Employment and Welfare Effects of Short-Time Work in Germany*

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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 a unique matched employer-employee data set that contains the universe of workers and employers for the metropolitan area of Nuremberg, we document the intensive and extensive margin of short-time work. 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

Even though Germany's gross domestic product (GDP) fell by more than 5% between 2008 and 2009, unemployment only increased by half a percentage point from 8% to 8.5%. The German experience during this recession was markedly different from that of the United States,

*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.

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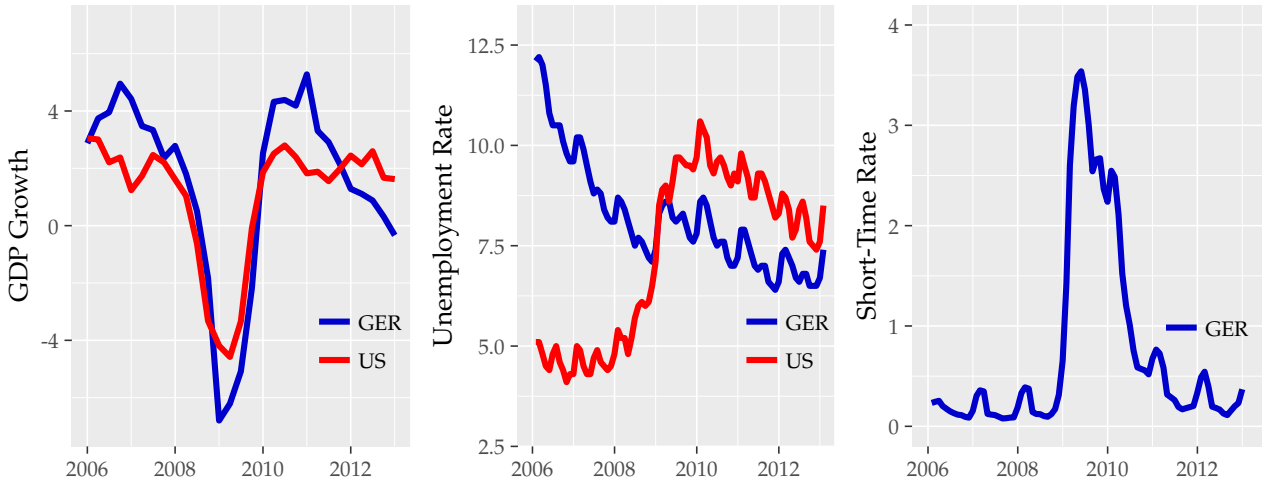
Figure 1: GDP Growth, Unemployment, and Short-Time Work



The graphs from left to right show, respectively: (i) GDP growth in the United States and Germany, (ii) the unemployment rates in the United States and Germany, (iii) the share of the labor force in short-time work in Germany. Note that even though German GDP fell by more than U.S. GDP, Germany's unemployment rate only increased slightly. At the same time, the share of German workers receiving short-time compensation soared to 3.75%.

where GDP fell by only 4.2%, but unemployment soared from 5% to more than 10% (see Figure 1). During the recession, the German labor market heavily relied on short-time work. Short-time work is a labor market instrument that allows firms to reduce their workers' hours and, proportionally, wages during a temporary downturn. Workers are then partially compensated — in Germany between 60% and 67% — for their lost income through the unemployment insurance system. While traditional unemployment insurance only pays benefits to workers that are fully laid off, short-time compensation pays benefits to workers that are *partially* laid off. At the peak of short-time work utilization in April 2009, about 1.5 million employees (or approximately 3.75% of Germany's labor force) were on short-time work. The volume of reduced working time corresponded to about 400,000 full time jobs in 2009 (or about 1% of Germany's labor force).

In this paper, we first explore who short-time workers are using detailed administrative data for a German metropolitan area. We then ask how many jobs Germany's extensive short-time scheme saved during the recession and whether short-time work improved overall welfare. To quantify the number of jobs saved, it is insufficient to only consider the volume of reduced working time, as some of the short-time workers may have continued to work full-time without short-time compensation. To quantify the welfare effects of short-time work, it is insufficient to only consider the direct costs and benefits of short-time work, as the policy may have prevented short-time workers from looking for and finding more productive matches. Therefore, our approach is structural.

We develop an equilibrium search model that features aggregate and match-specific pro-

ductivity shocks, human capital accumulation, recall, and an intensive margin. In our model, two features make short-time work distinctly different from layoffs. First, short-time workers keep accumulating human capital whereas unemployed workers' human capital depreciates. Second, short-time work keeps the connection between a worker and a firm intact, which ensures that the firm can quickly return to full production as productivity improves. When a worker is laid off, the firm can recall the worker when productivity improves. However, the firm then faces re-hiring costs. Re-hiring the worker may be impossible, for instance, because the worker has moved on and accepted a different job.

Whether firms make use of layoffs or short-time work during recessions depends on firms' expectations of how long the recession will last. Burda and Hunt (2011) argue that the reason for Germany's mild labor market response was due to the nature of the recession, which was expected to be, and was, short-lived. We explicitly model firm's expectation by allowing productivity shocks to differ in expected duration.

We use three unique administrative data sources that give a complete picture on the use of short-time compensation in the metropolitan area of Nuremberg, which, in 2008, had a population of 1.2 million, making it the fifth largest metropolitan area in Germany. The first data source includes the universe of short-time work applications submitted to the Federal Employment Agency between June 2008 and December 2010. The second data source comprises the full employment biographies of all workers that were gainfully employed during this time period. The third data source contains monthly establishment-level short-time utilization records for the universe of firms between January 2009 and March 2011. The data contains information on 56,584 short-time workers and 1,866 firms that implemented short-time work.

The raw data exhibits the following patterns: First, short-time work predominantly affects workers in manufacturing (82% of short-time spells take place in manufacturing even though this industry only accounts for 27% of the total workforce). The average duration of a short-time spell is about four months – about half as long as the average unemployment spell. The average reduction in hours is about 26%. Second, unconditionally, short-time workers are older, more experienced, and have longer tenure than both full-time workers and unemployed workers. When controlling for firm-fixed effects, we find that short-time workers are on average no different than full-time workers in terms of age and tenure. Short-time workers are slightly more experienced than full-time workers. However, short-time workers earn considerably less than their colleagues before the beginning of their short-time spell. Workers who are laid off are significantly younger, have less experience and tenure, and earn less than full-time and short-time workers. Third, firms that use short-time work tend to be larger and have an older, more experienced workforce than firms that never use short-time work. Fourth, virtually all (98%) short-time workers return to work full-time with their current employer. Merely 1.5% of short-time workers leave their old job to take up a new position with a different employer, only 0.5% transition to unemployment. The probability of being unemployed six months later is lower for

short-time workers than for full-time workers. Fifth, temporary unemployment exists. About 16% of workers who are laid off are eventually recalled by their previous employers.

We then use these data sources to estimate our structural model using indirect inference. Our estimated model implies that for every five workers on short-time work, one job was saved during the recession.

Our model emphasizes the notion that workers and firms value particular matches more than others. Search frictions ensure that once a worker and firm lose contact, they will never meet again. Worker-firm matches differ in their long-run mean productivity. In the short-run, the productivity of any given match fluctuates around this long-run mean. These shocks-run shocks are heterogeneous in their durations. When a worker-firm match is hit by a productivity shock, firms and workers observe its magnitude and its expected duration. The firm and worker then can choose among three options: i) The match continues with the worker working full-time. When employed, the worker accumulates human capital. ii) The firm can lay the worker off. A layoff entails an option to recall the worker in the future. However, while laid-off, the worker's human capital depreciates. Unemployed workers receive unemployment insurance. iii) The firm can place the worker into short-time work. During short-time work, the worker receives short-time compensation proportional to the reduced number of working hours. While on short-time compensation, the worker cannot shop for other jobs. The worker accumulates human capital yet potentially at a slower rate than when working full-time.

Which of these options a worker-firm pair uses depends on how much the firm and worker value their connection in the long-run and on the magnitude and expected duration of the short-run productivity shock. The magnitude and expected duration manifests itself in two competing option values. On the one hand, there is the option value associated with the current match that may potentially improve in the future. On the other hand, when the worker searches he or she may find a better match.

The model has non-trivial welfare implications. There is scope for government intervention in the labor market for several reasons. The fundamental inefficiency is that there is no private market that insures risk-averse workers against layoff risk. Unemployment insurance fills this gap, but it does so imperfectly. First, unemployment insurance results in moral hazard on the worker-side by discouraging search. Second, unemployment insurance results in excess layoffs. The negative externalities of unemployment insurance in our model are particularly severe as unemployment insurance *cannot* condition on the expected duration or the magnitude of productivity shocks. On the one hand, the government should make unemployment insurance generous to provide insurance to workers who were laid off for exogenous reasons or whose match productivity suffers from long-lasting negative productivity shock. On the other hand, the government should make unemployment insurance not too generous as it will result in excess temporary unemployment even for matches whose negative productivity shocks are only short-lived. We show that welfare can be improved by offering short-time compensation

that is attractive for matches with short-lived productivity shocks.

We build in part on Fujita and Moscarini (2013) who document that a vast number of transitions from unemployment to employment in the United States consists of workers who return to a previous employer. Like them, we find that recall is a common occurrence in the German labor market, where about 16% of all unemployed workers eventually get recalled to a previous employer.

Two other papers have studied short-time compensation using an equilibrium search model. Balleer, Gehrke, Lechthaler, and Merkl (2015) study the short-time episode in Germany between 2008 and 2010, Osuna and Perez (2015) study the counterfactual introduction of short-time work into the Spanish economy while emphasizing the distinction between long-term and temporary employment contracts. Neither consider recall as an alternative to short-time work, model workers' human capital, or allow for productivity shocks to differ in duration. Also, neither use worker-level micro data for estimation.

Existing empirical studies on short-time work broadly fall into three categories.[1] The first category uses macro data and infers effects of short-time work on employment from variation across countries. Using data from OECD countries, Cahuc and Carcillo (2011) and Hijzen and Venn (2011) both find that short-time work has a positive effect on permanent employment, but no effect on temporary employment. Boeri and Bruecker (2011) find that short-time work contributed to reduce job loss during the 2008-2009 recession. However, the number of jobs saved (which they estimate at 300,000) is considerably smaller than the number of workers involved in these programs. The second category of papers uses data from the IAB Establishment Panel.[2] Despite ample operational data, the information elicited on short-time work is very coarse. The survey asks whether an establishment made use of short-time work in the first halves of 2008 and 2009, respectively, and if so, how many workers were affected. Crimmann, Wiessner, and Bellmann (2010) look at the determinants of short-time work and find that firms are more likely to implement short-time work when they experienced a bad profit situation in the previous year. Negative expectations about the future make firms more likely to adopt short-time work. Bellmann and Gerner (2011) and Boeri and Bruecker (2011) investigate whether firms that implement short-time work have different employment patterns than firms that do not. Bellmann and Gerner find that firms with short-time work schemes reduced employment significantly in 2009 regardless of whether affected by the crisis. Firms that do not use short-time work reduced their employment only if adversely affected by the crisis. Boeri and Bruecker use an instrumental variable strategy to control for the endogeneity of short-time work uptake. Their point estimate implies that out of the 1.15 million workers affected by

[1] This literature review focuses on the case of Germany. There is a small number of papers on other countries, such as the United States (Walsh, London, McCanne, Needels, Nicholson, and Kerachsky, 1997) and France (Calavrezo, Duhautois, and Walkowiak, 2010). However, no other country's implementation of short-time work has received as much attention.

[2] The IAB Establishment Panel is a representative annual survey of German firms administered by the German Institute for Employment Research (IAB) containing information on almost 16,000 establishments.

short-time work in 2009, about 400,000 jobs were actually saved. The third category contains two studies that use micro-data that has considerably more detailed information on short-time work than the IAB establishment panel. These studies rely on the same data that we use in this paper. Kruppe and Scholz (2014) merge billing lists from Germany's Federal Employment Agency with the IAB establishment panel. The billing lists gives them a monthly break down of the number of workers affected by short-time work per firm and the average percentage reduction in hours. They compare employment patterns of firms that implemented short-time work to those that are similar but did not. They find no differences between the two. Scholz (2012) uses worker-level data for the metropolitan area of Nuremberg and investigates whether firms selectively placed workers into short-time work. Scholz finds that seniority, education, and skill have little if any effect on workers' hazards of short-time work, but all of these factors do affect workers' hazards of unemployment. We replicate some of these and expand on these findings in Section 3.

On the theory side, Burdett and Wright (1989) study the welfare and employment effects of regular unemployment insurance vis-à-vis short-time work. They find that an environment that features only "regular" unemployment insurance may induce inefficient temporary layoffs. An environment with short-time work does not induce inefficient layoffs, but it might lead to inefficient choice of hours. Van Audenrode (1994) finds that the generosity and nature of short-time compensation has major impacts on its effects on the labor market. In particular, short-time compensation systems do not always lead to fully flexible hours. Short-time compensation must be proportionally more generous than traditional unemployment insurance systems to induce workers into accepting variable hours. If short-time compensation is too low, it may result in both inefficient employment and inefficient choice of hours. Braun and Brügemann (2014) build on Burdett and Wright (1989) and include a distinction between insurable and uninsurable risk. There are some shocks, for which the firm will stop producing and will layoff all workers. Against all other shocks, the firm can obtain perfect insurance. When firms can insure well, then work sharing can be welfare improving by reducing inefficient layoffs that are caused by the unemployment insurance system. If firms are poorly insured, then short-time work cannot improve welfare.

The remainder of the paper is structured as follows. Section 2 gives an overview of short-time work in Germany. In Section 3, we introduce our data and develop some stylized facts on short-time work in the metropolitan area of Nuremberg between 2008 and 2010. In Section 4, we introduce our model that we then estimate in Section 5. Section 6 has some counterfactuals and Section 7 concludes.

2 Short-Time Work in Germany

Short-time work has existed in Germany for almost a century. The idea is that when a firm faces "temporary" and "unavoidable" financial difficulties, it can reduce its workers' hours and reduce pay proportionally instead of laying workers off. The firm needs to apply in writing to the local branch of the Federal Employment Agency that administers the unemployment insurance program. If the request is approved by the agency and by the firm's workers' council, then workers will receive between 60 and 67 percent of their lost net wages from the unemployment insurance fund.[3] In practice, short-time pay is administered through the firm. There are three types of short-time work: First, firms can apply for business cycle short-time compensation during recessions or in response to unforeseeable events that lead to a temporary and unavoidable reduction in labor inputs. Seconds, firms in industries that are greatly affected by the seasons such as construction can make use of seasonal short-time work, which is to support off-season employment and avoid temporary layoffs. Third, there is the so called transfer short-time work for firms that experience restructuring or are permanently going out of business. The focus here and throughout will be on business cycle short-time compensation that workers may receive during recessions. In principle, firms can apply for short-time work at any point in time, independent of the general state of the economy, region or their respective industrial sector. However, whether short-time work is approved is at the discretion of the federal employment agency. During the 2008-2010 recession, the federal employment agency very leniently approved requests for short-time compensation. In addition, the rules for short-time work were gradually adjusted to make it more attractive to workers and firms. These rules pertain to the firm's eligibility, the duration of short-time compensation, and the share of social security contributions to be paid by the firm.

For firms to be eligible for short-time compensation, the usual requirement is that at least one third of employees incur a 10 percent loss in earnings. From January 2009 to December 2011, this requirement was reduced and even a single worker on reduced working time was sufficient to qualify for short-time subsidies (see for instance Brenke, Rinne, and Zimmermann (2013)).

The usual duration for firms to claim short-time compensation is six months. In November 2008, the maximum period was increased to 18 months, and in May 2009, to 24 months, though this only applied to short-time work started in 2009. Under a further amendment passed in December 2009, taking effect on January 1st 2010, workers whose hours were reduced were eligible for the short-time work allowance for a maximum period of 18 months. In December 2010, the maximum period was reset to 12 months, which remained in effect until December 2014, when the duration was finally reset to 6 months.

Short-time work is associated with considerable cost to employers, because they have to

[3] In Germany, workers' councils are establishment-level organizations that represent workers' interests often in conjunction with but not necessarily related to workers' unions.

pay social security contributions on the worker's full time wage. Furthermore, during short-time work, the firm also bears the workers' share of the social security contribution on the lost hours. Calculations for the manufacturing sector indicate that under these regulations, the residual costs for each working hour lost amounted to 46 per cent of usual labor costs (Bach and Spitznagel, 2009). During the 2008 and 2009 crisis, these rules were loosened, too. From January 2009 to December 2011, employers only needed to pay 50% of the social security contributions on the loss in hours during the first six months of short-time work (the remaining half was covered by the unemployment insurance fund). After the sixth month of short-time work, the federal employment agency fully covered the social security contributions on the workers' lost hours.

Note that short-time compensation is generally more favorable to workers than actual unemployment, because workers' are considered to be full-time employed for social security (pension, disability, health) purposes. Also, short-time work does not alter the duration of eligibility for unemployment benefits.

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, when a worker receives short-time compensation, he or she is considered a full-time employee 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. To remedy the apparent lack of worker-level short-time data, the IAB underwent the immense effort of digitizing firms' typewritten applications for short-time compensation between June 2008 and December 2010. This task was only performed for short-time compensation applications submitted to and approved by the branch of the federal employment agency that is serving the Nuremberg metropolitan area.[4] 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 hours reduced, regular earnings, and short-time compensation received. While these data contain the universe of records submitted

[4]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 synonymously as the "metropolitan area of Nuremberg." Note that employment agency districts were redrawn in January 2013. Today's Nuremberg district is substantially smaller.

to the employment agency in Nuremberg, it does not necessarily include short-time compensation on every individual 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. Likewise, firms that are located outside the Nuremberg employment agency district, but manage their payroll at a branch in Nuremberg, may have applied for short-time compensation at the Nuremberg office of the employment agency.

The second data set contains an excerpt from the IAB's *Integrated Employment Biographies* (IEB).[5] Our data set comprises every individual who was employed in the Nuremberg metropolitan area at least once between June 2008 and December 2010. For each of these workers, we observe the complete employment biography starting in 1975 up to 2011. These employment biographies include every spell of employment and unemployment as well as job search activity.[6] The employment biographies contain information on all work and unemployment spells, wages, age, gender, occupation, vocational training, and education. For each individual who is employed, the data also contain a unique employer identifier. Since we observe full employment biographies, we can construct measures of tenure and experience. These employment biographies notably do not contain information on hours (other than a part-time dummy) and no information on short-time compensation. We therefore link workers' employment biographies with the Nuremberg-area worker-level data on short-time work and augment workers' biographies with information on short-time spells between June 2008 and December 2010.

The third data set is an establishment-level data set collected and maintained by the federal employment agency. It contains the universe of German firms and contains information on the number of short-time workers on 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.[7] We then link this data set to the employment biographies using the unique employer IDs. We use this data set to address measurement error concerns. The Nuremberg data may misreport 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. The firm-level data set allows us to quantify the extent of this measurement error.

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. This makes the data set unique. No other data sources – administrative or otherwise – in Germany give a similarly detailed account on short-

[5]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.

[6]Job search activity is recorded whenever workers interact with the federal employment agency.

[7]Data prior to January 2009 is based on a different application procedure. In January 2009 the decentralized electronic processing system "coLei PC Kug" was introduced. Data thenceforth is more accurate and not comparable to earlier years.

time compensation.

In the following we summarize the key aspects of our data. While we do so primarily to motivate our structural model, we believe that this section is interesting in its own right as there is virtually no research on short-time work using precise individual-level data (with the exception of Scholz (2012)).

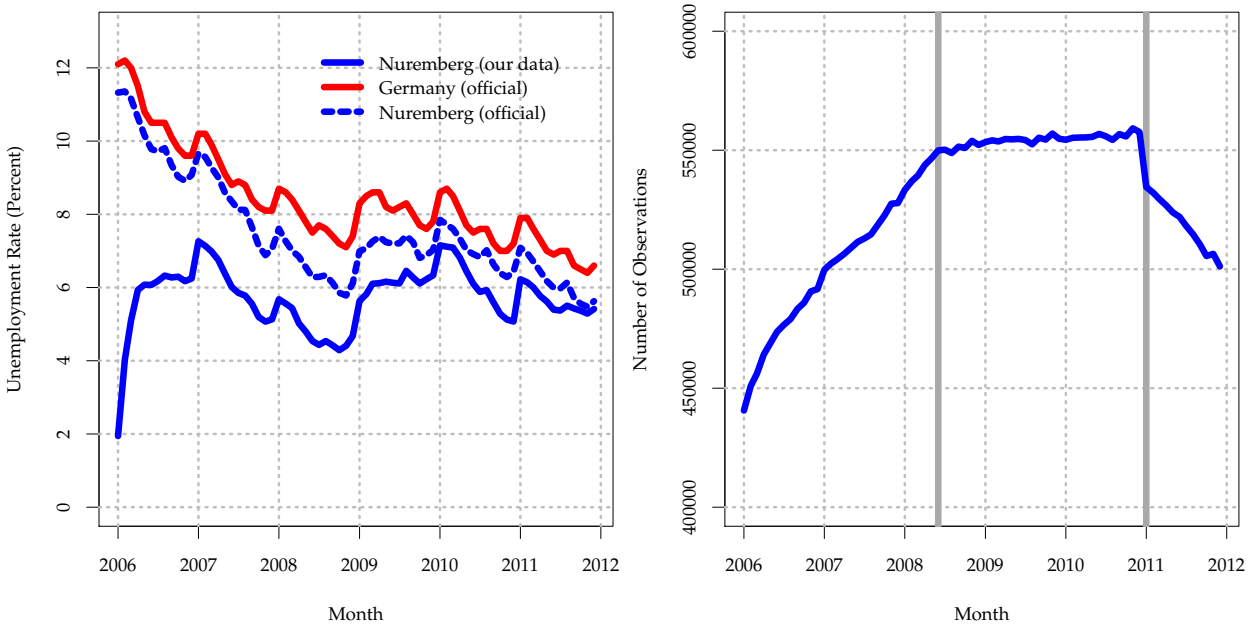
3.2 Summary Statistics

In 2008, the Nuremberg district of the federal employment agency had a population of 1,210,671, making it the fifth largest in Germany. To observe a person in our data set at a particular point in time, two conditions must be met. (i) The individual must be employed subject to social security contributions, marginally employed, receive benefits of some sort, or be registered as searching for work at the federal employment agency. Note that the data exclude civil servants and the self-employed. (ii) The individual must have been employed in the Nuremberg area subject to social security contributions at least once between June 2008 and December 2010. In our data, we observe 745,414 unique persons. The workers in our data set work at 210,221 different establishments nationwide. Among these establishments, 1,866 are situated in the Nuremberg district and introduced short-time work at some point between June 2008 and December 2010. In total, short-time compensation affected 56,584 workers in our data.

We restrict our sample to the 725,162 individuals aged 18 to 65. We only consider individuals whose primary job is located in Nuremberg or who reside in the Nuremberg metropolitan area in case they are unemployed. For individuals who move to the Nuremberg area, we use their full employment biography to compute statistics such as work experience and occupational tenure. However, we exclude these individuals during months when they work or live outside of the Nuremberg area. After excluding these observations, our sample contains a total of 38,441,958 worker-months observations. In Tables 1 and 2, we report summary statistics for the individuals in our sample for a cross-section in January 2009. The average individual in our sample is 39.72 years old, has 14.73 years of experience, and 7.35 years of tenure with his or her current employer. About 46.6% of all individuals in our sample are female. 63.2% of individuals do have vocational training. 12.7% of individuals have a college degree. The remaining 24.2% have neither. Among those who were employed in January 2009, 25.1% hold a job in manufacturing.

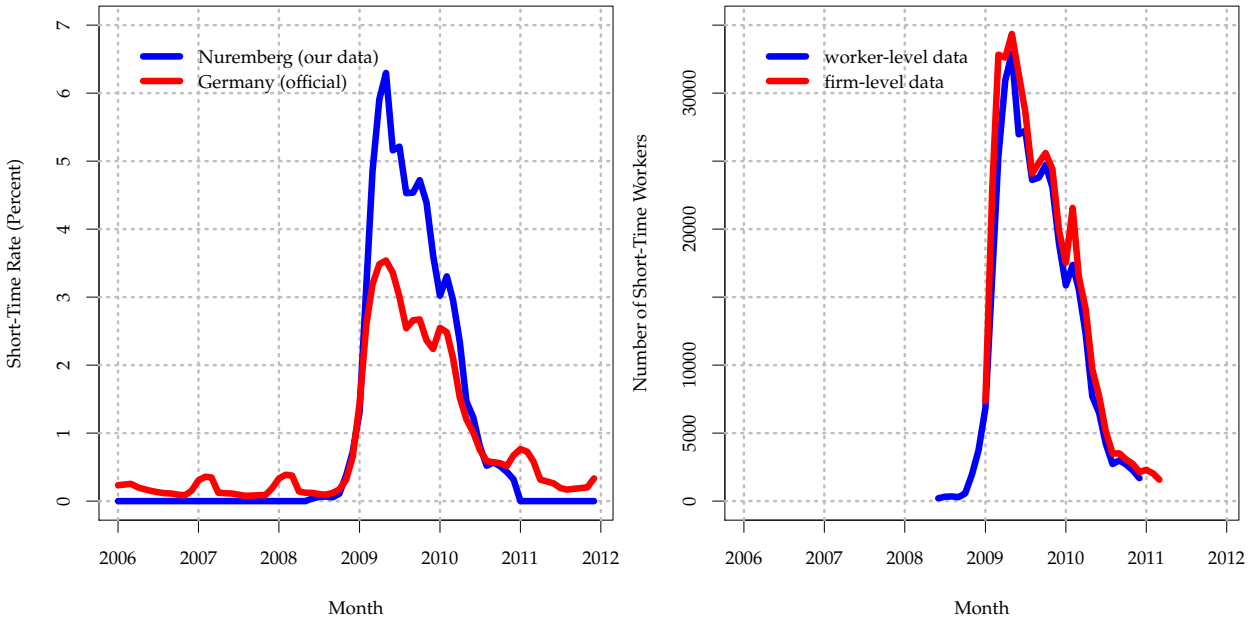
In the left panel of Figure 2, we compare unemployment in the Nuremberg area to the rest of Germany. Note that the *official* unemployment rate for Nuremberg – though slightly lower – tracks the national rate very closely. Note that the official unemployment rate Nuremberg – as reported by the Federal Employment Agency – is notably different from the unemployment rate that we computed based on our dataset. That is due two primarily two reasons: First, our data sources only contain forms of employment that are subject to social security contributions. It thereby excludes civil servants, the self-employed, and some of the marginally employed.

Figure 2: Unemployment in Germany and Nuremberg



Notes: The left panel compares the unemployment rate in Nuremberg to the unemployment rate of Germany. The official statistics are provided by the Federal unemployment agency. The official Nuremberg unemployment rate tracks the national average fairly closely. The unemployment rate implied by our data is somewhat lower than the official statistics, because our data does not include the long-term unemployed. The right panel shows the number of observations in our data by month. Note that our data contains all individuals who were at some point between June 2008 and December 2012 (indicated by the black vertical bars) employed in the Nuremberg area. Because of movers and retirees, our data set grows until June 2008 and shrinks after December 2012.

Figure 3: Short-Time Workers in Germany and Nuremberg



Notes: The left panel compares the short-time rate in Nuremberg to the short-time rate of Germany. The right panel compares the number of short-time workers in our worker-level data to the number of short-time workers in our firm-level data. The latter were sourced from electronic billing lists for the universe of German firms. Note that the worker-level data slightly understate the true uptake of short-time work.

Table 1: Age, Tenure, and Experience in January 2009

	Obs.	Mean	St. Dev.	Q1	Q2	Q3
Age	532,010	39.72	11.66	30.00	40.00	49.00
Experience	353,362	14.73	9.57	6.47	13.90	22.00
Tenure	353,362	7.35	7.41	1.73	5.00	10.25

Notes: The table provides a cross-sectional summary of workers' characteristics in January 2009. Age is observed for all workers in our sample. Tenure and experience are only reported if a worker is employed in January 2009.

Table 2: Gender, Education, Manufacturing in January 2009

	Count	Total	Ratio
Female	247,930	532,010	0.466
No Degree	128,533	532,010	0.242
Vocational Training	336,102	532,010	0.632
College Degree	67,375	532,010	0.127
Manufacturing	111,994	353,362	0.251

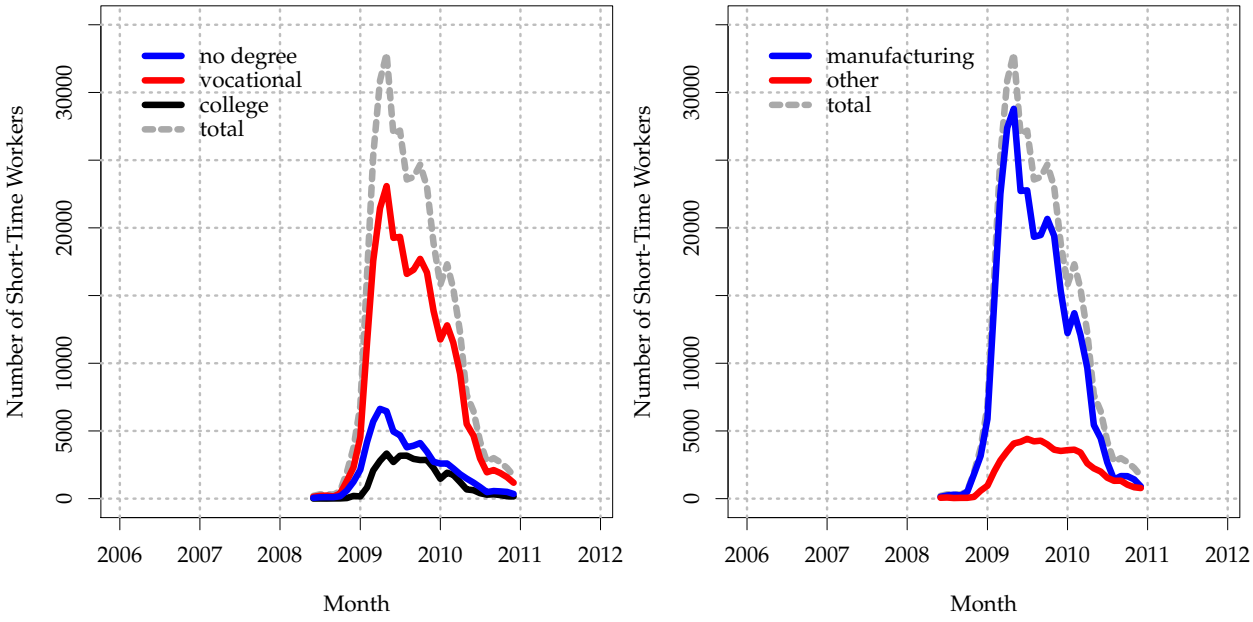
Notes: The table provides a cross-sectional summary of workers' characteristics in January 2009. Gender is reported for all workers in our sample. Missing education values are imputed using the procedure by Fitzenberger (2006). "Manufacturing" refers to the employer's industry classification in January 2009 for those workers who are employed.

Second, our data set only contains individuals who were employed at least once between June 2008 and December 2010 in the Nuremberg area.[8] In the right panel of Figure 2, we plot the number of monthly observations in our data. Before June 2008, our sample is growing as new workers move to Nuremberg and young workers start working. After December 2010, our sample is shrinking as workers move away from Nuremberg without being replaced by new arrivals and old workers retire without being replaced by young workers. Note that due to the sample selection, our dataset will not include the long-term unemployed.

In the left panel of Figure 3, we compare the short-time rate – defined as the number of short-time workers divided by the labor force – in Nuremberg to the short-time rate in Germany as a whole. Note that short-time uptake is almost twice as high in Nuremberg than for the rest of the country. This is mostly due to the composition of jobs in the Nuremberg area, where manufacturing is over-represented relative to the national average. Note that our Nuremberg short-time worker data only contains information on recession short-time work. In contrast, the national short-time worker count also includes seasonal short-time workers, which accounts for the modest baseline level of short-time work before and after the recession. In the right panel of Figure 3, we plot the number of short-time workers for the Nuremberg area from both our worker-level data source (from June 2008 to December 2010) and our firm-level data source

[8] Note that our analysis also misses all of those workers who were never employed on the first day of a month.

Figure 4: Short-Time Workers By Education and Sector



Notes: In the left graph, we break short-time work uptake down by workers' education. "No degree" refers to workers who have neither a college nor a vocational training degree. "Vocational" refers to workers with a vocational training degree, but not college degree. "College" refers to workers with at least a college degree (including applied and professional degrees, e.g. from a "Fachhochschule"). In the right graph, we break short-time uptake down by industry.

(from January 2009 to March 2011) over time. At the peak of short-time utilization in May 2009, there were 34,379 short-time workers and 1,071 short-time establishments. Note that the firm-level data source always slightly exceeds the worker-level data source. This is owed to the way the worker-level data were collected. Firms that employed their workers in Nuremberg but managed their payroll outside of Nuremberg may have applied for short-time work with a different branch of the Federal Employment Agency. This measurement error in the short-time data is small (about 10%) but non-negligible. We address measurement error concerns explicitly when we estimate our structural model.

3.3 The Extensive Margin of Short-Time Work

In this subsection, we investigate which workers ended up in short-time work and how they differ from their full-time employed and unemployed counterparts.

In Figure 4 we show the incidence of short-time work by education and sector. The left panel shows that short-time work concentrates among workers with vocational training (on average 71%, which is higher than 63%, the average of individuals with a vocational degree in our sample). Only 10% of short-time workers have a university degree, fewer than the

sample average of 13%. 18% of short-time workers have no degree, fewer than the sample of average of 23%. The right panel shows that the vast majority of short-time workers have jobs in manufacturing (on average 82% — almost three times the sample average of 27%).

In Table 3, we break down workers' average age, tenure, experience, and monthly earnings by employment status for the calendar year of 2009. The average short-time worker is 41.78 years old, 1.27 years older than the average full-time worker. The average short-time worker was 2.85 years older than the average unemployed worker. Short-time workers also have more experience (17.14 years) than both full-time workers (15.19 years) and unemployed individuals (8.39 years). The same pattern holds for tenure. Short-time workers have on average 9.63 years of tenure — almost two more years than full-time workers. The pattern does not continue to hold once we look at monthly earnings. At €2,911, short-time workers' average regular salary is about €254 less than that of full-time workers.

Short-time workers tend to be older, have more experience and longer tenure than full-time workers. These stylized facts could be due to two (not mutually exclusive) reasons: (i) Employers select their older, more experienced work-force into short-time work (see Scholz (2012)). (ii) Firms that make use of short-time work tend to have an older, more experienced workforce. Telling these two explanations apart is important to develop an understanding of how the short-time compensation affects the labor market.

To investigate if firms select their workforce into short-time work, we compare workers to their coworkers at their current employer — exploiting the fact that we have matched employer-employee data. In Table 5, we show how workers' differ from their coworkers conditional on making a particular labor market transition. In the first row, we show that workers who stay with their employer (*E to E*) are on average 0.07 years older than their average coworker. Workers who will be in short-time work in the subsequent months are on average 0.02 years older than their average coworker. Workers who move from employment to unemployment (*E to U*) are on average 1.83 years younger than their coworkers. A similar pattern applies to workers' tenure. Workers who transition from full-time to short-time only slightly differ in tenure compared to their coworkers. Workers who transition to unemployment, have on average 2.05 years shorter tenure than their coworkers. Workers who stay on full-time with their current employer tend to have above-average earnings (on average €83 more than their coworkers). Workers who transition into short-time work tend to earn €302 less than their coworkers. Workers who transition into unemployment tend to earn €335 less than their coworkers. This means that workers who transition from full-time employment to short-time work are not older and do not have longer tenure than their coworkers. However, short-time workers tend to earn considerably lower wages than their average coworker. As one might expect, workers who transition into unemployment are younger, less experienced, have shorter tenure, and earn less than their coworkers.

Table 5 suggests that selection within the firm is mostly a function of wage – not so much a

function of age, experience, and tenure. However, since we do observe that short-time workers are notably different from full-time workers (see Table 3), this must mean that the firms that self-select into short-time work differ in their work-force from employers that do not self-select into short-time work. Table 4 shows that this in fact the case. In the left column, we plot the averages of firm-level worker characteristics for firms that have never made use of short-time work in 2009. In the right column, we plot the averages for firms that have – at some point – made use of short-time work in 2009. Notably, firms that made use of short-time work are considerably larger than firms that never do (103.13 vs 12.90 workers). The former also have a workforce that is on average slightly older (42.38 vs. 42.06), more experience (14.37 vs. 10.36) and has longer tenure (6.83 vs. 3.45) than that of the latter. Also, the average salary of firms that never use short-time compensation is far below the average salary of a firm that at some point uses short-time compensation.[9] In Table A1, we tabulate industries by their use of short-time compensation. Short-time work is clearly concentrated in manufacturing, where 5,340,008 out of 6,455,364 short-time hours originate.

3.4 The Intensive Margin of Short-Time Work

In this subsection we consider two measurements of the intensive short-time work: the hours reduced and the duration of short-time spells. On average, short-time workers' hours were reduced by 26%. Hours were reduced by more than half for only about 10% of short-time workers. In the left panel of Figure 5, we show the evolution of the average number of reduced hours over time. We contrast these with workers' regular hours that we impute using the reported short-time hours, the reported regular compensation, and the amount of short-time compensation that the worker receives. The average number of reduced hours remained approximately constant throughout. We find no noteworthy dependence of hours reduced on worker or employer observables.

The average duration of short-time work before workers transition back to full-time employment with their current employer is 3.98 months. The average duration of short-time work before workers transition into unemployment is 3.48 months. In the right panel of Figure 5, we show the evolution of the average duration of beginning short-time spells over time. We compare the duration of short-time spells with the duration of unemployment spells, which tend to be more than twice as long as short-time spells. Unemployment spells that end in the worker being recalled to his or her previous employer are only 15% longer than the average short-time spell.

[9] Clearly, this is because the firm size distribution in the economy is heavily skewed. So we shouldn't read too much into these numbers.

Table 3: Worker Characteristics by Employment Status

	Full-Time	Short-Time	Unemployed
Age	40.51	41.78	38.93
	(11.78)	(10.51)	(12.41)
Tenure	7.65	9.63	NA
	(7.51)	(7.89)	(NA)
Experience	15.19	17.14	8.39
	(9.86)	(9.72)	(7.91)
Earnings	3,166.63	2,911.84	NA
	(3,226.69)	(977.16)	(NA)
Observations	5,602,166	280,474	410,005

Notes: The table summarizes workers' characteristics by employment status for all workers in the Nuremberg area in 2009. The unit of observation is a worker-month.

Table 4: Employer Characteristics by Employment State

	No Short-Time	Short-Time
Age	42.06	42.38
	(10.69)	(6.20)
Tenure	3.45	6.83
	(4.50)	(5.26)
Experience	10.36	14.37
	(7.06)	(5.62)
Earnings	1,332.59	2,146.79
	(1,000.95)	(801.01)
Firm Size	12.90	103.13
	(110.44)	(806.57)

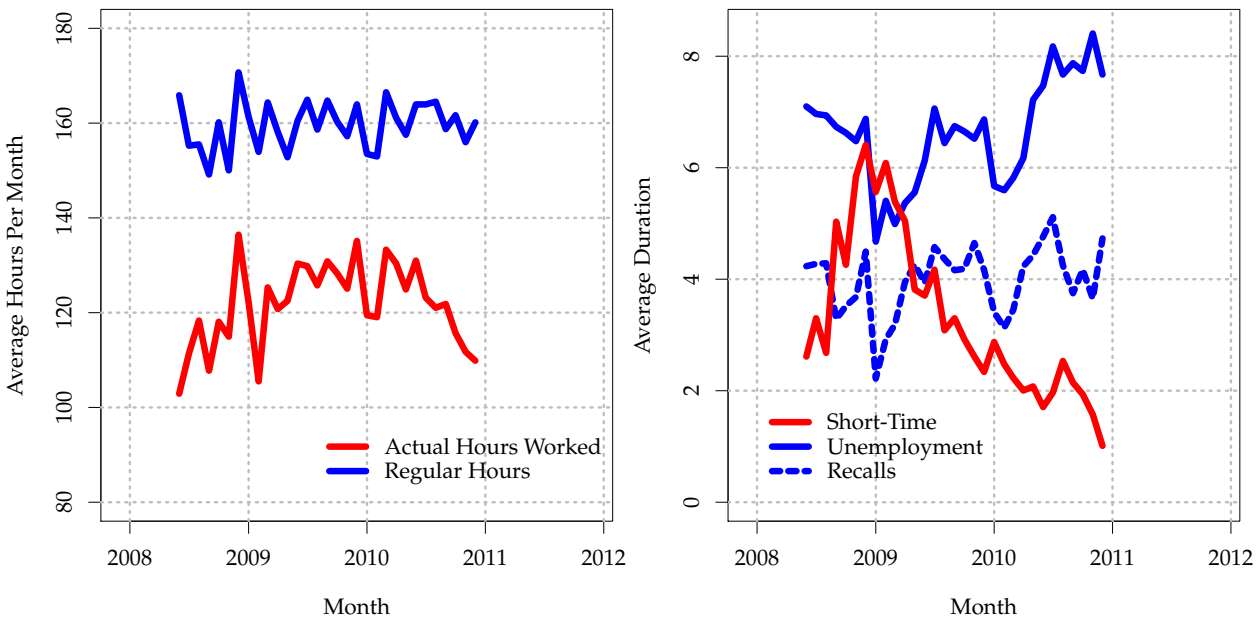
Notes: The table summarizes firms' characteristics by short-time utilization in the Nuremberg area in 2009. The unit of observation is a firm-month.

Table 5: Worker Characteristics Relative to Coworkers by Labor Market Transition

	E to E	E to E′	E to S	E to U	E to O
Δ Age	0.074	-2.887	0.021	-1.831	-2.528
	(0.003)	(0.030)	(0.034)	(0.040)	(0.030)
Δ Tenure	0.046	-1.703	-0.008	-2.052	-1.035
	(0.002)	(0.015)	(0.022)	(0.017)	(0.021)
Δ Experience	0.077	-2.118	-0.275	-2.242	-2.182
	(0.003)	(0.027)	(0.032)	(0.034)	(0.032)
Δ Earnings	82.969	-37.074	-302.358	-334.651	-1,009.736
	(0.821)	(6.402)	(7.212)	(4.852)	(5.677)
Observations	12,300,000	119,868	89,931	75,008	137,675

Notes: The table summarizes workers' characteristics by the type of labor market transition for time between June 2008 and December 2010. The unit of observation is a worker-month. This table contains all workers in our sample. See Tables A2 and A3 in the Appendix for breakdowns for workers in manufacturing only and for skilled workers in manufacturing only.

Figure 5: Hours Worked by Short-Time Workers and the Duration of Short-Time Spells



Notes: The left panel shows the hours worked by short-time workers and their regular hours. Regular hours are imputed using the reported regular income, the amount of short-time work received, and numbers of short-time hours reported. The right panel shows the duration of beginning short-time spells, unemployment spells, and unemployment spells that end in a worker's return to his or her previous employer.

Table 6: Transitions from and to Short-Time Work (and Unemployment)

All Workers in all Industries

	Total	Recalled	Find New Job	Laid off
Short-Time Work	94,281	92,590	1,520	507
Unemployment	188,500	30,399	144,211	

All Workers in Manufacturing

	Total	Recalled	Find New Job	Laid off
Short-Time Work	78,369	76,943	1,290	377
Unemployment	27,739	4,583	14,446	

Notes: The table can be read as follows (first row): In total, we observe 94,281 short-time workers in our data. Among these, 92,950 are return to full-time at their present position, 1,520 find a new job, and 507 transition to unemployment. The top panel refers to all workers across all industries. The bottom panel refers to workers who work or whose last job was in manufacturing. Note that the three right most columns do not sum to the total number of workers because of attrition.

3.5 What Happened to Short-Time Workers vs. Unemployed Workers?

Hitherto, we have shown which workers and firms are affected by short-time and to what extent. We will now discuss what happened to short-time workers after their short-time spell and compare the transitions between employment states of short-time workers to other workers. In our data, we observe 92,590 short-time workers who eventually transition back to full-time employment (See Table 6). In contrast, we only observe 507 workers who transition from short-time work to unemployment. Among those workers who return from short-time work to full-time employment, virtually all of them stay with the current employer. Temporary unemployment exists. Among all workers who transition from unemployment to regular employment, about 16% return to their previous employer.

Table 7 shows the transition probability matrix from one employment state to another six months apart. The probability that a regularly employed worker remains in regular full-time employment six months later equals 91.8% in 2008. The probability that a regularly employed worker is working short-time six months later was 4.1% in 2008, which is larger than the probability of being unemployed (3.2%). The probability that a short-time worker would be regularly employed six months later was 51.2%. The probability that a short-time worker would be out of work six months later was 4.6%. The probability that an unemployed worker would find full-time employment six months later was 27.8%. In 2009, the probability that a short-time worker returns to full-time employment six months later was 55.7%. The probability that a short-time worker would be unemployed six months later was 1.4% – considerably lower than 2.9%, the probability with which a full-time worker would end up in unemployment. The probability that an unemployed worker is in full-time employment six months later was 30.5%. In 2010, the probability that a short-time worker returns to full-time employment six months later was

Table 7: Employment Status Six Months Later

June 2008 – December 2008

	Full-Time	Marginal	Short-Time	Unemployment
Full-Time	0.918	0.009	0.041	0.032
Marginal	0.131	0.828	0.001	0.041
Short-Time	0.512	0.000	0.443	0.046
Unemployment	0.278	0.094	0.001	0.627

January 2009 – December 2009

	Full-Time	Marginal	Short-Time	Unemployment
Full-Time	0.945	0.008	0.018	0.029
Marginal	0.124	0.836	0.000	0.040
Short-Time	0.557	0.001	0.428	0.014
Unemployment	0.305	0.080	0.001	0.613

January 2010 – December 2010

	Full-Time	Marginal	Short-Time	Unemployment
Full-Time	0.970	0.009	0.001	0.021
Marginal	0.150	0.811	0.000	0.038
Short-Time	0.865	0.001	0.122	0.012
Unemployment	0.359	0.080	0.000	0.561

Notes: The table can be read as transition frequency matrix. The worker's current employment state is in the rows. The worker's employment state six months from now is in the columns. The time horizons printed above the tables refer to the *current* employment state.

86.5%. The probability that a short-time worker is unemployed six months later was 1.2% – considerably lower than 2.1%, the probability with which a full-time worker ends up in unemployment. The probability that an unemployed worker is in full-time employment six months later equalled 35.9%.

Based on the above, we conclude with several stylized facts about short-time work in Germany: First, short-time work predominantly affects workers in manufacturing (82% of short-time spells take place in manufacturing even though manufacturing only accounts for 27% of the total workforce). The average duration of a short-time spell is about four months – about half as long as the average unemployment spell. The average reduction in hours is about 26%. Second, unconditionally, short-time workers are older, more experienced, and have longer tenure than full-time workers and unemployed workers. When controlling for firm-fixed effects, we find that short-time workers are on average no different from full-time workers in terms of age and tenure. On average, short-time workers are slightly more experienced but earn considerably less than their coworkers on full-time work. Workers who are laid off are considerably younger, have less experience and tenure, and earn less than full-time and short-time workers. Third, Firms that use short-time work at some point between June 2008 and December 2010, tend to be larger and have an older, more experienced workforce than firms

that never use short-time work. Fourth, virtually all (98%) short-time workers return to work full-time with their current employer. 1.5% of short-time workers switch firms to a different employer. Only 0.5% of short-time workers transition to unemployment. The probability of being unemployed six months from now is lower for short-time workers than for full-time workers. Fifth, Temporary unemployment exists. About 16% of workers who are laid off are eventually recalled to work at their previous employer.

4 Model

In this section, we introduce a partial equilibrium model of the German labor market.

4.1 Primitives

Time is discrete and lasts forever with $t = 1, 2, \ldots$. There is a continuum of workers of measure one. Every period, workers retire with probability χ. Workers who retire are replaced by "young" workers. Workers' per-period preferences for consumption c_t and hours worked h_t are given by $u(c_t, h_t)$, with $u_c(c_t, h_t) > 0$, $u_h(c_t, h_t) < 0$, $u_{cc}(c_t, h_t) < 0$. The unit of analysis is the firm-worker match. Firms are risk-neutral and maximize expected profits. Workers and firms discount the future with discount factor β. When matched, firms and workers produce output equal to

$$f(\mathbf{y}_t, \mathbf{x}_t)h_t, \tag{1}$$

where $\mathbf{y}_t$ and $\mathbf{x}_t$ are vectors with match- and worker-specific characteristics. $h_t \in [0, 1]$ refers to hours worked, where we interpret $h_t = 1$ as full-time.

The aggregate state of the economy is denoted by $z_t \in \mathcal{Z}$. z_t is a Markov process and evolves exogenously according to the distribution function $\Psi(z_t|z_{t-1})$. As made explicit in (1), the aggregate state does not affect output of the firm-worker match directly. Instead, the aggregate state will affect the *evolution* of match-specific productivity $\mathbf{y}_t$. $\mathbf{y}_t$ evolves according to the distribution function $\Phi(\mathbf{y}_t|\mathbf{y}_{t-1}, z_t)$ with corresponding density $\phi(\mathbf{y}_t|\mathbf{y}_{t-1}, z_t)$.

The vector with match-specific characteristics $\mathbf{y}_t = [y^*, \varepsilon_t, p_t] \in \mathcal{Y}$ consists of the persistent match type y_t^*, a transitory productivity shock, ε_t, and the persistence, p_t, of this transitory shock. Whenever a match draws a productivity shock, it draws a tuple (ε_t, p_t). With probability $1 - p_t$, the firm gets to draw a new productivity shock in the subsequent period. With probability p_t, the productivity shock stays at its current level. As such, $1/(1 - p_t)$ is the expected duration of the shock ε_t. More precisely,

$$\mathbf{y}_{t+1} \equiv (y_{t+1}^*, \varepsilon_{t+1}, p_{t+1}) = \begin{cases} \mathbf{y}_t = (y_t^*, \varepsilon_t, p_t) & \text{with probability } p_t \\ (y_t^*, \tilde{\varepsilon}, \tilde{p}) & \text{with probability } 1 - p_t, \end{cases}$$

where $\tilde{\varepsilon}$ and $\tilde{p}$ are random variables that are drawn from the distribution $\Gamma(\tilde{\varepsilon}, \tilde{p}|z_t)$, which depends on the aggregate state z_t. When a worker and a firm initially meet, they draw a vector of match productivity from the distribution $\Phi(\mathbf{y}_t|z_t)$.

The vector with worker-specific characteristics, $\mathbf{x}_t = [e_t, b_t]$, includes the worker's level of human capital, e_t, and a moving average of worker's earnings, b_t. The latter – to which we will refer as *benefit class* – will be used to assess unemployment insurance benefits and short-time compensation, which pay out a fraction, $b(z_t)$ and $s(z_t)$, respectively, of the benefit class. The evolution of $\mathbf{x}_t$ depends on hours worked to account for the fact that workers may accumulate human capital at different rates depending on how many hours they work. The evolution also depends on the current wage to account for the impact of wages on a worker's benefit class. The transition distribution function is given by $\Omega(\mathbf{x}_{t+1}|\mathbf{x}_t, h_t, w_t)$ with corresponding density $\omega(\mathbf{x}_{t+1}|\mathbf{x}_t, h_t, w_t)$. We will model both the worker's experience and the worker's benefit class as discrete ladders.

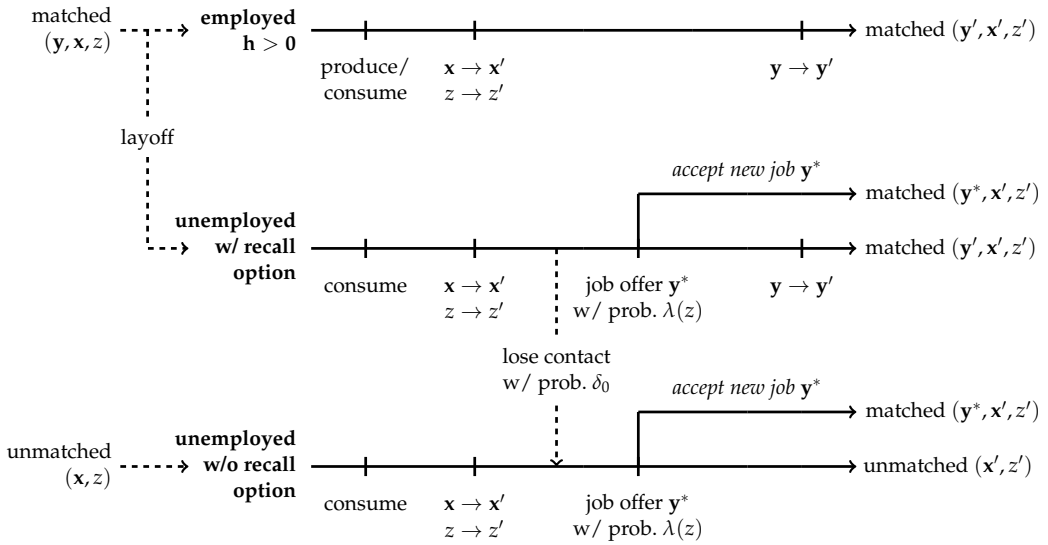
We denote the ladder of experience by $e_1, e_2, \ldots, e_{K_e}$, where K_e denotes the number of rungs of the experience ladder. A worker with current experience e_k will climb to the next rung, e_{k+1}, on the experience ladder with probability $\omega_{e\uparrow}(e_{k+1}|e_k, h)$. The worker will remain at e_k with probability $1 - \omega_{e\uparrow}(e_{k+1}|e_k, h)$. Similarly, a worker who is unemployed will fall from e_k to e_{k-1} with probability $\omega_{e\downarrow}(e_{k-1}|e_k, h)$ and stay on the same rung with probability $1 - \omega_{e\downarrow}(e_{k-1}|e_k, h)$. This process allows workers to learn on the job and accumulate experience and forget off the job as their experience depreciates.

We model the worker's benefit class in a similar way. The worker's benefit class can take on K_b distinct values, $b_1, b_2, \ldots, b_{K_b}$. Whenever a worker in benefit class b_k earns a wage w that exceeds b_{k+1}, then he or she will move up to b_{k+1} with probability $\omega_{b\uparrow}(b_{k+1}|b_k)$. The worker will stay at the current benefit class with probability $1 - \omega_{b\uparrow}(b_{k+1}|b_k)$. Similarly, whenever a worker in benefit class b_k is working at a wage $w < b_k$, he or she will fall down a rung on the benefit class ladder with probability $\omega_{b\downarrow}(b_{k-1}|b_k)$. With probability $1 - \omega_{b\downarrow}(b_{k-1}|b_k)$, the worker will stay in place. The benefit class is therefore slowly tracking workers' incomes over time. It is a tractable way to model that benefits may depend on past income without expanding the state space to include workers' earnings histories.

When a worker is a benefit recipient – either through short-time work or unemployment insurance benefits – the benefit level remains constant. However, the worker may fall down to benefit level b_1 with some positive probability δ_b. This feature will later allow us to mimic term limits for unemployment insurance benefits and short-time compensation.

Each period, a worker can either be matched or unmatched. Workers who are unmatched are *permanently unemployed*. These workers search for jobs and meet potential employers with probability $\lambda(z_t, \mathbf{x}_t)$. Upon meeting a potential employer, the worker-firm pair becomes matched and draws – after the realization of z_{t+1} – an initial vector of match productivity $\mathbf{y}_{t+1}$ from the distribution $\Phi(\mathbf{y}_{t+1}|z_{t+1})$. If an unmatched worker does not meet a potential employer, the

Figure 6: Timing within Period



worker remains unmatched and consumes unemployment insurance benefits.

For workers who are matched to a firm, the worker and firm will both observe the current period's match productivity $\mathbf{y}_t$ and then jointly decide if the match engages in production or if the match is *mothballed*. Workers who are matched and work a positive number of hours are considered to be *employed*. Workers who are matched but whose match is mothballed are considered *temporarily unemployed*. For all worker-firm matches, match productivity evolves over time according to the distribution $\Phi(\mathbf{y}_{t+1}|\mathbf{y}_t, z_{t+1})$ regardless of whether the worker is working or temporarily laid off. Workers who are temporary laid off receive unemployment insurance benefits. Matched workers can become unmatched with probability δ if the worker is employed and with probability δ_0 if the worker is temporarily laid-off. Employed workers do not search for jobs. In contrast, workers who are temporarily laid-off do search for jobs. Just like permanently unemployed workers, temporarily unemployed workers meet potential employers with probability $\lambda(z_t, \mathbf{x}_t)$. Upon meeting a potential employer, the worker-firm pair draws an initial vector of match productivity $\mathbf{y}^*_{t+1}$ and the worker needs to decide whether to become matched to the new firm (and become unmatched with the previous employer) or to forgo the offer and to stay matched with the previous employer.

Workers and firms determine hours and wages using Nash bargaining. Workers' bargaining power is given by α. When a worker and firm bargain, the respective threat points are given from mothballing the match — not from breaking up the match entirely.

We now detail the timing of events within a period. See Figure 6 for an illustration. At the beginning of a period, workers are either matched or unmatched.

1. Matched workers and firms jointly decide if they want to produce in the current period or if they want to mothball the match. If the worker and the firm choose to produce, wages

and hours are determined by Nash bargaining. If the worker and the firm choose not to produce, the worker becomes temporarily unemployed.

2. Employed workers work and consume their wages. Temporarily and permanently unemployed workers do not work and consume unemployment insurance benefits.

3. Unemployed workers search for jobs and meet potential employers with probability $\lambda(z_t, \mathbf{x}_t)$.

4. Existing matches are destroyed with probability δ if active and with probability δ_0 if mothballed. Workers in these matches will enter the next period as permanently unemployed.

5. Worker-specific characteristics evolve from $\mathbf{x}_t$ to $\mathbf{x}_{t+1}$.

6. The aggregate state evolves from z_t to z_{t+1}.

7. Unemployed workers who meet a new prospective employer draw and immediately observe the new match's initial productivity, $\mathbf{y}^*_{t+1}$. If the worker was permanently unemployed, the firm and the worker form a match irrespective of the realization of $\mathbf{y}^*_{t+1}$.[10] If the worker was temporarily unemployed, the worker has to choose between remaining attached to his or her previous employer or to become matched to the newly found employer with match productivity $\mathbf{y}^*_{t+1}$.

8. Match productivity for all matches — except for those that were just formed — $\mathbf{y}_{t+1}$ evolves conditional on $\mathbf{y}_t$ according to $\Phi(\mathbf{y}_{t+1}|\mathbf{y}_t, z_{t+1})$.

We consider two types of government policies: unemployment insurance and short-time compensation. Workers who are unemployed (temporarily or permanently) receive unemployment insurance benefits, $b(\mathbf{x}_t, z_t)$. Whenever a worker works less than full-time (i.e. whenever $h < 1$), the worker receives short-time compensation $s(\mathbf{x}_t, z_t)(1-h)$. The amount of unemployment benefits and short-time compensation that a worker receives is a function of the workers benefit class, hence the dependence on $\mathbf{x}_t$. In principle, unemployment insurance and short-time compensation can also depend on the aggregate state of the world. For our empirical application, we will think of short-time compensation as only being available during recessions. In addition to the generosity, the government may also control for how long workers and firms may receive short-time compensation and unemployment insurance benefits. Both labor market policies are funded through a payroll tax, $T(w)$, levied on employers.

4.2 Value and Policy Functions

We drop time subscripts. We refer to a generic state z_t by z and to z_{t+1} by z'. The value functions we consider are "interim" value functions. They characterize the continuation value of both

[10] They can decide to mothball the match right away in the next period.

the worker and the firm depending on whether a match was mothballed, i.e. after Step 1 in the timing of events above.

The value function of an employed worker, who works at firm $\mathbf{y}$ with worker-specific characteristics $\mathbf{x}$ at wage w for h hours, is given by

$$W(\mathbf{y},\mathbf{x},z,w,h) = u(w+(1-h)s(\mathbf{x},z),h) + \beta\int\int\left[\delta U(\mathbf{x}',z') + (1-\delta)\int \tilde{W}(\mathbf{y}',\mathbf{x}',z')d\Phi(\mathbf{y}'|\mathbf{y},z')\right]d\Omega(\mathbf{x}'|\mathbf{x},w,h)d\Psi(z'|z). \quad (2)$$

In the two outer most integrals, we take expectations with respect to the evolution of the aggregate states and the worker-specific characteristics. In the inner most integral, we take the expectation with respect to the future match productivity. The value from being temporarily unemployed is given by

$$W_0(\mathbf{y},\mathbf{x},z) = u(b(\mathbf{x},z),0) + \beta\int\int\left[\delta_0 U(\mathbf{x}') + (1-\delta_0) \times\left(\int \tilde{W}(\mathbf{y}',\mathbf{x}',z')d\Phi(\mathbf{y}'|\mathbf{y},z') + \lambda(z,\mathbf{x})S(\mathbf{y},\mathbf{x}',z')\right)\right]d\Omega(\mathbf{x}'|\mathbf{x})d\Psi(z'|z). \quad (3)$$

$S(\mathbf{y},\mathbf{x}',z')$ is the expected gain from search and $\tilde{W}(\mathbf{y}',\mathbf{x}',z')$ is the worker's beginning-of-period value from being matched. We define both of these objects next. The value from search is given by

$$S(\mathbf{y},\mathbf{x}',z') = \int \max\left\{\tilde{W}(\mathbf{y}'',\mathbf{x}',z') - \int \tilde{W}(\mathbf{y}',\mathbf{x}',z')d\Phi(\mathbf{y}'|\mathbf{y},z'),0\right\}d\Phi(\mathbf{y}''|z').$$

The productivity of the new match, $\mathbf{y}''$, is a draw from the unconditional distribution $\Phi(\mathbf{y}''|z')$. The worker will only switch jobs if he or she prefers the certain match productivity $\mathbf{y}''$ over the expected productivity $\mathbf{y}'$ at the current match. For a given wage policy function $\tilde{w}(\mathbf{y}',\mathbf{x}',z')$ and hours policy function $\tilde{h}(\mathbf{y}',\mathbf{x}',z')$, the beginning-of-period value of a match is given by

$$\tilde{W}(\mathbf{y}',\mathbf{x}',z') = \begin{cases} U(\mathbf{x}',z') & \text{if firm/worker prefer breaking up} \\ W_0(\mathbf{y}',\mathbf{x}',z') & \text{if firm/worker prefer mothballing} \\ W(\mathbf{y}',x',\tilde{w}(\mathbf{y}',\mathbf{x}',z'),\tilde{h}(\mathbf{y}',\mathbf{x}',z'),z') & \text{if firm/worker prefer employment.} \end{cases}$$

The value from being permanently unemployed is given by

$$U(\mathbf{x},z) = u(b(\mathbf{x},z),0)+ \beta\int\int\left[U(\mathbf{x}',z') + \lambda(z,\mathbf{x})\int \max\{\tilde{W}(\mathbf{y}',\mathbf{x}',z') - U(\mathbf{x}',z'),0\}d\Phi(\mathbf{y}'|z')\right]d\Omega(\mathbf{x}'|\mathbf{x})d\Psi(z'|z). \quad (4)$$

The firm's value function from employing a worker with experience x in a match $\mathbf{y}$ at wage

w for h hours is:

$$J(\mathbf{y},\mathbf{x},z,w,h) = f(y,\mathbf{x})h - T(w) + \beta(1-\delta)\int\int\int \tilde{J}(\mathbf{y}',\mathbf{x}',z')d\Phi(\mathbf{y}'|\mathbf{y},z')d\Omega(\mathbf{x}'|\mathbf{x},w,h)d\Psi(z'|z), \quad (5)$$

$\tilde{J}(\mathbf{y}',\mathbf{x}',z')$ refers to the firm's beginning-of-period value function when it is matched to a worker x' with match productivity $\mathbf{y}'$. The firm's value from a temporary layoff is given by

$$J_0(\mathbf{y},\mathbf{x},z) = \beta(1-\delta_0)\int\int \overbrace{\left[1-\lambda(z,\mathbf{x})\int \mathbf{1}\left\{\tilde{W}(\mathbf{y}'',\mathbf{x}',z') > \int \tilde{W}(\mathbf{y}',\mathbf{x}',z')d\Phi(\mathbf{y}'|\mathbf{y},z')\right\}d\Phi(\mathbf{y}''|z')\right]}^{\text{Probability that worker does not find different job}} \times \int \tilde{J}(\mathbf{y}',\mathbf{x}',z')d\Phi(\mathbf{y}'|\mathbf{y},z')d\Omega(\mathbf{x}'|\mathbf{x})d\Psi(z'|z). \quad (6)$$

When a worker is temporarily laid off, the firm's flow profits are zero. The firm only receives a non-zero continuation value if the match is not destroyed exogenously *and* if the worker does not find a better job. For a given wage policy function $\tilde{w} = w(\mathbf{y},\mathbf{x},z)$ and hours policy function $\tilde{h} = h(\mathbf{y},\mathbf{x},z)$, the beginning of period value of a match is given by

$$\tilde{J}(\mathbf{y},\mathbf{x},z) = \begin{cases} 0 & \text{if firm/worker prefer breaking up} \\ J_0(\mathbf{y},\mathbf{x},z) & \text{if firm/worker prefer layoff} \\ J(\mathbf{y}',x',\tilde{w}(\mathbf{y}',\mathbf{x}',z'),\tilde{h}(\mathbf{y}',\mathbf{x}',z'),z') & \text{if firm/worker prefer employment.} \end{cases}$$

We denote the policy function that a worker will be laid off by

$$\tilde{m}(\mathbf{y}',\mathbf{x}',z') = \mathbf{1}\{W_0(\mathbf{y}',\mathbf{x}',z') > \max\{W(\mathbf{y}',x',\tilde{w}(\mathbf{y}',\mathbf{x}',z'),\tilde{h}(\mathbf{y}',\mathbf{x}',z'),z'),U(\mathbf{x}',z')\} \quad (7)$$
$$\wedge \quad J_0(\mathbf{y}',\mathbf{x}',z') > \max\{J(\mathbf{y}',x',\tilde{w}(\mathbf{y}',\mathbf{x}',z'),\tilde{h}(\mathbf{y}',\mathbf{x}',z'),z'),0\}.$$

The hours and wage policy functions are determined by Nash bargaining,

$$(\tilde{w}(\mathbf{y},\mathbf{x},z),\tilde{h}(\mathbf{y},\mathbf{x},z)) \in \arg\max_{w,h}\left[W(\mathbf{y},x,z,w,h) - W_0(\mathbf{y},\mathbf{x},z)\right]^{\alpha}\left[J(\mathbf{y},x,z,w,h) - J_0(\mathbf{y},\mathbf{x},z)\right]^{1-\alpha}. \quad (8)$$

We solve the model on a grid of hours choices. For each choice of hours, we will compute the Nash bargaining solution to find the corresponding wage. We then choose the hours-wage pair that maximizes the Nash product.

4.3 Equilibrium

We consider this economy in partial equilibrium. The equilibrium is partial, because we treat job offer arrivals rates as exogenous. The equilibrium consists of

- a wage policy function $w(\mathbf{y}, \mathbf{x}, z)$,
- an hours policy function $h(\mathbf{y}, \mathbf{x}, z)$,
- a mothballing decision $m(\mathbf{y}, \mathbf{x}, z)$,
- value functions for the worker $W(\mathbf{y}, x, z, w, h)$, $W_0(\mathbf{y}, x, z)$, and $U(x, z)$,
- value functions for the firm $J(\mathbf{y}, x, z, w, h)$, $J_0(\mathbf{y}, x, z)$

such that the wage and hours policy functions solve (8), the mothballing decision solves (7), the worker's value functions solve (2), (3), (4), and the firm's value functions solve (5) and (6). We solve for value and policy functions using value function iteration.

5 Estimation (TBC)

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.

Indirect inference also provides a natural solution to deal with several of the idiosyncrasies of our dataset. Our data contains the full-employment biographies of the universe of workers in the Nuremberg area who were employed at least once between June 2008 and December 2010. We therefore under sample the long-term unemployed. Also, prior to June 2008, our data set is growing from month to month as young workers join the labor force. After December 2010, our dataset is shrinking from month to month as old workers retire without being replaced by young workers. Also, recall that our dataset mis-measures the number of short-time workers. Some short-time workers are employed by firms that may have applied for short-time work with branches of the employment agencies outside of Nuremberg. We assume that this measurement error is independently distributed on the firm-worker-match-level. After we simulate the data we will classify 10% of short-time workers as full-time employed, which is the approximate rate of underreporting we determined by comparing our Nuremberg worker-level data set against the firm-level data we obtained.

We obtain our simulated data as follows. We restrict the aggregate state of the world to take on two values, *normal* and *recession*. We then estimate the Markov transition matrix of this aggregate process using data on past recessions in Germany starting in 1961. Using this sequence of the aggregate state, we then simulate individual-level data for a large number I of

individuals. Anytime a worker leaves our sample in the simulated data (due to the exogenous death shock χ), the worker is replaced by a "young" worker without any work-experience. We also allow for workers to leave our data set without retiring ("movers"). Movers are replaced by identical workers. We then discard all simulated data referring to periods before January 2006. We are left with a balanced panel with I individuals over 72 months that is the analog to our actual data set. We then apply the above mentioned sample selection criteria to this simulated data, i.e. we remove all individuals who do not have a single employment spell between June 2008 and December 2010. Also, we randomly switch the status of 10% of the firm-worker pairs from short-time work to full-time work to account for the measurement error. We then proceed by fitting auxiliary models to this simulated data set.

We use several auxiliary models to infer our models parameters. The first group of auxiliary models consists of employment status for a particular number of years of work experience at different points in time. The second group of auxiliary models consists of survival functions of employment status at different points in time. E.g., for all workers who were unemployed in January 2008, what is the probability that these workers are still unemployed t months later? The third group of models includes conditional wage means for a particular number of years of work experience at different points in time as well as a set of mincer regressions. The fourth group of models consists of a linear probability model on the decision to take up short-time work, where we regress the decision to take up short-time work on the workers age, experience, and tenure.

We set the benefit parameters b and s to 67% of a worker's benefit class. We choose the parameters of the benefits accumulation process such that it takes an average of one year for a worker to reach the benefit class right below his current wage. We choose the probability of dropping to the lowest benefit class such that the average person can expect to receive twelve months of short-time compensation or unemployment insurance benefits. Lastly, we levy a linear tax on firms equal to 3% to capture the unemployment insurance tax.

We parameterize our model as follows (also see Table 8): Matches produce output with production function $y^* \times \varepsilon \times e_k \times h$, where e_k is the worker's experience. The worker's human capital ladder consists of four rungs, $e_1, ..., e_4$. The persistence of productivity shocks can take on two values, p_1 and p_2. The probability of drawing p_1, which we denote by $\pi_1(z)$, depends on the aggregate state z. The magnitude of productivity shocks, ε, is drawn from normal distributions whose mean and standard deviations depend on the aggregate state. Workers receive job offers with probability $\lambda(z)$ that also depends on the aggregate state. Workers' preferences for consumption are characterized by a constant absolute risk aversion utility function. Workers' disutility from working is linear in hours worked and experience.

In Table 9, we report our model estimates. We estimate the duration parameter p_1 to be equal to 0.91 (which corresponds to a duration of about 11 months) and p_2 to be equal to 0.76 (which corresponds to a duration of about 4 months). During normal economic times, more

Table 8: Parametric Assumptions

Model Feature	**Functional Form**
Worker's experience ladder	e_1, e_2, e_3, e_4
Worker's preferences for consumption c and hours worked h	$1 - \exp(-\gamma c) - \kappa h$
Firm's production technology	$y^\star \times \varepsilon \times e_k \times h$
Persistence of productivity shocks	p_1, p_2
Probability of drawing p_1	$\pi_1(z)$
Distribution of ε	$\mathcal{N}(\mu(z), \sigma(z))$
Aggregate state	$\underline{z}, \overline{z}$
Worker age	$\underline{a}, \overline{a}$

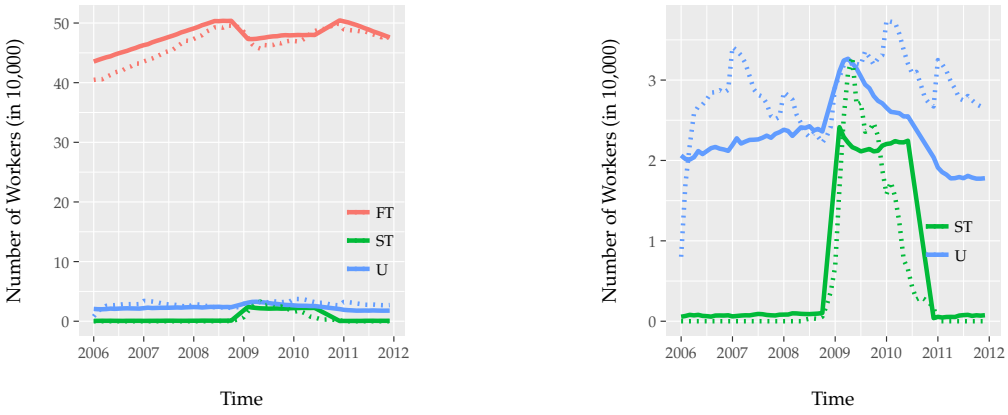
than 97% of productivity shocks are of the more persistent type. During recessions, productivity shocks are less persistent, when only 55% of productivity shocks are of the more persistent type. However, during recessions, the distribution of productivity shocks has a lower mean (2.23) than during normal times (2.64). Therefore, our model interprets recessions as times when productivity shocks tend to be drawn from a distribution with lower mean and lower persistence. We report our model's fit in Figures 7 and 8.

Table 9: Model Estimates

	x
Persistence p_1	0.9459
Persistence p_2	0.7612
Weight $\pi_{p1}(z = \underline{z})$	0.9717
Weight $\pi_{p1}(z = \overline{z})$	0.3072
Mean shock $\mu(z = \underline{z})$	2.8333
Std. dev shock $\sigma(z = \underline{z})$	1.9775
Mean shock $\mu(z = \overline{z})$	3.0282
Std. dev shock $\sigma(z = \overline{z})$	2.6860
Long-run productivity $y_2 - y_1$	0.3076
Long-run productivity weight π_{y1}	0.0282
Returns to experience e_2	0.0598
Returns to experience e_3	0.0213
Returns to experience e_4	0.2209
Experience accumulation $\omega_{e\uparrow}$	0.0457
Experience depreciation $\omega_{e\downarrow}$	0.0995
Lose contact δ_0	0.1164
Disutility from work	0.0000
Job finding probability $\lambda(z = \underline{z}, \underline{a})$	0.2838
Job finding probability $\lambda(z = \overline{z}, \underline{a})$	0.5314
Job finding probability $\lambda(z = \underline{z}, \overline{a})$	0.1404
Job finding probability $\lambda(z = \overline{z}, \overline{a})$	0.2413
Bargaining power α	0.5000
CARA	2.0000
Discount Factor β	0.9950
Prob. of staying in good aggregate state	0.9843
Prob. of staying in bad aggregate state	0.8875
Prob. of death χ	0.0020
Prob. of moving	0.0030
Prob. of aging	0.0040
Prob. of death	0.0040

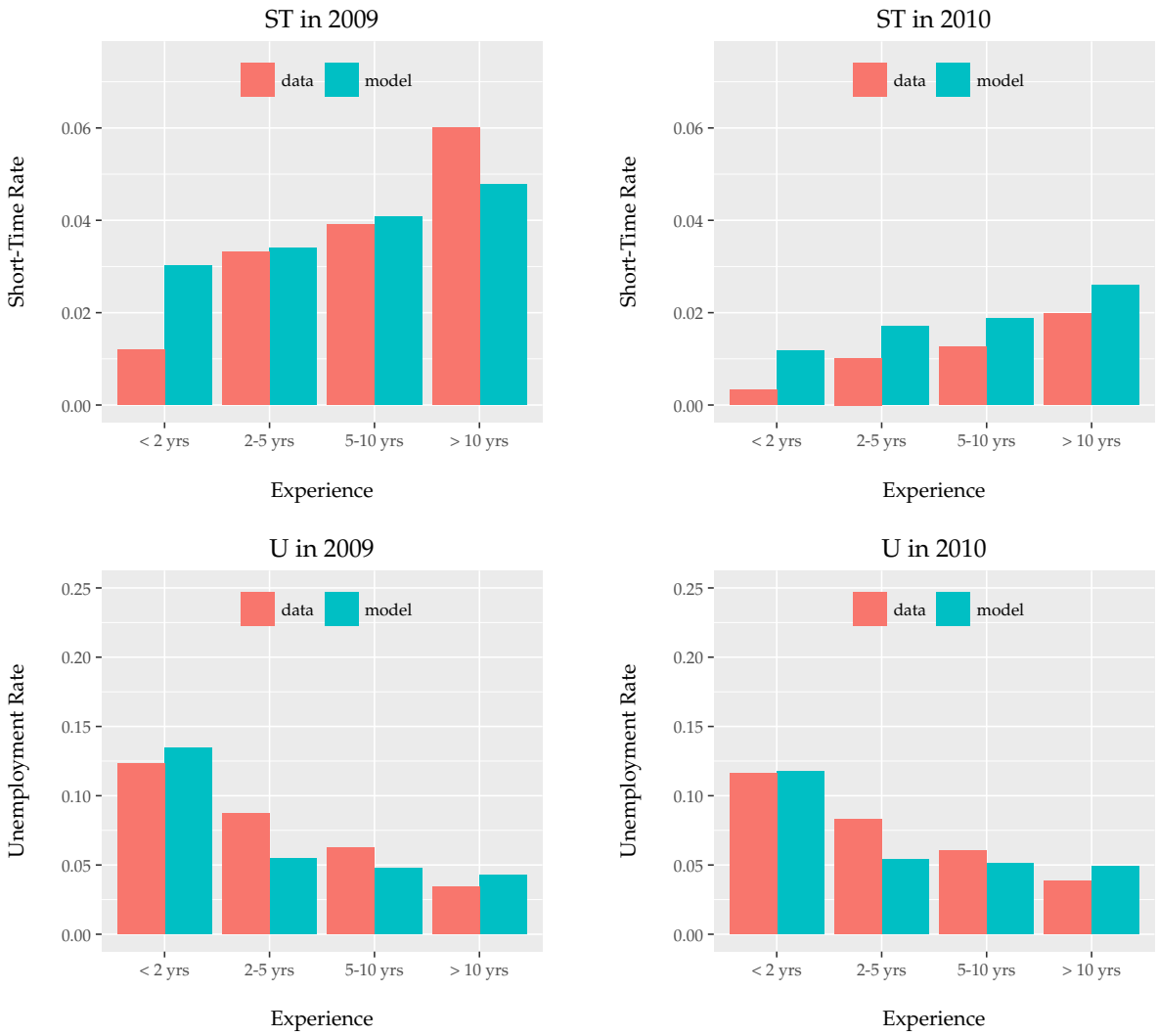
Notes: All parameters are estimated except for the bargaining power α, the CARA coefficient, and the discount factor.

Figure 7: Aggregate Employment: Model vs. Data



Notes: Evolution of the number of workers across employment types in the data (dashed lines) and the model (solid lines). Because of movers and retirees, our data set grows until June 2008 and shrinks after December 2012. We emulate this sample selection in our estimated model by including a probability of moving and a probability of death. Workers who move are replaced by identical workers. Workers who die are replaced by young workers.

Figure 8: Employment By Experience: Model vs. Data



6 Counterfactuals (TBC)

How many jobs did short-time compensation save between 2008 and 2010? To answer this question, we set the generosity of short-time compensation to zero in our estimated model. In Table 10, we report the unemployment and short-time rates of this counterfactual and compare them to our estimated model. In the counterfactual economy, unemployment would have been 6.5% compared to 5.7% percent in the estimated model. With the average take up of short-time work equal to 4.2%, we conclude that one in five short-time workers would have been laid off without short-time compensation.

Table 10: Counterfactual: No Short-Time Compensation

	Factual	Counterfactual
Unemployment rate 2008	0.045	0.047
Unemployment rate 2009	0.057	0.067
Unemployment rate 2010	0.059	0.061
Short-time rate 2008	0.012	0.000
Short-time rate 2009	0.047	0.000
Short-time rate 2010	0.024	0.000

Notes: The table at the top compares the unemployment rates implied by the estimated model to the unemployment rates to the counterfactual when the generosity of short-time compensation is set to zero. The bottom table compares short-time rates.

7 Conclusion (TBC)

A1 Additional Graphs and Tables

Table A1: Incidence of Short-Time Work by Industry

	Total Hours Reduced
Manufacturing	5,340,008
Wholesale and Retail Trade	416,568
Professional, Scientific and Technical Activities	291,178
Information and Communication	117,608
Water Supply; Sewerage, Waste Management, etc.	112,188
Transportation and Storage	74,125
Administrative and Support Service Activities	54,691
Other	9,326
Real Estate Activities	8,233
Accommodation and Food Service Activities	7,941
Education	7,143
Arts, Entertainment and Recreation	5,941
Human Health and Social Work Activities	5,200
Financial and Insurance Activities	2,278
Public Administration and Defence	1,965
Electricity, Gas, Steam	973

Notes: The table displays the total number of short-time hours by industry.

Table A2: Worker Characteristics Relative to Colleagues by Labor Market Transition in Manufacturing

	E to E	E to E′	E to S	E to U	E to O
Δ Age	0.036	-3.021	-0.121	-2.135	-1.777
	(0.006)	(0.071)	(0.036)	(0.102)	(0.069)
Δ Tenure	0.043	-2.895	0.001	-3.414	-1.148
	(0.004)	(0.040)	(0.025)	(0.055)	(0.048)
Δ Experience	0.089	-2.629	-0.299	-3.383	-2.211
	(0.005)	(0.064)	(0.034)	(0.084)	(0.066)
Δ Earnings	94.099	-40.504	-337.615	-598.625	-1,719.537
	(2.107)	(23.174)	(8.049)	(17.359)	(16.922)
Observations	3,516,265	22,336	76,532	12,792	32,327

Table A3: Worker Characteristics Relative to Colleagues by Labor Market Transition in Manufacturing for Skilled Workers

	E to E	E to E′	E to S	E to U	E to O
Δ Age	0.017	-2.538	0.059	-2.296	-0.282
	(0.013)	(0.177)	(0.065)	(0.215)	(0.182)
Δ Tenure	0.016	-1.902	0.085	-3.341	-0.525
	(0.009)	(0.090)	(0.041)	(0.112)	(0.105)
Δ Experience	0.032	-2.288	0.095	-3.529	-1.030
	(0.011)	(0.154)	(0.058)	(0.172)	(0.152)
Δ Earnings	13.875	-70.383	-22.379	-271.546	-687.613
	(1.056)	(10.695)	(2.877)	(11.434)	(18.474)
Observations	646,220	3,585	26,009	2,765	4,575

Notes: The table summarizes workers' characteristics by the type of labor market transition for the time between June 2008 and December 2010. The unit of observation is a worker-month.

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