < 0)$			0.021*** (0.007)			0.049*** (0.014)
$\Delta z_{jt-4}\mathbb{1}(\Delta z_{jt-4} < 0)$			0.034*** (0.007)			0.057*** (0.014)
$\Delta z_{jt-5}\mathbb{1}(\Delta z_{jt-5} < 0)$			0.001 (0.007)			0.000 (0.014)
$\Delta z_{jt}\mathbb{1}(\Delta z_{jt} \geq 0)$		0.005 (0.006)	0.018*** (0.007)		0.054*** (0.013)	0.082*** (0.014)
$\Delta z_{jt-1}\mathbb{1}(\Delta z_{jt-1} \geq 0)$			0.028*** (0.007)			0.065*** (0.014)
$\Delta z_{jt-2}\mathbb{1}(\Delta z_{jt-2} \geq 0)$			0.024*** (0.007)			0.055*** (0.014)
$\Delta z_{jt-3}\mathbb{1}(\Delta z_{jt-3} \geq 0)$			0.040*** (0.007)			0.087*** (0.014)
$\Delta z_{jt-4}\mathbb{1}(\Delta z_{jt-4} \geq 0)$			0.008 (0.007)			0.035** (0.013)
$\Delta z_{jt-5}\mathbb{1}(\Delta z_{jt-5} \geq 0)$			0.014** (0.007)			0.034** (0.013)
$(\Delta z_{jt} + \tau^z)\mathbb{1}(\Delta z_{jt} < -\tau^z)$		−0.006 (0.007)	−0.012 (0.008)		−0.040*** (0.015)	−0.050*** (0.016)
$(\Delta z_{jt-1} + \tau^z)\mathbb{1}(\Delta z_{jt-1} < -\tau^z)$			−0.010 (0.008)			−0.042*** (0.016)
$(\Delta z_{jt-2} + \tau^z)\mathbb{1}(\Delta z_{jt-2} < -\tau^z)$			−0.006 (0.008)			−0.014 (0.017)
$(\Delta z_{jt-3} + \tau^z)\mathbb{1}(\Delta z_{jt-3} < -\tau^z)$			−0.004 (0.008)			0.000 (0.016)
$(\Delta z_{jt-4} + \tau^z)\mathbb{1}(\Delta z_{jt-4} < -\tau^z)$			−0.025*** (0.008)			−0.045*** (0.017)
$(\Delta z_{jt-5} + \tau^z)\mathbb{1}(\Delta z_{jt-5} < -\tau^z)$			0.005 (0.008)			0.005 (0.017)
$(\Delta z_{jt} - \tau^z)\mathbb{1}(\Delta z_{jt} > \tau^z)$		−0.001 (0.007)	−0.006 (0.008)		−0.053*** (0.016)	−0.059*** (0.016)
$(\Delta z_{jt-1} - \tau^z)\mathbb{1}(\Delta z_{jt-1} > \tau^z)$			−0.019** (0.008)			−0.029* (0.016)
$(\Delta z_{jt-2} - \tau^z)\mathbb{1}(\Delta z_{jt-2} > \tau^z)$			−0.012 (0.008)			−0.029* (0.016)
$(\Delta z_{jt-3} - \tau^z)\mathbb{1}(\Delta z_{jt-3} > \tau^z)$			−0.031*** (0.008)			−0.059*** (0.017)
$(\Delta z_{jt-4} - \tau^z)\mathbb{1}(\Delta z_{jt-4} > \tau^z)$			0.001 (0.008)			−0.015 (0.016)
$(\Delta z_{jt-5} - \tau^z)\mathbb{1}(\Delta z_{jt-5} > \tau^z)$			−0.012 (0.007)			−0.024 (0.016)
Cumulative effect, −1SD(Δz_{jt})	−0.001* (0.001)	0.000 (0.002)	−0.062*** (0.009)	−0.006*** (0.001)	−0.009*** (0.002)	−0.087*** (0.008)
Cumulative effect, +1SD(Δz_{jt})	0.001* (0.001)	0.004 (0.002)	0.075*** (0.009)	0.006*** (0.001)	0.011*** (0.002)	0.097*** (0.008)
Firms	19,772	19,772	19,772	19,772	19,772	19,772
Observations	291,316	291,316	291,316	291,316	291,316	291,316

Notes: Robust standard errors in parentheses. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. All regressions include controls for quarter effects, industry effects, their interactions and firm fixed effects.

Figure 2: Vacancy posting responses to value added and revenue growth

(a) Value added (b) Revenue



Notes: Vacancy posting responses to value added growth in panel (a) are constructed from the lag distributions reported in columns (3) in Table 17. Vacancy posting responses to value added growth in panel (b) are constructed from the lag distributions reported in columns (6) in Table 17. The vertical lines in the plots delineate ±1 SD quarterly value added or quarterly revenue growth rate in the estimation data.

Finally, we estimate the separate responses of vacancy posting to permanent and transitory shocks (i.e. innovations to the permanent and transitory components). The econometric challenge in this latter exercise is that we do not separately observe "permanent" and "transitory" shocks but, rather, we have to infer them from the evolution of the common growth series. We confront this challenge by applying the methodology from Guiso, Pistaferri, and Schivardi (2005), developed for the purpose of estimating the pass-through of productivity shocks to earnings.

5.2.1 A characterization of the value added, sales and purchases processes

The basic descriptive statistics on value added and revenue growth in Table 3 revealed substantial cross-sectional dispersion in both series, particularly for value added growth; we now provide an empirical characterization of the dynamics of these processes.

Residualization. Our focus is on residual dynamics. Let Y_{jt} and R_{jt} denote observed quarterly value added and revenue for firm j in period t, and let $y_{jt} \equiv \log Y_{jt}$ and $r_{jt} \equiv \log R_{jt}$. We residualize these series with respect to calendar quarter, industry, and their interactions using the regression

$$z_{jt} = \mu^z_{\mathrm{Q}(t)} + \nu^z_{\mathrm{I}(j)} + \xi^z_{\mathrm{Q}(t)\mathrm{I}(j)} + \epsilon^z_{jt}, \tag{7}$$

where $z \in \{y, r\}$ (i.e. z denotes value added or revenue); $\mathrm{Q}(t) : \{1, 2, ..., T\} \mapsto \{1, 2, 3, 4\}$ maps observation period t to a calendar quarter, and $\mu^z_{\mathrm{Q}(t)}$ is a common quarter effect for series z; $\mathrm{I}(j)$ maps firm j to its one-digit industry, and $\nu^z_{\mathrm{I}(j)}$ is the common industry effect for the z-series; finally, $\xi^z_{\mathrm{Q}(t)\mathrm{I}(j)}$ is the quarter-industry interaction for series z.

Table 18: Residual autocovariance functions

	1-quarter growth		4-quarter growth	
	$\Delta\widehat{y}_{jt}$	$\Delta\widehat{r}_{jt}$	$\Delta_4\widehat{y}_{jt}$	$\Delta_4\widehat{r}_{jt}$
Lag 0	0.844*** (0.006)	0.279*** (0.004)	0.661*** (0.005)	0.263*** (0.004)
Lag 1	−0.404*** (0.004)	−0.110*** (0.002)	0.041*** (0.001)	0.084*** (0.002)
Lag 2	0.031*** (0.002)	−0.008*** (0.002)	0.039*** (0.001)	0.050*** (0.001)
Lag 3	−0.103*** (0.002)	−0.046*** (0.002)	0.030*** (0.001)	0.023*** (0.001)
Lag 4	0.189*** (0.003)	0.100*** (0.003)	−0.246*** (0.003)	−0.059*** (0.001)
Lag 5	−0.107*** (0.002)	−0.045*** (0.002)	0.013*** (0.001)	0.000 (0.001)
Lag 6	0.026*** (0.002)	−0.008*** (0.002)	0.002 (0.001)	0.002** (0.001)
Lag 7	−0.097*** (0.002)	−0.043*** (0.002)	0.001 (0.001)	0.003*** (0.001)
Lag 8	0.173*** (0.003)	0.095*** (0.003)	−0.003** (0.001)	0.003*** (0.001)
Lag 9	−0.093*** (0.002)	−0.042*** (0.002)	0.000 (0.001)	0.004*** (0.001)
Lag 10	0.016*** (0.002)	−0.008*** (0.002)	−0.004** (0.002)	0.001 (0.001)
Lag 11	−0.089*** (0.002)	−0.042*** (0.002)	−0.001 (0.002)	−0.002** (0.001)
Lag 12	0.165*** (0.003)	0.091*** (0.003)	0.000 (0.002)	−0.002 (0.001)
Firms	27,575	28,112	26,612	27,070
Observations	484,859	559,586	417,468	476,701

Notes: Asymptotic standard errors in parentheses. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. The log value added and log sales series are residualized with respect to quarter, industry and interaction effects; see (7) and main text for details.

The residualized log value added and log revenue series are given by

$$\begin{aligned}\widehat{y}_{jt} &\equiv \widehat{\epsilon}^{y}_{jt} = y_{jt} - \widehat{\mu}^{y}_{\mathrm{Q}(t)} - \widehat{\nu}^{y}_{\mathrm{I}(j)} - \widehat{\xi}^{y}_{\mathrm{Q}(t)\mathrm{I}(j)},\\ \widehat{r}_{jt} &\equiv \widehat{\epsilon}^{r}_{jt} = r_{jt} - \widehat{\mu}^{r}_{\mathrm{Q}(t)} - \widehat{\nu}^{r}_{\mathrm{I}(j)} - \widehat{\xi}^{r}_{\mathrm{Q}(t)\mathrm{I}(j)}.\end{aligned}$$

The rest of our econometric analysis treats $\widehat{y}_{jt}$ and $\widehat{r}_{jt}$ as known, and not pre-estimated, quantities.

Quarter-on-quarter and four-quarter growth. We estimate the autocovariances of the residualized series' growth over one and four quarters, which we denote Δz_{jt} and $\Delta_4 z_{jt}$, respectively.[28] Table 18 reports the estimated autocovariance functions.

The autocovariances of quarter-on-quarter growth of value added and revenues have two characteristics that are empirically and theoretically unappealing. First, quarter-on-quarter growth features autocovariances that are statistically and quantitatively significant even at very long lags (e.g. 12 quarters), suggesting that the (growth rate) series might even be non-stationary, or feature Moving Average components with very long memory. This hinders standard parsimonious $ARIMA$-representations of the $\widehat{y}_{jt}$- and $\widehat{r}_{jt}$-series. Second, quarter-on-quarter growth features oscillatory dynamics, as the au-

[28]Estimation of the autocovariance functions follows Abowd and Card (1989).

tocovariances periodically switch from positive to negative and back to positive. Such behavior is counter-intuitive; indeed, it is difficult to envisage the root-causes of such strongly oscillatory shocks.[29]

It turns out, however, that these characteristics essentially disappear when we examine four-quarter growth rates: in both series the empirical autocovariance becomes quantitatively (and, most times, statistically) insignificant after four or five quarters and there is no evidence of oscillatory dynamics. These findings are consistent with significant *firm-specific* seasonality (recall that we have removed common quarter effects from the series): if a firm, say, has consistently higher sales in the first quarter of the year than in the other three quarters, then it will always report large sales growth in Q1 and large sales decline in Q2 every year, leading to significant autocorrelation over long lags (Q1 growth and Q2 decline in every subsequent year) and oscillatory dynamics.

As we shall see next, accounting for firm-specific seasonality admits an empirically valid, intuitive, and very parsimonious representation of $\widehat{y}_{jt}$- and $\widehat{r}_{jt}$-series as the sum of a firm-specific season effect, a unit root process, and a low-order Moving Average process. Furthermore, such a representation predicts that the fourth lag has to be negative and, therefore, the negative sign in the fourth lag of the autocovariance table 18 is not a pathological feature of the data. Indeed, the analysis to come, the relatively large fourth order autocovariance in $\Delta_4\widehat{y}_{jt}$ and $\Delta_4\widehat{z}_{jt}$ dictates substantial variance to the transitory shocks, while the relatively small fifth order autocovariances stipulate that transitory shocks are very short-lived. Finally, the non-zero second order autocovariances will confirm the presence of a permanent (unit root) component in both series.

Parametric statistical models of log value added and log revenue. The evolution of log value added and log revenue is described by the following process,

$$\widehat{z}_{jt} = \mu^z_{j\mathrm{Q}(t)} + u^z_{jt} + w^z_{jt}, \tag{8}$$

where $\widehat{z}_{jt}$ is (residualized) log value added or log revenue, $\mu^z_{j\mathrm{Q}(t)}$ is a *firm-specific* quarter fixed effect, u^z_{jt} is an unit root process and w^z_{jt} is a Moving Average (MA) process.

We assume,

$$u^z_{jt} = u^z_{jt-1} + \varepsilon^z_{jt}, \tag{9}$$

$$w^z_{jt} = \zeta^z_{jt} + \theta^z \zeta^z_{jt-1}, \tag{10}$$

where ε^z_{jt} and ζ^z_{jt} are innovations that are independent from each other and across time with $\mathrm{E}[\varepsilon^z_{jt}] = 0$, $\mathrm{Var}[\varepsilon^z_{jt}] = \sigma^2_{\varepsilon^z}$, $\mathrm{E}[\zeta^z_{jt}] = 0$ and $\mathrm{Var}[\zeta^z_{jt}] = \sigma^2_{\zeta^z}$, and where θ^z is the MA parameter. The MA-process (10) is of order 1. Higher order processes can be accommodated but, foreshadowing results to come, with the inclusion of firm-quarter fixed effects, an $MA(1)$-process suffices to reproduce the observed autocovariances in $\Delta\widehat{y}_{jt}$ and $\Delta\widehat{r}_{jt}$; in fact, we shall estimate θ^z to be relatively small, and a $MA(0)$-version of (10), restricting $\theta^z = 0$, also fits the data well.

[29] Guiso, Pistaferri, and Schivardi (2005) model persistence in the first-differenced value added series by adding a lagged dependent variable to account for "predictable dynamics" arising through, for example, pre-committed sales. In our case, accounting for the effects of lagged dependent variables would of course reduce residual autocovariances, also at longer lags. However, the autoregressive parameters would capture both the long memory of the $\Delta\widehat{y}_{jt}$- and $\Delta\widehat{r}_{jt}$-series as well as the oscillating autocovariance structure, thus generating counter-intuitive long-lasting and oscillating impulse response functions to innovations to the $\Delta\widehat{y}_{jt}$- and $\Delta\widehat{r}_{jt}$-series.

Estimation of $\sigma^2_{\varepsilon^z}$, $\sigma^2_{\zeta^z}$, and θ^z. The postulated statistical structure (8), (9) and (10) implies

$$\Delta_4 \widehat{z}_{jt} = \Delta_4 u^z_{jt} + \Delta_4 w^z_{jt}, \tag{11}$$

where, as above, Δ_4 denotes four-quarter growth. Simple calculations yield

$$\Delta_4 u^z_{jt} = \varepsilon^z_{jt} + \varepsilon^z_{jt-1} + \varepsilon^z_{jt-2} + \varepsilon^z_{jt-3}, \tag{12}$$

$$\Delta_4 w^z_{jt} = \zeta^z_{jt} + \theta^z \zeta^z_{jt-1} - \zeta^z_{jt-4} - \theta^z \zeta^z_{jt-5}; \tag{13}$$

that is, $\Delta_4 u^z_{jt}$ is an $MA(3)$-process and $\Delta_4 w^z_{jt}$ is an $MA(5)$-process. Under the restriction $\theta^z = 0$, the latter series is an $MA(4)$ process.

Using (11), (12) and (13), the implied autocovariance function for $\Delta_4 \widehat{z}_{jt}$ is:

$$\mathrm{E}[\Delta_4 \widehat{z}_{jt} \Delta_4 \widehat{z}_{jt-s}] = \begin{cases} 4\sigma^2_{\varepsilon^z} + 2(1+\theta^z\theta^z)\sigma^2_{\zeta^z} & \text{if } s = 0, \\ 3\sigma^2_{\varepsilon^z} + 2\theta^z\sigma^2_{\zeta^z} & \text{if } |s| = 1, \\ 2\sigma^2_{\varepsilon^z} & \text{if } |s| = 2, \\ \sigma^2_{\varepsilon^z} - \theta^z\sigma^2_{\zeta^z} & \text{if } |s| = 3, \\ -(1+\theta^z\theta^z)\sigma^2_{\zeta^z} & \text{if } |s| = 4, \\ -\theta^z\sigma^2_{\zeta^z} & \text{if } |s| = 5, \\ 0 & \text{if } |s| \geq 6. \end{cases} \tag{14}$$

The autocovariance function imposes three restrictions which suffice to identify the three unknown parameters $\sigma^2_{\varepsilon^z}$, $\sigma^2_{\zeta^z}$, and θ^z.[30] We estimate these by fitting (14) to the empirical autocovariances reported in Table 18 in a Minimum Distance estimation procedure, using orders 0 to 5 when treating θ^z as a parameter to be estimated, and orders 0 to 4 when imposing $\theta^z = 0$.

Before we turn to the formal estimates, we note that casual inspection of (14) and Table 18 shows that the relatively large negative empirical order-4 autocovariances and the relatively small negative order-5 autocovariances will tend to imply that $\sigma^2_{\zeta^z}$ is relatively large, while θ^z is relatively small, and negative. The variance of the permanent innovations, $\sigma^2_{\varepsilon^z}$, is determined by the order-2 autocovariance.

Estimation results. Table 19 presents the estimated parameters $\sigma^2_{\varepsilon^z}$, $\sigma^2_{\zeta^z}$, and θ^z under two specifications, $w^z_{jt} \sim MA(1)$ and $w^z_{jt} \sim MA(0)$, for the value added and revenue series, obtained from a Equally Weighted Minimum Distance (EWMD) estimator. The fit to the empirical autocovariances is good as evidence by the near-zero EWMD objective function values reported in Table 19.[31]

We note the following three features of the estimated parameters. First, in both series the estimates for the variance of innovations to the transitory component ($\sigma^2_{\zeta^z}$) and permanent component ($\sigma^2_{\varepsilon^z}$) are, essentially, the same with and without the restriction $\theta^z = 0$. The parameter θ^z itself is statistically significant in the value added series, yet quantitatively small; for revenue, the point estimate of θ^z is statistically insignificant. Second, in both series the transitory shocks are considerably more volatile than permanent shocks; specifically, the estimated variance of transitory shocks is an order of magnitude

[30] The six non-zero autocovariances contains three linear dependencies, for example: $\frac{1}{2}\mathrm{E}[\Delta_4 \widehat{z}_{jt} \Delta_4 \widehat{z}_{jt-2}] + \mathrm{E}[\Delta_4 \widehat{z}_{jt} \Delta_4 \widehat{z}_{jt-5}] - \mathrm{E}[\Delta_4 \widehat{z}_{jt} \Delta_4 \widehat{z}_{jt-3}] = 0$, $2\mathrm{E}[\Delta_4 \widehat{z}_{jt} \Delta_4 \widehat{z}_{jt-2}] - 2\mathrm{E}[\Delta_4 \widehat{z}_{jt} \Delta_4 \widehat{z}_{jt-4}] - \mathrm{E}[\Delta_4 \widehat{z}_{jt} \Delta_4 \widehat{z}_{jt}] = 0$, and $\frac{2}{3}\mathrm{E}[\Delta_4 \widehat{z}_{jt} \Delta_4 \widehat{z}_{jt-2}] - 2\mathrm{E}[\Delta_4 \widehat{z}_{jt} \Delta_4 \widehat{z}_{jt-5}] - \mathrm{E}[\Delta_4 \widehat{z}_{jt} \Delta_4 \widehat{z}_{jt-1}] = 0$.

[31] Appendix B presents almost identical estimates from the asymptotically efficient Classical Minimum Distance (CMD) estimator, as in Chamberlain (1982, 1984).

Table 19: EWMD estimates of the value added and revenue processes

	VALUE ADDED		REVENUE	
	(1)	(2)	(3)	(4)
VARIANCE, PERMANENT SHOCK $\sigma^2_{\varepsilon^z}$	0.021***	0.025***	0.029***	0.028***
	(0.001)	(0.001)	(0.001)	(0.001)
VARIANCE, TRANSITORY SHOCK $\sigma^2_{\zeta^z}$	0.279***	0.272***	0.071***	0.072***
	(0.002)	(0.003)	(0.002)	(0.003)
$MA(1)$-PARAMETER θ^z		−0.054***		0.009
		(0.004)		(0.010)
EWMD OBJECTIVE FUNCTION VALUE	0.002	0.001	0.000	0.000
FIRMS	26,612	26,612	27,070	27,070

Notes: Asymptotic standard errors in parentheses. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. Value added is $z = y$, revenue is $z = r$. Estimates obtained by Equally Weighted Minimum Distance estimation. The row labeled EWMD reports the objective function value at the estimated parameters.

greater than that of permanent shocks for value added and about four times greater for revenue. Third, the estimates for the variance of permanent shocks is similar across the value added and revenue series while the estimates for the variance of transitory shocks for the revenue series is three times lower than that for value added. All parameters are very precisely estimated.

5.2.2 The effect of permanent and transitory shocks on vacancy-posting

Having documented the presence of permanent and transitory shocks in the value added and revenue series, and estimated the parameters governing these shocks, we move to the main object of study: the association between the two types of shocks, permanent and transitory, and firms' vacancy posting. In this section we describe a statistical association between vacancy-posting and shocks to value added or revenue and estimate the strength of the association.

Vacancy-posting model. We posit a statistical model where vacancy-posting depends on the growth of value added ($\Delta\widehat{z}_{jt} = \Delta y_{jt}$) or revenue ($\Delta\widehat{z}_{jt} = \Delta r_{jt}$), and this dependence is potentially heterogeneous for permanent and transitory shocks to value added or revenue. Recall from (8) that quarterly growth in variable z can be written as $\Delta\widehat{z}_{jt} = \Delta\mu^z_{j\mathrm{Q}(t)} + \Delta u^z_{jt} + \Delta w^z_{jt}$, and that v_{jt} is a binary variable that takes value 1 if firm j posts a vacancy in period t. Then, we stipulate the following vacancy posting process,

$$v_{jt} = \lambda^z \Delta\mu^z_{j\mathrm{Q}(t)} + \alpha^z \Delta u^z_{jt} + \beta^z \Delta w^z_{jt} + \kappa^z_{jt}. \tag{15}$$

where κ^z_{jt} is a (heteroscedastic) error term which is independent of innovations to the permanent and transitory components in the variable z.[32] That is,

$$\mathrm{E}[\kappa_{jt}\varepsilon_{jt-s}] = \mathrm{E}[\kappa_{jt}\zeta_{jt-s}] = 0 \quad \text{for all } t, s. \tag{16}$$

The parameters λ^z, α^z, and β^z are loading coefficients on the three components of variable-z growth, namely firm-specific deterministic seasonal growth $\Delta\mu^z_{j\mathrm{Q}(t)}$, a permanent shock Δu^z_{jt}, and a transitory

[32] We do not need to specify the κ^z_{jt}-process beyond the the orthogonality conditions in (16); however, given $\mu^z_{j\mathrm{Q}(t)}$, Δu^z_{jt}, and Δw^z_{jt}, the error term κ^z_{jt} rationalizes the observed distribution of vacancy postings, including the autocovariances reported in Table 6.

shock, Δw^z_{jt}. Our interest centers on quantifying α^z and β^z, the extent to which permanent and transitory value added or revenue shocks generates vacancy posting.

Estimating the loading coefficients. In the data we observe v_{jt} and variable-z growth, $\Delta\widehat{z}_{jt}$, but not the permanent shock (Δu^z_{jt}), the transitory shock (Δw^z_{jt}) nor the firm-specific deterministic seasonal growth effect ($\Delta\mu^z_{j\mathrm{Q}(t)}$). We must therefore infer the effects of the two different unobserved shocks from their sum, $\Delta\widehat{z}_{jt}$, which is further contaminated by the firm-specific seasonal fixed effect, a nuisance parameter in this context.

To eliminate $\Delta\mu^z_{j\mathrm{Q}(t)}$ from (15), we define $V_{jt} \equiv \sum_{s=0}^{3} v_{jt-s}$ and $K^z_{jt} \equiv \sum_{s=0}^{3} \kappa^z_{jt-s}$, and note that $\sum_{s=0}^{3} \Delta\mu^z_{j\mathrm{Q}(t-s)} = 0$, $\sum_{s=0}^{3} \Delta u_{jt} = \Delta_4 u_{jt}$ and $\sum_{s=0}^{3} \Delta w_{jt} = \Delta_4 w_{jt}$. We can therefore restate (15) as a linear count model where $V_{jt} \in \{0, 1, 2, 3, 4\}$ is the number of quarters within the last year that a firm has posted vacancies. Indeed,

$$V_{jt} = \alpha^z \Delta_4 u^z_{jt} + \beta^z \Delta_4 w^z_{jt} + K^z_{jt}, \tag{17}$$

where (16) implies

$$\mathrm{E}[K_{jt}\varepsilon_{jt-s}] = \mathrm{E}[K_{jt}\zeta_{jt-s}] = 0 \quad \text{for all } t, s. \tag{18}$$

Importantly, (17) is free of $\Delta\mu^z_{j\mathrm{Q}(t)}$.

We note that if $\alpha^z = \beta^z$, such that permanent and transitory shocks yield the same vacancy posting responses, (17) reads $V_{jt} = \alpha^z \Delta_4 \widehat{z}_{jt} + K^z_{jt}$ and the common loading parameter α^z can be consistently estimated by OLS. In general, however, a regression of V_{jt} on $\Delta_4\widehat{z}_{jt}$ identifies neither α^z, nor β^z.

To estimate α^z and β^z we apply the estimation procedure introduced in Guiso, Pistaferri, and Schivardi (2005), who devise an appropriate set of moment restrictions that identify the two loading coefficients. First, for estimation of α^z, note that

$$\mathrm{E}\left[\left(\sum_{s=-5}^{5} \Delta_4\widehat{z}_{jt-s}\right)(V_{jt} - \alpha^z \Delta_4\widehat{z}_{jt})\right] = 0, \tag{19}$$

which follows from $\mathrm{E}[\varepsilon_{jt}\zeta_{jt-s}] = 0$, $\mathrm{E}[\varepsilon_{jt}\Delta_4 K_{jt-s}] = 0$, $\mathrm{E}[\zeta_{jt}\Delta_4 K_{jt-s}] = 0$ for all t, s, and a convenient property of any $MA(q)$-process x_t, namely that $\mathrm{E}\left[\sum_{s=-(q+k)}^{q+k} \Delta_k x_{t-s}\Delta_k x_t\right] = 0$, where $\Delta_k \equiv 1 - L^k$, and L is the lag operator (Meghir and Pistaferri, 2004). In our case, we can apply this property to $w_{jt} \sim MA(1)$ with $k = 4$.[33]

We can implement the orthogonality condition (19) by an instrumental variable regression of V_{jt} onto $\Delta_4\widehat{z}_{jt}$, instrumenting $\Delta_4\widehat{z}_{jt}$ by $\sum_{s=-5}^{5}\Delta_4\widehat{z}_{jt-s}$. This provides a consistent estimator for α^z.[34] Furthermore, since $\Delta_4\widehat{z}_{jt}$ is an exogenous regressor in a regression of V_{jt} onto $\Delta_4\widehat{z}_{jt}$ if and only if $\alpha^z = \beta^z$, a Difference-in-Sargan test for regressor exogeneity in the instrumental variable regression (19) provides a test for $\alpha^z = \beta^z$.

For estimation of β^z, note that

$$\mathrm{E}\left[\Delta_4\widehat{z}_{jt+4}(V_{jt} - \beta^z \Delta_4\widehat{z}_{jt})\right] = 0, \tag{20}$$

[33] As pointed out by Guiso, Pistaferri, and Schivardi (2005), the proposed estimator of α^z remains consistent under classical measurement errors in $\widehat{z}_{jt}$, serial correlation in ε^z_{jt} and in the case where ε^z_{jt} and ζ^z_{jt} are correlated.

[34] As noted above, it is in general not possible to identify α^z by regressing V_{jt} onto $\Delta_4\widehat{z}_{jt}$ because the error term from this regression, $V_{jt} - \alpha^z\Delta_4\widehat{z}_{jt} = (\beta^z - \alpha^z)\Delta_4 w^z_{jt} + K_{jt}$, covaries with $\Delta_4\widehat{z}_{jt}$ through the common component $\Delta_4 w^z_{jt}$. The first stage projection of $\Delta_4\widehat{z}_{jt}$ onto $\sum_{s=-5}^{5}\Delta_4\widehat{z}_{jt-s}$ retains exactly the variation in $\Delta_4\widehat{z}_{jt}$ that is orthogonal to $\Delta_4 w^z_{jt}$, and thus facilitates identification of α^z.

which follows from $\mathrm{E}[\varepsilon^z_{jt}\zeta^z_{jt-s}] = 0$, $\mathrm{E}[\varepsilon^z_{jt}K_{jt-s}] = 0$, $\mathrm{E}[\zeta^z_{jt}K_{jt-s}] = 0$ for all t, s, and $\mathrm{E}[\varepsilon^z_{jt}\varepsilon^z_{jt-s}] = 0$ for $|s| \neq 0$. The restriction (20) is directly amendable to estimation as it defines an instrumental variable regression of V_{jt} onto $\Delta_4\widehat{z}_{jt}$, this time instrumenting $\Delta_4\widehat{z}_{jt}$ by $\Delta_4\widehat{z}_{jt+4}$.[35]

Like Guiso, Pistaferri, and Schivardi (2005) we exploit that, since $\sum_{s=-5}^{5}\Delta_4\widehat{z}_{jt-s}$ and $\Delta_4 v_{jt+4}$ are valid instrumental variables, so are $\left(\sum_{s=-5}^{5}\Delta_4\widehat{z}_{jt-s}\right)^2$ and $\left(\Delta_4\widehat{z}_{jt+4}\right)^2$. The additional instruments are useful because they generate testable over-identifying restrictions. Below we test the overidentifying restrictions Hansen's J-statistic (Hansen, 1982).

5.2.3 Estimated loading coefficients

We present the estimated loading coefficients for the vacancy posting responses to permanent and transitory shocks (parameter α^z and β^z, respectively) to value added and revenue in Table 20. We discuss specification validity and then comment on the estimated parameters.

Specification validity. The reported loading estimates are obtained from an over-identified instrumental variable regressions of V_{jt} onto $\Delta_4\widehat{z}_{jt}$ using $\sum_{s=-5}^{5}\Delta_4\widehat{z}_{jt-s}$ and $\left(\sum_{s=-5}^{5}\Delta_4\widehat{z}_{jt-s}\right)^2$ as instrumental variables for $\Delta_4\widehat{z}_{jt}$ to estimate α^z, and using $\Delta_4\widehat{z}_{jt+4}$ and $(\Delta_4\widehat{z}_{jt+4})^2$ as instrumental variables for $\Delta_4\widehat{z}_{jt}$ to estimate β^z. This gives us one over-identifying restriction for each regression. Table 20 also shows the F-statistic for the first stage regression in the instrumental variable estimation procedure, a Difference-in-Sargan test for regressor exogeneity, and a Hansen-test of the over-identifying restriction.[36] Table B.2 in Appendix B presents estimates for just-identified specifications; the estimates are practically identical to those reported here.

The first stage regressions represents strong relationships between the endogenous regressor $\Delta_4\widehat{z}_{jt}$ and the instrumental variables, and instrument irrelevance is rejected at all significance level for all four regressions in Table 20. Moreover, for the regressions identifying α^z in columns (1) and (3), the Hansen-test does not reject the validity of the over-identifying restriction, lending further credence to the instrumental variables used in those regressions. We do, however, reject the over-identifying restriction for the regressions identifying β^z in columns (2) and (4). While we briefly comment on the estimated β^z-parameters below, we caution that our analysis do not produce strong identification of the β^z-loadings, i.e. of the vacancy posting response of transitory shocks to value added and revenue.

As is evident from casual inspection of the point estimates in Table 20, the Difference-in-Sargan test emphatically rejects the hypothesis that $\alpha^z = \beta^z$; the distinction between permanent and transitory shocks is relevant for understanding firms' vacancy posting behavior.

We note that the estimates of the loadings on permanent shocks are robust to classical measurement errors in value added or revenue, serial correlation in the permanent innovations, and correlation between the innovations to the permanent and transitory components.

[35]The first stage of the instrumental variable regression retains the variation in $\Delta_4\widehat{z}_{jt}$ that is orthogonal to $\Delta_4 u^z_{jt}$, the common component inducing correlation between the regressor $\Delta_4\widehat{z}_{jt}$ in a regression of V_{jt} onto $\Delta_4\widehat{z}_{jt}$ and the error term in that regression, $V_{jt} - \beta^z\Delta_4\widehat{z}_{jt} = (\alpha^z - \beta^z)\Delta_4 u^z_{jt} + K_{jt}$.

[36]In our model, regressor exogeneity is equivalent to $\alpha^z = \beta^z$, and we report only one Difference-in-Sargan test for each of the variables value added and revenue.

Table 20: Vacancy posting response to permanent and transitory shocks

	Value Added		Revenue	
	α^z	β^z	α^z	β^z
Loading coefficient	0.592*** (0.031)	0.012** (0.006)	0.477*** (0.018)	0.078*** (0.014)
1st stage, F	1,363.17 [0.000]	15,026.90 [0.000]	3,086.00 [0.000]	1,951.94 [0.000]
Difference-in-Sargan $\sim \chi^2(1)$	370.969 [0.000]		592.084 [0.000]	
Hansen's $J \sim \chi^2(1)$	0.472 [0.492]	54.817 [0.000]	1.315 [0.252]	47.501 [0.000]
Observations	139,357	311,438	223,055	369,214

Notes: Robust standard errors in parentheses. p-values in square brackets. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. The reported estimates are based on over-identified instrumental variable regressions of V_{jt} onto $\Delta_4\widehat{z}_{jt}$ using $\sum_{s=-5}^{5}\Delta_4\widehat{z}_{jt-s}$ and $\left(\sum_{s=-5}^{5}\Delta_4\widehat{z}_{jt-s}\right)^2$ as instrumental variables for $\Delta_4\widehat{z}_{jt}$ to estimate α^z, and using $\Delta_4\widehat{z}_{jt+4}$ and $(\Delta_4\widehat{z}_{jt+4})^2$ as instrumental variables for $\Delta_4\widehat{z}_{jt}$ to estimate β^z.

Vacancy posting responses to permanent shocks. For value added, we estimate that $\alpha^y = 0.59$ and for revenue we obtain $\alpha^r = 0.48$, both highly statistically significant. Starting with the response to a permanent value added shock, note that the variance of an innovation to the permanent component of value added was estimated to be $\sigma^2_{\varepsilon^y} = 0.025$, see column (2) in Table 19. This is also the variance to a quarterly permanent shock to value added, Δu^y_{jt}. Hence, a 1 standard deviation permanent shock to quarterly value added increases the probability that a firm posts a vacancy in that quarter by $0.59 \times \sqrt{0.025} = 9$ percentage points. On average, the quarterly vacancy posting is rate is 21.5 percent. The vacancy posting response to a 1 standard deviation permanent value added shock is thus sizeable, representing 43 percent of the baseline vacancy posting rate. For revenue, we estimated $\sigma^2_{\varepsilon^y} = 0.028$. A 1 standard deviation permanent revenue shock is estimated to increase the probability that a firm posts a vacancy in that quarter by $0.48 \times \sqrt{0.028} = 8$ percentage points, a 37 percent increase on the baseline vacancy rate.

Vacancy posting responses to transitory shocks. While our estimates of the loading on the transitory shocks are sensible, as discussed above, our instrumental variable regressions do not provide an overly convincing estimates of β^y. For value added, the point estimate is $\beta^y = 0.01$. The variance of the transitory innovations were estimated to be $\sigma^2_{\zeta^y} = 0.29$. The estimated $MA(1)$-parameter θ^y is sufficiently small (point estimate at $\theta^y = -0.05$) that we can ignore the MA dynamics for these back-the-envelope calculations and take the variance of the transitory shock component Δw_{jt} to be $\sigma^2_{\zeta^y}$. Hence, a one standard deviation transitory shock to quarterly value added increases the probability that a firm is posting a vacancy by less than a percentage point, a quantitatively negligible effect. For revenue, the point estimate is $\beta^z = 0.08$, the variance of the transitory innovations were estimated to be $\sigma^2_{\zeta^y} = 0.07$, and the $MA(1)$-parameter essentially zero. Put together, a 1 standard deviation transitory revenue shock is estimated to increase the vacancy posting rate by 2 percentage points.

5.3 Summary

Our analysis in this section shows that growth in value added and revenues predict firm recruiting effort. This is demonstrated through a distributed lag regression allowing for asymmetric and non-linear effects, and through a permanent-transitory shock model of value added and revenue growth. The two approaches give broadly similar quantitative responses to a 1 standard deviation shock: the probability of vacancy posting increases by approximately 8 percentage points, which is 40 percent of the unconditional mean. The added structure of the permanent-transitory shock model provides the more palatable interpretation of the time distribution of firms' recruiting effort responses, in that it follows permanent, rather than transitory shocks.

One implication of these findings is that growth in firm output and revenues appear to precede firms' desire to grow and, hence, post vacancies. This observation is consistent with demand driving the expansion in firm employment.

6 Conclusions

We merge job advertisement data from an extensive online job board in Denmark with three administrative datasets that provide a comprehensive picture of employment and production in the country. We use these rich data sources to study several aspects of vacancy posting.

We examine the effect of vacancy posting on firms' hiring rates and find a strong response which is spread over two quarters—hiring therefore is a time-consuming activity. Vacancy-posting has a stronger effect on hiring from employment and such hiring generally takes longer to materialize. Turning to firm heterogeneity, we find that large and fast-growing firms have smaller responses, and the response of highly-productive firms (and, to a lesser extent, fast-growing firms) takes longer to materialize. We also find that separations predict vacancy posting, especially when they are few in number (so, are likely not related to downsizing) and associated with an employment-to-employment transition by the departing worker (more likely related to poaching). This finding is supportive evidence for the existence of vacancy chains.

Finally, we examine the relationship of firm growth, regarding revenue and value added, and vacancy-posting. We find that growth strongly predicts vacancy posting. Furthermore, it is permanent shocks to revenue and value added that lead to vacancy posting while transitory shocks do not.

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Appendix

A Vacancies and the intensive and extensive margin of hiring

This appendix examines the effect of vacancy posting separately on the extensive and intensive margin of hiring.

All hiring. To document extensive margin effects on all hiring, we estimate (3) and use as dependent variable an indicator variable that records whether *any* hiring took place, i.e. $z_{jt} = \mathbb{1}(h_{jt} > 0)$; that is, we estimate a linear probability model of $\Pr(h_{jt} > 0)$. To document intensive margin effects we estimate (3) and use as dependent variable the hiring rate conditional on some hiring taking place, i.e. $z_{jt} = h_{jt}$, but condition on $h_{jt} > 0$.

Table A.1: Vacancy posting and extensive and intensive margin effects on all hiring

Dependent variable:	$\mathbb{1}(h_{jt} > 0)$	$h_{jt} \vert h_{jt} > 0$
v_{jt}	0.122*** (0.002)	0.024*** (0.001)
v_{jt-1}	0.085*** (0.002)	0.008*** (0.001)
v_{jt-2}	0.007*** (0.002)	−0.006*** (0.001)
v_{jt-3}	0.001 (0.002)	−0.005*** (0.001)
v_{jt-4}	0.008*** (0.002)	0.000 (0.001)
Cumulative response	0.223*** (0.003)	0.021*** (0.002)
Firms	26,335	24,671
Observations	454,144	291,558

Notes: Robust standard errors in parentheses. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. All regressions include controls for quarter effects, industry effects, quarter-industry interactions and firm fixed effects. The average shares of firms hiring in the estimation sample is 0.644. Conditional on $h_{jt} > 0$, the average and standard deviation of h_{jt} in the estimation sample are 0.193 and 0.184, respectively.

The estimated models are tabulated in Table A.1, and all specifications include firm fixed effects (in addition to industry, quarter and industry-quarter interaction effects). Table A.1 shows that the timing of the response to vacancy posting is similar along both extensive and intensive margins, and also similar to the response of the overall hiring rate: the peak response is the contemporaneous effect, and there are quantitatively significant effects at a one-quarter lag; the effect of a vacancy posting is very small at longer lags. The peak and cumulative effects of vacancy posting on the probability of engaging in hiring (the extensive margin) are 12 and 22 percent, respectively, which correspond to 20 percent and one-third of the unconditional share of firms that engage in hiring in a given quarter. The peak and cumulative responses of the hiring rate for the firms that engage in hiring (the intensive margin) are 2.4 and 2 percent, respectively, which correspond to 8 and 10 percent of the unconditional hiring rates for firms that engage in hiring in a given quarter.

The estimated vacancy posting responses in Table A.1 show that the overall effect of vacancy posting on the hiring rate operates on both the extensive and the intensive margin, with relatively stronger effects on the extensive margin. In summary, when a firm posts a vacancy it is more likely to hire at least one worker over the course of the next quarters. In addition, conditional on strictly positive hiring, firms that posted vacancies, tend to hire more workers.

Hiring from employment and non-employment. We investigate the effects of vacancy posting on the extensive and intensive hiring margins separately for hires from employment and from non-employment. Table A.2 shows estimates of the effect of a vacancy posting on $\Pr(h_{jt}^{EE} > 0)$ and $\Pr(h_{jt}^{NE} > 0)$ and on $h_{jt}^{EE}|h_{jt} > 0$ and $h_{jt}^{NE}|h_{jt} > 0$, as estimated from (3).

The estimated lag distributions for both types of hiring and on both margins share the features that the peak response occurs contemporaneously. On the extensive margins, there are also quantitatively relevant effects after one quarter, whereas this effect is quite small on the intensive margins; indeed, it is statistically significant when we consider hiring from non-employment. Comparing the extensive margin responses to a vacancy posting for hiring from employment and non-employment, we see that the peak response (and also the one quarter lag effect) is slightly stronger on hiring from employment. In a typical quarter, 50 percent of firms hire from employment, while 44 percent hire from non-employment. The estimated peak response to a vacancy posting on the probability of hiring from employment is estimated to be 0.125, which represents a 25 percent increase on the baseline. The estimated peak response on the probability of hiring from non-employment is estimated to be 0.096, which represents a 22 percent increase on the baseline. The cumulative responses to a vacancy posting on the probability of hiring from employment and non-employment are 0.227 and 0.172, respectively.

Table A.2: Vacancy posting and the extensive and intensive margin EE- and NE-hiring rates

	Extensive margin		Intensive margin	
Dependent variable:	$\mathbb{1}(h_{jt}^{EE} > 0)$	$\mathbb{1}(h_{jt}^{NE} > 0)$	$h_{jt}^{EE}\|h_{jt} > 0$	$h_{jt}^{NE}\|h_{jt} > 0$
v_{jt}	0.125***	0.096***	0.016***	0.008***
	(0.002)	(0.002)	(0.001)	(0.001)
v_{jt-1}	0.090***	0.051***	0.008***	0.000
	(0.002)	(0.002)	(0.001)	(0.001)
v_{jt-2}	0.010***	0.006***	−0.003***	−0.003***
	(0.002)	(0.002)	(0.001)	(0.001)
v_{jt-3}	−0.001	0.002	−0.004***	−0.001**
	(0.002)	(0.002)	(0.001)	(0.001)
v_{jt-4}	0.007***	0.011***	−0.002***	0.001**
	(0.002)	(0.002)	(0.001)	(0.001)
Cumulative response	0.227***	0.172***	0.015***	0.006***
	(0.004)	(0.004)	(0.001)	(0.001)
Firms	26,335	26,335	24,671	24,671
Observations	454,144	454,144	291,558	291,558

Notes: Robust standard errors in parentheses. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. All regressions include controls for quarter and industry effects, as well as their interactions, and firm fixed effects. The share of firm-quarters in the estimation sample with hiring from employment, respectively, non-employment is 0.506, respectively, 0.444. Conditional on $h_{jt} > 0$, the average and standard deviation of h_{jt}^{EE} in the estimation sample are 0.104 and 0.126, respectively. Conditional on $h_{jt} > 0$, the average and standard deviation of h_{jt}^{NE} in the estimation sample are 0.089 and 0.137, respectively.

Comparing the intensive margin responses to a vacancy posting for hiring from employment and non-employment, which provides a decomposition of the intensive margin response on all hiring in Table A.1, shows that hiring from employment responds stronger than hiring from non-employment.[37] Conditional on some hiring,

[37] Note that $h_{jt}^{EE}|h_{jt}^{EE} > 0$ and $h_{jt}^{NE}|h_{jt}^{NE} > 0$ does not decompose $h_{jt}|h_{jt} > 0$ because the three quantities are estimated from different subsamples of the data.

the average rate of hiring from employment in the estimation sample is 0.104, and the estimated peak response of 0.016 therefore constitutes a 15 percent increase on the baseline rate. The average rate of hiring from non-employment, conditional on some hiring, is 0.089, and the estimated peak response of 0.008 represents only a 9 percent increase on the baseline. The evidence in Table A.2 therefore suggests that, on the intensive margin, a vacancy posting shifts hiring towards hiring from employment. This, of course, is consistent with the finding from Table 10 that overall hiring seems to tilt towards hiring from employment following a vacancy posting.

A formal decomposition of the extensive margin hiring response. While it is natural to measure the extensive margin responses for hiring from employment and hiring from non-employment using $\Pr(h_{jt}^{EE} > 0)$ and $\Pr(h_{jt}^{NE} > 0)$, hiring from employment and non-employment are not mutually exclusive events, and $\Pr(h_{jt}^{EE} > 0)$ and $\Pr(h_{jt}^{NE} > 0)$ do not decompose the extensive margin for all hiring, $\Pr(h_{jt} > 0)$. This is evident in Table A.2 where the estimates for the extensive margin responses for hiring from employment and non-employment do not add up to the overall extensive margin responses in Table A.1.

To complement this analysis, we propose a decomposition of hiring into three mutually exclusive events: hiring from employment *only*, hiring from non-employment *only*, and hiring from employment *and* non-employment. Accordingly, we define the following hiring rates: let $\widetilde{h}_{jt}^{EE}$ be the rate of hiring from employment *only*, so that $\widetilde{h}_{jt}^{EE} \equiv h_{jt}^{EE}\mathbb{1}(h_{jt}^{NE} = 0)$ where $\mathbb{1}(\cdot)$ is the indicator function; let $\widetilde{h}_{jt}^{NE}$ be the rate of hiring from non-employment *only* so that $\widetilde{h}_{jt}^{NE} \equiv h_{jt}^{NE}\mathbb{1}(h_{jt}^{EE} = 0)$; finally, let $\widetilde{h}_{jt}^{EE,NE}$ be the rate of simultaneous hiring from employment *and* non-employment, so that $\widetilde{h}_{jt}^{EE,NE} \equiv h_{jt}\mathbb{1}(h_{jt}^{EE} > 0)\mathbb{1}(h_{jt}^{NE} > 0)$. From these definitions it follows that:

$$\Pr(h_{jt} > 0) = \Pr(\widetilde{h}_{jt}^{EE} > 0) + \Pr(\widetilde{h}_{jt}^{NE} > 0) + \Pr(\widetilde{h}_{jt}^{EE,NE} > 0)$$

and furthermore

$$h_{jt} = \widetilde{h}_{jt}^{EE} + \widetilde{h}_{jt}^{NE} + \widetilde{h}_{jt}^{EE,NE}. \tag{A1}$$

We can now decompose the extensive and intensive margin responses of hiring from employment, non-employment or both by estimating (3) and using the appropriate dependent variable. Table A.3 presents the decomposition of the extensive margin responses to vacancy-posting.

Table A.3: Decomposition of the extensive margin hiring responses to vacancy posting

Dependent variable:	$\mathbb{1}(h_{jt} > 0)$	$\mathbb{1}(\widetilde{h}_{jt}^{EE} > 0)$	$\mathbb{1}(\widetilde{h}_{jt}^{NE} > 0)$	$\mathbb{1}(\widetilde{h}_{jt}^{EE,NE} > 0)$
v_{jt}	0.123*** (0.002)	0.027*** (0.002)	−0.002 (0.001)	0.098*** (0.002)
v_{jt-1}	0.085*** (0.002)	0.034*** (0.002)	−0.006*** (0.001)	0.056*** (0.002)
v_{jt-2}	0.007*** (0.002)	0.001 (0.002)	−0.003** (0.001)	0.009*** (0.002)
v_{jt-3}	0.001 (0.002)	−0.001 (0.002)	0.001 (0.001)	0.001 (0.002)
v_{jt-4}	0.008*** (0.002)	−0.003 (0.002)	0.001 (0.001)	0.009*** (0.002)
Cumulative response	0.218*** (0.004)	0.035*** (0.004)	−0.009*** (0.003)	0.181*** (0.004)
Firms	26,335	26,335	26,335	26,335
Observations	454,144	454,144	454,144	454,144

Notes: Robust standard errors in parentheses. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. All regressions include controls for quarter and industry effects, as well as their interactions, and firm fixed effects. The shares of firms-quarters in the estimation sample with $\widetilde{h}_{jt}^{EE} > 0$, $\widetilde{h}_{jt}^{NE} > 0$, and $\widetilde{h}_{jt}^{EE,NE} > 0$ are 0.200, 0.138, and 0.306, respectively.

Table A.4: Decomposition of the intensive margin hiring responses to vacancy posting

Dependent variable:	$h_{jt} \mid h_{jt} > 0$	$\widetilde{h}_{jt}^{EE} \mid h_{jt} > 0$	$\widetilde{h}_{jt}^{NE} \mid h_{jt} > 0$	$\widetilde{h}_{jt}^{EE,NE} \mid h_{jt} > 0$
v_{jt}	0.024***	−0.001*	−0.005***	0.030***
	(0.001)	(0.000)	(0.000)	(0.001)
v_{jt-1}	0.008***	0.001*	−0.005***	0.012***
	(0.001)	(0.000)	(0.000)	(0.001)
v_{jt-2}	−0.006***	−0.002***	−0.001***	−0.002**
	(0.001)	(0.000)	(0.000)	(0.001)
v_{jt-3}	−0.005***	−0.002***	0.000	−0.003***
	(0.001)	(0.000)	(0.000)	(0.001)
v_{jt-4}	0.000	−0.002***	0.001	0.001
	(0.001)	(0.000)	(0.000)	(0.001)
Cumulative response	0.020***	−0.008***	−0.010***	0.038***
	(0.002)	(0.001)	(0.001)	(0.002)
Firms	24,671	24,671	24,671	24,671
Observations	291,558	291,558	291,558	291,558

Notes: Robust standard errors in parentheses. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. All regressions include controls for quarter and industry effects, as well as their interactions, and firm fixed effects. Conditional on $h_{jt} > 0$, the averages of $\widetilde{h}_{jt}^{EE}$, $\widetilde{h}_{jt}^{NE}$, and $\widetilde{h}_{jt}^{EE,NE}$ in the estimation sample are 0.050, 0.038, and 0.105, respectively, while the standard deviations are 0.111, 0.107, and 0.180.

For completeness Table A.4 decomposes the intensive margin response according to (A1), conditional on $h_{jt} > 0$. The first decomposition is implemented by estimating (3) with $z_{jt} = h_{jt}^{EE}$ and $z_{jt} = h_{jt}^{NE}$ on the subsample of firm-quarters where $h_{jt} > 0$; the second decomposition is implemented by estimating (3) with $z_{jt} = \widetilde{h}_{jt}^{EE}$, $z_{jt} = \widetilde{h}_{jt}^{NE}$, and $z_{jt} = \widetilde{h}_{jt}^{EE,NE}$, also on the subsample of firm-quarters where $h_{jt} > 0$.

Overall, we can see that the results are qualitatively similar to those we had earlier and the quantitative differences are minor.

B Additional estimates for the permanent-transitory shock model

Table B.1 presents the estimates from the asymptotically efficient Classical Minimum Distance (CMD) estimator, as in Chamberlain (1982, 1984). The estimates are almost identical to those in Table 19. The only notable difference is that the CMD estimate of θ^r is statistically significant, but small with a point estimate of 0.041. We prefer the EWMD estimates for the reasons outlined in Altonji and Segal (1996), although our estimation dataset is relatively large. A useful feature of the CMD estimator is that a test for overidentifying restrictions is immediately available. Here, we have 3 overidentifying restrictions, which the CMD estimates reject. The rejection, however, is driven by very precisely estimated empirical autocovariances, see Table 18, rather than a bad fit, and we do not deem the rejection to be a serious concern.

Table B.1: CMD estimates of the value added and revenue processes

	Value added		Revenue	
	(1)	(2)	(3)	(4)
Variance, permanent shock $\sigma^2_{\varepsilon^z}$	0.021*** (0.001)	0.023*** (0.001)	0.026*** (0.001)	0.025*** (0.001)
Variance, transitory shock $\sigma^2_{\zeta^z}$	0.290*** (0.001)	0.286*** (0.002)	0.071*** (0.001)	0.072*** (0.002)
$MA(1)$-parameter θ^z		−0.057*** (0.003)		0.041 (0.008)
CMD objective function value	1,676	1,236	609	677
Firms	26,612	26,612	27,070	27,070

Notes: Asymptotic standard errors in parentheses. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. Value added is $z = y$, revenue is $z = r$. Estimates obtained by Classical Minimum Distance estimation. The row labeled CMD reports the objective function value at the estimated parameters. The CMD objective function is specified such that, at the estimated parameters, it is a $\chi^2(3)$-variate where the 3 degrees of freedom emanates from the 3 over-identifying restrictions that are imposed in the estimation; see (14) in the main text.

Table B.2: Vacancy posting response to permanent and transitory shocks: the just-identified case

	Value Added		Revenue	
	α^z	β^z	α^z	β^z
Loading coefficient	0.592*** (0.031)	−0.013** (0.007)	0.476*** (0.018)	0.032** (0.016)
1st stage, F	2,686.33 [0.000]	16,765.60 [0.000]	6,014.84 [0.000]	3,333.69 [0.000]
Difference-in-Sargan $\sim \chi^2(1)$	371.101 [0.000]		593.535 [0.000]	
Observations	139,357	311,438	223,055	369,214

Notes: Robust standard errors in parentheses. p-values in square brackets. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. The reported estimates are based on just-identified instrumental variable regressions of V_{jt} onto $\Delta_4\widehat{z}_{jt}$ using $\sum_{s=-5}^{5}\Delta_4\widehat{z}_{jt-s}$ as an instrumental variable for $\Delta_4\widehat{z}_{jt}$ to estimate α^z, and using $\Delta_4\widehat{z}_{jt+4}$ as an instrumental variable for $\Delta_4\widehat{z}_{jt}$ to estimate β^z.

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