Short-Time Work in Germany during the Great Recession: A Quantitative Investigation*

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June 15, 2016

PRELIMINARY AND INCOMPLETE

Abstract

We study the employment and welfare effects of short-time work in Germany during the recession between 2008 and 2010. Using matched employer-employee data of the universe of workers and employers for the metropolitan area of Nuremberg, we document a set of stylized facts on short-time. We exploit plausibly exogenous variation in the timing of the recession per industry and changes in the implementation of the policy to estimate the causal effect of short-time work on job destructions. We then develop and estimate an equilibrium search model in which worker-firm matches are subject to productivity shocks that differ in expected duration. After observing the realization of productivity, a worker-firm match decides whether to work full-time, lay off the worker, or use short-time work. Employed workers accumulate human capital whereas unemployed workers' human capital depreciates. Laid off workers can be recalled by their previous employers. We find that for every four workers on short-time work, one job was saved during the recession.

1 Introduction

2 Background: Short-Time Work in Germany

Short-time work has existed in Germany for almost a century. When a firm faces temporary and unavoidable financial difficulties, it can reduce its workers' hours and reduce pay proportionally instead of laying workers off. Workers then receive between 60 and 67 percent of their lost after-tax income from the unemployment insurance system.

While working short-time, the worker's social security contributions are paid in full on the worker's regular full-time salary. In Germany, social security contributions are split between the employer and the worker. These contributions include payments for pension, health, disability,

*This study uses various administrative data sources from the Institute for Employment Research (IAB) and the German Federal Employment Agency (BA). Data access was provided via on-site use at the FGDir of the IAB. We are grateful to the director of the IAB, Joachim Moeller, and his research staff, particularly Florian Lehmer, for their hospitality and for making this research project possible. We also thank the staff of the Research Data Centre (FDZ) at the IAB for providing the data. We thank Hanming Fang, Guido Menzio, and Andrew Shephard for guidance and valuable feedback. We are grateful to Qing Gong, Rossa O'Keeffe-O'Donovan, Nick Janetos, and Kris Shaw for helpful comments.

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and unemployment insurance. In total, social security contributions can amount to as much as 40% of a worker's gross salary. The short-time worker is only responsible for paying social security contributions on the reduced salary. The employer has to pay the remaining share including the worker's share of the reduced income. These social security contributions represent the main direct costs that employers incur when firms make use of short-time work.

There are three versions of short-time work: Business cycle short-time compensation is paid to workers that are adversely affected during recessions. Seasonal short-time compensation is paid to workers affected by the seasons (e.g. construction or tourism). Restructuring short-time compensation is paid to workers at firms that are wound down. Here and throughout, we focus on business cycle short-time compensation only as the other two instrument are hardly used in practice. Business cycle short-time compensation is largely a discretionary policy instrument for two reasons: First, the federal government needs to determine whether to make short-time compensation available during a particular period. Second, the Federal Employment Agency decides whether to approve firms' applications for short-time work on a case-by-case basis. Employers have to prove necessity, in particular, employers need to show that the current difficulties are unavoidable and temporary.

During the recessionary period between 2008 and 2010, the rules for short-time work were adjusted repeatedly to make it more attractive to workers and firms. In particular, beginning in 2009, the Federal Employment Agency began to approve virtually all requests for short-time work. In addition, in January and February 2009 three additional changes were implemented:

- Employers can implement short-time work on a per-worker level as long as the reduction in monthly working hours surpasses a minimum threshold of 10%. Previously, employers could only apply for short-time work if they reduced earnings of at least 33% of the workforce by at least 10%.
- The maximum duration for short-time compensation receipt is extended from 12 months to 18 months.
- The government pays for 50% of the social security contributions on the reduced part of worker's income. Before the employers was responsible for the entire social security contributions of reduced part on worker's income. For short-time workers with spells exceeding six months, the government pays 100% of the social security contributions on the reduced part of workers' income.

The recession between 2008 and 2010 was not the only period in which the German economy has heavily used short-time work arrangements. The recessions in the 1970s and 1980s saw similar levels of short-time work as in the recession between 2008 and 2010. In contrast, the recession in the early 2000 was not accompanied by a substantive increase in short-time work, highlighting the fact that the implementation of short-time work is largely discretionary.

3 Data

3.1 Data Sources

We use three administrative data sources provided by the *Institute for Employment Research* (IAB), the research unit of Germany's Federal Employment Agency (BA). The IAB makes German social security records available to researchers in various data products that are widely used. Yet, none of those contain information on short-time compensation. In Germany, short-time workers are

considered full-time employees for social security purposes since social security contributions are paid on the worker's regular full-time salary. As German administrative data sources solely collect data that are relevant for social security purposes, short-time work or hours worked are not separately recorded.

The first of our three data sources contains short-time compensation records for the universe of workers in the Nuremberg metropolitan area. Employers with short-time workers send monthly reports to the Federal Employment Agency. These reports contain a list of short-time workers in the previous months, their reduction in working hours, their regular salary, and the amount of short-time compensation that each worker is entitled to. The agency transfers the total amount of short-time compensation to the employer. Workers then receive their reduced wage and short-time compensation through their employer's payroll system.

The Federal Employment Agency has divided Germany into 178 districts.[1] Firms interact with the branch of the Federal Employment Agency in their district.

The IAB digitized firms' typewritten reports for short-time compensation between June 2008 and December 2010 that were submitted to the Nuremberg district of the Federal Employment Agency. [2] This digitized data set contains information on individual workers' use of short-time work, a unique worker identifier, a unique firm identifier, the number of reduced hours, regular earnings, and short-time compensation received.

Our data set includes all short-time work applications submitted to the employment agency in Nuremberg. However, it does not necessarily include the records for every short-time worker who lived or worked in the Nuremberg area. Firms that manage their payroll outside of Nuremberg may have applied for short-time compensation at a different branch of the Federal Employment Agency.

Our second data source is the universe of German social security records made available by the IAB in their *Integrated Employment Biographies* (IEB).[3] The IEB contain information for all individuals that are employed subject to social security contributions (which excludes civil servants and the self-employed) and individuals who receive unemployment insurance or social assistance. From the universe of German social security records, we select every individual with at least one employment or unemployment spell in the Nuremberg area between January 2000 and December 2014. For each individual, we observe the entire employment biography starting in 1975 up until 2014. The employment biographies are spell data and can contain multiple spells per person. The employment biographies contain information on all work and unemployment spells, wages, age, gender, occupation, vocational training, and education. Earnings data is reported before taxes and capped at the social security contribution threshold (which corresponds to monthly earnings of EUR 5,950 in 2014). For each employed worker we observe an employer identifier (on the establishment level), which allows us to compare individuals to their co-workers. Information is also recorded when individuals interact with Federal Employment Agency because they are looking for jobs — even if they are concurrently in full-time employment or out of the labor force. The employment biographies notably do not contain any information on short-time compensation or hours worked.[4] In particular, short-time workers appear as full-time employees in the IEB.

[1] This number refers to 2009. The districts are redrawn on a regular basis. We use the geographic definitions from 2009 throughout this paper.

[2] The district of the employment agency of Nuremberg comprises Nuremberg, Erlangen, Fuerth, Lauf, Schwabach, and parts of Roth. Throughout the paper we will refer to this district as the "metropolitan area of Nuremberg." Note that employment agency districts were redrawn in January 2013. Today's Nuremberg district is substantially smaller.

[3] The IEB are the source for the Sample of Integrated Labor Market Biographies (SIAB), the 2% sample of German social security records that is commonly used by empirical researchers.

[4] We observe a part-time dummy.

	Mean	SD	p25	p50	p75	N
Experience	13.57	9.40	5.33	12.08	20.75	4,541,738
Tenure	7.10	7.37	1.50	4.33	10.33	3,983,728
Occupation Tenure	8.28	8.10	1.83	5.42	12.83	3,983,728
Earnings	3,109.65	1,347.36	2,124.72	2,904.01	4,023.51	3,984,362
Age	40.63	11.15	31.00	41.00	49.00	4,541,738
Female	0.38	0.48	0.00	0.00	1.00	4,541,738
Manufacturing	0.31	0.46	0.00	0.00	1.00	3,974,890

Table 1: Summary Statistics

Note: The summary statistics refer to a snapshot taken at January 1 for each year between 2000 and 2014. The sample is restricted to individuals who live in the Nuremberg area and are aged 19 to 65. By construction, the sample does not include civil servants or the self-employed.

We transform the spell data into a monthly panel. For each month, we classify individuals as full-time employed, part-time employed, unemployed, or out of the labor force. If a month contains multiple spells, we use the longest spell to determine an individual's employment status. We link workers' employment biographies to the Nuremberg-area worker-level data on short-time work and augment workers' monthly employment biographies with information on short-time spells between June 2008 and December 2010.

The third data set contains establishment-level data collected and maintained by the Federal Employment Agency. It contains the entire population of German firms with information on the number of short-time workers at the establishment level and the average reduction of hours due to short-time compensation. This information is recorded on a monthly basis and covers the time period from January 2009 to March 2011. We combine this data set with our other sources using a unique establishment identifier. We this employer level information to address measurement error concerns. As mentioned previously, the Nuremberg data underreports the short-time status of workers if their employers applied for short-time compensation through a branch of the Federal Employment Agency outside of Nuremberg.

Combined, these three data sources contain the universe of workers and firms in the metropolitan area of Nuremberg with detailed information on short-time compensation utilization on both the individual worker and the firm level. The data set used in this paper is unique as it is the only data set for Germany that combines information on short-time work with worker-level biographies.

3.2 Descriptive Analysis

In this section, we explore the data and carve out some stylized facts on short-time work and unemployment in Nuremberg during the recession. We proceed in four steps. First, we take a look at the Nuremberg labor market in aggregate. Second, we then investigate who the short-time workers are and how they differ from workers who continue to work fulltime and from workers who get laid off. Third, we show at how short-time workers careers evolved after their short-time spell. Fourth, we take a look at the role of the durations of industry-specific recessions on the uptake of short-time work and layoffs.

The Nuremberg Labor Market

The Nuremberg district of the Federal Employment agency is pre-dominantly urban and is composed of the city of Nuremberg, the city of Erlangen, the city of Fuerth, and surrounding areas.

In 2009, this district had a population of about 1.2 million. The Nuremberg area is an industrial stronghold. About one third of the work force is employed in manufacturing. Items manufactured in the area include electrical equipment, mechanical and optical products, motor vehicles and motor vehicle parts, and printing. Among the largest employers in the district are companies such as Siemens, Schaeffler, Bosch, MAN, and adidas.

For our primary data set we select all individuals with their main place of residence in the Nuremberg district.[5] Per month, we observe about 470,000 such individuals between the age of 19 and 65. Throughout our data set, people enter and leave the Nuremberg area. For individuals who enter the Nuremberg area, we observe their full employment biography prior to entering the Nuremberg area, which we use to construct workers' employment histories including experience and tenure.

Table 1 contains summary statistics for our primary data set from 2000 to 2014. For each of the 15 years in our data, we take a snapshot on January 1. The average person in our data set is approximately 41 years old with about 12 years of work experience and about 7 years of tenure. The median earnings before taxes equals about EUR 2,700. **To do** (1)

In Figure 1, we show the unemployment and short-time rates for Germany and Nuremberg. We define the short-time rate as the number of short-time workers divided by the labor force. Short-time uptake in Nuremberg closely mirrors the rest of the country. Short-time work begins to increase in late 2008, then peaks at about 3.5% in the first half of 2009, and subsequently decreases to almost zero by the end of 2010. Even though the information on short-time work in our data set is limited to the time period between June 2008 and December 2010, the aggregate data suggests that our data covers the relevant time period in its entirety. While the short-time rates for Germany and Nuremberg look very similar, the Nuremberg unemployment rate is consistently lower than the nation wide average. The make up of the Nuremberg labor force differs from Germany as a whole, as Nuremberg relies more heavily on manufacturing and its labor force tends to be younger and more educated than the rest of the country. **To do** (2)

Who are the short-time workers?

Short-time work predominantly affected workers in manufacturing. In Figure 2, we plot short-time and unemployment rates by sector. Unemployed workers are classified according to the sector of their most recent employer. In manufacturing, 10% of the entire workforce was on short-time work in the first half 2009. However, even among workers in manufacturing, there exists substantial heterogeneity in short-time work utilization. In Table 2, we list the top ten industries and occupations by short-time work uptake using four-digit industry and occupation codes. Within manufacturing, we observe a wide range of industries including industrial machinery, metal production, motor vehicle parts, electrical equipment, transportation, information technology and computer services. In addition, we observe a wide variety of occupations that are affected by short-time work including production workers and white collar back office staff.

In Figure 3, we break down the unemployment and short-time rates by age, work experience, and education. The patterns for short-time workers and unemployed workers markedly differ along all three dimensions. The short-time rate is modestly increasing in age, whereas unemployment is u-shaped in age. Short-time rates are increasing in experience, while unemployment

[5] Alternatively, we could have selected our main data set based on place of work. However, using the place of residence allows us to use the same clearly defined sample definition for unemployed and employed workers. This avoids changes in the composition of our data due to changes in labor supply. Whenever we are interested in the composition of the workforce on the firm-level, we use data on *all* workers employed at the establishment, even if these workers live outside the Nuremberg district.

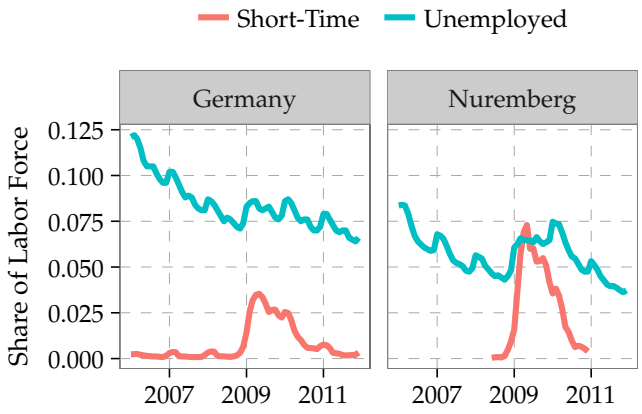

Figure 1: Unemployment and Short-Time Rates in Germany and Nuremberg

Note: The left panel shows the official unemployment and short-time rates for Germany. The latter contains both seasonal and business cycle short-time work. The right panel shows the unemployment and short-time rates for Nuremberg as reported in our data. The short-time series excludes seasonal short-time work and underreports the true extent of short-time uptake, because some firms report their short-time workers to branches of the Federal Employment Agency other than Nuremberg. In the Nuremberg data, we only observe short-time status between June 2008 and December 2010.

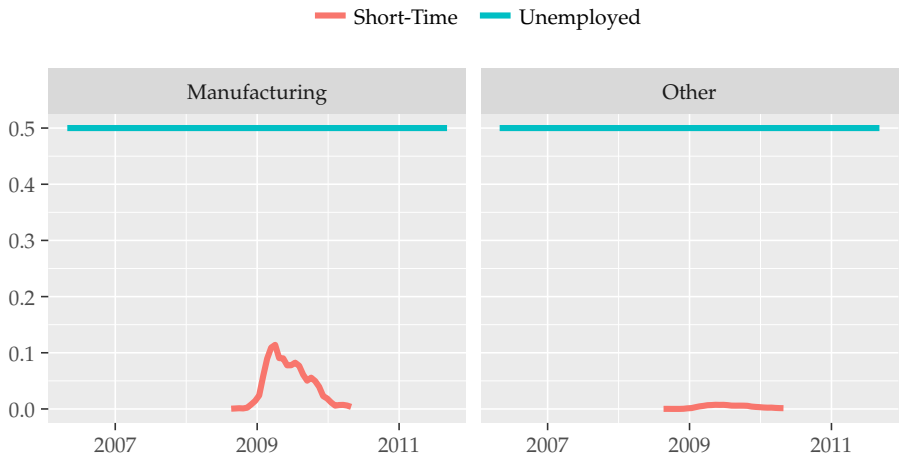

Figure 2: Unemployment and Short-Time Rates by Sector

	Number	Industry
1	149,114	Installation of industrial machi...
2	8,185	Casting of light metals
3	7,852	Repair of electronic and optical...
4	7,359	Manufacture of other parts and a...
5	4,910	Manufacture of other electrical ...
6	4,380	Activities of head offices
7	4,246	Other transportation support act...
8	3,577	Repair of other equipment
9	3,128	Other non-ferrous metal producti...
10	2,789	Manufacture of fasteners and scr...
11	81,711	Other

	Number	Occupation
1	33,946	Occupations in machine-building ...
2	33,822	Office clerks and secretaries (w...
3	19,822	Occupations in electrical engine...
4	14,330	Occupations in technical researc...
5	14,107	Occupations in warehousing and l...
6	13,145	Occupations in metalworking: cut...
7	12,349	Occupations in metalworking (wit...
8	10,134	Occupations in tool making
9	8,277	Technical occupations in the aut...
10	8,274	Machine and equipment assemblers...
11	104,354	Other

Table 2: Top 10 Industries and Occupations by the Number of Short-Time Worker-Months

Note: The table on the left shows the top 10 industries by the number of short-time worker-months using a four digit industry code. The table on the right shows the top 10 occupations by the number of short-time worker-months using a four digit occupation code.

sharply decreases as workers gain more experience. Short-time rates are approximately constant across education categories. In contrast, unemployment sharply decreases in education.

When comparing the unemployment and short-time rates of different subpopulations, we are comparing very different groups of workers. For instance, short-time workers are mostly made up of workers who recently transitioned from full-time work to unemployment. The pool of unemployed workers includes both the recently laid-off and the long-term unemployed. To better understand who the short-time workers are, it is instructive to compare workers who transition from full-time to short-time work with workers who transition from full-time to unemployed and workers who stay in full-employment.

In Table 3, we show the characteristics of full-time workers in the month before they transition into a new state. Workers can either be laid off (top row), enter short-time work (middle row), or stay in full-time employment (bottom row). Workers who end up on short-time tend to be about 42 years of age, almost four years older than the average worker who is laid off. Short-time workers also tend to earn more than both workers who are laid-off, have more work-experience and more tenure than workers who continue to work full-time or are laid off. We also compare residual wage earnings across groups after running a Mincer regression, in which we control for education, age, tenure, and experience.[6] After controlling for unobservables, the residual wages for unemployed workers at the time of layoff are 21% lower than predicted by their observables. The residual wages for short-time workers are 2% lower than predicted by their observables. The residual wages for workers who continue to work full-time are equal to zero, which is almost by construction as the workers who continue to work full-time make up the vast majority of observations.

Table 3 compares workers across employers. Which of these differences between full-time, short-time, and laid-off workers continue to hold once we only compare workers who work for the same employer? We use the unique firm identifiers in our data to compare individual workers to their co-workers. Table 4 shows how workers who transition from full-time to short-time, unemployment, or stay in full-time employment differ from their co-workers. We find that short-time workers tend to be slightly younger than their co-workers who continue to work full-time. Short-time workers also earn about EUR 120 less per month. However, short-time workers tend to have more experience and tenure than their colleagues. Workers who are laid off are younger,

6 **To do** (3)

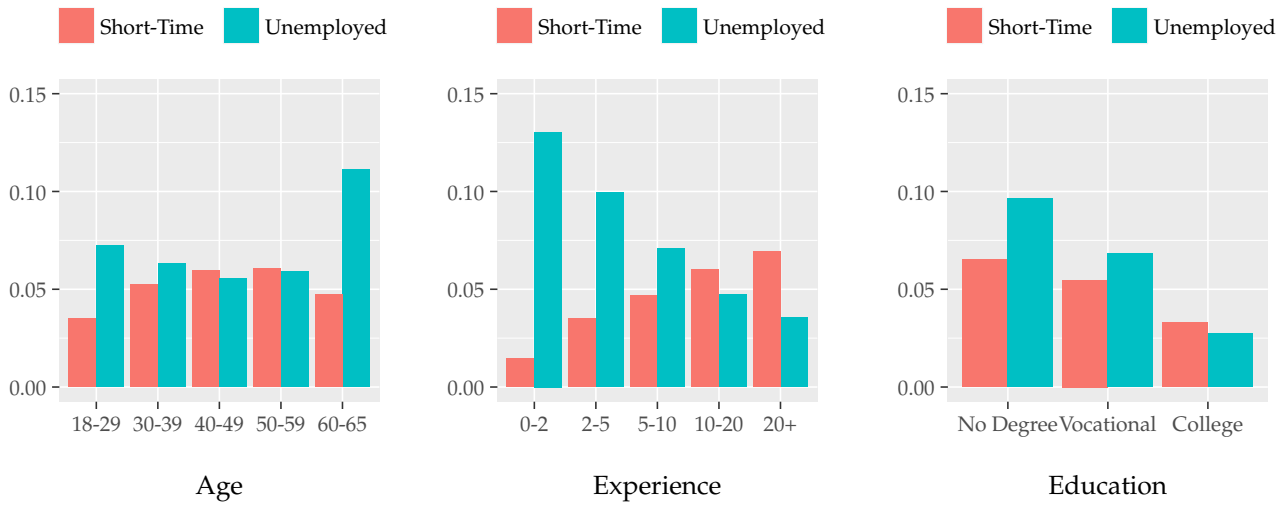

Figure 3: Unemployment and Short-Time Rates by Age, Experience, and Education

Note: The left panel shows unemployment and short-time rates by age. The middle panel shows unemployment and short-time rates by work experience. The right panel breaks unemployment and short-time uptake down by education.

earn less, and have less work experience and less tenure. Note that even though short-time workers tend to have more experience and longer tenures than their co-workers, they tend to earn *less*. Relative to their co-workers, laid-off workers' residual wages are 4% lower than their co-workers'. Short-time workers' residual wages are 1% lower than their co-workers. Within the firm, there appears to be a clear hierarchy in terms of both wages and residual wages: Workers who continue full-time earn more than short-time workers who in turn earn more than workers who are laid off.

The left panel of Figure 4 shows the distribution of durations for both short-time work and unemployment spells that started between June 2008 and December 2010. Short-time work spells tend to be shorter than unemployment spells. The right panel of the same figure shows the distribution of weekly short-time hours, i.e. the number of hours for which workers received short-time compensation. The average hours reduction equals a little bit more than 10 hours per week.

What happened to short-time workers?

What happened to workers after they were put on short-time work? In the left panel of Table 5 we show the destinations of all short-time workers in our data once their short-time spell ends. We focus on workers' initial short-time spell in our sample. The overwhelming majority, 95.7%, returns to their previous employer and resumes working full-time. On average, these workers spend 5.65 months in short-time work. Only 2.1% of short-time workers switch jobs from short-time work to employment with a different employer. Only a negligible fraction (0.6%) of short-time workers transitions from short-time work into unemployment. The number of short-time workers who either leave our data set (i.e. leave the labor force or accept a job that is not subject to social security contributions) or switch to part-time employment is 1.6%.

In contrast, the picture looks very different for workers who were laid off. In the right panel of Table 5 we show the destinations of all laid-off workers in our data once their unemployment spell ends. We limit our attention to unemployment spells that began between June 2008 and

	Age	Experience	Occ. Tenure	Tenure	Wage	Residual
Layoff	38.15	10.12	5.00	2.57	1924.96	-0.22
	(11.80)	(8.84)	(6.55)	(4.41)	(1014.53)	(0.41)
Short-Time	41.69	16.73	11.34	9.26	3117.22	-0.02
	(10.45)	(9.31)	(8.44)	(7.54)	(1049.75)	(0.30)
Stay	40.16	14.14	9.61	7.06	3024.08	0.00
	(11.13)	(9.60)	(8.42)	(7.34)	(1393.88)	(0.39)

Table 3: Worker Characteristics before Transition

Notes: The table shows average worker characteristics at the time that a worker transitions from full-time to unemployment (first row), short-time work (second row), or stays in full-time employment (third row).

	Age	Experience	Occ. Tenure	Tenure	Wage	Residual
Layoff	-1.01	-1.57	-1.69	-1.48	-236.59	-0.06
	(9.59)	(7.09)	(5.26)	(3.60)	(674.55)	(0.30)
Short-Time	-0.04	0.09	0.10	0.22	-175.99	-0.01
	(9.92)	(8.70)	(7.73)	(6.26)	(786.98)	(0.23)
Stay	0.01	0.01	0.01	0.01	4.41	0.00
	(9.62)	(8.09)	(7.06)	(5.79)	(853.07)	(0.28)

Table 4: Worker Characteristics Relative to Co-Workers before Transition

Notes: The table shows average worker characteristics relative to co-workers at the time that a worker transitions from full-time to unemployment (first row), short-time work (second row), or stays in full-time employment (third row).

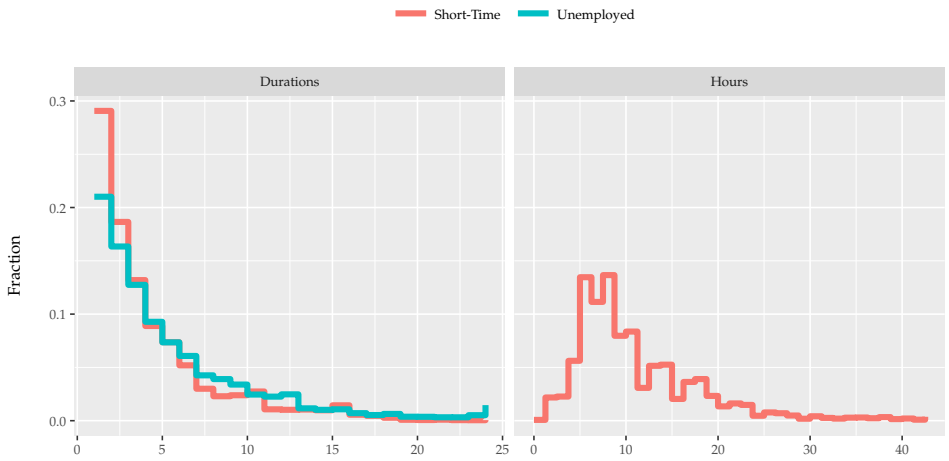

Figure 4: Distribution of Durations and Hours Reduced

Notes: The histogram on the left shows the duration of short-time work and unemployment. The data covers all short-time and unemployment spells that began between June 2008 and December 2012. The histogram on the right shows the number of short-time hours (i.e. the number of hours for which short-time compensation was received) per months.

	Short-Time Workers			Laid-off Workers		
	Count	%	Duration	Count	%	Duration
Total	51,803	100.0	5.64	124,313	100.0	6.82
Full-Time (Same Firm)	49,562	95.7	5.65	14,117	11.4	4.73
Full-Time (Switch)	1,108	2.1	5.02	68,142	54.8	6.46
Part-Time	287	0.6	7.94	15,224	12.2	7.89
Short-Time				88	0.1	5.90
Layoff	315	0.6	4.38			
Leave Data Temporarily	440	0.8	5.62	19,544	15.7	7.70
Leave Data Permanently	91	0.2	7.41	7,198	5.8	9.78

Table 5: Transition out of Short-Time Work and Unemployment

Note: The left panel of the table breaks down the destination of short-time workers in our data. The rows refer to the destination after the end of the initial short-time spell between June 2008 and December 2010. The table on the right breaks down all initial unemployment spells by destination for the same time period. In both panels, the duration column refers to months spend in short-time work or unemployment before the destination was reached.

December 2010. Among the laid-off, only about 11% return to a previous employer to work in full-time employment. Workers who are recalled spend on average 4.7 months in unemployment. About 55% of the laid off transition into full-time employment with an employer for whom they have not worked for before. Such a transition occurs after an average of about 6.5 months. Of the laid-off, a large fraction (12.2%) switches to part-time employment. An even larger fraction (21.5%) leave our data.

Table 5 indicates that short-time work presents only a temporary – though not negligible – interruption to a worker's careers. Most short-time workers return to their previous employer. Unemployment has more permanent effects, with a large number of transitions to new employers and to other employment states (e.g. part-time and leaving the labor force).

Above, we looked at the immediate transition that followed a short-time work spell. We now turn to the longer-run consequences of short-time work. Especially, we try to establish stylized facts of how the consequences of short-time work differ from the consequences of being laid-off. We borrow some of the methodology used in the literature on scarring effects (e.g. Jacobson, LaLonde, and Sullivan (1993) and Davis and von Wachter (2011)). We select from our data all individuals who are in full-time employment in January 2009 with at least six months of tenure in the current job. As in the literature on scarring effects, we drop all individuals who do not return to work in a full-time job for at least six months between their initial transition to short-time work or unemployment and December 2014. We then follow these individuals over time and compare how full-time employment and after-tax earnings evolve in response to an initial transition into either short-time work or unemployment.

Throughout, we focus on after-tax earnings, because short-time compensation and unemployment insurance benefits are tax free. When we compute after-tax earnings we use a conservative approach and treat every person as a single household with labor earnings as the only source of income. We index calendar time by t, where $t = 0$ refers to January 2009. We define the variables τ_i^S and τ_i^U to refer to the time period when individual i initially transitioned from full-time work to short-time work and from full-time work to unemployment. When no such transition occurred between January 2009 and December 2014, we set the respective variable to negative one.

To capture the long-run consequences of short-time work and unemployment on future full-

time employment, we estimate the statistical model

$$y_{it} = \sum_{s=0}^{T} \alpha_s \times \mathbf{1}\{t - s = \tau_i^U\} + \sum_{s=0}^{T} \beta_s \times \mathbf{1}\{t - s = \tau_i^S\} + X_{it}'\mu + \gamma_t + \varepsilon_{it},$$

where y_{it} equals one if worker i works full-time in period t and equals zero otherwise. The coefficients α_s captures the effect of a transition to short-time work at time $t - s$ on full-time employment at time t. Similarly, β_s captures the effect of a layoff at time $t - s$ on full-time employment at time t. The coefficients γ_t refer to monthly calendar time-dummies. X_{it} is a vector of worker-specific covariates that only includes the worker's age and age squared in the most restrictive specification that we employ. In other specifications, X_{it} also includes worker characteristics at time zero, such as experience, experience squared, tenure, tenure squared, education dummies, and industry dummies. In our richest model, we also include a firm-fixed effect that corresponds to the employer at time zero. We only use covariates that are pre-determined at time zero, to make the coefficients easier to interpret.

In the left panel of Figure 5, we show the coefficient estimates for α_s and β_s for our most-restrictive specification that only includes for worker's age and calendar time. Initially, both a transition to short-time work and a layoff are associated with a large decrease in the probability of full-time employment. The estimates for α_s and β_s only diverge after about five months. Short-time workers return to full-time work faster. After ten months, a short-time work only reduces the probability of full-time employment by about 0.2, whereas unemployment reduced the probability of full-time by more than 0.3. After about 18 months, there is no detectable effect of short-time work on full-time employment. In contrast, unemployment has a long-lasting effect on full-time employment even after 48 months. Notice that for short-time workers, the coefficient estimates for α_s turn positive after about 22 months implying that short-time workers have a *higher* probability of working full-time than individuals that were not put on short-time work or laid-off at time 0. In the long-run, the gap in full-time employment between workers who were laid off at time zero and those who transitioned to short-time work at time zero is about 15 basis points.

These results are robust to the inclusion of additional worker-characteristics and firm fixed effects. In the middle panel of Figure 5, we show the estimates of α_s and β_s when include additional worker characteristics into X_{it}. In the right panel of Figure 5, we show the estimates of α_s and β_s when control for worker characteristics and firm-fixed effects.

Note that we observe similar patterns for individuals' after-tax earnings. To assess the effects on earnings, we employ the following statistical model of earnings growth:

$$\log w_{it} - \log w_{i0} = \sum_{s=0}^{T} \alpha_s \times \mathbf{1}\{t - s = \tau_i^U\} + \sum_{s=0}^{T} \beta_s \times \mathbf{1}\{t - s = \tau_i^S\} + X_{it}'\mu + \gamma_t + \varepsilon_{it},$$

where w_{it} is the sum of an individual's after tax earnings and transfers at time t. For short-time workers, w_{it} refers to the sum of after-tax wage earnings and total short-time compensation received. For unemployed workers, w_{it} refers to the amount of unemployment insurance that workers receive. For workers who ran out of unemployment insurance benefits, w_{it} refers an imputed measure of social assistance.

In Figure 6, we plot the estimates for α_s and β_s for our three different specifications of X_{it}. The initial drop in earnings for short-time workers is about 15% percent, while the initial drop in earnings for unemployed workers is about 45%. Short-time workers catch up with their peers after approximately 18 months and subsequently outperform them. Even four years after the initial layoff, unemployed workers do not catch up. These results are robust to including additional

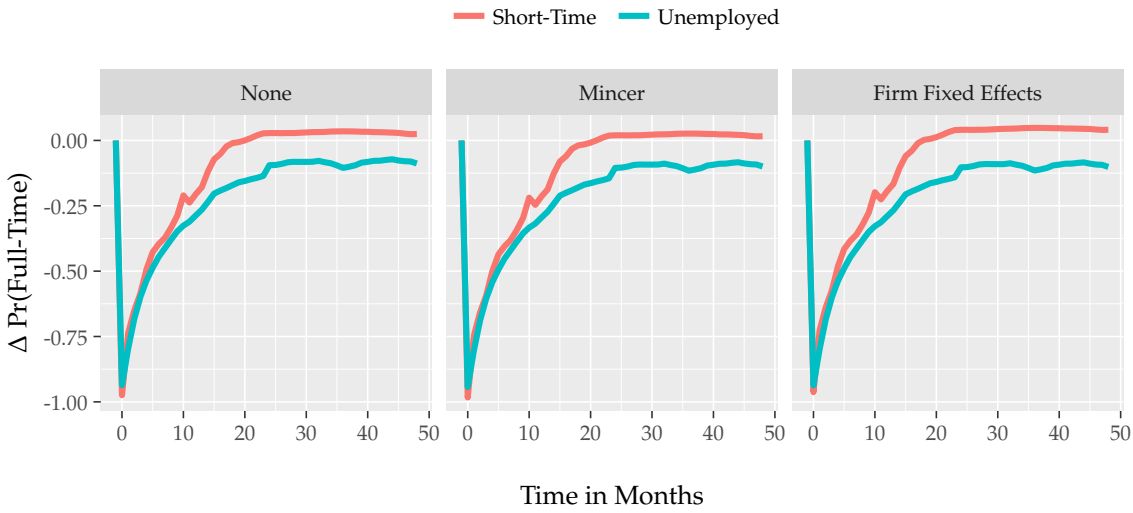

Figure 5: Evolution of Full-Time Employment

Notes: The graph shows the probability of full-time work for individuals that transitioned from full-time employment to short-time work or unemployed at time zero. In the left panel, we show the raw data. In the middle panel, we include the usual controls for Mincer regressions. All of our control variables refer to January 2009. In the right panel, we also include a fixed effect for the firm that the worker was employed at in January 2009.

Figure 6: Evolution of After-Tax Earnings

Notes: The graph shows the change in log earnings for individuals that transitioned from full-time employment to short-time work or unemployed at time zero. In the left panel, we show the raw data. In the middle panel, we include the usual controls for Mincer regressions. All of our control variables refer to January 2009. In the right panel, we also include a fixed effect for the firm that the worker was employed in January 2009.

Figure 7: Number of Short-Time Workers by Source

Notes: The graph shows the number of short-time workers by data source.

controls for worker characteristics and firm-fixed effects.

While these graphs only represent correlations, the results indicate that short-time workers do not face negative long-term consequences from the short-time spell. However, the initial loss in earnings is substantial. The average short-time workers loses about 7.5% of an annual after-tax earnings.

In our worker-level data, short-time uptake is under-reported, because we only have short-time records for employers in the Nuremberg area that reported short-time utilization to the Nuremberg district of the Federal Employment Agency. Some employers that do their payroll processing outside of Nuremberg may have reported their short-time utilization to a different district. Therefore, some of the workers that we classify as full-time employed may in fact be short-time workers. To quantify the extent of the measurement error we rely on an additional establishment-level data source that covers the period from January 2009 to March 2011. This data set has an accurate count of short-time workers (and the average reduction in hours) on the establishment level. We find that between January 2009 and December 2010, the true number of short-time worker-months is about 15% higher than reported in our worker-level data set.

3.3 Causal Inference

Thus far, our analysis of the data was entirely descriptive. In this section we attempt to make causal statements on the effects of short-time work on employment. In particular, we seek to answer the following question: How many jobs would have been destroyed if there had not been any short-time compensation?

Answering this question is difficult: Selection into short-time work depends on employer and worker characteristics that are unobserved by the econometrician. Therefore, we cannot interpret the estimates that we report in Figure 5 as causal. Short-time workers are likely to substantially differ form workers who are laid-off even after controlling for all observable characteristics in our data. Econometricians usually overcome these challenges using either variation of labor market policies across space, e.g. by using a differences-in-differences approach as commonly done for

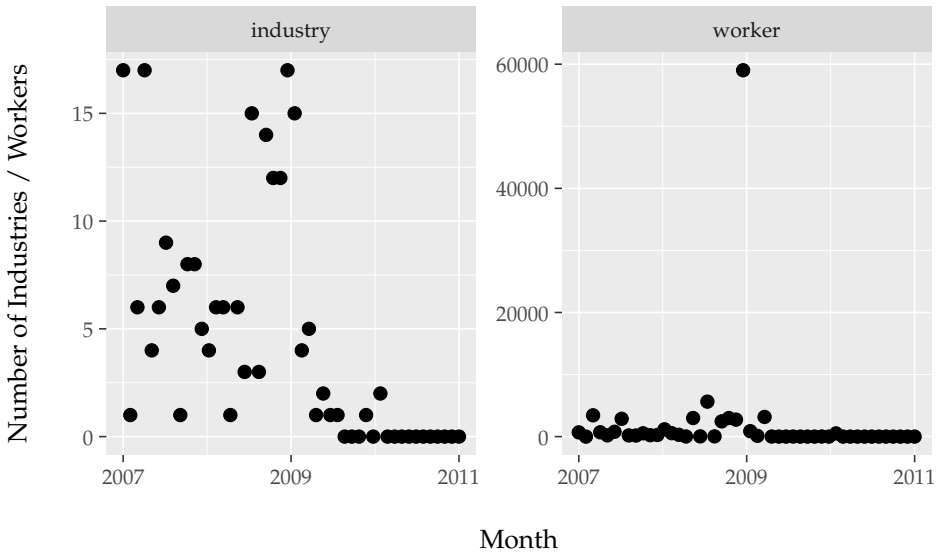

Figure 8: Number of Industries / Workers Entering an Industry-Specific Recession

Notes: The left panel shows the number of industries in manufacturing that were classified as entering an industry-specific specific recession at a particular point month. The right panel shows the number of workers that were working in an industry that was classified as entering an industry-specific recession at a particular month in time.

studies on the U.S. labor market where different states implement different policies. In our case, short-time work is a federal policy, meaning that even if we had data on more than one geographic region, we could not exploit variation in the policy across space, because there is none.

In the absence of variation across space, we will exploit variation of the policy across time, by relying on the combination of two different sources of quasi-exogenous variation. The first source of variation is a comprehensive change in the administration of short-time compensation policy in the beginning of 2009. **To do** (4) The second source of variation is that the recession affected different industries at different points in time. We establish the effect of short-time compensation on job destruction rates by comparing industries that saw their largest decline in output before January 2009 when short-time compensation was difficult to access to industries that saw their largest decline in output after January 2009 when short-time work was widely available.

We then consider the job destruction rates around around the beginning of industry specific recessions. We introduce two simple linear probability models for workers' transitions from full-time employment to unemployment and short-time work. Individual workers are indexed by i and calendar time by t. We denote the point in time when worker i's industry enters the industry specific recession by $\tau(i)$. We denote the left-hand side variable by y_{it}, which may either refer to a job destruction or a transition to short-time work.

$$y_{it} = \sum_{s=0}^{5} \alpha_s \times \mathbf{1}\{\tau(i) + s = t\} D_i^{\text{before}} + \sum_{s=0}^{5} \beta_s \times \mathbf{1}\{\tau(i) + s = t\} D_i^{\text{after}} + X_{it}'\mu + \gamma_t + \varepsilon_{it},$$

where γ_t are calendar time-dummies, D_i^{before} is a dummy that equals one if i experienced the recession before a particular cutoff date, D_i^{after} is a dummy that equals one if i experienced the recession after the cutoff. X_{it} is a vector of worker-specific covariates. α_s and β_s are our coefficients of interest. α_s is the change in job destruction rates at time s for industry i with short-time compensation

	e2u	e2u	e2s	e2s
Before	0.0018	0.0017	-0.0001	0.0001
	(0.0002)	(0.0003)	(0.0000)	(0.0000)
After	-0.0013	-0.0013	0.0108	0.0120
	(0.0002)	(0.0002)	(0.0005)	(0.0005)
Covariates	no	yes	no	yes
Calendar time dummies	yes	yes	yes	yes

Table 6: Coefficient Estimates for α and β

relative to all other industries at the same time. β_s is the change in job destruction rates at time $\tau(i) + s$ for industry i without short-time compensation relative to all other industries at the same time.

We report the estimates for α_s and β_s in Table 6 for a specification where α_s and β_s do not vary in s. We find that the average job-destruction rate is about a quarter of a percentage point higher for workers in industries that were affected by the recession before the cutoff than for workers in industries that were affected by the recession after the cutoff. As to be expected, transition rates to short-time work are zero for workers who were affected by the recession before the cutoff and are large for workers who were affected by the recession after the cutoff.

The magnitudes of the estimated difference in job-destruction rates is economically meaningful. A difference of a quarter of a percentage point corresponds to about $1,000$ layoffs per months for our sample (with a full-time employed workforce of $400,000$).

4 Model

In this section, we introduce an equilibrium search model in the tradition of Mortensen and Pissarides (1994). We add an intensive margin, temporary layoffs, and general and firm-specific human capital.

4.1 Primitives

The unit of analysis is the firm-worker match. Time is discrete and lasts forever with $t = 1, 2, \ldots$. There is a continuum of workers of measure one. Workers' per-period preferences for consumption c_t and hours worked h_t are given by $u(c_t, h_t)$, with $u_c(c_t, h_t) > 0$, $u_h(c_t, h_t) < 0$, $u_{cc}(c_t, h_t) \leq 0$. Workers discount the future with factor β.

A worker is characterized by her type $\mathbf{x}_t = [e_t, a_t]$, which captures the worker's general human capital e_t and the worker's age a_t. Both age and general human capital are modeled as ladders. Ex-ante all workers are identical and start out on the lowest rung of the age and the human capital ladders. Workers age stochastically over time climbing rung by rung of the age ladder. Workers on the highest rung of the age ladder reture with a fixed probability. General human capital also evolves stochastically. When employed, workers accumulate human capital – which may depend on hours worked. When unemployed, workers lose human capital stochastically. We denote the transition distribution function for the worker's type $\mathbf{x}$ by $\Omega(\mathbf{x}_{t+1} \mid \mathbf{x}_t, h_t)$.

There is a positive measure of firms. A firm is characterized by its match productivity $\mathbf{y}_t$. Match productivity $\mathbf{y}_t = [\mu_t, \varepsilon_t, p_t]$ is a vector that contains a persistent match value, μ_t, a shock ε_t, and the persistence of that shock p_t. When matched to a worker x_t who works h_t hours, the

firm-worker pair produces output

$$f(\mathbf{y_t}, \mathbf{x}_t, h_t) = h_t \left[\mu_t e_t - \varepsilon_t\right] \tag{1}$$

The persistent match value μ_t is modeled as a ladder. It evolves according to the transition distribution function $\Lambda(\mu_{t+1}|\mu_t, h)$. We interpret μ_t as firm-specific human capital that increases stochastically with tenure. Firm-specific human capital depreciates when the firm and worker are temporarily separated and firm-specific human capital is lost when the worker and firm permanently separate.

The aggregate state of the world is denoted by $z_t \in \{\underline{z}, \overline{z}\}$, where $\underline{z}$ refers to recessions and $\overline{z}$ to normal economic times. As made explicit in (1), The aggregate state of the economy does not affect productivity directly. It does only affect the stochastic transitions of the shocks to match productivity (ε_t, p_t), which evolve as follows:

$$(\varepsilon_{t+1}, p_{t+1}) = \begin{cases} (\varepsilon_t, p_t) & \text{with probability } p_t \\ (\tilde{\varepsilon}, \tilde{p}) & \text{with probability } 1 - p_t, \end{cases} \tag{2}$$

where $(\tilde{\varepsilon}, \tilde{p}) \sim \Gamma(\tilde{\varepsilon}, \tilde{p}|z_t)$. The magnitude of the shock is captured by ε_t. The persistence of the shock is captured by p_t. With probability $1 - p_t$, the firm-worker match draws a new tuple $(\tilde{\varepsilon}_t, \tilde{p}_t)$. With probability p_t, the firm-worker match keeps their existing tuple (ε_t, p_t). Thus, the average duration of the shock ε_t is equal to $1/p_t$. The distribution from which the magnitude and persistence are drawn, $\Gamma(\tilde{\varepsilon}, \tilde{p}|z_t)$, depends on the aggregate state of the world, z_t. The productivity process implies that workers and firms know the persistence of the productivity shock and therefore can act upon it.

The labor market is segmented by workers' types x_t. Firms enter the labor market by creating vacancies at cost c. Upon creating a vacancy, the firm chooses which labor market x_t to search in. Searching workers and open vacancies are brought together by a matching function. We denote the current state of the labor market by ζ_t. ζ_t contains the distribution of employed and unemployed workers across states at time t. We denote the tightness of the submarket x_t by $\theta(x_t, z_t, \zeta_t)$. The probability that a firm meets a worker of type x_t is given by $q(\theta(x_t, z_t, \zeta_t))$. The probability that a worker meets a firm is given by $p(\theta(x_t, z_t, \zeta_t))$. We will later show that the free entry condition implies that the market tightness will only depend on the aggregate state z_t, not on the entire distribution of workers across states, ζ_t.

Firms and workers jointly determine wages and hours through Nash bargaining. A choice of zero hours corresponds to a separation. Separations are not necessarily permanent. The Nash bargaining assumption guarantees that hours and continuation decisions are jointly efficient.

The model has two types of unemployment. First, some workers are *permanently* unemployed. These workers have no recall option. All permanently unemployed workers search for jobs and receive job offers with probability $p(\theta(x_t, z_t, \zeta_t))$. Upon meeting a firm, the worker and the firm form a match and draw their initial realization of match productivity $\mathbf{y}_{t+1}$.

Second, some workers are *temporarily* unemployed. These workers are still in contact with their previous employer. As in Fujita and Moscarini (2013), match productivity $\mathbf{y}_t$ continues to evolve. Temporary separations become permanent with probability δ_0. While in temporary unemployment, workers can be recalled to work by their previous employer instantly, e.g. in response to an improvement of $\mathbf{y}_t$. When a temporarily laid-off worker is recalled, the worker-firm match bypasses the matching function. Workers who are temporarily unemployed need to decide whether to search. We refer to temporarily unemployed workers who do not search for other jobs as rest

unemployed.[7] These workers wait for conditions in their previous job to improve. Temporarily unemployed workers who decide to search for jobs meet firms with probability $p(\theta(x_t, z_t, \zeta_t))$. Upon meeting a firm, a worker has to decide whether to form a match *before* observing the initial realization of $\mathbf{y}_t$.[8] That means that an unemployed worker with a recall option has to forgo the recall option before observing the new match value.[9]

We consider a limited set of labor market policies. Unemployed workers receive unemployment insurance benefits, $b(x_t, z_t)$ that may depend both on the workers state and the aggregate state of the economy. Workers who work reduced hours may receive short-time compensation, $s(x_t, z_t, h_t)$. The amount of short-time compensation that a worker receives is a function of the worker's type, the aggregate state of the economy, and the number of hours worked. Short-time compensation is not necessarily a linear function in hours. For instance, there may be minimum hours requirement in order to be eligible for short-time work. Unemployment insurance and short-time compensation are funded through a payroll tax. This payroll tax, $\tau(z_t, w_t)$, is levied on firms. This payroll tax may include both a lump sum and a proportional component.

4.2 Value Functions

For ease of notation, we denote a generic variable a_t by a and a_{t+1} by a'. Consider a worker of type x who works at firm $\mathbf{y}$ in aggregate state z. The expected life-utility of such a worker when working h hours and receiving a total after-tax wage of w is given by

$$W(\mathbf{y}, x, z, w, h) = u(w + s(x, z, h), h) + \beta \mathbb{E}_h \left[\overline{W}(\mathbf{y}', x', z') \mid \mathbf{y}, x, z \right], \tag{3}$$

where $\overline{W}(\mathbf{y}', x', z')$ the expected value for a type x' worker to be matched to firm y' in aggregate state z' at the beginning of next period before hours and wages are negotiated. In the expectation operator, we make the dependence on the number of hours worked explicit as these may affect the evolution of $\mathbf{y}'$ and x'.

The life-time utility of a type x worker who is unemployed without recall option is given by

$$U(x, z) \;=\; u(b(x, z), 0) + \beta \mathbb{E}_0 \big[U(x', z') + p(\theta(x, z, \zeta)) \{ \overline{W}(\tilde{\mathbf{y}}, x', z') - U(x', z') \} \mid x, z \big]. \tag{4}$$

This worker receives benefits $b(x, z)$ and receives job offers with probability $p(\theta(x, z, \zeta))$. We assume that a worker will match with every firm she meets regardless of the realization of $\tilde{\mathbf{y}}$. This assumption is without loss of generality, as the match may dissolve in the subsequent period before production takes place. In the expectation operator, we condition on the worker working zero hours, which affects the evolution of x. This is made explicit by the subscript zero.

Next consider a worker who is temporarily unemployed. Denote the current match productivity by $\mathbf{y}$ and the worker type by x. This worker's lifetime utility equals

$$\begin{aligned} W_0(\mathbf{y}, x, z) = u(b(x, z), 0) &+ \delta_0 \mathbb{E}_0 \left[U(x', z') \mid x, z \right] + (1 - \delta_0) \mathbb{E}_0 \left[\overline{W}(\mathbf{y}', x', z') \mid \mathbf{y}, x, z \right] \\ &+ (1 - \delta_0) p(\theta(x, z, \zeta)) \max \left\{ 0, \mathbb{E}_0 \left[\overline{W}(\tilde{\mathbf{y}}, x', z') \mid x, z \right] - \mathbb{E}_0 \left[\overline{W}(\mathbf{y}', x', z') \mid \mathbf{y}, x, z \right] \right\}. \end{aligned} \tag{5}$$

With probability δ_0, this worker will become permanently unemployed. With probability $1 - \delta_0$,

[7] We borrow the terminology from Alvarez and Shimer (2011).

[8] We assume that the firm always wants to form a match. This assumption is harmless, because the firm's profits are bound from below by zero as firms may dismiss the worker before production begins.

[9] This assumption allows us to close the model with entry without having to keep track of the entire distribution of unmatched workers. The assumption that match productivity is an experience good is also entertained elsewhere, e.g. in Menzio and Shi (2011).

the worker stays in touch with his current firm. The worker makes an active choice of whether to search. Since temporarily laid off workers need to forgo their recall option before observing the new productivity draw $\tilde{\mathbf{y}}$, a worker who decides to search will accept any match. We denote the decision to search by

$$S(\mathbf{y}, x, z) = \mathbf{1}\left\{\mathbb{E}_0\left[\overline{W}(\tilde{\mathbf{y}}, x', z') \mid x, z\right] > \mathbb{E}_0\left[\overline{W}(\mathbf{y}', x', z') \mid \mathbf{y}, x, z\right]\right\}. \tag{6}$$

Note that the worker makes the decision to search unilaterally.

Next, consider the value functions of the firm. A type $\mathbf{y}$ that is matched to a worker x in aggregate state z at wage w and with h hours is given by

$$J(\mathbf{y}, x, z, w, h) = f(\mathbf{y}, x, h) - w - \tau(z, w) + \beta \mathbb{E}_h\left[\overline{J}(\tilde{\mathbf{y}}, x', z') \mid \mathbf{y}, x, z\right]. \tag{7}$$

Next, consider the value function of a firm with a worker that is temporarily laid off. The continuation value depends on whether this worker searches,

$$J_0(\mathbf{y}, x, z) = \beta(1-\delta_0)\left[1 - p(\theta(x, z, \zeta))S(\mathbf{y}, x, z)\right]\mathbb{E}_0\left[\overline{J}(\mathbf{y}', x', z') \mid \mathbf{y}, x, z\right]. \tag{8}$$

Firms can post vacancies at cost c. Firms can choose which worker type x to target. When a firm chooses to target workers of type x, the firm will only meet workers of this type. The firm's value from posting a vacancy in aggregate state z is therefore

$$V(z) = -c + \max_x q(\theta(x, z, \zeta))\mathbb{E}_0\left[\overline{J}(\mathbf{y}', x', z') \mid x, z\right]. \tag{9}$$

In equilibrium, the expected value from entry will be zero. By construction, the market tightness does not depend on the distribution of workers across states. The market tightness is only a function of x and z, i.e. $\theta(x, z, \zeta) = \theta(x, z)$.

4.3 Policy Functions

We already described the search policy function $S(\mathbf{y}, x, z)$ in (6). We now characterize the employment, hours, and wage policy functions. Consider a match in state $(\mathbf{y}, x, z)$. The hours and wage policy functions solve

$$(w(\mathbf{y}, x, z), h(\mathbf{y}, x, z)) \in \underset{w,h}{\operatorname{argmax}}\left[W(\mathbf{y}, x, z, w, h) - W_0(\mathbf{y}, x, z)\right]^{\alpha}\left[J(\mathbf{y}, x, z, w, h) - J_0(\mathbf{y}, x, z)\right]^{1-\alpha}, \tag{10}$$

where α denotes the worker's bargaining power. Note that the thread point corresponds to temporary unemployment. In practice, we solve for the choice of hours on a grid, find the corresponding wage, and then pick the combination of wage and hours that maximizes the Nash product. A worker is temporarily laid-off when there exists no pair (w, h) with $w > 0$ and $h > 0$ such that

$$W(\mathbf{y}, x, z, w, h) \geq W_0(\mathbf{y}, x, z) \ \wedge \ J(\mathbf{y}, x, z, w, h) \geq J_0(\mathbf{y}, x, z)$$

We denote the corresponding dismissal policy function by

$$D(\mathbf{y},x,z)=\begin{cases}1 & \text{if } \exists (w,h)\in\mathbb{R}^2_+ \quad \text{s.t. } W(\mathbf{y},x,z,w,h) \geq W_0(\mathbf{y},x,z)\\ & \qquad\qquad\quad \wedge\, J(\mathbf{y},x,z,w,h) \geq J_0(\mathbf{y},x,z)\\ 0 & \text{otherwise.}\end{cases} \tag{11}$$

With these policy functions, we can now defined the beginning-of-period value functions $\overline{W}(\mathbf{y},x,z)$ and $\overline{J}(\mathbf{y},x,z)$. A type x worker's value from being matched to a firm of type $\mathbf{y}$ in aggregate state z is given by

$$\overline{W}(\mathbf{y},x,z)=\begin{cases}W(\mathbf{y},x,z,w(\mathbf{y},x,z),h(\mathbf{y},x,z)) & \text{if } D(\mathbf{y},x,z)=0\\ W_0(\mathbf{y},x,z) & \text{if } D(\mathbf{y},x,z)=1.\end{cases}$$

Similarly, the type $\mathbf{y}$ firm's value from being matched to a type x worker in aggregate state z is given by

$$\overline{J}(\mathbf{y},x,z)=\begin{cases}J(\mathbf{y},x,z,w(\mathbf{y},x,z),h(\mathbf{y},x,z)) & \text{if } D(\mathbf{y},x,z)=0\\ J_0(\mathbf{y},x,z) & \text{if } D(\mathbf{y},x,z)=1.\end{cases}$$

4.4 Equilibrium

A non-stationary search equilibrium consists of

- wage and hours policy functions $w(\mathbf{y},x,z)$ and $h(\mathbf{y},x,z)$
- dismissal and search policy functions $D(\mathbf{y},x,z)$ and $S(\mathbf{y},x,z)$
- market tightness $\theta(x,z)$
- workers' value functions $W(\mathbf{y},x,z,\cdot,\cdot)$, $W_0(\mathbf{y},x,z)$, and $U(x,z)$
- firms' value functions $J(\mathbf{y},x,z,\cdot,\cdot)$, $J_0(\mathbf{y},x,z)$

such that for all $\mathbf{y},x,z$

- the value functions satisfy (3), (4), (5), (7), and (8) ,
- the policy functions satisfy (6), (10), and (11), and
- free entry holds (9) with $V(z)=0$.

4.5 Discussion

5 Estimation

We estimate our model using indirect inference. For a given vector of model parameters, we simulate data from our model and then fit the same set of auxiliary models to both the simulated and the real data. We then search for the vector of model parameters that minimizes the distance between the estimates of the auxiliary models.

5.1 Auxiliary Models

In this section we detail the auxiliary models that we use for the estimation and how we construct the auxiliary models from the model-generated data.

A1 Model Appendix

A1.1 Solving the Model

A1.2 Extensions

We consider several extensions of the model.

Aggregate Demand Externality

Layoff Taxes

Credit Constraints

A2 Data Appendix

To do (5)

To do (6)

To do (7)

A3 Estimation Appendix

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To do...

- ☐ 1 (p. 5): Refer to the appendix, where we compare key summary statistics from our data set to the SIAB.
- ☐ 2 (p. 5): Refer to the appendix, where we compare key summary statistics from our data set to the SIAB.
- ☐ 3 (p. 7): Put corresponding Table in Appendix
- ☐ 4 (p. 14): Add details on the change in policy.
- ☐ 5 (p. 21): Comparison Nuremberg with SIAB
- ☐ 6 (p. 21): Include Mincer regression that corresponds to Table 3
- ☐ 7 (p. 21): Include details on how we compute after tax earnings