I Z A Institute
of Labor Economics
Initiated by Deutsche Post Foundation

DISCUSSION PAPER SERIES

IZA DP No. 14436

Vacancies, Employment Outcomes and Firm Growth: Evidence from Denmark

Jesper Bagger
Francois Fontaine
Manolis Galenianos
Ija Trapeznikova

JUNE 2021

I Z A Institute
of Labor Economics

Initiated by Deutsche Post Foundation

DISCUSSION PAPER SERIES

IZA DP No. 14436

Vacancies, Employment Outcomes and Firm Growth: Evidence from Denmark

Jesper Bagger
Aarhus University and University of London

Francois Fontaine
Paris School of Economics, Université Paris 1–Panthéon Sorbonne and IZA

Manolis Galenianos
University of London

Ija Trapeznikova
University of London

JUNE 2021

ISSN: 2365-9793

IZA – Institute of Labor Economics

Schaumburg-Lippe-Straße 5–9
53113 Bonn, Germany

Phone: +49-228-3894-0
Email: publications@iza.org

www.iza.org

ABSTRACT

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

We use comprehensive data from Denmark that combine online job advertisements with a matched employer-employee dataset and a firm-level dataset with information on revenues and value added to study the relationship between vacancy-posting and various firm outcomes. Posting a vacancy is associated with a 4.5 percentage point increase in a firm's hiring rate and two-thirds of the additional hiring occurs within two months. The response of hiring from employment is twice as large as the response of hiring from non-employment. Firms that are smaller, low-wage and fast-growing are associated with larger hiring responses and that response materializes faster at larger firms, low-wage firms and fast-growing firms. We also find that separations are associated with subsequent vacancy posting and this effect is stronger for separations to employment, consistent with replacement hiring and the presence of vacancy chains. Growth in revenue and value added strongly predict vacancy-posting, with negative shocks having a stronger effect than positive shocks and larger shocks having less-than-proportional responses.

JEL Classification: J23, J63

Keywords: vacancies, hiring, separations, employment growth, firm growth, value added, revenue

Corresponding author:
François Fontaine
Paris School of Economics
48 boulevard Jourdan
75014 Paris
France

E-mail: francois.fontaine@univ-paris1.fr

* We thank Carlos Carrillo-Tudela and Leo Kaas for encouraging us to write this paper and editing the special volume on vacancies at Labour Economics, two referees, our discussant Marek Ignaszak, Steven Davis, Theodore Papageorgiou and conference participants for useful comments. We further thank Jobindex.dk for making the job advertisement data available to us, Henning Bunzel for his help with data processing, and the Dale T. Mortensen Centre at Aarhus University for support. Bagger and Galenianos acknowledge financial support from BA/Leverhume Grant SG151681. Fontaine acknowledges financial support from Institut Universitaire de France and Cepremap.

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 for firms to find suitable employees. This approach can rationalize the coexistence of unemployed workers and vacancies, a key feature of labor markets, and it provides a coherent framework with which to study the process of matching in labor markets. 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 at the macro levels.

This paper uses unique data 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. We merge a large dataset of online job advertisements from 2003-2009 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 information on firm revenues, purchases and value added.

We first examine the effect of vacancy-posting on hiring outcomes. We find that vacancy-posting is associated with an increase of 4.5 percentage points in the monthly hiring rate, a rise of more than 70% over the baseline no-vacancy hiring rate. Approximately two-third of this effect occurs in the month of vacancy-posting and the subsequent month and the final third occurs in the next two months. The hiring rate when no vacancies are posted is also highly significant, consistent with the findings in the literature (e.g. Davis, Faberman, and Haltiwanger, 2013). These findings are consistent with online advertisements playing an important, though not exclusive, role in firms' recruiting effort and with a lengthly and potentially very costly recruiting process.

We decompose this effect to hiring from employment and non-employment, based on newly-hired workers' labor market status in the previous month. We find that vacancy-posting is associated with a doubling of the hiring rate from employment and a 50% increase in the hiring rate from non-employment, while the former materialize at a slower pace than the latter. Therefore, vacancy-posting affects the type of workers who are hired, at least in terms of their prior employment status.

In our firm heterogeneity analysis we find that, following vacancy-posting, firms with lower employment, lower wages and higher employment growth rates experience a larger increase in their hiring rates. Furthermore, the response materializes faster at larger firms, low-wage firms and fast-growing firms. Finally, there is substantial heterogeneity across different industries in the hiring response to vacancy-posting. Overall, we find evidence for substantial heterogeneity in terms of the hiring response of different types of firms where, interestingly, the magnitude and the speed of the response do not necessarily co-move across firm types.

Turning to the determinants of vacancy-posting, we explore the effect of separations on the probability of posting a vacancy. We find that a one standard deviation increase in the separation rate is associated with a increase in the vacancy rate by 0.9 percentage point, a 90% increase over the no-separation baseline. As with hiring, the full effect takes 3-4 months to materialize. Furthermore,

separations to employment have more than twice the effect on vacancy-posting than separations to non-employment. These findings are consistent with replacement hiring at the firm level, which generates vacancy chains and propagates labor market shocks.

Finally, we explore the effect of revenue and value added growth on vacancy-posting. We find that a one standard deviation change in revenue growth is associated with a 9-11 percentage point change in the quarterly probability of vacancy-posting, depending on the specification. Negative revenue shocks are associated with larger effects on vacancy-posting than positive shocks and we find significant evidence of concavity in that response. Shocks to value added growth generate similar, though slightly smaller quantitatively, effects.

Our paper contributes to the empirical literature that studies the effect of vacancies on hiring outcomes, early contributions to which include van Ours and Ridder (1992) and Burdett and Cunningham (1998). Davis, Faberman, and Haltiwanger (2013) is probably the most prominent work in this literature and uses the US firm survey JOLTS to document several interesting features, particularly about the heterogeneous hiring outcomes of vacancy-posting across different establishment types and the large share of hires that occur without reporting an available vacancy. Carrillo-Tudela, Gartner, and Kaas (2021) and Mueller, Osterwalder, Zweimüller, and Kettemann (2020) combine vacancy information with match employer-employee datasets in Germany and Austria, respectively, and study the determinants of vacancy duration and vacancy yield. Our paper is also related to empirical work on vacancies using online job board data such as 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. In a companion paper, Bagger, Fontaine, Galenianos, and Trapeznikova (2020), we use the same data sources to study the relationship at the firm level between growth in output (value added and revenues) and various employment outcomes such as employment growth, hires and separations.

The rest of the paper is organized as follows: Section 2 describes the data that we use in our analysis. Section 3 examines the effect of vacancy-posting on various hiring outcomes. Section 4 examines the effect of separations on vacancy posting, and section 5 examines the effect of output growth on vacancy-posting.

2 Data

2.1 Data sources

Our data originates from Denmark and we combine information from three distinct sources: a matched employer-employee dataset, a firm panel with information about revenues and purchases, and a dataset with real-time online job advertisements. We describe each data source in turn.

Labor market spells dataset. The labor market spells dataset is a matched employer-employee dataset containing detailed information on employment spells for all legal residents in Denmark aged 15-70 starting on January 1st, 1985. It is constructed at Aarhus University using income tax reports obtained from the administrative registers Registerbaseret Arbejdsstyrke Statistik (CONS/RAS, covering 1985-2007) and Beskæftigelse For Lønmodtagere (BFL, covering 2008 onwards), and data on

employer contributions to the employee pension fund Arbejdsmarkedets Tillægs Pension, which covers the universe of workers.[1] These administrative registers are provided by Statistics Denmark.

The unit of observation in the labor market spells dataset is a worker-spell-year. An observation contains the worker's social security number (CPR-number),[2] the firm's registration number in the Danish Central Business Registry (CVR-number), start- and end-dates of the job spell and annual worker earnings pertaining to the job. In addition, it contains the industry classification of the firm where the worker is employed (see Appendix A.1) and an estimate of each worker's annual number of hours in the job from which we compute a worker's average hourly wage rate (see Lund and Vejlin (2016)). We define a job spell as a period of continuous primary employment at a given firm, where a worker's firm of primary employment for a particular month is defined to be the firm where the worker has the greatest number of hours worked for that month and the next two calendar months and a worker's firm of primary employment is determined separately for every calendar month. Periods when no job spells are recorded for a worker are nonemployment spells; we do not observe whether the worker is unemployed or out of the labor force during a nonemployment spell. We have access to the data between January 1st, 1985 ad December 31st, 2013.

VAT accounts dataset. Firms that operate in Denmark and whose expected annual revenues exceed a very low threshold are legally required 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.[3] The VAT accounts dataset is a firm panel which starts in January, 2001 and contains monthly information on revenues and purchases at the firm level, where firms are identified by their CVR-number. Statistics Denmark imputes monthly information for the firms that settle VAT accounts at a quarterly or semi-annual frequency and an indicator is included with the frequency at which each firm settles their VAT accounts. We have access to the data between January, 2001 and December, 2012.

Vacancy dataset. 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 scrapes daily job advertisements from the Danish part of the World Wide Web (e.g. from individual firms' web pages, other job boards, public job centers, etc.), operates an algorithm to detect identical advertisements posted at multiple online outlets, and

[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 dataset from the raw administrative records. Our access to the labor market spells dataset is provided by the Dale T. Mortensen Centre at Aarhus University.

[2] The CPR-number is issued to every legal resident of Denmark, is unique to the individual and time-invariant.

[3] As of 2021, firms with expected annual revenues exceeding DKK 50,000 (approximately USD 8,000) must have a VAT account. Firms with expected annual revenues of more than DKK 50 mill. (approximately USD 8 mill.) must settle VAT at a monthly frequency, firms with expected revenues in the range DKK 5 mill. (approximately USD 800,000) to DKK 50 mill. must settle at least at a quarterly frequency, while firms that expect annual revenues below DKK 5 mill. must settle at least 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 revenues would stipulate. Firms in their first year of existence must settle VAT accounts quarterly for at least six quarters, independently of expected annual revenues.

re-posts all unique job advertisements on its job-board to attract traffic from job-seekers.[4] It covers up to 90% of the job advertisements posted online in Denmark during the relevant period.[5] 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, for approximately two-thirds of the observations, the advertising firm's CVR-number.[6] We have access to job advertisement data from June 1st, 2002 to August 31st, 2009 and use the period starting on Jan 1st, 2003.[7] The vacancy dataset contains 1,918,966 online job advertisements.

In the empirical analysis our interpretation will be that a firm has a vacant position when it posts an online job advertisement, and we will use the terms "vacancy" and "advertisement" interchangeably. There are two caveats to this interpretation. First, a given advertisement might refer to multiple positions. Although this is a potential concern, most of our analysis will not use the intensive margin of recruiting effort and, therefore, the number of positions per advertisement will not make a difference (see section 3). Second, it is possible for a firm to have a vacant position without posting an online job advertisement, for example because the firm uses different search channels to recruit. Our empirical analysis will take this feature into account by allowing for "no-vacancy" hiring.[8]

2.2 Data merging and variable construction

Data merging and cleaning. We merge the three datasets using the firm ID (CVR number) and use their information to create a monthly and a quarterly firm panel on the 2003M1-2009M6/2003Q1-2009Q2 observation window for which we have data on employment, output and vacancies. We discard approximately one-third of the total number of observed advertisements (681,633 ads out of a total 1,918,966 advertisements) because they do not include the posting firm's CVR number and, so, we cannot merge these observations with our other datasets. We match 83% of the CVR numbers in the vacancy dataset with those in the labor market spells dataset, which we view as a high success rate given that the source of the vacancy data is not an administrative register. We discard firms that belong to the non-business sector,[9] and firms that settle VAT at a semi-annual frequency (these firms have negligible employment). We delete observations on the entry- and exit-periods for entering and exiting firms and, for firms with multiple entry and exit events during the observation window, we only use data up until the first exit event. To facilitate estimation of dynamic regressions, we discard firms

[4] Brodersen, Dimova, and Rosholm (2016) report the sources of job advertisements posted on Jobindex as: 35% direct posting on Jobindex, 35% other job databases, 25% public job centers and 5% firm websites. This information refers to a slightly different time period than the data we use.

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

[6] 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.

[7] Jobindex began scraping data off the Web in June, 2002 and the data is considered reliable since the beginning of 2003.

[8] This is a robust feature also in datasets that measure vacancies more fully than our dataset: in JOLTS 42% of hires occur at firms that report no vacancies. This is striking because JOLTS is a firm survey and its measure of vacancies does not depend on the usage of a particular search channel by the firm; see Davis, Faberman, and Haltiwanger (2013).

[9] According to NACE 2.0 the non-business sector consists of the following industries: Agriculture, forestry and fishing; Public administration and Defence and compulsory social 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. See table 6 for a list of the business sector industries.

with fewer than seven consecutive monthly observations. All nominal variables are expressed in 2009 Danish Kroner (DKK) and deflated using the Danish consumer price index.

Monthly employment and wage variables. We measure a firm's employment on the first day of every month and denote it by N_{jt}, where j is the firm and t is the month.[10] A worker who is not on firm-j's payroll on the first day of month t and is on firm-j's payroll on the first day of month $t+1$ is counted as a hire by firm j in month t; we denote the number of hires of firm j in month t by H_{jt}. We split the total hires of firm j in month t into hires from employment (denoted H_{jt}^{EE}) and hires from non-employment (denoted H_{jt}^{NE}) depending on the newly-hired employees' employment status on the first day of month t; by construction $H_{jt} = H_{jt}^{EE} + H_{jt}^{NE}$. To define the relevant rates we normalize these variables by firm employment, averaged over two months. Specifically, the hiring rate of firm j in month t is $h_{jt} = H_{jt}/((N_{jt} + N_{jt+1})/2)$ and similarly for the EE- and NE-hiring rates (which we denote h_{jt}^{EE} and h_{jt}^{NE}, respectively).

A worker who is on firm-j's payroll on the first day of month t and is not on firm-j's payroll on the first day of month $t+1$ is counted as a separator from firm j in month t; we denote the number of separations from firm j in month t by S_{jt}. We split the total separations from firm j in month t into separations to employment and separations to non-employment (denoted S_{jt}^{EE} and S_{jt}^{EN}, respectively) depending on the separating employees' employment status on the first day of month $t+1$; by construction $S_{jt} = S_{jt}^{EE} + S_{jt}^{EN}$. We define the separation rate (denoted s_{jt}) and the EE- and EN-separation rates (denoted s_{jt}^{EE} and s_{jt}^{EN}, respectively) analogously to the hiring rates.

The law of motion for the employment of firm j is $N_{jt+1} = N_{jt} + H_{jt} - S_{jt}$. A firm that enters in month t has $N_{jt} = 0$, $N_{jt+1} = H_{jt}$ and $S_{jt} = 0$. A firm that exits in month t has $S_{jt} = N_{jt}$, $H_{jt} = 0$ and $N_{jt+1} = 0$. We compute the average hourly wage rate among all workers employed by firm j in month t and denote it by $\overline{w}_{jt}$.[11]

Quarterly output variables. We aggregate the monthly VAT account information to a quarterly frequency. We denote revenues and value added of firm j in quarter s by R_{js} and Y_{js}, respectively. These variables are not contaminated by imputation since we discard firms that settle their VAT-accounts semi-annually.

Vacancy variables. We aggregate the daily vacancy data to create monthly and quarterly variables for vacancy-posting. We first create a variable a_{jt} which measures the number of online advertisements posted by firm j in month t. We create a monthly vacancy indicator variable I_{jt}^{M} which takes the value 1 if firm j posts one or more online advertisements in month t and 0 otherwise, and a quarterly vacancy indicator variable I_{js}^{Q} which takes the value 1 if firm j posts one or more online advertisements in quarter s and 0 otherwise. We create a monthly vacancy rate variable by dividing the number of advertisements posted by firm j in month t by the average employment of months t and $t+1$: $v_{jt}^{M} = a_{jt}/((N_{jt} + N_{jt+1})/2)$. We create a quarterly vacancy rate variable by dividing the number of advertisements posted by firm j in quarter s by the average employment of quarters s and $s+1$.

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

[11] By construction, a worker's measured hourly wage rate at a particular job is constant during the calendar year. This does not restrict our analysis because we do not examine within-year wage growth.

Table 1: Summary Statistics

	Avg.	SD	Zero
Monthly employment growth rate	0.003	0.209	0.428
Monthly hiring rate	0.070	0.157	0.508
Monthly EE-hiring rate	0.026	0.070	0.686
Monthly NE-hiring rate	0.044	0.130	0.634
Monthly separation rate	0.067	0.153	0.509
Monthly EE-separation rate	0.024	0.066	0.696
Monthly NE-separation rate	0.043	0.129	0.633
Quarterly revenue growth rate	0.017	0.526	
Quarterly value added growth rate	0.019	0.946	
Monthly vacancy indicator	0.116		
Quarterly vacancy indicator	0.239		
Monthly vacancy rate	0.014	0.152	0.884
Quarterly vacancy rate	0.042	0.399	0.761

Notes: The monthly statistics are computed on 1,307,128 observations on 20,625 firms. The quarterly statistics are computed on 436,568 observations on the same 20,625 firms. The column labeled "Zero" contains the share of firm-months or firm-quarters where the relevant variable is identically zero.

Denoting the months of quarter s by t, $t+1$ and $t+2$ and of quarter $s+1$ by $t+3$, $t+4$ and $t+5$, and noting that a quarter's employment is measured on the first month of the quarter we have: $v_{js}^{Q} = (a_{jt} + a_{jt+1} + a_{jt+2})/((N_{jt} + N_{jt+3})/2)$.

Firms without measured vacancies. We discard firms that are never observed to post online job advertisements over the 78 months of the observation period 2003M1-2009M6. These firms are unlikely to have refrained from active recruiting over these 6.5 years; indeed, they account for roughly one-third of all hires in the labor market spells dataset over that period. Rather, these firms probably advertise without an observable CVR-number and, therefore, are mostly a source of mismeasurement. We note that, though numerous, the firms we discard tend to be much smaller than the firms that we use in our analysis and account for less than 30% of total employment and less than a quarter of total revenue or value added. Therefore, the firms that we keep account for most of the economic activity, employment, hires and job creation in the Danish business sector. We present a more detailed comparison between the firms with and without measured vacancies in Appendix A.2.

Summary. We create two firm panels, at a monthly and a quarterly frequency. The monthly and the quarterly panel consists of the same 20,625 firms. The monthly firm panel contains 1,307,128 firm-months between 2003M1 and 2009M6 with information about vacancies, employment, hires, separations and wages. The quarterly firm panel contains 436,568 firm-quarters between 2003Q1 and 2009Q2 with information about vacancies, revenues and value added.

2.3 Descriptive statistics

Table 1 presents some descriptive statistics of the data that we use in our analysis. The top three panels in Table 1 (rows 1 through 7) present various rates that relate to employment transitions. Monthly employment growth is 0.3 percent on average and very volatile, with most firm-months featuring some change in employment. Workers flows are also very volatile and the average firm hires 7.0 percent of its workforce and separates from a further 6.7 percent every month. Approximately two-third of monthly hires and separations involve transitions from and to non-employment.

The fourth panel in Table 1 (rows 8 and 9) presents output data. Revenues and value added increase at almost 2% on average per quarter, which is quite high and might be related to our sample selection of, generally, larger, more productive and faster-growing firms. The volatility of these series is, also, very large.[12]

In the final two panels of Table 1 (rows 10 through 13), we see that a firm in our data on average post some vacancies in 12 percent of the months and 24 percent of quarters. The average vacancy rate is 1.4 percent at a monthly frequency and 4.2 percent at a quarterly frequency.

3 Vacancies and hiring outcomes

In this section we investigate the relationship between vacancy-posting and hiring outcomes. To that end, we document the *correlation* between the variables of interest and note that the estimated parameters do not warrant a causal interpretation.

3.1 The hiring rate

We investigate the relationship between the hiring rate and vacancy-posting. We estimate several variations of the distributed lag panel data regression

$$h_{jt} = \beta + \sum_{k=0}^{6} \pi_k z_{jt-k} + \mathbf{x}'_{jt}\boldsymbol{\delta} + \rho_j + \epsilon_{jt}, \tag{1}$$

where h_{jt} is the hiring rate of firm j in month t, β is a constant, z_{jt} is the vacancy-posting variable which measures firms' recruiting effort and is specified below, $\mathbf{x}_{jt}$ is a vector of industry-dummies, month-dummies and month-dummies interacted with industry-dummies, ρ_j is a firm fixed effect, and ϵ_{jt} is the error term.

The vacancy-posting variable z_{jt} is included with a truncated lag distribution, where the lag-k weight is π_k. We allow for 6 lags; we have found that longer lags are statistically and quantitatively insignificant and they do not affect the estimates of other parameters. The constant term β is the predicted average hiring rate for firms that post no vacancies over a six months period, which we will refer to as the *no-vacancy baseline hiring rate*. We estimate the parameters β and π_k for $k = 0, 1, ..., 6$ by OLS.

We use two different vacancy-posting variables to measure firms' recruiting effort. First, we use the monthly vacancy indicator variable ($z_{jt} = I^M_{jt}$) which takes value 1 if any online advertisement is

[12]The 25th, 50th, and 75th percentiles in the quarterly revenue growth rate distribution are −0.19, 0.10, and 0.22, respectively. The corresponding percentiles in the quarterly value added growth rate distribution are −0.37, 0.02, and 0.40, respectively.

Table 2: Regressing the hiring rate on the vacancy posting indicator

Dependent variable: h_{jt}	(1)	(2)	(3)
No-vacancy baseline, β	0.065^{***} (0.000)	0.063^{***} (0.000)	0.062^{***} (0.000)
Lag-0 weight, π_0	0.017^{***} (0.001)	0.009^{***} (0.001)	0.010^{***} (0.001)
Lag-1 weight, π_1		0.018^{***} (0.001)	0.019^{***} (0.001)
Lag-2 weight, π_2		0.011^{***} (0.001)	0.012^{***} (0.001)
Lag-3 weight, π_3		0.004^{***} (0.001)	0.006^{***} (0.000)
Lag-4 weight, π_4		-0.001^{**} (0.001)	0.001 (0.000)
Lag-5 weight, π_5		-0.002^{***} (0.001)	-0.001 (0.000)
Lag-6 weight, π_6		-0.004^{***} (0.001)	-0.002^{***} (0.000)
Cumulative response, Π	0.017^{***} (0.001)	0.034^{***} (0.002)	0.045^{***} (0.001)
Cumul. resp. relative to no-vacancy baseline, Π/β	0.256^{***} (0.012)	0.546^{***} (0.029)	0.734^{***} (0.023)
Share of Π realized within 2 months, Λ		0.778^{***} (0.030)	0.652^{***} (0.017)
Dynamic effects	No	Yes	Yes
Firm fixed effects	No	No	Yes
Number of firms	20,625	20,625	20,625
Number of observations	1,183,378	1,183,378	1,183,378

Notes: Standard errors (in parentheses) are clustered at the firm-level. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. All regressions include controls for month and industry effects and their interactions.

posted in that month and 0 otherwise and, hence, focuses on the *extensive margin* of firm recruiting effort. Second, we use the monthly vacancy rate ($z_{jt} = v_{jt}^M$) which normalizes the number of online advertisements by firm employment and, hence, also takes into account the *intensive margin* of firm recruiting effort.

We define the *cumulative response* of the hiring rate to vacancy-posting as

$$\Pi = \sum_{k=0}^{6} \pi_k,$$

Π measures the full response over time of hiring to vacancy-posting.

We denote the share of the cumulative response that occurs in the contemporaneous vacancy-posting month (lag 0) and subsequent month (lag 1) by

$$\Lambda = \frac{\pi_0 + \pi_1}{\Pi}.$$

Λ is a summary measure of the speed with which the cumulative response materializes.

Finally, for the specifications where the vacancy-posting variable is the vacancy rate, we denote the response of the hiring rate to a one-standard deviation change in the vacancy rate by

$$\Omega(\sigma_v) = \Pi\sigma_v$$

where σ_v is the standard deviation of v_{jt}^M.

Table 2 presents the estimates of the first set of specifications where z_{jt} is the vacancy indicator variable I_{jt}^M. Column (1) reports the results of a regression without firm fixed effects (i.e. $\rho_j \equiv 0$) and

without dynamic responses to vacancy posting (i.e. where $\pi_k \equiv 0$ for $k \geq 1$). The first thing to note is that the estimate of the no-vacancy baseline hiring rate is statistically significant and quantitatively large, corresponding to a no-vacancy hiring rate of 6.5% for the average firm. The contemporaneous effect of vacancy-posting is to increase the hiring rate by 1.6 percentage points, i.e by one-quarter over the no-vacancy baseline.

The large magnitude of the estimate for the constant, which is a robust feature across different empirical specifications, means that a significant amount of hiring occurs without measured recruiting effort, at least through the online advertisement channel. The restriction of our data to one recruiting channel is unlikely to fully explain this finding, as it is observed in other datasets without that restriction. For example, Davis, Faberman, and Haltiwanger (2013) document that 42% of hires occur without a reported vacancy using JOLTS, an establishment-level survey where measured vacancies are self-reported by the establishment and are, hence, not restricted to any recruiting channel.

The specification in column (2) in Table 2 estimates the dynamic response to a vacancy-posting event by allowing for $\pi_k \neq 0$ for $k = 0, 1, ..., 6$. The contemporaneous effect of vacancy-posting on the hiring rate is reduced by half to 0.9 percentage points but remains highly statistically significant. The effect in the subsequent months is highly statistically significant and quantitatively large. Specifically, the hiring rate increases by 1.8 percentage points one month after the vacancy-posting, by a further 1.1 percentage points two months later, and by 0.4 percentage points three months later. The cumulative response of a vacancy-posting event (also taking into account the quantitatively smaller effects of subsequent months) is to increase the hiring rate by 3.4 percentage points, a 55% increase over the no-vacancy baseline. A little more than three-quarters of the cumulative effects materialize within the first two months after a vacancy posting.

Finally, the specification in column (3) in Table 2 introduces firm fixed effects, i.e. allows for $\rho_j \neq 0$ for all j, and it is our preferred specification. The estimates are qualitatively similar in terms of timing and quantitatively larger to those in column (2), yielding a cumulative increase in the hiring rate of 4.5 percentage points, which corresponds to a 73% increase over the baseline hiring rate. Approximately two-thirds of that response occur in the month when the vacancy is posted and the next month.

Comparing specifications (1) and (2) in Table 2 demonstrates that the dynamic response of hiring to vacancy-posting is significant and that it takes up to three months for the bulk of the effect to materialize. Further comparison to specification (3) show that the significant dynamic responses are sustained and magnified quantitatively by the inclusion of firm fixed effects in the regression.

Comparing specifications (2) and (3) in Table 2 demonstrates that controlling for firm fixed effects has important quantitative implications for the predicted hiring response to vacancy-posting: the cumulative response is one-third higher in column (3). This substantial difference arises because the estimated parameters in specification (2), without firm fixed effects, reflect both within- and between-firm variation in the hiring rate and vacancy posting, whereas the parameter estimates in specification (3) reflect within-firm variation only. Evidently, vacancy posting is systematically related to firm-specific hiring rate heterogeneity. Specifically, the larger estimated response in specification (3) suggests that firms with above average-hiring rates (so, positive firm fixed effects ρ_j) post vacancies less frequently. We prefer specification (3) in Table 2 because it yields the predicted response to a vacancy posting conditional on time-invariant firm-specific hiring rate heterogeneity.

Table 3 presents the estimates of the second specification where the vacancy-posting variable z_{jt} is

Table 3: Regressing the hiring rate on the vacancy rate

Dependent variable: h_{jt}	(1)	(2)	(3)
No-vacancy baseline, β	0.067^{***}	0.067^{***}	0.066^{***}
	(0.000)	(0.000)	(0.000)
Lag-0 weight, π_0	0.017^{**}	-0.012^{***}	-0.006^{*}
	(0.007)	(0.003)	(0.003)
Lag-1 weight, π_1		0.055^{***}	0.058^{***}
		(0.011)	(0.012)
Lag-2 weight, π_2		0.018^{***}	0.020^{***}
		(0.004)	(0.005)
Lag-3 weight, π_3		-0.003	-0.001
		(0.003)	(0.003)
Lag-4 weight, π_4		-0.007^{***}	-0.005^{**}
		(0.003)	(0.002)
Lag-5 weight, π_5		-0.015^{***}	-0.012^{***}
		(0.003)	(0.002)
Lag-6 weight, π_6		-0.011^{***}	-0.008^{***}
		(0.003)	(0.002)
Cumulative response, Π	0.017^{**}	0.025^{**}	0.046^{***}
	(0.007)	(0.011)	(0.018)
Cumul. resp. relative to no-vacancy baseline, Π/β	0.253^{**}	0.368^{**}	0.687^{**}
	(0.099)	(0.166)	(0.269)
Share of Π realized within 2 months, Λ		1.749^{***}	1.124^{***}
		(0.341)	(0.151)
Cumulative response to 1SD change in v_{jt}^M, $\Omega(\sigma_v)$	0.003^{**}	0.004^{**}	0.007^{***}
	(0.001)	(0.002)	(0.003)
Dynamic effects	No	Yes	Yes
Firm fixed effects	No	No	Yes
Number of firms	20,625	20,625	20,625
Number of observations	1,183,378	1,183,378	1,183,378

Notes: Standard errors (in parentheses) are clustered at the firm-level. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. All regressions include controls for month and industry effects and their interactions.

the monthly vacancy rate v_{jt}^M. As before, specification (1) reports the estimates for the specification without firm fixed effects and without dynamic responses, column (2) adds dynamic responses and column (3) further adds firm fixed effects. The estimates for the no-vacancy baseline rate β are very similar to Table 2. While the parameter estimates that describe the hiring response are quite similar to those of Table 2, the quantitative implications are very different: a cumulative response of 0.046 (specification (3) in Table 3) means that a 10 percentage point increase in the vacancy rate increases the hiring rate by 0.46 percentage points or 7% over the no-vacancy baseline. Furthermore a one-standard deviation increase in the vacancy rate is associated with a 0.7 percentage point increase in the hiring rate, which corresponds to an 11% increase over the no-vacancy baseline. This is a very small response and, taken at face value, implies that the vacancy rate does not correlate strongly with hiring.

There appears to be some tension between the estimation results from the two different ways of measuring firms' recruiting intensity. The first specification, which uses the extensive margin of vacancy-posting to measure firms' recruiting effort, finds that the effects of vacancy-posting on hiring outcomes are quantitatively very significant. The second specification, which uses the intensive margin of firms' recruiting effort, finds very small effects of vacancy-posting on hiring outcomes. The two specifications, therefore, seem to reach different qualitative conclusions. To understand these results, note that the second specification assumes a very restrictive linear relationship between the vacancy rate and the hiring rate response. If the actual response is in fact non-linear (specifically, concave) this would tend to reduce the estimates of the linear regression. Evaluating this hypothesis, though certainly interesting, is beyond the scope of the present paper. For the remaining of this section's analysis of firms' recruiting effort on hiring outcomes we focus on our first specification where z_{jt} is the vacancy indicator variable.

3.2 Hiring from employment and non-employment

We next examine the effect of vacancy-posting on hiring from employment (EE-hiring) and non-employment (NE-hiring). We re-estimate equation (1) using as dependent variables the hiring rate from employment of firm j in month t (h_{jt}^{EE}) and, separately, from non-employment (h_{jt}^{NE}). Table 4 reports the results. Column (1) in Table 4 reproduces the estimates reported in column (3) in Table 2 for ease of comparison, column (2) reports the estimates for the EE-hiring rate and column (3) reports the estimates for the NE-hiring rate. The two hiring channels exactly decompose total hiring and, therefore, the estimates for the two channels sum up to the aggregate regression's estimates.

A few remarks are in order. First, the estimate of the no-vacancy baseline hiring rates, which corresponds to hires that occur without vacancy-posting, is twice larger for NE-hiring than for EE-hiring, consistent with the unconditional hiring rates documented in Table 1. Second, each channel yields approximately half of the overall hiring response to vacancy-posting. Third, and related, the response of hiring to vacancy-posting is proportionally twice as large for EE hires than for NE hires: the hiring rate from employment more than doubles in response to vacancy-posting, while the hiring rate from non-employment increases by little more than 50%. Finally, hiring from employment is considerably slower to materialize than hiring from non-employment: within two months of vacancy-posting the share of the response that has materialized is more than three-quarters for hiring from non-employment and just over half for hiring from employment.

Table 4: Regressing the EE- and NE-hiring rates on a vacancy posting indicator

Dependent variable:	h_{jt}	h_{jt}^{EE}	h_{jt}^{NE}
No-vacancy baseline, β	0.062^{***} (0.000)	0.022^{***} (0.000)	0.039^{***} (0.000)
Lag-0 weight, π_0	0.010^{***} (0.001)	0.004^{***} (0.000)	0.006^{***} (0.000)
Lag-1 weight, π_1	0.019^{***} (0.001)	0.009^{***} (0.000)	0.010^{***} (0.000)
Lag-2 weight, π_2	0.012^{***} (0.001)	0.007^{***} (0.000)	0.005^{***} (0.000)
Lag-3 weight, π_3	0.006^{***} (0.000)	0.004^{***} (0.000)	0.001^{***} (0.000)
Lag-4 weight, π_4	0.001 (0.000)	0.001^{***} (0.000)	-0.000 (0.000)
Lag-5 weight, π_5	-0.001 (0.000)	-0.000^{**} (0.000)	-0.000 (0.000)
Lag-6 weight, π_6	-0.002^{***} (0.000)	-0.001^{***} (0.000)	-0.001^{***} (0.000)
Cumulative response, Π	0.045^{***} (0.001)	0.023^{***} (0.001)	0.022^{***} (0.001)
Cumul. resp. relative to no-vacancy baseline, Π/β	0.734^{***} (0.023)	1.057^{***} (0.028)	0.553^{***} (0.029)
Share of Π realized within 2 months, Λ	0.652^{***} (0.017)	0.556^{***} (0.013)	0.755^{***} (0.032)
Dynamic effects	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes
Number of firms	20,625	20,625	20,625
Number of observations	1,183,378	1,183,378	1,183,378

Notes: Standard errors (in parentheses) are clustered at the firm-level. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. All regressions include controls for month and industry effects and their interactions.

These findings suggest that vacancy-posting affects not just the quantity of hires but also their source (employment vs non-employment) and, potentially, other worker characteristics. Specifically, the differential speed in the hiring response from employment and non-employment is suggestive evidence of heterogeneity in the respective worker pools and vacancy-posting shifts hiring towards the employed group.

3.3 Firm heterogeneity

We conduct our heterogeneity analysis by splitting our firm sample in groups according to size, productivity, firm growth and industry and replicate our earlier analysis separately for each group.

Our measures of a firm's size are employment and quarterly value added averaged over the observation period. Our measures of a firm's productivity are the average hourly wage and the average quarterly value added per worker over the observation period. We measure firm growth as average monthly employment growth and average quarterly value added growth for each calendar year and, as our sample spans seven calendar years, each firm has up to seven observations. Finally, we measure a firm's industry by the NACE 2.0 sector classification.

Letting $b(t)$ denote the calendar year of month t, we assign each firm j to group $\ell = \ell(j, b(t))$. A firm's assigned group ℓ depends only on firm identity j when we split the sample by size, productivity, and industry and it depends on both firm identity j and calendar year $b(t)$ when we split the sample by growth. We estimate the following distributed lag panel data model, which is the same as equation

(1) except that the parameters are now indexed by firms' groups:

$$h_{jt} = \beta_\ell + \sum_{k=0}^{6} \pi_{k,\ell} I^M_{jt-k} + \mathbf{x}'_{jt}\boldsymbol{\delta}_\ell + \rho_{j,\ell} + \epsilon_{jt}, \tag{2}$$

where $\ell \equiv \ell(j, b(t))$ as outlined above, and where, as before, h_{jt} is the hiring rate of firm j in month t, I^M_{jt} is the vacancy posting indicator, $\mathbf{x}_{jt}$ is a vector of industry-dummies, month-dummies and their interactions (industry dummies and interactions excluded when splitting the sample by industry), $\rho_{j,\ell}$ is a firm-group fixed effect, and ϵ_{jt} is the error term. We estimate the parameters β_ℓ and $\pi_{k,\ell}$, $k = 0, 1, \ldots, 6$ by OLS, group-by-group.

Table 5 reports the parameter estimates for employment size, average hourly wage and employment growth and Table 6 reports the estimates of the hiring regression separately by industry. The estimates for value added size, value added per worker and value added growth turn out to be qualitatively very similar to the employment- and wage-based splits in Table 5 and, so, we report them in Appendix B. To keep the tables manageable, we do not report estimated lag distribution weights and, instead, use the share of the hiring response that materializes within two months of vacancy-posting (i.e. Λ) to summarize response dynamics.

Panel A of Table 5 splits firms in four size groups according to employment: 1-10 workers (micro firms), 10-50 (small firms), 50-250 (medium-sized firms), 250+ (large firms). The proportion of months when vacancies are posted increases monotonically in firm size from 6% for micro firms to 57% for large firms. The estimate for the no-vacancy baseline hiring rate is quite similar across size groups. The size-specific estimates of the cumulative hiring response to a vacancy-posting, Π_ℓ are, essentially, monotonically decreasing in size which leads to a similar relationship for the increase of the hiring rate over the no-vacancy baseline, i.e. Π_ℓ/β_ℓ. This is likely an artifact of the particular dependent variables we are using: hiring one worker corresponds to a 20% hiring rate in a 5-person firm and a 2% hiring rate in a 50-person firm.

The speed with which the hiring response materializes, as measured by Λ_ℓ is, generally, increasing in firm size: in the two months after vacancy-posting micro firms complete less than 60% of their hiring, which increases to almost 70% for small firms and to more than 80% for medium-size firms. For large firms the point estimate of Λ is less than 25% and statistically insignificant. This is likely due to fact that these firms post vacancies very frequently which makes it harder to identify the weights of the lag distribution and, for this reason, we do not necessarily interpret the estimate to suggest that these firms hire very slowly.

Panel B of Table 5 splits firms in the four quartiles of the distribution of average hourly wages. The proportion of months with vacancies increases monotonically, but modestly, with the average wage, from 11% in the lowest-wage quartile to 13% in the highest-wage quartile. The estimate for the baseline no-vacancy hiring rate β_ℓ is strongly decreasing in the average wage. The hiring response to vacancy-posting is also decreasing in the average wage and the proportional increase of the hiring rate over the no-vacancy baseline is relatively similar across the average wage groups. Finally, the speed with which that response materializes decreases significantly in the average wage. This result is interesting because several prominent models of labor search predict that high-wage firms hire faster in the context of homogeneous workers (e.g. models with on-the-job search or directed search). Therefore, to rationalize the timing of the hiring response to vacancy-posting across different wage-groups, a model with worker

or match heterogeneity might be necessary.

Panel C of Table 5 splits *firm-years* in the four quartiles of the distribution of average monthly employment growth across firm-years. The proportion of months with vacancies is increasing in firm growth, though somewhat modestly from 9% in the lowest-growth quartile to 12% in the highest-growth quartile. The baseline no-vacancy hiring rate is U-shaped in firm growth and is considerably higher for firms in the fastest-growing quartile, at a monthly 9.5%. The response of hiring to vacancy-posting as a proportion over the no-vacancy baseline is decreasing in firm growth and the share of the response that occurs within two months is somewhat U-shaped in firm growth. Overall, it appears that high employment growth is not achieved through more vacancy-posting or a greater hiring response to vacancy postings but, rather, through no-vacancy hiring.

This outcome is in contrast with the finding of Davis, Faberman, and Haltiwanger (2013). They report that the vacancy yield (hires per vacancy) increases sharply in establishments' employment growth (when growth is positive) which can be interpreted as high-growth firms enjoying a greater hiring response to vacancy-posting.[13] This difference might be due to at least two reasons. First, we follow different methodologies in defining the hiring response to vacancy-posting. Davis, Faberman, and Haltiwanger (2013) define the vacancy yield at the aggregate establishment-group level (e.g. the group of establishments whose employment grows at a certain monthly rate), by dividing all of the group's hires by all of the group's measured vacancies regardless of whether the establishment reporting the vacancy is the same as the establishment that is doing the hiring. We, instead, associate hires with vacancy-posting *at the firm level*, through the timing of posting and hiring. Although we find that, as one would expect, fast-growing firms hire a lot, many of these hires do not correspond to earlier vacancy-posting and, therefore, do not contribute to the response of the hiring rate to vacancy-posting. Second, our data is collected in a different way. JOLTS is an establishment survey which, presumably, captures a larger share of available positions since measuring a vacancy is not contingent on the establishment taking a particular recruiting action. Our data depends on the firm posting an online advertisement and, hence, might undercount available positions.

Table 6 split firms by industry. We observe some heterogeneity in the response of hiring to vacancy-posting: in industries such as Construction and Accommodation the hiring rate increases by 5.8 and 6.6 percentage points, respectively, while in Administrative Services and the combined Financial and Insurance Activities/Real Estate Activities, it rises by less than 3 percentage points. Furthermore, vacancy-posting almost doubles the hiring rate in comparison to the no-vacancy baseline in Construction and Wholesale Trade and increases it by less than a quarter in Administrative Services. Finally, the response of the hiring rate is fastest in Administrative Services, Construction, Transport and Accommodation.

4 Vacancies and separations

This section explores the extent to which separations predict vacancy-posting at the firm level, i.e. whether separations are followed by increased recruitment effort by the firm to replace the departing worker(s). The goal of this analysis is to assess the empirical relevance of "vacancy chains", the

[13] Carrillo-Tudela, Gartner, and Kaas (2021) report similar findings using the Job Vacancy Survey from Germany, using the same methodology as Davis, Faberman, and Haltiwanger (2013).

Table 5: Firm heterogeneity

		A. firm size			
Dependent variable: h_{jt}	All	1-10	10-50	50-250	250+
No-vacancy baseline, β	0.062***	0.064***	0.060***	0.064***	0.063***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.003)
Cumulative response, Π	0.045***	0.106***	0.040***	0.011***	0.015***
	(0.001)	(0.003)	(0.002)	(0.003)	(0.005)
Π relative to no-vacancy baseline, Π/β	0.734***	1.661***	0.673***	0.166***	0.241**
	(0.023)	(0.054)	(0.031)	(0.044)	(0.097)
Share of Π realized within 2 months, Λ	0.652***	0.595***	0.680***	0.767***	0.245
	(0.017)	(0.016)	(0.026)	(0.163)	(0.202)
Share of months w/ vacancies	0.120	0.059	0.107	0.258	0.572
Average number of workers	49.299	5.886	22.264	101.760	869.778
Dynamic effects	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes
Number of firms	20,625	9,125	8,847	2,170	483
Number of observations	1,183,378	450,908	555,269	144,272	32,929
		B. Hourly wage			
Dependent variable: h_{jt}	All	1st quartile	2nd quartile	3rd quartile	4th quartile
No-vacancy baseline, β	0.062***	0.089***	0.062***	0.053***	0.046***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Cumulative response, Π	0.045***	0.065***	0.050***	0.038***	0.035***
	(0.001)	(0.004)	(0.003)	(0.002)	(0.002)
Π relative to no-vacancy baseline, Π/β	0.734***	0.731***	0.813***	0.716***	0.762***
	(0.023)	(0.044)	(0.046)	(0.047)	(0.058)
Share of Π realized within 2 months, Λ	0.652***	0.822***	0.750***	0.607***	0.343***
	(0.017)	(0.036)	(0.033)	(0.035)	(0.032)
Share of months w/ vacancies	0.120	0.105	0.106	0.131	0.134
Average hourly wage	211.192	139.697	181.294	215.735	302.256
Dynamic effects	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes
Number of firms	20,625	5,157	5,156	5,156	5,156
Number of observations	1,183,378	269,835	304,159	313,307	296,077
		C. Employment growth rate			
Dependent variable: h_{jt}	All	1st quartile	2nd quartile	3rd quartile	4th quartile
No-vacancy baseline, β	0.062***	0.057***	0.042***	0.056***	0.095***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Cumulative response, Π	0.045***	0.061***	0.043***	0.032***	0.053***
	(0.001)	(0.003)	(0.002)	(0.002)	(0.004)
Π relative to no-vacancy baseline, Π/β	0.734***	1.067***	1.021***	0.566***	0.561***
	(0.023)	(0.060)	(0.059)	(0.036)	(0.041)
Share of Π realized within 2 months, Λ	0.652***	0.656***	0.570***	0.617***	0.686***
	(0.017)	(0.028)	(0.027)	(0.034)	(0.039)
Share of months w/ vacancies	0.120	0.093	0.105	0.160	0.122
Average monthly growthrate	0.001	−0.038	−0.003	0.007	0.040
Dynamic effects	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes
Number of firms	20,625	16,190	15,415	13,041	15,678
Number of observations	1,183,378	291,462	322,254	293,185	276,170

Notes: Standard errors (in parentheses) are clustered at the firm-level. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. All regressions include controls for month and industry effects and their interactions.

Table 6: By industry

Dependent variable: h_{jt}	All	Manu	Cons	Whol	Tran	Acco	Info	Prof	Admi	Fina	Mini
No-vacancy baseline, β	0.062***	0.052***	0.062***	0.053***	0.065***	0.135***	0.054***	0.059***	0.117***	0.057***	0.052***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Cumulative response, Π	0.045***	0.041***	0.057***	0.049***	0.042***	0.070***	0.041***	0.036***	0.026***	0.023**	0.048***
	(0.001)	(0.003)	(0.003)	(0.002)	(0.006)	(0.008)	(0.005)	(0.004)	(0.007)	(0.011)	(0.012)
Π relative to no-vacancy baseline, Π/β	0.734***	0.785***	0.924***	0.937***	0.653***	0.519***	0.752***	0.609***	0.223***	0.403**	0.919***
	(0.023)	(0.058)	(0.055)	(0.047)	(0.099)	(0.063)	(0.113)	(0.073)	(0.061)	(0.197)	(0.239)
Share of Π realized within 2 months, Λ	0.652***	0.656***	0.963***	0.464***	0.773***	0.795***	0.292***	0.387***	1.550***	0.733***	0.400***
	(0.017)	(0.038)	(0.044)	(0.021)	(0.083)	(0.078)	(0.062)	(0.064)	(0.347)	(0.275)	(0.103)
Share of months w/ vacancies	0.120	0.135	0.077	0.109	0.125	0.141	0.151	0.130	0.220	0.157	0.089
Dynamic effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of firms	20,625	3,920	3,549	6,466	1,025	1,148	1,044	1,867	846	495	265
Number of observations	1,183,378	248,040	206,697	373,723	59,846	53,616	54,887	101,235	42,973	25,809	16,552

Notes: Standard errors (in parentheses) are clustered at the firm-level. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. All regressions include controls for month effects. Industries are NACE 2.0 sectors: Manufacturing (Manu), Construction (Cons), Wholesale and Retail Trade, Repair of Motor Vehicles and Motor Cycles, Transport and Storage (Tran), Accommodation and Food Service Activities (Acco), Information and Communication (Info), Professional, Scientific, and Technical Services (Prof), and Administrative and Support Service Activities (Admi). Finally, the Fina-label covers the two NACE 2.0 sectors Financial and Insurance Activities and Real Estate Activities, and the Mini-label covers the three NACE 2.0 sectors Mining and Quarrying, and Electricity, Gas, Steam and Airconditioning, and Water Supply and Sewerage Contractors.

process where a separation event leads to a sequence of vacancy-posting, worker-poaching, and yet more vacancy-posting, thereby contributing to the volatility of labor markets.[14]

We estimate how a firm's vacancy rate responds to the firm's separation rate using a number of different specifications. Appendix C presents the estimates of the effect of the separation rate on the vacancy posting indicator variable, which turns out to yield qualitatively similar results.

The starting point for this part of our empirical analysis is the following distributed lag model for the monthly vacancy rate v_{jt}^M of firm j in month t,

$$v_{jt}^M = \beta + \sum_{k=0}^{6} \pi_k s_{jt-k} + \mathbf{x}_{jt}'\boldsymbol{\delta} + \rho_j + \epsilon_{jt}, \tag{3}$$

where s_{jt} is the separation rate of firm j in month t, β is a constant measuring the no-separation baseline vacancy rate, $\mathbf{x}_{jt}$ is a vector of month-dummies, industry-dummies and their interactions, ρ_j is a firm fixed effect and ϵ_{jt} is the error term. The separation rate s_{jt} is included with a truncated lag distribution with up to 6 months lag, and the lag-k weight is π_k.

We define the cumulative response of the vacancy rate to a marginal change in the separation rate as $\Pi = \sum_{k=0}^{6} \pi_k$, and the share of this marginal response that materializes within two months by $\Lambda = (\pi_0 + \pi_1)/\Pi$. We report the vacancy rate response to a one standard deviation separation rate change, which we denote by $\Omega(\sigma_s)$, where σ_s is the standard deviation of the separation rate.

Table 7 presents the results. Column (1) reports the estimates of a static specification that only includes the contemporaneous separation rate, i.e. where $\pi_k \equiv 0$ for $k \geq 1$. The baseline monthly vacancy rate when there are no contemporaneous separations is 1.3%, and the vacancy rate response to a marginal change in the contemporaneous separation rate is 1.1 percentage points. A "typical" one standard deviation increase of the separation rate is associated with an increases in the vacancy rate by 0.2 percentage points, a 15% increase over the baseline no-separation vacancy rate.

Column (2) in Table 7 reports the estimates of the full specification which allows for the dynamic effects of separations, i.e. for $\pi_k \neq 0$ for $k = 0, 1..., 6$. The baseline no-separation vacancy rate is reduced slightly to 1%. The cumulative response to a separation event is five times greater than in the static specification, highlighting the importance of accounting for dynamic responses. Indeed, only half of the total vacancy-posting response occurs within the month of the separation and the subsequent month. A typical one standard deviation separation event is associated with an increase in the vacancy rate of 0.9 percentage points, a 90% increase compared to the baseline vacancy rate.

Next, we extend our analysis to examine the heterogeneous effect of separations to employment and separations to non-employment on vacancy-posting. This is potentially interesting since separations to non-employment might include downsizing by firms and, therefore, be associated with less replacement hiring while separations to employment might be due to poaching, leading to more replacement and the propagation of a vacancy chain.

To this end, we amend equation (3) in a straightforward way to distinguish between the separation

[14] See Elsby, Michaels, and Ratner (2019) and Mercan and Schoefer (2020) for a more detailed description of vacancy chains and the evidence about replacement hiring. These studies infer the presence of replacement hiring by observing that firms facing quits often report stable employment, i.e. they also report that hires exactly offset their earlier separations. Faberman and Nagypal (2008) find that the monthly vacancy rate more than doubles at establishments reporting worker quit(s) in comparison to those without quits.

Table 7: Separations and vacancies

Dependent variable v_{jt}	(1)	(2)	(3)	
			EE	EN
No-separation baseline, β	0.013***	0.010***	0.009***	
	(0.000)	(0.000)	(0.001)	
Lag-0 weight, π_0	0.011***	0.011***	0.025***	0.007***
	(0.001)	(0.001)	(0.003)	(0.001)
Lag-1 weight, π_1		0.018***	0.028***	0.016***
		(0.002)	(0.005)	(0.002)
Lag-2 weight, π_2		0.008***	0.015***	0.006***
		(0.001)	(0.004)	(0.001)
Lag-3 weight, π_3		0.007***	0.018***	0.004***
		(0.001)	(0.007)	(0.001)
Lag-4 weight, π_4		0.005***	0.011**	0.003***
		(0.001)	(0.004)	(0.001)
Lag-5 weight, π_5		0.004***	0.005	0.004***
		(0.001)	(0.003)	(0.001)
Lag-6 weight, π_6		0.004***	0.007*	0.003**
		(0.001)	(0.004)	(0.001)
Cumulative response, Π	0.011***	0.058***	0.109***	0.043***
	(0.001)	(0.007)	(0.020)	(0.006)
Share of Π realized within 2 months, Λ		0.514***	0.484***	0.535***
		(0.030)	(0.056)	(0.043)
Cumulative response to 1SD s-shock, $\Omega(\sigma_s)$	0.002***	0.009***	0.007***	0.005***
	(0.000)	(0.001)	(0.001)	(0.001)
Dynamic effects	No	Yes	Yes	
Firm fixed effects	Yes	Yes	Yes	
Number of firms	20,625	20,625	20,625	
Number of observations	1,183,378	1,183,378	1,183,378	

Notes: Standard errors (in parentheses) are clustered at the firm-level. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. All regressions include controls for month and industry effects and their interactions. σ_s is the standard deviation of the overall separation rate in columns (1) and (2), of the separation rate to employment in column (3-EE) and of the separation rate to non-employment in column (3-EN).

rates into employment (denoted s_{jt}^{EE}) and non-employment (denoted s_{jt}^{EN}):

$$v_{jt}^{M} = \sum_{k=0}^{K} \pi_{k}^{EE} s_{jt-k}^{EE} + \sum_{k=0}^{K} \pi_{k}^{EN} s_{jt-k}^{EN} + \mathbf{x}_{jt}'\boldsymbol{\delta} + \rho_{j} + \epsilon_{jt}, \tag{4}$$

The remaining right-hand side variables in (4) are defined analogously to equation (3). Note that equation (4) does not decompose equation (3).

Column (3) of Table 4 reports the estimates. We do, indeed, find that separations to employment generate a much stronger vacancy-posting response than separations to non-employment: the cumulative response Π to EE-separation events is more than twice as large as the cumulative response to EN-separation events. The timing of the responses is quite similar, with approximately half of the overall effect occurring within the separation month and subsequent month. The effect of a one standard deviation separation into employment event increases the baseline vacancy-posting rate by 0.7 percentage points, or 77% over baseline; a typical separation into non-employment event increases the baseline vacancy-posting rate by 0.5 percentage points, or 55% over baseline. For these computations we use the empirical standard deviation of EE- and EN-separations, $\sigma_{s^{EE}}$ and $\sigma_{s^{EN}}$, rather than the standard deviation of the overall separation rate, σ_{s}.

These results are consistent with replacement hiring and vacancy chains: separations lead to an increase in recruitment effort by firms, presumably to replace the separator(s). This effect is much stronger for separations into employment, which provides direct evidence of shock propagation through vacancy chains. A notable feature is that vacancy-posting takes some time to materialize and the static model of column (1) captures less than a fifth of the overall effect. Furthermore, our estimates suggest that one would need to examine time periods that last at least two quarters to evaluate whether replacement hiring is taking place: our estimated lag distributions (not reported) imply that it takes around 2 months to generate half of the vacancy-posting response, another 2 months to reach three-quarters of the vacancy-posting response and then another 3 months to reach a similar proportion of the hiring response of vacancy-posting.

5 Output growth and vacancies

In this final part of paper, we examine the extent to which output growth predicts vacancy-posting. We measure output using firm revenue and value added and, since these variables are available only on a quarterly frequency, our analysis of output growth and vacancy-posting is conducted using the quarterly firm-panel (see our data description in section 2 for further details). This section presents the estimated vacancy-posting responses to revenue growth. Appendix D reports responses to value added growth, which turn out to be similar.

We document the empirical relationship between vacancy-posting, measured by the *quarterly* vacancy-posting indicator variable I_{jt}^{Q} and the *quarterly* vacancy rate v_{jt}^{Q}, and growth in log quarterly revenue $r_{jt} \equiv \log(R_{jt})$ using a set of distributed lag regressions, in line with the preceding sections.

Specifically, we estimate several variations of the following equation:

$$z_{js} = \beta + \sum_{k=0}^{6} \pi_{1,k}^{+}[\Delta r_{js-k}]_{+} + \sum_{k=0}^{6} \pi_{2,k}^{+}[\Delta r_{js-k} - \sigma_{\Delta r}]_{+} + \sum_{k=0}^{6} \pi_{1,k}^{-}[\Delta r_{js-k}]_{-} + \sum_{k=0}^{6} \pi_{2,k}^{-}[\Delta r_{js-k} + \sigma_{\Delta r}]_{-} + \mathbf{x}_{js}'\boldsymbol{\delta} + \rho_j + \epsilon_{js}, \quad (5)$$

where Δr_{js} denotes revenue growth between quarters $s-1$ and s, $\sigma_{\Delta r}$ is the cross-sectional standard deviation of Δr_{js}, $\mathbf{x}_{js}$ is a vector of quarter-dummies, industry dummies, and quarter-dummies interacted with industry-dummies, ρ_j is a firm fixed effect, ϵ_{js} is the error term, and where

$$[x]_{+} \equiv \begin{cases} x & \text{if } x > 0 \\ 0 & \text{if } x \leq 0 \end{cases} \quad \text{and} \quad [x]_{-} \equiv \begin{cases} 0 & \text{if } x \geq 0 \\ x & \text{if } x < 0 \end{cases}.$$

The dependent variable z_{js} in (5) is either the quarterly vacancy-posting indicator variable I_{js}^{Q}, in which case this is a linear probability model, or the quarterly vacancy rate v_{js}^{Q}.

Equation (5) allows flexible vacancy-posting responses to revenue growth. As before, we allow for contemporaneous and lagged growth events to impact vacancy-posting by including lag distributions, truncated at six quarters. We allow for asymmetric responses to positive and negative growth events, which we indicate by superscripting the lag weights by "+" and "−", respectively. Furthermore, we allow for separate nonlinear responses to large positive and negative growth using a linear spline specification with a single knot at the cross-sectional standard deviation of revenue growth, σ.[15]

The cumulative response to a marginal increase in revenue growth is $\Pi_1^{+} = \sum_{k=0}^{6} \pi_{1,k}^{+}$ for $\Delta r \in (0, \sigma_{\Delta r}]$, $\Pi_2^{+} = \sum_{k=0}^{6}(\pi_{1,k}^{+} + \pi_{2,k}^{+})$ for $\Delta r \in (\sigma_{\Delta r}, \infty)$, $\Pi_1^{-} = \sum_{k=0}^{6} \pi_{1,k}^{-}$ for $\Delta r \in [-\sigma_{\Delta r}, 0)$, and $\Pi_2^{-} = \sum_{k=0}^{6}(\pi_{1,k}^{-} + \pi_{2,k}^{-})$ for $\Delta r \in (-\infty, -\sigma_{\Delta r})$. Then, the cumulative vacancy posting response to a revenue growth shock of size Δr is given by

$$\Omega(\Delta r) = \begin{cases} \Pi_1^{-}\sigma_{\Delta r} + \Pi_2^{-}(\Delta r + \sigma_{\Delta r}) & \text{if } \Delta r \in (-\infty, -\sigma_{\Delta r}), \\ \Pi_1^{-}\Delta r & \text{if } \Delta r \in [-\sigma_{\Delta r}, 0), \\ \Pi_1^{+}\Delta r & \text{if } \Delta r \in (0, \sigma_{\Delta r}], \\ \Pi_1^{+}\sigma_{\Delta r} + \Pi_2^{+}(\Delta r - \sigma_{\Delta r}) & \text{if } \Delta r \in (\sigma_{\Delta r}, \infty). \end{cases} \quad (6)$$

We report $\Omega(\sigma)$, $\Omega(2\sigma)$, $\Omega(-\sigma)$, and $\Omega(-2\sigma)$.

Table 8 reports the estimates for $z_{jt} = I_{jt}^{Q}$ for 5 different specifications based on equation (5). We do not report the estimated effect of each lag and we present the dynamics of the response graphically in figure 1. Column (1) presents the estimate of the simplest specification with static, symmetric and linear effects: $\pi_{1,k}^{+} = \pi_{1,k}^{-}$ for all k and equal to zero for $k \geq 1$; $\pi_{2,k}^{+} = \pi_{2,k}^{-} = 0$ for all k. The contemporaneous effect is estimated at 1.1%, meaning that a one-standard deviation revenue shock changes the probability of vacancy-posting by 0.5 percentage points, on a baseline quarterly vacancy-posting probability of 26.4% when there are no shocks to revenues. Column (2) introduces dynamic effects: the coefficients are allowed to differ from 0 when $k = 0, 1..., 6$ but the effects are still constrained to be linear and symmetric around 0. Under this specification, the estimated effect of a revenue shock on

[15] For robustness, we have run the regressions with the knot at 0.5 standard deviations and 2 standard deviations. The results are quantitatively very similar to those we present here.

Table 8: Distributed Lag regressions of the vacancy indicator on revenue growth

Dependent variable I_{jt}^{Q}	(1)	(2)	(3)	(4)	(5)
Constant, β	0.264*** (0.000)	0.263*** (0.000)	0.260*** (0.001)	0.267*** (0.002)	0.268*** (0.004)
Π_1	0.011*** (0.001)	0.145*** (0.013)	0.170*** (0.016)		
Π_2			0.143*** (0.014)		
Π_1^-				0.163*** (0.016)	0.227*** (0.027)
Π_2^-					0.099*** (0.023)
Π_1^+				0.136*** (0.016)	0.183*** (0.027)
Π_2^+					0.078*** (0.023)
Cumul. resp. to negative 1SD Δr_{js}-shock, $\Omega(-\sigma_{\Delta r})$	−0.005*** (0.001)	−0.071*** (0.007)	−0.084*** (0.008)	−0.080*** (0.008)	−0.112*** (0.013)
Cumul. resp. to negative 2SD Δr_{js}-shock, $\Omega(-2\sigma_{\Delta r})$	−0.011*** (0.001)	−0.143*** (0.013)	−0.154*** (0.014)	−0.160*** (0.015)	−0.160*** (0.016)
Cumul. resp. to positive 1SD Δr_{js}-shock, $\Omega(\sigma_{\Delta r})$	0.005*** (0.001)	0.071*** (0.007)	0.084*** (0.008)	0.067*** (0.008)	0.090*** (0.013)
Cumul. resp. to positive 2SD Δr_{js}-shock, $\Omega(2\sigma_{\Delta r})$	0.011*** (0.001)	0.143*** (0.013)	0.154*** (0.014)	0.133*** (0.015)	0.128*** (0.016)
Dynamic effects	No	Yes	Yes	Yes	Yes
Nonlinear effects	No	No	Yes	No	Yes
Asymmetric effects	No	No	No	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes
Number of firms	18,305	18,305	18,305	18,305	18,305
Number of observations	290,846	290,846	290,846	290,846	290,846

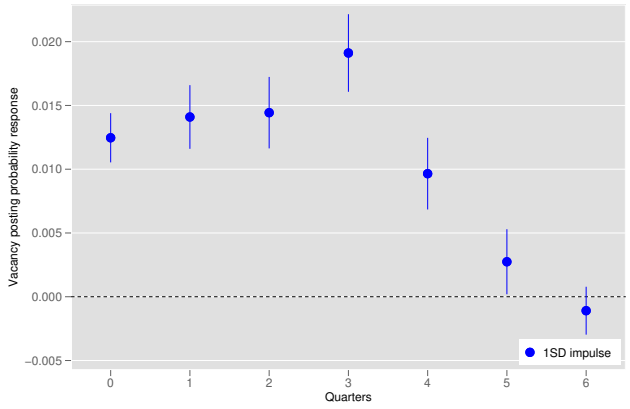
Notes: Standard errors (in parentheses) are clustered at the firm-level. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. All regressions include controls for month and industry effects and their interactions.

vacancy-posting increases more than ten-fold to 14.5% and a one-standard deviation shock is associated with a 7.1 percentage point change in the probability of vacancy-posting.

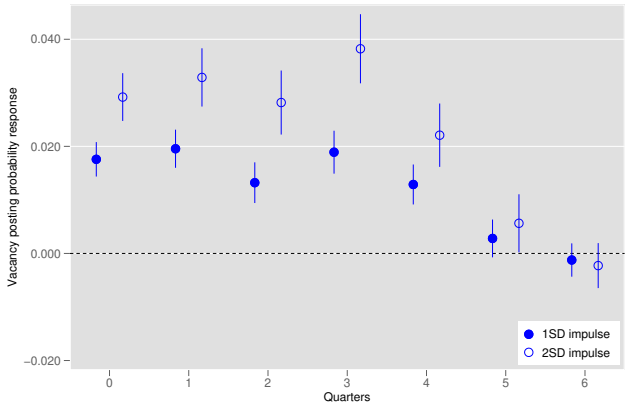
Column (3) introduces the possibility of non-linearities by allowing large revenue shocks (larger than a standard deviation in absolute value) to have a different effect on vacancy-posting than smaller shocks. The estimated effect of large shocks is quite similar to the overall effect from the linear and symmetric specification, but the effect of small shocks is approximately 20% greater than in the linear case pointing to a mildly non-linear response. Specifically, a one-standard deviation shock to revenue growth yields an 8.4 percentage point change in the probability of vacancy-posting while a two-standard deviations shock changes it by 15.4 percentage point, which is 8% lower than if the response were linear. Column (4) introduces an asymmetric vacancy-posting response to positive and negative revenue shocks, with linear effects, and the effects of negative shocks are estimated to be 20% larger than those of positive shocks.

Finally, column (5) includes asymmetric and non-linear effects and is our preferred specification. The difference between the effect of positive and negative shocks is now greater than before and the non-linearities are more pronounced. Specifically, the response of vacancy-posting to negative shocks is 25% greater than that to positive shocks, both for one- and two-standard deviation shocks, as compared to 20% greater in the linear specification of column (4). Furthermore, a one standard deviation shock changes the vacancy-posting probability by 9 or 11 percentage points (following a positive or negative shock, respectively) while a two standard deviations shock by 13 or 16 percentage points, 30% less than if the response were linear. These results suggest that asymmetries and non-linearities interact in a non-trivial way and a flexible model is required to account for the effect of revenue shocks on

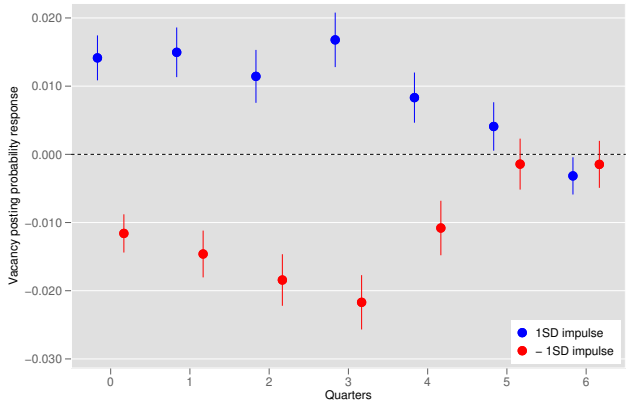
Figure 1: Distributed Lag regressions of the vacancy indicator on revenue growth



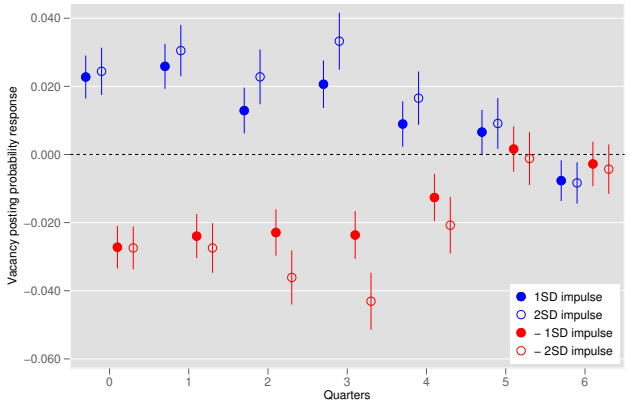
A: Estimates from Table 8, column (2)



B: Estimates from Table 8, column (3)



C: Estimates from Table 8, column (4)



D: Estimates from Table 8, column (5)

Notes: The plotted regression coefficients refer to regression specificiations tabulated in Table 8. Vertical bars represent 95% confidence intervals with clustering at the firm-level.

vacancy-posting.

The dynamic behavior of the responses is depicted in Figure 1, which graphs the impulse response of vacancy-posting to a one- and two-standard deviation shock in the four dynamic specifications that we consider (columns 2-5 in Table 8). The qualitative features of the response are quite similar across specifications: the response is significant on impact, it generally peaks three quarters later and declines thereafter, to statistical insignificance around quarter five.

A noticeable feature of our results is that the estimated impulses are significant after many quarters: vacancy-posting seemingly respond to revenue shocks that occurred a full year ahead. This result, which we also find in the value-added analysis, is quite counter-intuitive and worthy of additional study.

Table 9 repeats the regressions with the quarterly vacancy rate as the dependent variable in equation (5). The key, and only, feature of these regressions is that there appears to be no statistical relationship between the vacancy rate and revenue growth. As in our earlier analysis of the relationship between vacancy-posting and hiring, this is likely due to strong non-linearities in the response of vacancy-posting to revenue growth which are poorly captured in the specifications of equation (5).

Table 9: Distributed Lag regressions of the vacancy rate on revenue growth

Dependent variable v_{jt}	(1)	(2)	(3)	(4)	(5)
Constant, β	0.040*** (0.000)	0.040*** (0.000)	0.040*** (0.001)	0.041*** (0.002)	0.042*** (0.006)
Π_1	0.001* (0.001)	−0.007 (0.012)	−0.003 (0.012)		
Π_2			−0.006 (0.014)		
Π_1^-				−0.003 (0.019)	0.006 (0.045)
Π_2^-					−0.012 (0.011)
Π_1^+				−0.007 (0.009)	−0.010 (0.017)
Π_2^+					−0.010 (0.012)
Cumul. resp. to negative 1SD Δr_{js}-shock, $\Omega(-\sigma_{\Delta r})$	−0.001* (0.000)	0.003 (0.006)	0.002 (0.006)	0.002 (0.009)	−0.003 (0.022)
Cumul. resp. to negative 2SD Δr_{js}-shock, $\Omega(-2\sigma_{\Delta r})$	−0.001* (0.001)	0.006 (0.012)	0.005 (0.011)	0.003 (0.018)	0.003 (0.023)
Cumul. resp. to positive 1SD Δr_{js}-shock, $\Omega(\sigma_{\Delta r})$	0.001* (0.000)	−0.003 (0.006)	−0.002 (0.006)	−0.003 (0.004)	−0.005 (0.008)
Cumul. resp. to positive 2SD Δr_{js}-shock, $\Omega(2\sigma_{\Delta r})$	0.001* (0.001)	−0.006 (0.012)	−0.005 (0.011)	−0.007 (0.009)	−0.010 (0.008)
Dynamic effects	No	Yes	Yes	Yes	Yes
Nonlinear effects	No	No	Yes	No	Yes
Asymmetric effects	No	No	No	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes
Number of firms	18,305	18,305	18,305	18,305	18,305
Number of observations	290,846	290,846	290,846	290,846	290,846

Notes: Standard errors (in parentheses) are clustered at the firm-level. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. All regressions include controls for month and industry effects and their interactions.

6 Conclusions

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

We examine the effect of vacancy posting on firms' hiring rates and find a strong response which is spread over several months—hiring is thus a lengthy and potentially very costly activity. Vacancy-posting has a stronger effect on hiring from employment and such hiring generally takes longer to materialize. Turning to firm heterogeneity, we document larger response for small, low-wage and fast-growing firms and faster responses for larger, low-wage and fast-growing firms. Furthermore, the responses are highly heterogeneous across industries. We also find that separations predict vacancy posting, especially when associated with an employment-to-employment transition by the departing workers. This finding is supportive evidence for the existence of vacancy chains. Finally, we examine the relationship of firm growth, in revenue and value added, and vacancy-posting. We find that revenue and value added growth strongly predict vacancy posting, that negative growth is associated with larger responses than positive growth and that larger shocks lead to proportionally weaker responses.

References

Bagger, J., F. Fontaine, M. Galenianos, and I. Trapeznikova (2020): "On the Dynamics of Firm Employment and Output," Mimeo.

Banfi, S., and B. Villena-Roldan (2019): "Do high-wage jobs attract more applicants? Directed search evidence from the online labor market," *Journal of Labor Economics*, 37(3), 715–746.

Brodersen, S. T. N., S. Dimova, and M. Rosholm (2016): "Do ALMPs affect the demand side of the labor market? The effect of meetings with caseworkers on vacancy duration," Discussion paper, Aarhus University.

Burdett, K., and E. J. Cunningham (1998): "Toward a Theory of Vacancies," *Journal of Labor Economics*, 16(3), 445–478.

Carrillo-Tudela, C., H. Gartner, and L. Kaas (2021): "Recruitment Policies, Job-Filling Rates and Matching Efficiency," *Mimeo*.

Davis, S. J., R. J. Faberman, and J. C. Haltiwanger (2013): "The Establishment-Level Behavior of Vacancies and Hiring," *Quarterly Journal of Economics*, 128(2), 581–622.

Davis, S. J., and B. Samaniego de la Parra (2017): "Application Flows," *Working Paper*.

Elsby, M., R. Michaels, and D. Ratner (2019): "Vacancy Chains," Discussion paper, University of Edinburgh.

Faberman, R. J., and E. Nagypal (2008): "Quits, worker recruitment, and firm growth: theory and evidence," Discussion paper.

Hejlesen, M. (2016): "Documentation Spell Dataset - documentation of SAS programs used to construct initial employment observations," Discussion paper, Aarhus University.

Hershbein, B., and L. B. Kahn (2018): "Do Recessions Accelerate Routine-Biased Technological Change? Evidence from Vacancy Postings," *American Economic Review*, 108(7), 1737–72.

Lund, C., and R. M. Vejlin (2016): "Documenting and Improving the Hourly Wage Measure in the Danish IDA Database," *Danish Journal of Economics*, 1, 1–35.

Marinescu, I., and R. Wolthoff (2020): "Opening the Black Box of the Matching Function: The Power of Words," *Journal of Labor Economics*, 38(2).

Mercan, Y., and B. Schoefer (2020): "Jobs and Matches: Quits, Replacement Hiring, and Vacancy Chains," *AER: Insights*, 2(1), 101–124.

Modestino, A. S., D. Shoag, and J. Ballance (2019): "Upskilling: Do Employers Demand Greater Skill When Workers are Plentiful?," *The Review of Economics and Statistics*, Accepted, 1–46.

Mueller, A. I., D. Osterwalder, J. Zweimüller, and A. Kettemann (2020): "Vacancy Durations and Entry Wages: Evidence from Linked Vacancy-Employer-Employee Data," *IZA Discussion Paper*, 11852.

van Ours, J., and G. Ridder (1992): "Vacancies and the Recruitment of New Employees," *Journal of Labor Economics*, 10(2), 138–155.

Appendices

A Data Appendix

A.1 Industry classification of firms

To assign an industry classification to firms in the labour market spells datasets we use a separate matched employer-employee panel, the Integreret Database for Arbejdsmarkedforskning (IDA). IDA is a comprehensive matched employer-employee panel which links workers and firms via their employment relationships in the last week of November and covers the entire Danish population and all firms with economic activity. IDA is constructed, updated and maintained by Statistics Denmark using administrative records and is organized in three main components: *IDA-P* contains person-information (e.g. age, gender, education, labor market experience); *IDA-S* contains information on every establishment (physical workplace) in Denmark (e.g. location, industry classification), including a unique establishment ID (variable $LBNR$); *IDA-N* contains information on all employment relationships in the last week of November (e.g. worker ID, establishment ID, earnings and hours).

Industry information is coded according to the NACE 2.0 classification scheme. 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 classifies each establishment according to both the new and the old NACE-scheme which allows us to construct an empirical correspondence table between the old and new NACE classifications. We use the 2003 correspondence table to assign NACE 1.1 codes to the pre-2003 establishment-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 establishment-years.

We use workers' unique ID number (CPR number) to match, essentially, every person in the labor market spells data to an individual in the IDA data. In November of each year we observe every worker's employer both on the IDA dataset and the labor market spells dataset which allows us to create a mapping from the establishment ID $LBNR$ that we observe in IDA to the firm CVR number that we observe in the labor market spells data (noting that multiple establishments might be mapped to the same firm). This mapping matches more than 90% of the observations in the spells data with IDA information. We aggregate the establishment industry information to the firm-year level by assigning to a firm-year in the merged labor market spells/IDA data the industry affiliation of the establishment with the largest number of employed workers.[16]

A.2 Comparison of firms with and without vacancies

The firm panel that we construct from our three datasets before discarding the firms without online advertisements consists of approximately 125,000 firms.[17] Table A.1 provides a comparison of the subset of these firms that we use in our analysis (i.e. the firms for which we observe at least one online advertisement at some point in the observation period) with the firms that we discard (i.e. the firms for which we do not observe any online job advertisements).

The top panel of Table A.1 reports that 21,126 firms are observed to post an online job advertisement at some point during 2003M1-2009M6 and 104,575 are not. The firms used in the analysis consist of 17% of the total number of firms and make up 34% of the firm-month observations. The number of firms with job advertisements

[16] A natural alternative merging procedure where we first aggregate IDA information to the firm-level and then merge this aggregated firm-level panel to the labor market spells data by the firm ID (CVR-number) yields significantly fewer matched firm-years.

[17] This refers to the number of firms before we drop firms obeserved with fewer than seven consecutive monthly observations; see section 2.2.

Table A.1: Characteristics of firms in vacancy and non-vacancy panels

	w/ online job advert.	w/o online job advert.
Number of firms	21,126	104,575
Number of observations	1,309,417	2,569,832
Employment per firm-month	48.327	9.604
Revenue per firm-month (in DKK 1,000)	7,634.199	1,298.149
Value added per firm-month (in DKK 1,000)	2,334.244	397.798
Hires per firm-month	2.963	0.693
Net job creation	107,224	−58,407
Share of total employment	0.719	0.281
Share of total revenue	0.750	0.250
Share of total value added	0.749	0.251
Share of hires	0.685	0.315
Share of net job creation	2.196	−1.196

Notes: In May, 2021 the exchange rate of the Danish Krone to the US Dollar was approximately 1 USD = 6.2 DKK.

and the number of observations in Table A.1 are slightly larger from those used in the empirical analysis because they include some firms with fewer than 7 consecutive monthly observations which are dropped from the analysis (see section 2). The middle panel of the Table shows that the firms with observed online advertisements are, on average, five times larger in terms of employment and almost six times larger in terms of revenues and value added than firms without observed online advertisements. Moreover, firms with observed online job advertisements hired four times more workers per month and created more than 100,000 jobs over the observation period, whereas firms without observed online job advertisements shrank during the observation period, shedding close to 60,000 jobs in the process. Overall, firms with observed online job advertisements account for 72% of employment, 75% of revenue, 75% of value added, 69% of hires, and close to 120% of net job growth.

B Firm heterogeneity by value added

We replicate the analysis of section 3.3 using value added to split firms in different size, productivity and growth groups and report the results in Table B.1.

Panel A reports that the cumulative response Π to vacancy-posting is monotonically decreasing in firm size, as is the speed of the response (unlike the employment-based size measure).[18] Furthermore, the no-vacancy baseline hiring rate β is quite similar across different size groups, with the partial exception of the smallest firms.

Panel B in Table B.1 splits firms in quartiles according to value added per worker, a measure of firm productivity. The baseline no-vacancy hiring rate is decreasing in productivity and the response of the hiring rate to vacancy-posting (essentially) declines with productivity, although there is no strong pattern regarding the response's proportional change over the no-vacancy baseline. The speed of the response decreases in productivity.

Panel C in Table B.1 splits firm-years in quartiles according to each year's value added growth rate. The baseline no-vacancy hiring rate and the hiring response both have very modest U-shape in firm growth, while the response as a proportion of the baseline is modestly decreasing in firm growth. The speed of the response is increasing in firm growth.

Overall, most of these responses are qualitatively quite similar to those reported in section 3.3, using employment and wages to create similar firm groupings.

[18] Of course, the caveats regarding identification of dynamic responses among the largest firms, that post vacancies frequently and post many vacancies simultaneously, applies here as well.

Table B.1: Firm heterogeneity

		A. Quarterly value added			
Dependent variable: h_{jt}	All	$< 1M$	$1M$-$5M$	$5M$-$15M$	$\geq 15M$
No-vacancy baseline, β	0.062***	0.071***	0.056***	0.054***	0.057***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)
Cumulative response, Π	0.045***	0.091***	0.042***	0.020***	0.010***
	(0.001)	(0.003)	(0.002)	(0.003)	(0.003)
Π relative to no-vacancy baseline, Π/β	0.734***	1.284***	0.739***	0.372***	0.176***
	(0.023)	(0.048)	(0.034)	(0.058)	(0.064)
Share of Π realized within 2 months, Λ	0.652***	0.671***	0.638***	0.570***	0.103
	(0.017)	(0.019)	(0.025)	(0.073)	(0.189)
Share of months w/ vacancies	0.120	0.070	0.104	0.189	0.381
Avg. quarterly value added (mill. DKK)	7.208	0.175	2.333	8.476	76.873
Dynamic effects	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes
Number of firms	20,625	9,513	7,783	2,157	1,172
Number of observations	1,183,378	467,835	492,021	144,493	79,029
		B. Value added per worker			
Dependent variable: h_{jt}	All	1st quartile	2nd quartile	3rd quartile	4th quartile
No-vacancy baseline, β	0.062***	0.090***	0.060***	0.053***	0.049***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Cumulative response, Π	0.045***	0.049***	0.052***	0.044***	0.039***
	(0.001)	(0.003)	(0.002)	(0.002)	(0.003)
Π relative to no-vacancy baseline, Π/β	0.734***	0.539***	0.863***	0.827***	0.803***
	(0.023)	(0.040)	(0.044)	(0.048)	(0.057)
Share of Π realized within 2 months, Λ	0.652***	0.801***	0.766***	0.655***	0.381***
	(0.017)	(0.045)	(0.031)	(0.032)	(0.029)
Share of months w/ vacancies	0.120	0.137	0.102	0.114	0.129
Quarterly value added per worker (1000 DKK)	167.619	22.200	89.297	123.082	404.071
Dynamic effects	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes
Number of firms	20,625	5,157	5,156	5,156	5,156
Number of observations	1,183,378	246,389	305,559	318,666	312,764
		C. Quarterly value added growth rate			
Dependent variable: h_{jt}	All	1st quartile	2nd quartile	3rd quartile	4th quartile
No-vacancy baseline, β	0.062***	0.060***	0.058***	0.060***	0.067***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Cumulative response, Π	0.045***	0.053***	0.043***	0.044***	0.048***
	(0.001)	(0.003)	(0.002)	(0.003)	(0.003)
Π relative to no-vacancy baseline, Π/β	0.734***	0.884***	0.739***	0.722***	0.722***
	(0.023)	(0.057)	(0.046)	(0.047)	(0.055)
Share of Π realized within 2 months, Λ	0.652***	0.567***	0.631***	0.684***	0.709***
	(0.017)	(0.030)	(0.032)	(0.035)	(0.042)
Share of months w/ vacancies	0.120	0.107	0.126	0.131	0.112
Average quarterly value added growth rate	0.003	−0.356	−0.038	0.061	0.347
Dynamic effects	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes
Number of firms	20,625	15,947	14,089	14,140	15,769
Number of observations	1,183,378	262,818	306,712	304,976	255,850

Notes: Standard errors (in parentheses) are clustered at the firm-level. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. All regressions include controls for month and industry effects and their interactions.

C Separations and vacancy indicator variable

Table C.1: Separations and vacancies

Dependent variable I_{jt}^M	(1)	(2)	(3)	(4)	
				EE	*EN*
No-separation baseline, β	0.110*** (0.000)	0.098*** (0.001)	0.098*** (0.001)	0.093*** (0.001)	
Cumulative response (intercept), Π^0	0.020*** (0.001)	0.043*** (0.002)	0.043*** (0.002)	0.069*** (0.003)	0.020*** (0.003)
Cumulative response (magnitude), Π^1			0.007 (0.008)	−0.140*** (0.020)	0.025*** (0.009)
Share of Π^0 realized within 2 months, Λ^0		0.647*** (0.024)	0.662*** (0.030)	0.532*** (0.021)	0.710*** (0.075)
Share of Π^1 realized within 2 months, Λ^1			−0.026 (0.558)	0.209*** (0.050)	−0.066 (0.185)
Cumulative response to 1SD s-shock, $\Omega(\sigma)$	0.020*** (0.001)	0.043*** (0.002)	0.044*** (0.002)	0.059*** (0.003)	0.023*** (0.002)
Dynamic effects	No	Yes	Yes	Yes	
Firm fixed effects	Yes	Yes	Yes	Yes	
Number of firms	20,625	20,625	20,625	20,625	
Number of observations	1,183,378	1,183,378	1,183,378	1,183,378	

Notes: Standard errors (in parentheses) are clustered at the firm-level. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. All regressions include controls for month and industry effects and their interactions. σ_s is the standard deviation of the overall separation rate in columns (1), (2) and (3), of the separation rate to employment in column (4-EE) and of the separation rate to non-employment in column (4-EN).

We extend the analysis of Section 4 by estimating the effect on the binary vacancy indicator variable of the separation rate and the heterogeneous effect of the separation rate into employment and non-employment. We estimate the following linear probability distributed lag models for the vacancy-posting indicator variable I_{jt}^M:

$$I_{jt}^M = \beta + \sum_{k=0}^{6} \pi_k^0 \mathbb{1}(s_{jt-k} > 0) + \sum_{k=0}^{6} \pi_k^1 s_{jt-k} + \mathbf{x}_{jt}'\boldsymbol{\delta} + \rho_j + \epsilon_{jt}, \tag{C1}$$

$$I_{jt}^M = \beta + \sum_{k=0}^{6} \pi_k^{0,EE} \mathbb{1}(s_{jt-k}^{EE} > 0) + \sum_{k=0}^{6} \pi_k^{0,EN} \mathbb{1}(s_{jt-k}^{EN} > 0) + \sum_{k=0}^{6} \pi_k^{1,EE} s_{jt-k}^{EE} + \sum_{k=0}^{6} \pi_k^{1,EN} s_{jt-k}^{EN} + \mathbf{x}_{jt}'\boldsymbol{\delta} + \rho_j + \epsilon_{jt}, \tag{C2}$$

where $\mathbb{1}(\cdot)$ is the indicator function, and the remaining right-hand side variables are as in section 4. The regression (C1) includes a linear effect on the magnitude of the separation event (superscript "1") and a dummy variable and its lagged values (superscript "0") for any separations $\mathbb{1}(s_{jt-k} > 0)$. Similarly regression (C2) includes linear effects on the magnitude of the separation events into employment and into non-employment and dummies for any separations into employment and into non-employment.

The dummy variables capture the large inaction that we observe in the data (roughly half of firm-months feature $s_{jt} = 0$) and is necessary for the specification with the vacancy indicator variable. We estimated the effect of the separation rate on the vacancy rate including such a dummy variable and, in that specification, the intercept response is quantitatively insignificant and does not meaningfully change the other estimates. Since this variable only affects the specification when the dependent variable is the I_{jt}^M, we only include it in this analysis.

We estimate a model where the dummy variable is the only regressor and affects vacancy-posting statically (column 1) or dynamically (column 2). Column (3) introduces linear effects. Comparing columns 1 and 2 we conclude that dynamic effects are important, more than doubling the response to a 1SD separation event on the probability of posting a vacancy from 2.0 to 4.3 ppts, corresponding to a 44% increase over the baseline. The linear effect on column (3) is quantitatively and statistically insignificant and, therefore, the magnitude

of the separation event does not have additional predictive power. Column (4) reports the estimates of the heterogeneous effects of separations into employment and non-employment. A 1SD separation-to-employment event increases the probability of vacancy-posting by 5.9 percentage points, which is almost three times larger than the effect of a 1SD separation-to-non-employment event.[19] The probability of vacancy-posting increases by 64% over the baseline no-separation vacancy posting probability after a 1SD separation-to-employment event, and by 25% after a 1SD separation-to-non-employment event. Overall these results are qualitatively similar to the results of Section 4: separations predict vacancy-posting in a statistically and quantitatively significant way, the estimates are considerably larger when dynamics effects are included and separations to employment are associated with more vacancy-posting.

D Value added growth and vacancy-posting

Table D.1: Vacancies and value added growth

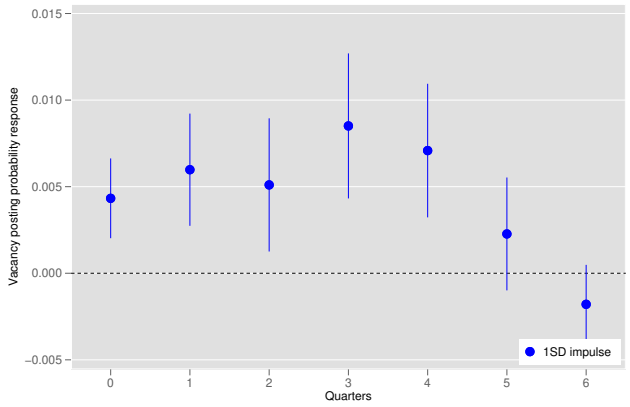
Dependent variable I^Q_{js}	(1)	(2)	(3)	(4)	(5)
Constant, β	0.264^{***} (0.000)	0.269^{***} (0.000)	0.269^{***} (0.001)	0.270^{***} (0.002)	0.269^{***} (0.005)
Π_1	0.001 (0.001)	0.038^{***} (0.011)	0.063^{***} (0.014)		
Π_2			0.048^{***} (0.016)		
Π_1^-				0.076^{***} (0.015)	0.087^{***} (0.021)
Π_2^-					0.051^{**} (0.022)
Π_1^+				0.069^{***} (0.015)	0.084^{***} (0.020)
Π_2^+					0.044^{**} (0.022)
Cumul. resp. to negative 1SD Δy_{js}-shock, $\Omega(-\sigma_{\Delta y})$	-0.001 (0.001)	-0.031^{***} (0.009)	-0.052^{***} (0.011)	-0.062^{***} (0.012)	-0.071^{***} (0.017)
Cumul. resp. to negative 2SD Δy_{js}-shock, $\Omega(-2\sigma_{\Delta y})$	-0.001 (0.001)	-0.063^{***} (0.019)	-0.091^{***} (0.023)	-0.125^{***} (0.024)	-0.114^{***} (0.026)
Cumul. resp. to positive 1SD Δy_{js}-shock, $\Omega(\sigma_{\Delta y})$	0.001 (0.001)	0.031^{***} (0.009)	0.052^{***} (0.011)	0.057^{***} (0.012)	0.069^{***} (0.017)
Cumul. resp. to positive 2SD Δy_{js}-shock, $\Omega(2\sigma_{\Delta y})$	0.001 (0.001)	0.063^{***} (0.019)	0.091^{***} (0.023)	0.114^{***} (0.024)	0.106^{***} (0.026)
Dynamic effects	No	Yes	Yes	Yes	Yes
Nonlinear effects	No	No	Yes	No	Yes
Asymmetric effects	No	No	No	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes
Number of firms	17,897	15,649	15,649	15,649	15,649
Number of observations	255,856	210,465	210,465	210,465	210,465

Notes: Standard errors (in parentheses) are clustered at the firm-level. ***, ** and * indicates statistical significance at the 1, 5, and 10 percent level, respectively. All regressions include controls for month and industry effects and their interactions.

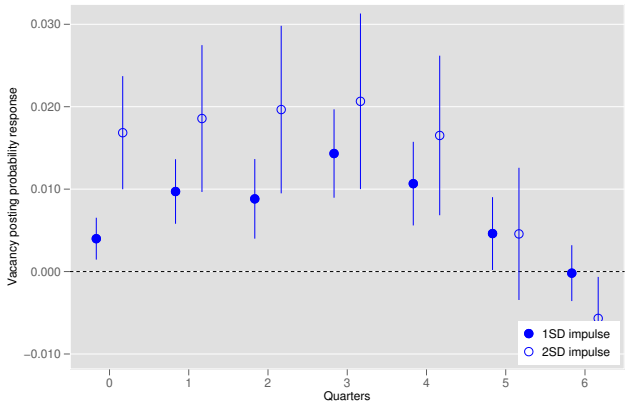
Table D.1 reports the estimates from a set of regressions similar to those in Table 8, with value-added growth on the right-hand side and the vacancy indicator variable on the left-hand side. As with revenues, having the vacancy rate as a dependent variable yields quantitatively and statistically insignificant estimates, so we do not report estimates of that specification. In Table D.1, $\sigma_{\Delta y}$ indicates 1SD in the cross section distribution of quarterly value-added growth. The pattern of value added growth's effect on vacancy-posting is similar to that of revenue growth, with somewhat smaller magnitudes. The magnitude of the vacancy-posting response increases when including dynamic, non-linear and asymmetric effects. Negative growth events have a stronger effect on vacancy-posting than positive growth events and there is evidence of non-linearities. Figure D.1 presents the timing of the vacancy-posting response which, again, features longs lags.

[19] As in the specification presented in the main text, the reported responses to 1SD separation events into employment and non-employment are computed using the empirical cross sectional standard deviations of s^{EE} and s^{EN}, respectively.

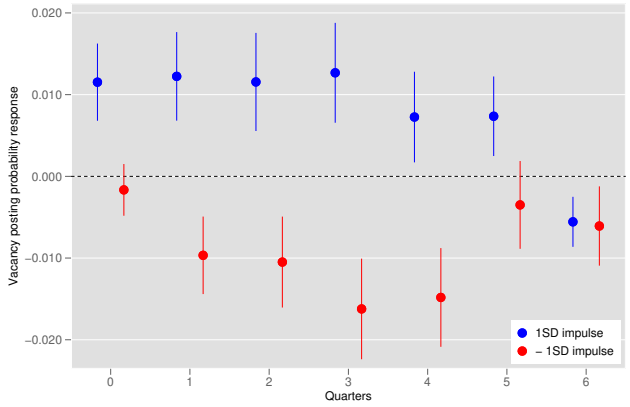
Figure D.1: Vacancies and value added growth



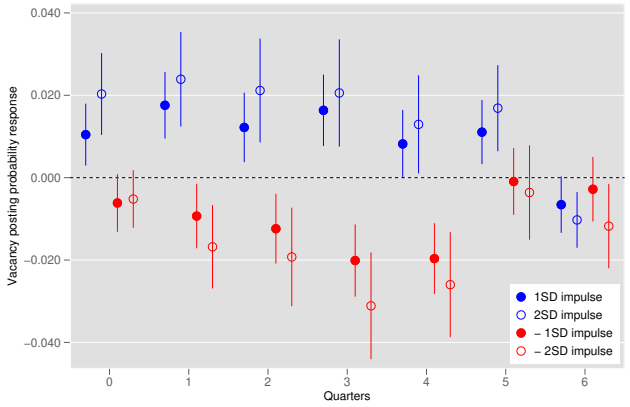
A: Estimates from Table D.1, column (2)



B: Estimates from Table D.1, column (3)



C: Estimates from Table D.1, column (4)



D: Estimates from Table D.1, column (5)

Notes: The plotted regression coefficients refer to regression specifications tabulated in Table D.1. Vertical bars represent 95% confidence intervals with clustering at the firm-level.