Firm Dynamics and Earnings Risk*

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Abstract

We study how firm and worker shocks shape workers' earnings dynamics. Using Danish matched employer-employee data, we document that large worker earnings losses occur throughout the firm revenue growth distribution, with rising incidence in shrinking firms. We interpret the evidence using an equilibrium search model with firm- and worker-level shocks. Firm shocks cannot generate large losses in growing firms, requiring worker shocks to cause them. Firm shocks account for roughly a third of the losses driven by productivity shocks. We use the model to evaluate insurance policies, which trade off insurance against the allocation of workers to firms.

Keywords: Earnings Risk, Firm Dynamics, Unemployment, Wages, Misallocation
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1 Introduction

Most workers' labor earnings change little from one year to the next, but a substantial tail of workers experiences large changes, including losses. Large literatures document properties of worker earnings dynamics, build models around statistical representations of these processes, and show that exposure to such income processes is associated with large household welfare losses.[1] We ask: what drives these earnings dynamics, in particular the large earnings losses that account for most of the welfare cost of earnings risk?

A natural place to look is the firm. A growing literature documents that firm-level outcomes display similar fat-tailed dynamics to worker earnings, with a small share of firms experiencing very large revenue changes.[2] Whether these firm-side dynamics are connected to the worker-side dynamics is, however, far from obvious. A long-standing literature going back to Baily (1974) and Azariadis (1975) shows that the optimal contract between a risk-neutral firm and a risk-averse worker fully insures the worker against firm shocks. Empirically, a substantial literature starting with Guiso, Pistaferri, and Schivardi (2005) has documented that pass-through does occur, on average. Building on this evidence, we ask: what share of the large worker earnings losses is generated by firm-level shocks, through the equilibrium separations and wage renegotiations they trigger in a frictional labor market?

To answer this question, we combine evidence from Danish administrative matched employer-employee data with a structural search model with idiosyncratic shocks at both the firm and the worker level. The data reveal that large worker earnings losses occur throughout the firm revenue growth distribution: while they are more common in shrinking firms, they are also observed in firms whose revenue is rising. Disciplined by this pattern, the model attributes roughly one third of the losses driven by productivity shocks to firm-level shocks. Through the lens of the model, a firm-level shock, which affects all workers at the firm, does not drive large losses in firms that are growing strongly, so those losses identify worker-level shocks. We then use the model to evaluate three policies designed to insure workers against earnings losses — unemployment insurance, progressive taxation, and layoff taxes — each of which has different effects on the allocation of heterogeneous workers to heterogeneous firms.

Our first set of results is empirical. We go beyond studying the worker earnings distribution in isolation by providing evidence on the joint distribution of earnings growth and firm revenue growth using Danish matched employer-employee data. Denmark is an unusually well-suited setting for studying how firm shocks reach worker earnings. The

[1] For earnings dynamics, see e.g. Guvenen, Karahan, Ozkan, and Song (2021); for incomplete-markets models, Aiyagari (1994); for welfare costs, De Nardi, Fella, and Paz-Pardo (2020). We discuss these literatures in more detail below.

[2] See Jaimovich, Terry, and Vincent (2025), Melcangi and Sarpietro (2025), and Salgado, Guvenen, and Bloom (2025).

labor market is flexible, with easy firing and largely local wage setting, so firm shocks have a fair chance of reaching workers. The data link the universe of employment relationships to firm financial accounts, allowing us to measure firm revenue growth and worker earnings growth jointly. Both display fat tails, or formally excess kurtosis, with many observations close to zero but a substantial share of very large changes.

Three key facts emerge from the joint distribution of firm revenue growth and worker earnings growth. First, large earnings losses occur along the entire firm revenue growth distribution: in the upper half, the 10th percentile of worker earnings growth is roughly constant at around -11.5%, and it falls to around -25% in firms shrinking by 40–50%. Second, the very largest losses are driven by transitions to unemployment, which rise sharply along the firm distribution: the probability of an unemployment spell in the next year is around 7% in growing firms but climbs to 12% in the most strongly shrinking firms. Third, the first pattern survives when we restrict attention to stayers — workers employed in two consecutive years at the same firm — although the magnitudes are smaller, with the 10th percentile of earnings growth ranging from -6% in growing firms to -11% in the most strongly shrinking firms. Beyond the lower tail, median earnings growth is roughly flat across the firm distribution and the 90th percentile rises modestly with firm growth.

Our second set of results comes from a structural search model designed to interpret the facts. The model has two-sided heterogeneity, with risk-averse workers and multi-worker firms; on-the-job search generating a job ladder; idiosyncratic productivity shocks at both the worker and the firm level; and wage setting under two-sided limited commitment, so that wages stay flat within a match unless productivity shocks cause a participation constraint to bind or the worker receives an outside offer. The discrete adjustment is a key feature motivated by our evidence showing mostly stable earnings accompanied by large infrequent earnings adjustments. As such, the fat tails of worker earnings and firm revenue growth are endogenous outcomes of the model: even with Gaussian productivity shocks, separations and discrete wage renegotiations generate the large changes that characterize both distributions in the data.

We calibrate the model to key features of the Danish labor market — the wage distribution, the firm size distribution, earnings and revenue growth distributions, and labor market flows — and use it to decompose worker earnings dynamics into worker- and firm-level shocks. Roughly one third of large earnings losses due to endogenous separations and wage cuts are caused by firm-level shocks. The decomposition is identified off the empirical pattern that large losses occur even in firms whose revenue is rising: a common firm-level shock does not drive such losses, so the model assigns them to worker shocks. In shrinking firms, by contrast, the firm shock is responsible for additional endogenous separations and downward wage renegotiations.

Our third set of results concerns policy. The model offers a natural laboratory for evaluating policies designed to insure workers against earnings losses, since the risk those policies aim to insure is itself endogenous to them. We study three policies that reflect distinct approaches to insurance taken across countries, particularly visible in pandemic-era responses: the U.S. mostly relied on direct income support to workers while many European countries instead used job-preservation schemes (Giupponi, Landais, and Lapeyre 2022). Mirroring this contrast, we study unemployment insurance and progressive taxation, which directly target workers, and layoff taxes, which aim to preserve jobs.

All three policies provide insurance in a labor market where the allocation of heterogeneous workers to heterogeneous firms is itself an equilibrium outcome, but they interact with that allocation in different ways. Unemployment insurance and progressive taxation transfer resources to workers suffering large losses but disincentivize search effort, slowing reallocation toward more productive firms. Layoff taxes raise the cost of separations and so preserve some matches, but firms anticipate these costs and adjust job creation in response. This feedback is heterogeneous: less productive firms, which face higher separation risk, are affected more strongly, and the most productive firms in equilibrium expand job creation as competition for workers eases. The result is that layoff taxes can improve worker-firm allocation even as they preserve marginal matches, a force absent from policies that operate through worker-side incentives alone.

1.1 Related Literature

Evidence. On the empirical side, our paper relates to two strands of the literature: the literature on worker earnings dynamics, and the literature on firm-shock pass-through. Departing from earlier work assuming Gaussian innovations,[3] a recent literature documents the leptokurtic, non-normal nature of worker earnings dynamics (Arellano, Blundell, and Bonhomme 2017; Geweke and Keane 2000; Guvenen et al. 2021), with similar patterns confirmed across countries by the Global Repository of Income Dynamics project (Guvenen, Pistaferri, and Violante 2022), including for Denmark (Leth-Petersen and Sæverud 2022).[4] A related literature shows that exposure to such income processes carries large welfare costs, particularly through their large negative realizations (Busch and Ludwig 2024; Constantinides 2025; De Nardi et al. 2020; Guvenen, Ozkan, and Madera 2024; Madera 2024).

Subsequent work has documented the relative contributions of unemployment, wages, and hours to earnings risk (De Nardi, Fella, Knoef, Paz-Pardo, and Van Ooijen 2021; Halvorsen, Holter, Ozkan, and Storesletten 2023; Hoffmann and Malacrino 2019; Pora

[3] See for example MaCurdy (1981).

[4] The large earnings losses we study relate to a long literature documenting the persistent earnings costs of job displacement (Bertheau, Acabbi, Barceló, Gulyas, Lombardi, and Saggio 2023; Davis and von Wachter 2011; Jacobson, LaLonde, and Sullivan 1993).

and Wilner 2020), a decomposition our facts speak to directly. Our focus, however, is on linking the earnings growth distribution to firm outcomes, where similar deviations from normality have recently been documented (Jaimovich et al. 2025; Melcangi and Sarpietro 2025; Salgado et al. 2025).[5]

This focus places our paper within the literature on the pass-through of firm shocks to worker wages. The seminal paper by Guiso et al. (2005) finds moderate pass-through from value-added shocks to wages using Italian data, but only if the shocks are permanent.[6] A few papers have extended the methodology in directions relevant to our paper. Friedrich, Laun, Meghir, and Pistaferri (2025) broaden the focus beyond stayers by accounting for participation and mobility decisions and attribute a quarter of the cross-sectional variance of wages at age 55 to firm pay levels and pass-through of shocks, based on Swedish data. Their statistical model of the earnings process is the closest antecedent to our decomposition; we instead embed firm-shock pass-through in an equilibrium model with firm dynamics, linking earnings risk to firm growth and to policy. Chan, Salgado, and Xu (2025), using Danish data, refines the methodology of Guiso et al. (2005) by correcting for selection of stayers and finds much larger pass-through of firm productivity shocks to wages, uncovering important heterogeneity across margins such as firm productivity and size as well as worker age and tenure. Also with Danish data, Maibom and Vejlin (2024) considers employment stability in addition to wages, finding that worse firm performance increases both transitions to unemployment and to other jobs. Deriving its motivation from the recent earnings dynamics literature, as part of the GRID project, Bowlus, Gouin-Bonenfant, Liu, Lochner, and Park (2022) documents that average earnings growth strongly increases with firm employment growth and that its dispersion is U-shaped in firm employment growth, using Canadian data. In our paper we use evidence from the joint distribution of worker earnings growth and firm revenue growth to discipline a structural decomposition of earnings risk into firm and worker shocks, with explicit attention to the tails.[7]

Theory. Our structural model builds most directly on Gulyas (2023), whose multi-worker-firm model of firm dynamics and sorting we extend with risk-averse workers to study earnings dynamics and policy. It relates more broadly to equilibrium search models with two-sided heterogeneity such as Bagger, Hejlesen, Sumiya, and Vejlin (2018), Bagger

[5]Further work documents business cycle variation in earnings risk (Guvenen, Ozkan, and Song 2014), as well as its secular decline, which Salgado, Bloom, Guvenen, Pistaferri, and Sabelhaus (2023) tie to falling firm-level volatility.

[6]Carlsson, Messina, and Skans (2016) and Souchier (2023) investigate the difference between firm-level and sectoral productivity shocks.

[7]A separate literature, building on Abowd, Kramarz, and Margolis (1999), decomposes wage levels into worker and firm components, with recent extensions allowing firm effects to vary over time (Engbom, Moser, and Sauermann 2023). Arellano, Attanasio, Borella, De Nardi, and Paz-Pardo (2026) use subjective expectations data to show that individual and individual-employer heterogeneity account for much of the measured persistence of earnings.

and Lentz (2019), and Lise, Meghir, and Robin (2016), which focus on sorting and the wage distribution rather than earnings risk.[8]

Several papers also use search frameworks to study earnings dynamics. Hubmer (2018) proposes a partial-equilibrium job ladder model to account for higher-order moments of earnings risk.[9] Ai and Bhandari (2021), Graber (2018), Harmenberg (2021), McKay and Papp (2012), and Pascal (2020) study cyclical income risk. The most closely related paper is Balke and Lamadon (2022), which features risk-averse workers, two-sided heterogeneity, and productivity shocks to both workers and firms in an equilibrium search model with optimal long-term contracts. The key distinction is that their optimal contract makes wages smoothly track productivity, providing partial insurance, whereas we focus on what drives large discrete earnings adjustments.[10]

For wage setting, we build on the literature on long-term wage contracts between risk-neutral firms and risk-averse workers, in particular contracts under two-sided limited commitment first developed in Thomas and Worrall (1988). Postel-Vinay and Turon (2010) provide an early application of this protocol to the study of earnings dynamics.

Policy. Finally, our paper relates to literatures studying each of the three policies we consider. The most widely studied is unemployment insurance, where the classic trade-off between consumption insurance and adverse effects on search effort (Baily 1978; Chetty 2006) has been refined in a long literature on optimal design (Acemoglu and Shimer 1999; Hopenhayn and Nicolini 1997; Shimer and Werning 2008).[11] Our contribution is to study how UI generosity affects the allocation of workers across heterogeneous firms. As an alternative worker-side policy that insures earnings losses while employed, we consider progressive taxation, which has been evaluated much less in equilibrium search models. Recent exceptions include Kreiner, Munch, and Whitta-Jacobsen (2015) quantifying efficiency losses from misallocation due to labor taxation with a partial equilibrium search model, Bagger et al. (2018) studying the effects of Danish tax reforms on equilibrium labor allocations in a model with fixed types and complete markets, Bagger, Moen, and Vejlin (2021) studying deadweight losses from taxation in an equilibrium search model, and Kaas, Lalé, and Siassi (2026) studying progressive taxation in an incomplete mar-

[8] We share the multi-worker-firm structure with a quickly growing literature on search with multi-worker firms, including Audoly (2023), Bilal, Engbom, Mongey, and Violante (2022), Elsby and Gottfries (2022), Elsby and Michaels (2013), McCrary (2022), and Moscarini and Postel-Vinay (2013) in the random-search and Kaas and Kircher (2015) and Schaal (2017) in the directed-search tradition.

[9] The framework builds on Lise (2013), the seminal paper combining job-ladder dynamics with precautionary savings.

[10] Kleven, Kreiner, Larsen, and Søgaard (2025) provides further evidence for such discrete adjustment using Danish administrative data.

[11] A more recent literature studies general-equilibrium amplification of the search-effort response to more generous benefits (Acosta, Mueller, Nakamura, and Steinsson 2025; Chodorow-Reich, Coglianese, and Karabarbounis 2019; Hagedorn, Manovskii, and Mitman 2025; Karahan, Mitman, and Moore 2025).

kets model with a job ladder, but ex ante homogeneous workers and firms and constant productivity heterogeneity.

A smaller literature argues that the presence of unemployment benefits calls for a layoff tax to correct the fiscal externality that firms do not internalize the benefits paid to laid-off workers (Blanchard and Tirole 2008; Cahuc and Zylberberg 2008). The employment effects of layoff taxes are debated: they can prevent separations but also feed back into hiring (Alvarez and Veracierto 1999; Bentolila and Bertola 1990; Hopenhayn and Rogerson 1993; Mortensen and Pissarides 1999; Saint-Paul 1995) — see Ljungqvist (2002) for a discussion of which force dominates in firm-dynamics versus search models.[12] We contribute by emphasizing heterogeneous incidence: layoff taxes feed back more strongly into the hiring of firms closer to a layoff margin, with implications for worker-firm allocation.

Roadmap. The remainder of the paper proceeds as follows. In Section 2 we present three key facts on the comovement of firm and worker outcomes. In Section 3 we describe the equilibrium search model. We bring the model to the data in Section 4 and perform the quantitative decomposition in Section 5 and the policy analysis in Section 6. Finally, we conclude in Section 7.

2 Key Facts on Joint Worker-Firm Outcomes

We aim to quantify how much of worker earnings dynamics is driven by common firm-level shocks as opposed to purely worker-level idiosyncratic risk. For that purpose, we first present three key facts, which are going to discipline a search model with two-sided heterogeneity to quantitatively decompose the role of firm- vs. worker-level shocks.

2.1 Data and Institutional Context

The key facts on the relationship between individual earnings changes and firm outcomes are based on Danish administrative data.[13] We restrict ourselves to the time period from 2008 to 2016 because for these years we have the highest quality information on employment spells and earnings.

Our data covers the universe of workers and firms in Denmark. We observe the start and the end date of all employment spells and an identifier for the firm at which the worker is employed. The earnings measure, available at monthly frequency, is of high quality as

[12] A separate strand evaluates layoff taxes and related employment subsidies alongside UI under exogenously rigid wages (Birinci, Karahan, Mercan, and See 2021; García-Cabo, Lipińska, and Navarro 2023; Jung and Kuester 2015).

[13] We combine information from several registries, which are described in detail in Appendix A.1 (Statistics Denmark 2008–2016).

it is third-party reported by tax authorities and it is not top-coded. We supplement this data with firm sales from value-added tax records.

Denmark is an interesting laboratory to investigate unemployment and wage risk stemming from the interaction of firms and workers because its labor market is very flexible. Through labor market reforms in the 1990s, Denmark adopted a system that has become known as "flexicurity", combining income security through generous unemployment insurance and means-tested transfer programs with very flexible hiring and firing.[14] In an OECD ranking of countries according to their strictness of employment protection, Denmark falls into the category with the weakest restrictions (OECD 2020). There are no substantive conditions for a dismissal for economic reasons. Flexibility extends to wage setting. There is no statutory minimum wage. While many employees are covered by collective bargaining agreements, for the vast majority of workers compensation is determined at the firm level. According to the Danish Employers' Association, around 60% of workers are covered by agreements specifying only minimum pay, 20% are uncovered, and for the remaining 20% a base wage is set but bonuses still allow individual deviations (Dahl, Le Maire, and Munch 2013). Bertheau, Kudlyak, Larsen, and Bennedsen (2025) designs a survey among Danish firms to understand when firms choose to lay off workers or cut wages, reporting that among firms experiencing a larger than 20% reduction in revenue more than half adjust employment and more than 30% adjust pay. There is no evidence of legal restrictions playing a major role in preventing wage cuts in Denmark.[15]

2.2 The Joint Distribution of Earnings and Revenue Growth

Earnings dynamics by firm revenue growth. For our analysis of joint firm-worker outcomes, we focus on annual growth rates. To analyze the comovement of worker earnings and firm revenues we match workers to firms in year $t-1$. We additionally require that workers are employed for the whole year at only one firm. Then, we group firms by their revenue growth from $t-1$ to t. We impose mild sample restrictions that are standard in the earnings dynamics literature. Specifically, we limit the analysis to workers who are between 25 and 60 years old, work at least 200 hours per year, and have minimum real 2015 annual earnings of DKK 20,000, which corresponds to roughly €2,700 or \$3,000.[16] We compute the worker earnings growth distribution, in log differences, from $t-1$ to t by firm group. We present two sets of results based on restrictions on workers' ongoing attachment. For the first case, we do not impose any restriction on whether or where workers work in year t. They may still be at the same firm, work for a different firm, be unemployed, or any combination of those. The earnings in year t may thus come from different employers and also overlapping spells. The second case restricts attention to

[14] For a detailed review of the features of "Danish flexicurity" see Kreiner and Svarer (2022).
[15] For more details on Danish labor market institutions and sector-specific evidence, see Appendix A.3.4.
[16] We adjust for inflation using the consumer price index (CPI) provided by Statistics Denmark.

stayers, who are employed at the same firm throughout years $t-1$ and t, isolating the intensive margin. To bridge the two, we also examine the extensive margin directly by characterizing the incidence of transitions to unemployment.[17]

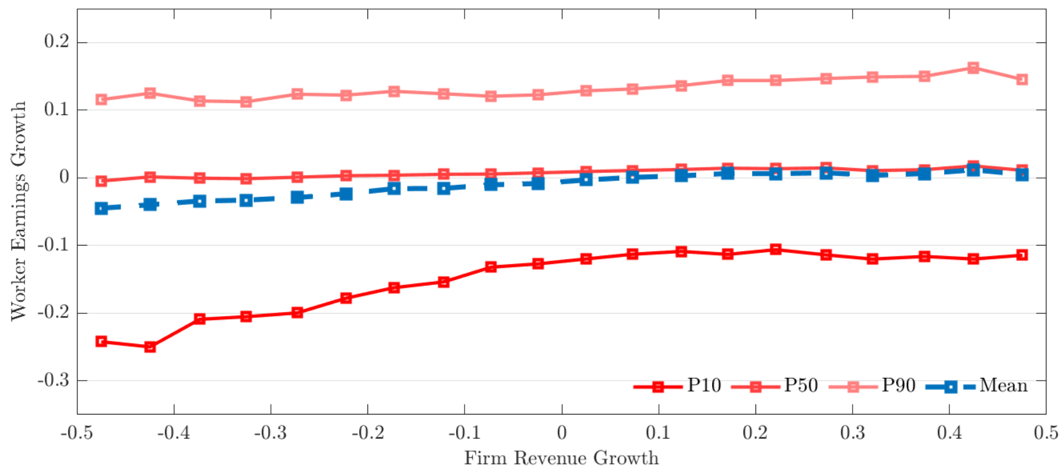

Figure 1: Worker Earnings Growth by Firm Revenue Growth

Notes: This figure shows moments of the annual earnings growth distribution, conditional on the revenue growth of the firm at which workers are employed in the initial year.

Figure 1 shows the mean, median, 10th, and 90th percentile of the worker earnings growth distribution for 20 groups of workers, characterized by the revenue growth of their firms. The range of revenue growth we plot here is from -0.5 to 0.5. These are large changes, but a meaningful share of workers are employed at such firms: the 10th and 90th percentiles of the employment-weighted firm revenue growth distribution are -34% and 29%, respectively.[18]

On average, earnings growth of workers is almost five percentage points higher in the firms that grow the most relative to the firms that are strongly shrinking. The overall average is negative because of the sample restriction that every worker is full-year employed in the base year but may experience unemployment in the second year. Note, however, that the median of the earnings growth distribution is essentially flat across the entire firm revenue growth distribution. The median worker across firm groups is unaffected by whether the firm's revenue is shrinking or growing strongly.

To a large extent, the lower mean of the earnings growth distribution in shrinking firms is driven by the lower tail of the earnings growth distribution. In these firms, it is much

[17] We focus here on the earnings growth distribution along the firm revenue growth distribution. See Appendix A.2.1 for details on the worker earnings growth distribution, which shares the property of strong excess kurtosis with the earnings growth distributions of many other countries, as documented in a quickly growing recent literature (Guvenen et al. 2022; Leth-Petersen and Sæverud 2022).

[18] For more details on the firm revenue growth distribution see Appendix A.2.2, where we report unweighted and employment weighted statistics of the annual revenue growth distribution from both value added tax and accounting data. The measure reported in the text is employment weighted based on value added tax data, trimming very large outliers.

more likely that workers experience very large earnings losses relative to growing firms. In firms with positive revenue growth, the 10th percentile of the worker earnings growth distribution is flat at around −11.5%. At the bottom of the revenue growth distribution it is −24%. Hence, workers in shrinking firms are much more likely to experience large earnings losses compared to workers in growing firms.

To a lesser extent, the mean relationship is also driven by differences in the right tail of the earnings growth distribution. The 90th percentile is around three to four percentage points higher for workers in strongly growing relative to strongly shrinking firms.[19]

We summarize the discussion in this section as the first key fact.

Key Fact 1 *Large earnings losses for workers are observed along the entire distribution of firm revenue growth. Their incidence is essentially constant in growing firms, but rises in shrinking firms.*

Up to now, we have not conditioned on workers' employment status in the second year. In particular, the gradient in the 10th percentile of the earnings growth distribution could be purely driven by different likelihoods of transitioning to unemployment, but also by a larger chance of wage losses for stayers. We now zoom in on the contributions of the extensive and the intensive margin.

Extensive margin. We first investigate the contribution of the extensive margin. Figure 2 shows the likelihood of experiencing unemployment spells of varying lengths in year t. The left panel shows the share of workers with no unemployment in year t. For workers in growing firms this share is fairly stable at around 93%. The more a firm's revenue goes down, the larger the share of workers with unemployment spells. Between growing firms and the most strongly shrinking firms the difference is around 5 percentage points: the unemployment incidence rises from roughly 7% to 12%.

The right panel shows how this larger probability of experiencing unemployment spells is distributed across different unemployment durations. Workers starting in shrinking firms are more likely to experience unemployment spells both of short and longer duration than those starting in growing firms. The pattern of unemployment risk along the firm distribution thus mirrors the gradient in large earnings losses from Fact 1.

Key Fact 2 *Transitions to unemployment are observed along the entire distribution of firm revenue growth. Their incidence is essentially constant in growing firms, but rises in shrinking firms.*

[19] In Appendices A.3.1, A.3.2, and A.3.3, we show robustness of the first key fact with respect to using alternative measures of firm growth, the state of the business cycle, and firm size. Across all versions, large earnings losses of workers are observed along the entire firm growth distribution, but are more common in shrinking firms, even if the exact magnitudes vary depending on the specification. In Appendix A.3.6, we verify that the relationship holds when considering longer run earnings and revenue growth rates.

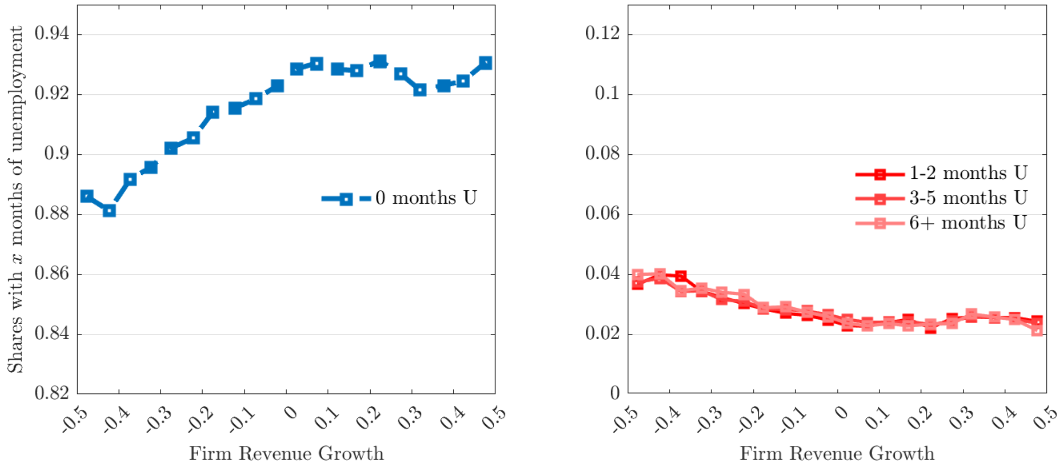

Figure 2: Unemployment Propensities by Firm Revenue Growth

Notes: This figure shows the likelihood of experiencing unemployment spells of varying duration, conditional on the revenue growth of the firm at which workers are employed in the initial year.

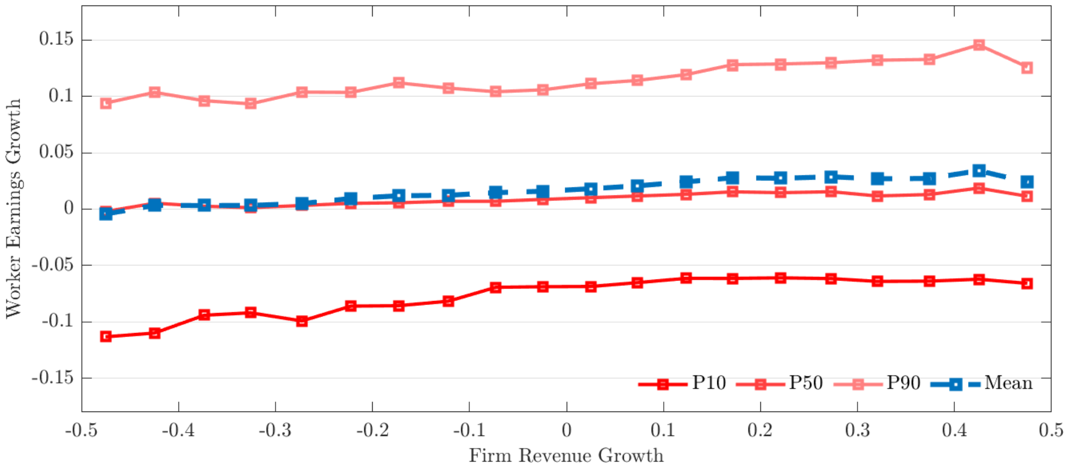

Figure 3: Worker Earnings Growth of Stayers by Firm Revenue Growth

Notes: This figure shows moments of the annual earnings growth distribution for workers staying at the same firm, conditional on the revenue growth of the firm.

Intensive margin. While job losses are important for the very largest earnings losses and are strongly associated with firm revenue growth, we now show that there is also a tight link between firm revenue growth and the likelihood of large earnings losses for stayers. To that end, we focus on a stayer sample, imposing the additional restriction that workers are employed at the same firm throughout years $t-1$ and t, without any unemployment spell or employment at a different firm.

Figure 3 shows that there is a positive relation between revenue growth and earnings growth for the stayer sample as well — on average, earnings growth is around three percentage points higher at the top of the firm revenue growth distribution than at the bottom. Again, this is mostly driven by the tails of the earnings growth distribution. While the median is slightly increasing along the firm distribution, the increase is much stronger for both the 10th and the 90th percentile. For stayers, large earnings losses are much more likely in firms whose revenue is going down, and large gains much more likely in firms whose revenue is going up. The 10th percentile ranges from around -6% in growing firms to around -11% in the most strongly shrinking firms, and a similar gradient of around three percentage points holds for the 90th percentile.[20]

Key Fact 3 *For job stayers, large earnings losses are more likely in shrinking firms and large earnings gains more likely in growing firms. Still, both are observed along the entire firm revenue growth distribution.*

Taking stock. The worker earnings growth distribution is characterized by excess kurtosis, with the majority of workers having stable earnings from one year to the next, but a considerable share experiencing very large gains and losses. In this section, we established three key facts. First, large earnings losses occur along the entire firm revenue growth distribution but are concentrated in shrinking firms. Second, this is partially driven by unemployment risk, with the likelihood of a transition to unemployment also higher in shrinking firms. Third, even though unemployment is important for the very large earnings losses, the same patterns hold for stayers. We now build a search model with two-sided heterogeneity to interpret these facts and decompose worker earnings dynamics into the contributions of worker- and firm-level productivity shocks.

3 Model

In this section, we describe the model environment. The model economy is populated by heterogeneous workers and firms. Workers differ in their employment status, productivity, and job search effort, whereas firms differ in their productivity, number of employees, and job creation choice. There is also a government, which raises taxes and provides unemployment insurance. We start the model description by discussing each of these agents.

3.1 Agents

Workers. The economy is populated by a unit mass of infinitely lived workers, who are heterogeneous in their labor productivity x. Worker productivity is stochastic, following a first-order Markov process with conditional transition probabilities denoted by

[20] Here we focus on total earnings of stayers, as this is the highest quality information that we have. In Appendix A.3.5 we discuss how these earnings changes split into hours and wage changes, with wage changes playing an important role. We also show in Appendix A.3.4 that the patterns are stronger in industries with more flexible wage setting institutions.

$p_w(x' \mid x)$ inducing stationary distribution $\phi_w(x)$. Workers can be either employed (E) or unemployed (U). If unemployed, they receive an unemployment benefit b and search for jobs. If employed, they receive a wage w and search on the job. Arrival rates of job offers are determined in equilibrium and depend on endogenous search effort.

The choice of search effort s is modeled similarly to Faberman, Mueller, Şahin, and Topa (2022).[21] The probability of meeting a vacant job depends on both individual search effort and equilibrium market tightness θ and is given by

$$\lambda_i(s,\theta) = \Lambda_i(s)\,\lambda(\theta), \quad i \in \{U, E\}, \tag{1}$$

where $\Lambda_i(s)$ translates search effort into efficiency units of search and $\lambda(\theta)$ is the equilibrium arrival rate of offers per efficiency unit of search. The cost of exerting search effort is given by an increasing and convex function $c_{w,i}(s)$, $i \in \{U, E\}$, allowing search costs to differ between unemployed and employed searchers.

Workers are hand-to-mouth; they cannot save or borrow. Hence, consumption is equal to the after-tax wage or benefit they receive every period.[22] They value consumption according to a utility function $u(c)$, which is assumed to be increasing and concave in c such that workers are risk-averse. Workers' discount factor is β.

Firms. There is a mass F of firms, who can employ many workers. Firm productivity y is also stochastic with stationary mass $\phi_f(y)$ and first-order Markov with transition probabilities $p_f(y' \mid y)$. Firms create jobs, which can be either vacant or filled. Job creation is a costly process: The job creation cost function $c_f\left(v^{\mathrm{N}}\right)$, where v^{N} denotes the measure of newly created jobs, is increasing and convex in v^{N}.

Jobs are costless to maintain. A filled job can become vacant again through an endogenous separation after adverse productivity shocks hitting either the worker or the firm or both or after a job-to-job transition of the worker. Additionally, both filled and vacant jobs can be exogenously destroyed with probability $\delta(x)$.[23] Through an exogenous destruction shock, the job disappears and the worker becomes unemployed. The modeling of vacant jobs is different from standard search models, in which all vacancies are newly created. We rather model vacant jobs as persistent, resulting from both creation of new vacancies and the opening of positions vacated through job-to-job transitions or voluntary quits. This approach is appealing for at least two reasons. First, it makes the decision of whether to create a match more realistic because upon a meeting it is not just the

[21] Earlier contributions modeling an endogenous search effort choice include Christensen, Lentz, Mortensen, Neumann, and Werwatz (2005), Hornstein, Krusell, and Violante (2011), and Bagger and Lentz (2019).

[22] Souchier (2025) studies firm-shock pass-through when workers can additionally self-insure through savings.

[23] The job destruction probability depends on worker productivity. For a vacant job, we assume the probability to be equal to that of the median productivity worker.

worker who has an option value of continuing to search for a better match, but also the firm. Second, it is supported empirically: A number of recent papers, including Faberman and Nagypal (2008), Mercan and Schoefer (2020), Elsby, Gottfries, Michaels, and Ratner (2025), and Qiu (2023), document that replacement hiring of quitting workers is quantitatively important.

A job filled with a worker of type x produces output $f(x, y)$. This output is independent of other matches, so that output of firm j is given by the sum of output over all its matches. This modeling choice preserves tractability because it allows for the contracting problem between firm and worker to be independent of other workers in the firm. At the same time, there is still a well-defined firm size distribution because of search frictions and convex job creation costs. In the frictionless limit, all workers would be employed at the most productive firm, but given the cost of job creation and delays of filling jobs because of labor market frictions, not all workers can be reallocated to the best firm. This is a common assumption in the literature to keep the problem tractable while still capturing a firm size distribution; see among others Moscarini and Postel-Vinay (2013) and Gulyas (2023).

Vacant jobs meet a searching worker with a probability that is determined in equilibrium. Firms maximize expected profits and are risk-neutral. They also discount future profits with discount factor β.

Government. The government pays benefits b to unemployed workers and finances some exogenous government spending, capturing non-modeled public expenditures. To balance its budget, the government raises income taxes using a progressive income tax function $T(\cdot)$, which is applied to both wages and unemployment benefits.[24]

3.2 Timing

The order of events in a period is as follows. At the beginning of the period there is the production stage. The distribution of matches and wages at the production stage is denoted with $\psi(x, y, w)$. We denote as $\tilde{\psi}(x, y)$ the distribution of matches, integrating out wages. At the production stage, output is produced, wages and benefits are paid out, and consumption takes place. Furthermore, firms decide how many new vacant jobs to create.

After production and the creation of new vacant jobs, exogenous job destruction shocks occur. This implies that a newly created vacant job can be destroyed immediately. If a filled job is destroyed, the worker becomes unemployed. A newly separated worker cannot search immediately but only in the next period, so that a separated worker will be unemployed for at least one period.

[24] For tractability, we assume that taxes are levied based on monthly income. In the data, the tax base is annual income; however, modeling this would require the introduction of another state variable.

Next, productivity shocks hit both workers and firms. This can lead to endogenous separations. If a match is dissolved, the job becomes vacant and the worker transitions to unemployment. Again, unemployed workers have to be unemployed for at least one period and the job also has to be vacant for a period.

A period concludes with the matching stage. Workers search, meetings realize, new matches between unemployed searchers and vacant jobs are created, and job-to-job transitions take place. The relevant distributions at this stage are the distribution of matches and wages at the search stage, $\psi^S(x, y, w)$, the distribution of unemployed workers $\mu_x(x)$, and the distribution of vacant jobs $\mu_y(y)$. Again, we introduce the distribution of matches at the search stage integrating out wages $\tilde{\psi}^S(x, y)$.

3.3 Labor Market

Search and Matching. Unemployed and employed searchers meet vacant jobs in the labor market, which we model with random search and matching. In a steady-state equilibrium, there is a distribution of unemployed $\mu_x(x)$ and employed workers at the search stage $\psi^S(x, y, w)$. Aggregate efficiency units of search are given by

$$L = \int_x \mu_x(x) \Lambda_U(s(x))\, dx + \int_x \int_y \int_w \psi^S(x, y, w) \Lambda_E(s(x, y, w))\, dwdydx. \tag{2}$$

We denote the mass of vacant jobs with $\mu_y(y)$ and the total number of vacant jobs with v. The number of meetings M is given by a standard constant returns to scale matching function $\mathcal{M}(L, v)$.[25] The probability of a vacant job meeting a worker is given by $\lambda_f = M/v$. Conditional on a meeting, the probability that the worker is unemployed is given by

$$p_U = \frac{\int_x \mu_x(x) \Lambda_U(s(x))\, dx}{L}. \tag{3}$$

Given market tightness $\theta = v/L$, the equilibrium arrival rate of offers per efficiency unit of search is given by $\lambda(\theta) = \mathcal{M}(1, \theta)$.

If a vacant job and an unemployed worker meet, given firm and worker productivity there is a maximum wage the firm is willing to pay, $\bar{w}_y(x, y)$, and a minimum wage the worker is willing to accept, $\underline{w}_x(x, y)$. As long as the firm is willing to pay more than the worker requires, the match is created. If a vacant job meets an employed worker, there will be a job-to-job transition if the potential employer can pay a higher wage than the incumbent. Otherwise, the worker stays at the incumbent firm.

Wage Setting. We assume a wage-setting protocol with two-sided limited commitment, similar to Thomas and Worrall (1988), Postel-Vinay and Robin (2002), and Cahuc, Postel-Vinay, and Robin (2006). Specifically, we assume that firms and workers agree upon a

[25] See Petrongolo and Pissarides (2001) and the references therein for a discussion of the returns to scale in the matching function.

constant wage at the beginning of the match. This wage is only adjusted in response to either side having a credible threat to otherwise leave the match, as we describe in detail now. This wage-setting protocol is empirically motivated because it can deliver stable wages for many workers, while still potentially generating large adjustments in some instances, which is an important feature of the data.[26]

If an unemployed worker meets a vacant job and it is possible to create a match, the worker has some bargaining power to extract a share of the surplus. As we discuss in more detail in the calibration section, this initial bargaining power is required because otherwise workers might be willing to accept implausibly low starting wages. Specifically, we assume that the initial wage negotiated between a firm of type y and a worker of type x is an average between the maximum wage the firm would pay and the minimum the worker would accept:

$$w^{\text{init}}(x,y) = (1-\alpha)\, \underline{w}_x(x,y) + \alpha \bar{w}_y(x,y)\,. \tag{4}$$

We will explain how to compute $\underline{w}_x(x,y)$ and $\bar{w}_y(x,y)$ below, after having introduced the value functions.

Employed workers can renegotiate their wages if they receive a relevant outside offer. Suppose a worker employed at a firm with productivity y, which is able to pay at most $\bar{w}_y(x,y)$, meets another firm with productivity $\tilde{y}$ being able to pay $\bar{w}_y(x,\tilde{y})$. Three cases can occur. First, if the maximum the potential poaching firm is willing to pay is below the current wage, this is an irrelevant outside offer and nothing will happen. Second, the current firm is able to pay more than the potential new firm, but the current wage is lower than the wage the new firm could pay. Then, the wage will be increased to this level, but the worker will stay at the old firm. This can generate large wage gains for stayers, and potentially larger in growing firms because they tend to have high productivity and can counter more outside offers. Third, if the new firm can pay a higher wage than the old firm, there will be a job-to-job transition and the worker will receive the maximum wage the old firm could have paid as the starting wage at the new firm.[27] Such employment-to-employment (EE) transitions will also generate some of the largest wage gains in the economy, again potentially more so in growing firms since outside offers tend to be more valuable.

Even without an outside offer, wages may change while a worker is employed. We assume that either side can demand a renegotiation of the wage if it has a credible threat to leave the match. For the worker that means that the wage can be renegotiated if

[26]We assume that search effort is solely the choice of the worker and cannot be contracted upon. As an example with jointly efficient search intensities in a model with risk-neutral workers and firms, see Bagger and Lentz (2019). For an optimal contracting problem with hidden search by the worker, see Lentz (2015).

[27]If the two firms have the same productivity, the tie breaking rule we assume is that there is a job-to-job transition in 50% of the cases.

quitting to unemployment is preferable to staying in the match at the current wage. For the firm it means that it can ask for a renegotiation if it prefers having a vacant job over employing the worker at the current wage. In both cases, wages are reset such that the agent demanding the renegotiation is just indifferent between staying in the match or leaving. Firm-demanded renegotiations are a key mechanism to generate wage losses in the model.

3.4 Value Functions

We can now write the value functions of an unemployed worker, an employed worker, a vacant job, and a filled job. We write all value functions from the perspective of the production stage.

Value of unemployment. We start with the value function of an unemployed worker:

$$
\begin{aligned}
U(x) = \; & \underbrace{u(b - T(b))}_{\text{Flow utility from benefit}} + \int_{x'} \max_{0 \leq s(x') \leq \bar{s}} \Bigg\{ \underbrace{-c_{w,U}(s(x'))}_{\text{Search effort cost}} \\
& \underbrace{+\beta(1 - \lambda_U(s(x'), \theta)) U(x')}_{\text{Continuation value: no meeting}} \\
& \underbrace{+\beta \lambda_U(s(x'), \theta) \int_{\tilde{y}} (1 - A_U(x', \tilde{y})) U(x') \frac{\mu_y(\tilde{y})}{v} d\tilde{y}}_{\text{Continuation value: meeting, but no match}} \\
& \underbrace{+\beta \lambda_U(s(x'), \theta) \int_{\tilde{y}} A_U(x', \tilde{y}) W\left(x', \tilde{y}, w^{\text{init}}(x', \tilde{y})\right) \frac{\mu_y(\tilde{y})}{v} d\tilde{y}}_{\text{Continuation value: new match}} \Bigg\} \\
& p_w(x' \mid x) \, dx'
\end{aligned} \tag{5}
$$

Unemployed workers consume their after-tax benefit and choose search effort after productivity shocks have realized, so that effort depends on the new productivity x'. A meeting with a vacant job of productivity $\tilde{y}$ leads to a match with probability $A_U(x', \tilde{y})$, in which case the worker transitions into employment with value $W(\cdot)$; otherwise, the worker remains unemployed.

Value of employment. The value of employment is a function of the productivities and the wage:

$$
\begin{aligned}
W(x,y,w) = {} & \underbrace{u(w - T(w))}_{\text{Flow utility from wage}} + \underbrace{\beta\delta(x)\int_{x'} U(x')\, p_w(x' \mid x)\, dx'}_{\text{Continuation value: exogenous separation}} \\
& \underbrace{+\beta(1-\delta(x))\int_{x'}\int_{y'}(1 - A_S(x',y'))\, U(x')\, p_w(x' \mid x)\, p_f(y' \mid y)\, dy'dx'}_{\text{Continuation value: endogenous separation}} \\
& + (1-\delta(x))\int_{x'}\int_{y'} A_S(x',y') \max_{0\le s(x',y',w)\le \bar{s}} \Bigg\{ \underbrace{-c_{w,E}(s(x',y',w))}_{\text{Search effort cost}} \\
& \underbrace{+\beta\int_{\tilde{y}} \lambda_E(s(x',y',w),\theta)\, A_E(x',y',\tilde{y})\, W(x',\tilde{y},\bar{w}_y(x',y'))\, \frac{\mu_y(\tilde{y})}{v} d\tilde{y}}_{\text{Continuation value: job-to-job transition}} \\
& \underbrace{+\beta\int_{\tilde{y}} \lambda_E(s(x',y',w),\theta)\, A_O(x',y',w,\tilde{y})\, W(x',y',\bar{w}_y(x',\tilde{y}))\, \frac{\mu_y(\tilde{y})}{v} d\tilde{y}}_{\text{Continuation value: renegotiation triggered by outside offer}} \\
& + \beta\int_{\tilde{y}} (1 - \lambda_E(s(x',y',w),\theta)\,[A_E(x',y',\tilde{y}) + A_O(x',y',w,\tilde{y})]) \\
& \underbrace{\times \min\{\max\{W(x',y',w), U(x')\}, W(x',y',\bar{w}_y(x',y'))\}\, \frac{\mu_y(\tilde{y})}{v} d\tilde{y}}_{\text{Continuation value: potential renegotiation after productivity shocks}} \Bigg\} \\
& p_w(x' \mid x)\, p_f(y' \mid y)\, dy'dx'
\end{aligned}
\tag{6}
$$

Employed workers consume their after-tax wage. A match ends exogenously with probability $\delta(x)$ or, after productivity shocks realize, endogenously with probability $1 - A_S(x',y')$, in both cases sending the worker into unemployment.[28] Surviving matches reach the search stage, where the worker incurs the search cost. If the worker meets a firm that can pay more than the incumbent, which happens with probability $A_E(x',y',\tilde{y})$ conditional on meeting a firm of productivity $\tilde{y}$, a job-to-job transition takes place and the worker starts at $\bar{w}_y(x',y')$, the maximum wage the incumbent could have paid. An outside offer that does not trigger a transition may still force a renegotiation, with probability $A_O(x',y',w,\tilde{y})$. Absent a relevant outside offer, the wage changes only if worker or firm has a credible threat to leave the match, as described in the wage-setting protocol above.

[28]For matches that would dissolve absent an outside offer, we assume the poaching firm would hire the worker at the reservation wage there rather than at the maximum wage the incumbent could have paid. The worker is then indifferent between being poached and separating, so the option to be poached out of a dissolving match carries no value and the survival decision reduces to the same feasibility condition as match formation. Hence $A_S(x,y) = A_U(x,y)$. We allow for the more general notation distinguishing the two cases anticipating that these probabilities will differ once we explore layoff taxes as a government policy, which are paid on separations but not when a meeting fails to produce a match.

Value of vacant job. On the firm side, we can write the values of vacant and filled jobs. Consider first the value of a vacant job:

$$
\begin{aligned}
V(y) = \beta\left(1-\delta\left(x^{\text{med}}\right)\right) \Bigg\{ & \underbrace{(1-\lambda_f)\int_{y'} V(y')\, p_f(y' \mid y)\, dy'}_{\text{Continuation value: no meeting}} \\
& \underbrace{+\lambda_f p_U \Bigg\{ \int_{y'}\int_{\tilde{x}} (1-A_U(\tilde{x},y')) \frac{L_U(\tilde{x})}{L_U} V(y')\, p_f(y' \mid y)\, d\tilde{x}dy'}_{\text{Continuation value: meeting with unemployed, no match}} \\
& \underbrace{+\int_{y'}\int_{\tilde{x}} A_U(\tilde{x},y') \frac{L_U(\tilde{x})}{L_U} J\left(\tilde{x},y',w^{\text{init}}(\tilde{x},y')\right) p_f(y' \mid y)\, d\tilde{x}dy' \Bigg\}}_{\text{Continuation value: new match with unemployed}} \\
& \underbrace{+\lambda_f(1-p_U) \Bigg\{ \int_{y'}\int_{\tilde{x}}\int_{\tilde{y}}\int_{\tilde{w}} (1-A_E(\tilde{x},\tilde{y},y')) \frac{L_E(\tilde{x},\tilde{y},\tilde{w})}{L_E} V(y')\, p_f(y' \mid y)\, d\tilde{w}d\tilde{y}d\tilde{x}dy'}_{\text{Continuation value: meeting with employed, no match}} \\
& \underbrace{+\int_{y'}\int_{\tilde{x}}\int_{\tilde{y}}\int_{\tilde{w}} A_E(\tilde{x},\tilde{y},y') \frac{L_E(\tilde{x},\tilde{y},\tilde{w})}{L_E} J(\tilde{x},y',\bar{w}_y(\tilde{x},\tilde{y}))\, p_f(y' \mid y)\, d\tilde{w}d\tilde{y}d\tilde{x}dy' \Bigg\}}_{\text{Continuation value: new match with employed}} \Bigg\}.
\end{aligned} \tag{7}
$$

There is no flow value to a vacant job, and an exogenously destroyed job has no continuation value. A surviving job that meets no worker remains vacant. Meetings, which occur with probability λ_f, are with an unemployed worker with probability p_U; the productivity composition of the workers a vacant job meets is governed by the efficiency units of search, $L_U(\tilde{x})$ for unemployed workers and $L_E(\tilde{x},\tilde{y},\tilde{w})$ for employed workers, with L_U and L_E without arguments denoting the corresponding totals. Whether a meeting turns into a match is determined by the acceptance rules A_U and A_E introduced above.

Job creation. A firm with productivity y creates new vacant jobs until the marginal cost of doing so equals the value of a vacant job:

$$
\begin{aligned}
& c_f'\left(v^{\text{N}}(y)\right) = V(y), \\
& \Rightarrow v^{\text{N}}(y) = {c_f'}^{-1}(V(y)).
\end{aligned} \tag{8}
$$

Value of filled job. Finally, we can write the value of a filled job:

$$
\begin{aligned}
&J(x,y,w) = \underbrace{f(x,y)-w}_{\text{Flow value: output net of wage}} + \beta(1-\delta(x)) \Bigg\{ \\
&\underbrace{+\int_{x'}\int_{y'}(1-A_S(x',y'))\,V(y')\,p_w(x'\mid x)\,p_f(y'\mid y)\,dy'dx'}_{\text{Continuation value: endogenous separation}} \\
&+\int_{x'}\int_{y'}A_S(x',y')\Bigg\{ \\
&\underbrace{\int_{\tilde{y}}\lambda_E(s(x',y',w),\theta)\,A_E(x',y',\tilde{y})\,V(y')\,\frac{\mu_y(\tilde{y})}{v}d\tilde{y}}_{\text{Continuation value: separation due to job-to-job transition}} \\
&+\underbrace{\int_{\tilde{y}}\lambda_E(s(x',y',w),\theta)\,A_O(x',y',w,\tilde{y})\,J(x',y',\bar{w}_y(x',\tilde{y}))\,\frac{\mu_y(\tilde{y})}{v}d\tilde{y}}_{\text{Continuation value: renegotiation triggered by outside offer}} \\
&+\int_{\tilde{y}}(1-\lambda_E(s(x',y',w),\theta)\,[A_E(x',y',\tilde{y})+A_O(x',y',w,\tilde{y})]) \\
&\underbrace{\times\min\{\max\{J(x',y',w),V(y')\},J(x',y',\underline{w}_x(x',y'))\}\,\frac{\mu_y(\tilde{y})}{v}d\tilde{y}}_{\text{Continuation value: potential renegotiation after productivity shocks}}\Bigg\} \\
&p_w(x'\mid x)\,p_f(y'\mid y)\,dy'dx'\Bigg\}.
\end{aligned}
\tag{9}
$$

The flow value of a filled job is the output of the match net of the wage paid to the worker. The continuation events mirror those in the value of employment: the job becomes vacant upon an endogenous separation or a job-to-job transition of the worker, and the wage may be renegotiated after an outside offer or when either side has a credible threat to leave the match.

Wages. The value functions can be used to compute the maximum wage a firm is willing to pay — the wage that leaves the firm indifferent between filling the job and keeping it vacant. They also pin down the minimum wage a worker is willing to accept — the wage that leaves the worker indifferent between employment and unemployment. The lowest wage a worker of type x accepts at a firm of type y is defined as follows:

$$\underline{w}_x(x,y):\ W(x,y,\underline{w}_x(x,y)) = U(x). \tag{10}$$

The highest wage a firm of type y is willing to pay to a worker of type x is given by

$$\bar{w}_y(x,y):\ J(x,y,\bar{w}_y(x,y)) = V(y). \tag{11}$$

3.5 Distributions

The acceptance rules, search policies, and wage policies described above induce laws of motion for the distributions of matches, unemployed workers, and vacant jobs. In a stationary equilibrium, these distributions reproduce themselves period by period. The central object is the distribution of matches and wages at the production stage, $\psi(x, y, w)$, where for readability we suppress the dependence of search effort on the state variables:

$$\begin{aligned}\psi(x,y,w) = {} & \underbrace{\lambda_U(s,\theta)\,A_U(x,y)\,\frac{\mu_y(y)}{v}\mu_x(x)\,\mathbb{1}_{w^{\text{init}}(x,y)=w}}_{\text{Inflow from unemployment}} \\ & + \underbrace{\int_{\tilde{y}}\int_{\tilde{w}} \lambda_E(s,\theta)\,A_E(x,\tilde{y},y)\,\psi^S(x,\tilde{y},\tilde{w})\,\frac{\mu_y(y)}{v}\mathbb{1}_{\bar{w}_y(x,\tilde{y})=w}d\tilde{w}d\tilde{y}}_{\text{Inflow through job-to-job transition}} \\ & + \underbrace{\int_{\tilde{y}}\int_{\tilde{w}} \lambda_E(s,\theta)\,A_O(x,y,\tilde{w},\tilde{y})\,\psi^S(x,y,\tilde{w})\,\frac{\mu_y(\tilde{y})}{v}\mathbb{1}_{\bar{w}_y(x,\tilde{y})=w}d\tilde{w}d\tilde{y}}_{\text{Renegotiation after outside offer}} + \\ & \underbrace{\int_{\tilde{y}}\int_{\tilde{w}} (1-\lambda_E(s,\theta)\left[A_E(x,y,\tilde{y}) + A_O(x,y,\tilde{w},\tilde{y})\right])\,\psi^S(x,y,\tilde{w})\,\frac{\mu_y(\tilde{y})}{v}\mathbb{1}_{w^{\text{reneg}}=w}d\tilde{w}d\tilde{y}}_{\text{No renegotiation/transition because of outside offer}}\end{aligned} \tag{12}$$

The four terms capture the four ways in which a match between a worker of productivity x and a firm of productivity y at wage w can come about, mirroring the events in the value functions. First, an unemployed worker meets a vacant job of type y and a match is created at the initial wage. Second, an employed worker moves to firm y through a job-to-job transition and starts at the maximum wage the previous employer was willing to pay. Third, a relevant outside offer triggers a renegotiation at the current firm, raising the wage to the maximum wage the poaching firm could have paid. Fourth, the worker receives no relevant outside offer and continues at the "renegotiated" wage w^{reneg}, which is equal to the previous wage unless either side had a credible threat to leave the match. Productivity transitions do not enter these flows because shocks realize between the production stage and the search stage. Integrating out wages yields the distribution of matches $\tilde{\psi}(x,y) = \int_w \psi(x,y,w)\,dw$ and, analogously, $\tilde{\psi}^S(x,y)$ at the search stage.

The distribution of matches and wages at the search stage differs from that at the production stage because of exogenous destruction, productivity shocks, and the endogenous separations that follow:

$$\psi^S(x',y',w) = \int_x\int_y (1-\delta(x))\,A_S(x',y')\,\psi(x,y,w)\,p_f(y' \mid y)\,p_w(x' \mid x)\,dydx. \tag{13}$$

The mass of unemployed workers follows as the difference between the exogenous distribution of worker types and the mass of employed workers, adjusted for worker productivity shocks:

$$\mu_x(x') = \int_x \left[\phi_w(x) - \int_y \tilde{\psi}(x, y)\, dy \right] p_w(x' \mid x)\, dx. \tag{14}$$

Newly separated workers cannot search in the period of separation, so they enter the pool of unemployed searchers only in the following period.

Finally, the distribution of vacant jobs $\mu_y(y)$ evolves analogously, combining newly created jobs $v^{\mathrm{N}}(y)$, vacant jobs that failed to meet a worker or to form a match, and jobs vacated through job-to-job transitions or endogenous separations. Its law of motion is mechanical but lengthy, so we relegate it to Appendix B.1.2.

3.6 Equilibrium

A stationary equilibrium consists of value functions, acceptance rules, search effort and job creation policies, wages, and distributions that are mutually consistent. The formal definition is standard and relegated to Appendix B.2. Its computation, however, is not standard. In models with risk-neutral workers, the value functions can typically be combined into a joint surplus function, and the model can be solved without reference to wages.[29] With risk-averse workers and progressive taxes, the wage is not a one-for-one transfer between worker and firm, so value functions, wages, and distributions have to be solved for jointly. Moreover, with endogenous search effort it is not sufficient to track the distribution of matches; the joint distribution of matches and wages becomes part of the fixed point. Appendix B.3 describes the numerical algorithm.

4 Calibration

We now bring the model to the data. We first present the calibration and then analyze how important firm- and worker-level shocks are as drivers of earnings dynamics.

4.1 Functional Forms

Utility function. For the instantaneous utility function over consumption, we assume log utility, a common choice in search models with risk-averse workers (Bagger et al. 2018; Hubmer 2018; Krusell, Mukoyama, and Şahin 2010):

$$u(c) = \log(c). \tag{15}$$

[29] See for example Lise and Robin (2017) and Gulyas (2023).

Search effort. For the cost and return of search effort we choose the functional forms proposed in Faberman et al. (2022). Consider first the cost function:

$$c_{w,i}(s) = \kappa_i^0 s^{1+\frac{1}{\kappa^1}}, \quad i \in \{U, E\}. \tag{16}$$

The return to search is given by the following functional form:

$$\Lambda_i(s) = \eta_i^0 + \eta_i^1 s. \tag{17}$$

We allow both the cost and the return parameters to differ by employment status, keeping only the curvature parameter κ^1 common, so that the search technology can differ between unemployed and employed workers.

Job creation. We choose the job creation cost function as in Gulyas (2023):[30]

$$c_f\left(v^{\mathrm{N}}\right) = \chi_0 \left(\frac{v^{\mathrm{N}}}{\chi_1}\right)^{\chi_1}. \tag{18}$$

Matching function. The matching function is a standard Cobb-Douglas function

$$\mathcal{M}(L, v) = \xi L^{\omega} v^{1-\omega}, \tag{19}$$

with scaling parameter ξ and matching function elasticity ω.

Productivity processes. For both firm and worker productivity, we assume AR(1) processes in logs. Persistence parameters are denoted with ρ_y and ρ_x; the standard deviations of the innovations are σ_y and σ_x.[31]

Production function. Match output is a function of both worker and firm productivity, following Gulyas (2023):

$$f(x, y) = \nu \left(x^{\frac{1}{\gamma}} + y^{\frac{1}{\gamma}}\right)^{\gamma}. \tag{20}$$

The parameter γ captures potential complementarities in production.

Exogenous separations. For the exogenous separation probabilities, we use the functional form proposed in Faberman et al. (2022):

$$\delta(x) = \bar{\delta} - \delta_x \log(x). \tag{21}$$

[30]This or similar functional forms are widely used in the literature; see among others Merz and Yashiv (2007), Kaas and Kircher (2015), Bagger and Lentz (2019), and Bilal et al. (2022).

[31]For the numerical implementation, we discretize the productivity processes using the Tauchen (1986) procedure, with 20 grid points each for worker and firm productivity. The extremes of the productivity grid are three standard deviations above and below the median, respectively.

Tax function. The government raises revenues with the log-linear tax function popularized by Feldstein (1969), Benabou (2002), and Heathcote, Storesletten, and Violante (2017):

$$T(w) = w - \tau^L w^{1-\tau^P}, \tag{22}$$

where τ^L governs the level of taxes and τ^P the tax progressivity. If τ^P is positive, the tax system is progressive, that is marginal and average tax rates are increasing in income. A negative τ^P implies regressive taxes. With $\tau^P = 0$, taxes are flat.

4.2 Externally Calibrated Parameters

We quantify the model to be consistent with key features of the Danish economy in general and the labor market in particular. A period in the model is one month.

We calibrate the model using a standard two-step procedure, fixing a number of parameters without solving the model and calibrating the remaining parameters internally. We set the monthly discount factor β to 0.995, corresponding to an annual discount factor slightly above 0.94, a standard value in the literature. The level parameters of the production function ν and the matching function ξ are normalizations. We also fix the curvature parameter of the matching function ω to 0.5, in line with a large literature following Petrongolo and Pissarides (2001). We also fix the initial bargaining power parameter α to 0.5. Without initial bargaining power, it is well known that starting wages in this class of models tend to be counterfactually low, as workers accept very low wages in exchange for getting on the job ladder (Postel-Vinay and Robin 2002). Worker risk aversion mutes this effect relative to the literature with typically risk neutral workers, but does not eliminate it.

For tax progressivity, we rely on the estimation results of Holter, Krueger, and Stepanchuk (2019), who estimate tax progressivity for a range of OECD countries based on the wedge in marginal income tax rates at different income levels. A measure based on income taxes only is appropriate for our setting, given the focus on workers with labor market attachment and the separate modeling of unemployment benefits. The estimated parameter for Denmark is 0.258, the highest among the OECD countries. All parameter values are summarized in Table 1.

4.3 Internally Calibrated Parameters and Identification

We choose the remaining parameters to match a rich set of moments of the Danish economy. These include standard moments such as labor market flows and unemployment durations, wage inequality, and the firm size distribution, as well as the joint distribution of worker and firm outcomes documented in Section 2. These 19 parameters, listed in Panel B of Table 1, are thus disciplined not only by standard scalar targets, such as

Table 1: Parameter Values

Parameter	Interpretation	Value	Source
Panel A: Externally calibrated			
β	Discount factor	0.995	Standard value
ν	Production function scale	0.934	Normalization
ξ	Matching function level	0.500	Normalization
ω	Matching function curvature	0.500	Petrongolo and Pissarides (2001)
α	Initial bargaining power	0.500	Avoids too low starting wages
τ^P	Income tax progressivity	0.258	Holter, Krueger, and Stepanchuk (2019)
Parameter	**Interpretation**	**Value**	**Closest associated moment**
Panel B: Internally calibrated			
ρ_x	Worker productivity persistence	0.993	Wage inequality
ρ_y	Firm productivity persistence	0.994	Wage inequality, average firm size
σ_x	Worker productivity innovation s.d.	0.051	Earnings growth dispersion
σ_y	Firm productivity innovation s.d.	0.038	Revenue growth dispersion
γ	Production complementarity	1.100	EE rate by wage
$\bar{\delta}$	Job destruction level	0.009	EU rate
δ_x	Job destruction slope	0.006	Unemployment durations (Fig. 2)
κ_U^0	Search cost scale, unemployed	0.060	Unemployment rate
κ_E^0	Search cost scale, employed	0.300	EE rate
κ^1	Search cost curvature	0.550	Unemployment durations (Fig. 2)
η_U^0	Search return intercept, unemployed	0.010	Unemployment durations (Fig. 2)
η_E^0	Search return intercept, employed	0.040	EE rate at top of wage distribution
η_U^1	Search return slope, unemployed	0.250	Job finding rate
η_E^1	Search return slope, employed	0.190	EE rate by wage
F	Mass of firms	0.130	Average firm size
χ_0	Job creation cost level	53.500	Share of small firms
χ_1	Job creation cost curvature	1.150	Firm size distribution tail
b	Unemployment benefit	1.110	50% of average wage
τ^L	Income tax level	0.571	Average marginal tax rate

Notes: The table reports all model parameters. Panel B parameters are calibrated jointly to the full set of target moments; the last column lists the most closely associated moment for each parameter, as discussed in Section 4.3.

aggregate labor market flows, but also by the shape of entire profiles and distributions. While all parameters affect all moments jointly, we discuss in the following which moments are most informative about which parameters.

Productivity processes. Pinning down the parameters of the productivity processes is the key part of the quantitative exercise, in order to distinguish how much risk originates from the firm vs. the worker side. Persistence and innovation standard deviations are primarily disciplined by wage inequality, the firm size distribution, the dispersion of worker earnings and firm revenue growth, and the joint distribution of these two growth rates.

Table 2: Scalar Calibration Targets

Moment	Data	Model
Panel A: Wage inequality		
Ventile 6 relative to ventile 1	1.58	1.40
Ventile 12 relative to ventile 1	1.93	1.79
Ventile 18 relative to ventile 1	2.73	2.47
Panel B: Earnings and revenue growth		
Std. dev. of earnings growth	0.33	0.29
Kurtosis of earnings growth	12.16	15.33
Std. dev. of revenue growth	0.56	0.56
Kurtosis of revenue growth	5.20	5.02
Panel C: Labor market flows		
Unemployment rate	5.00%	4.99%
Monthly EU rate	1.24%	0.95%
Monthly EE rate	1.35%	1.64%
Panel D: Firm size		
Average firm size	16.1	16.5
10th percentile of firm size	1	1
Median firm size	2-3	3

Notes: The table reports the scalar targeted moments in the data and the model; it is a subset of the full target set. Wage ventiles are ventiles of the monthly wage distribution; growth moments refer to annual worker earnings growth and annual firm revenue growth. The labor market flows reflect our sample selection of workers with reasonably strong labor market attachment and would increase if marginal employment were included. Beyond the moments listed, the calibration targets the 10th percentile of worker earnings growth by firm revenue growth, unconditionally and for stayers (Figures 1 and 3), the unemployment propensities by firm revenue growth and unemployment duration (Figure 2), and the EE rate along the wage distribution.

Generating a sufficient amount of wage inequality (Panel A of Table 2) requires that both productivity processes are quite persistent, with ρ_x and ρ_y in excess of 0.99. In particular, high-wage workers only exist because some workers and firms are persistently more productive than others, and with lower persistence their lifetime values would be too similar to sustain large wage differences. While wage inequality disciplines the overall degree of persistence, the firm size distribution is informative about the relative persistence of the two processes: the persistence of firm productivity is closely linked to average firm size, unlike the persistence of worker productivity.

Next to the wage distribution in levels, the productivity process parameters are also closely related to the distributions of worker earnings and firm revenue growth. Panel B of Table 2 reports the standard deviation and kurtosis of annual earnings growth on the worker side and annual revenue growth on the firm side. The dispersion of revenue growth is considerably larger than the dispersion of earnings growth, and both distributions are strongly leptokurtic. The two dispersions are closely related to the standard deviations of the innovations, σ_x and σ_y, respectively.

Key to producing the deviations from normality is the wage-setting protocol. Many small productivity shocks are absorbed by firms because neither participation constraint is violated, so that the wage remains unchanged. Once a participation constraint is hit, however, the resulting adjustment is large: the wage changes discretely or the match dissolves.

The relative dispersion of wages vs. firm sizes and the growth rates of earnings and revenues provide information about the importance of firm- vs. worker-level shocks. Additionally, we target the key facts documented in Section 2, which offer direct evidence on the transmission of the different shocks. We focus particularly on the 10th percentile of earnings growth by firm revenue growth, unconditionally (Figure 1) and for stayers (Figure 3), as well as the unemployment propensities by firm revenue growth (Figure 2). Worker shocks are independent of firm performance and can generate separations and earnings losses along the entire firm distribution. The larger incidence of large losses in shrinking firms is then produced by firm shocks: σ_y governs how much deeper the lower tail of earnings growth is in shrinking relative to growing firms—the gradient of the profile.

Figure 4 illustrates this argument. Both panels plot the 10th percentile of the annual earnings growth distribution of stayers by firm revenue growth, as in Figure 3, which isolates the renegotiation margin from the separation response. In the left panel, we re-solve the model with a lower and a higher value of σ_x, keeping all other parameters at their calibrated values; in the right panel, we vary σ_y instead. A higher σ_x shifts the entire profile down, including in growing firms, while leaving its slope largely unchanged. A higher σ_y instead rotates the profile: it deepens losses in the most strongly shrinking firms and raises the tenth percentile in growing firms.

Separations. The model generates EU transitions through both exogenous and endogenous separations. Endogenous separations occur after negative productivity shocks if there is no wage at which both firm and worker want to continue the match. They require low worker productivity and are most likely in firms of low productivity: if both parties are unproductive, match output is too low to compete with the unemployment benefit. Endogenous separations are nevertheless rare, as many matches are kept alive in the hope of positive productivity shocks. The relative importance of the two separation types is disciplined by the pattern of unemployment risk in Figure 2: across the entire positive part of the firm revenue growth distribution, the incidence of unemployment is essentially constant (left panel), which the model achieves with a large share of exogenous

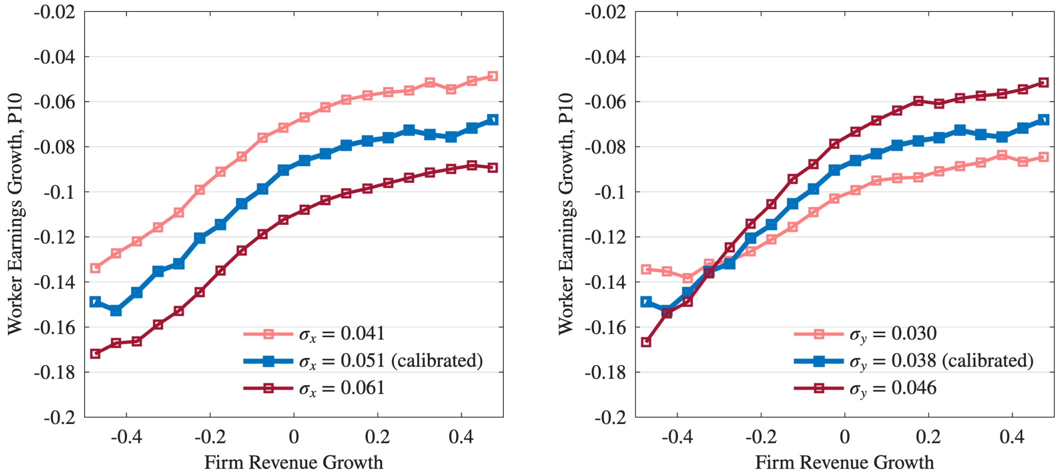

Figure 4: Identification of Worker- and Firm-Level Risk

Notes: Both panels show the 10th percentile of the annual worker earnings growth distribution of stayers, conditional on firm revenue growth, as in Figure 3. The left panel varies the standard deviation of worker productivity innovations σ_x by 20 percent around its calibrated value, the right panel the standard deviation of firm productivity innovations σ_y, keeping all other parameters fixed and re-solving the stationary equilibrium.

separations.[32] Together with the level of the EU rate (Panel C of Table 2), this pins down the job destruction level $\bar{\delta}$.

The slope parameter δ_x makes exogenous separation risk decreasing in worker productivity, in line with the evidence that job loss is concentrated among a small group of workers (Gregory, Menzio, and Wiczer 2025; Jarosch 2023; Jung and Kuhn 2019). A larger δ_x shifts unemployment toward low-productivity workers, who also remain unemployed for longer, generating the substantial share of long unemployment spells in the right panel of Figure 2. At the same time, recurrent job loss keeps these workers at the bottom of the wage distribution, which contributes to the targeted wage inequality (Panel A of Table 2).

Search technology. The parameters of the search technology are primarily disciplined by the labor market flows in Panel C of Table 2, the distribution of unemployment durations, and the EE rate along the wage distribution. For the unemployed, the cost scale κ_U^0 and the return slope η_U^1 jointly govern how much search effort is exerted and how effectively it translates into offers; they are closely tied to the unemployment rate and the job finding rate.[33] The return intercept η_U^0 generates offers that arrive independently of search effort and thereby limits how long unemployment spells can last, making it informative about the tail of the duration distribution. The common curvature parameter

[32] Consistent with this, Davis, Faberman, and Haltiwanger (2013) document that separations occur even in strongly growing establishments, which is hard to generate endogenously.

[33] We target an aggregate unemployment rate rather than what our micro data implies since in our main data set we cannot distinguish unemployment from non-participation.

κ^1 governs how strongly effort responds to differences in the value of employment, and with it the split of unemployment spells between short and long durations, which is why we calibrate it to the duration distribution.

For the employed, the cost scale κ_E^0 is closely tied to the average EE rate. The EE rate along the wage distribution then separates the return parameters. A positive intercept η_E^0 keeps job-to-job transitions positive even for high-wage earners, who have little incentive to search; its level is most closely associated with the EE rate at the top of the wage distribution. The slope η_E^1 governs how quickly transitions decline along the wage distribution. What helps to flatten the EE profile toward the data is positive complementarities in production ($\gamma > 1$): firm competition for productive workers keeps outside offers valuable also at higher wages. This is consistent with positive sorting in other equilibrium models of the Danish labor market (Bagger et al. 2018; Bagger and Lentz 2019).

Beyond these targets, we validate the search technology against the direct evidence on search behavior in Faberman et al. (2022), which measures search effort directly rather than through realized transitions, albeit for U.S. workers. Qualitatively in line with this evidence, the calibrated model predicts much higher search effort for the unemployed than for the employed and a lower share of offers resulting from free search for the unemployed than for the employed. The model is also consistent with a higher offer yield, the number of offers per unit of search, for the employed, supporting the calibrated split between search costs and returns. Faberman et al. (2022) also document that search of the employed is strongly decreasing in wages. The model reproduces this conditional on worker and firm productivity, but the cross-sectional profile is flatter: search effort also increases in worker productivity, as firm competition makes outside offers more valuable for more productive workers. A more strongly negative relation would require EE transition rates that are strongly decreasing in wages, at odds with the data.

Job creation. The mass of firms and the parameters of the job creation cost function are closely related to the firm size distribution (Panel D of Table 2). The mass of firms F does not pin down average firm size exactly, because some firms in the simulated economy do not employ any workers, but it is closely tied to it: with F equal to 0.13, mean firm size in the model is 16.5, compared to 16.1 in the data. We choose the parameters of the job creation cost function to generate a sufficient mass of small firms: the cost level χ_0 governs the overall amount of job creation and hence the share of small firms, while the curvature χ_1 limits how large the most productive firms grow. The model matches the 10th percentile of the firm size distribution of 1 and the median of 3 exactly. The model also produces a very reasonable probability for a vacant job to meet a worker of 0.39, for which we do not have a direct data counterpart, but which is well within the range of plausible values (Gulyas 2023).

Government. We model the unemployment benefit as a fixed payment to an unemployed worker. Unemployment insurance in Denmark is voluntary, but high subsidization of the unemployment insurance funds ensures high participation. Unemployment insurance can be received for up to two years, which is why we do not model a maximum duration or risk of losing unemployment benefits. The vast majority of workers in our sample with reasonably strong labor market attachment find jobs well within two years. In principle, unemployment benefits can go up to 90% of previous income. However, there is a rather tight cap on the maximum benefits, so setting a constant benefit only overstates the benefit level for some of the lowest earners. Hence, in line with the data, we set the unemployment benefit such that it is roughly 50% of the average monthly wage.

We set the level parameter τ^L to match an average marginal tax rate (AMTR) of 0.64, as reported by Bagger et al. (2021).[34]

Limitations. Three moments lie beyond what the model can match. First, the model understates the EU rate (Panel C of Table 2): EU transitions and the unemployment rate are tightly linked in the model, so matching the EU rate exactly would require a counterfactually high unemployment rate. Relatedly, the duration composition of unemployment spells in the model skews short relative to the data, overweighting spells of one to two months and underweighting spells of six months or more, reflecting the same tension between the job-finding rate and the targeted unemployment rate. Second, while the model generates large firms with hundreds of employees, the upper half of the firm size distribution is not well matched: it lacks a mechanism, such as permanent next to transitory (even if very persistent) differences in firm productivity, to generate the very large firms present in the data. Third, the model understates both wage inequality and the EE rate at the very top of the wage distribution. These misses share a root: the model lacks a mechanism, such as a Pareto tail in worker productivity, to produce the highest incomes observed in the data, and correspondingly provides no motive for the highest earners to keep climbing—promotions, careers, and poaching of top workers are outside the model. All three limitations are second order for our purposes: they matter little for the endogenous separations and wage renegotiations through which firm and worker shocks transmit to earnings.

5 Decomposing Earnings Risk into Firm and Worker Shocks

We now quantify the relative importance of firm- and worker-level shocks for large earnings changes. We proceed in the order of the three key facts of Section 2, all of which we

[34] This very high value for the AMTR is explained on the one hand by the high and progressive income taxes and on the other hand by the fact that it also accounts for consumption taxes.

targeted. We start with the model counterparts and then decompose each large earnings change according to whether the triggering shock hit the worker, the firm, or both.

5.1 Earnings Dynamics by Firm Revenue Growth

Figure 5 shows the model counterpart to Figure 1, the evidence behind Fact 1: worker earnings growth by firm revenue growth, not conditioning on staying in the same firm, together with the underlying data.

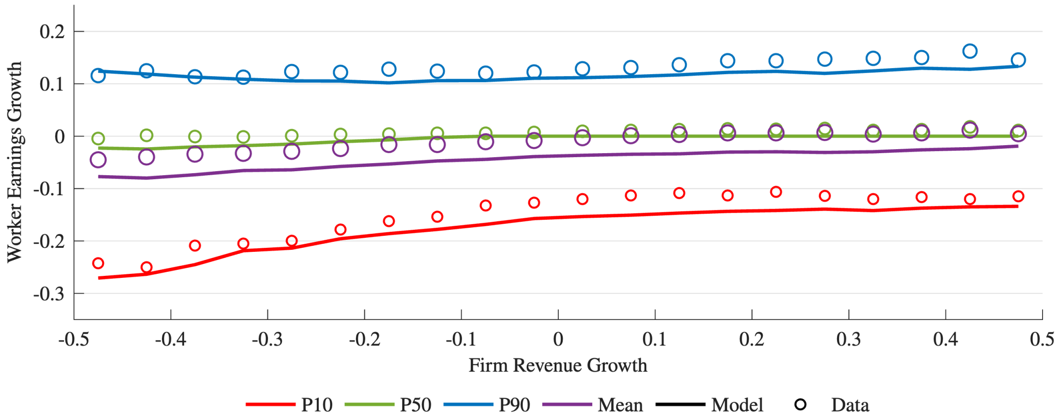

Figure 5: Worker Earnings Growth by Firm Revenue Growth – Model and Data

Notes: This figure shows moments of the annual earnings growth distribution, conditional on the revenue growth of the firm at which workers are employed in the initial year. Lines are model simulated moments, circles are the corresponding data moments of Figure 1.

On average, earnings growth of workers is around 6 percentage points higher in the firms that grow the most relative to the firms that are strongly shrinking, as in the data. Also as in the data, the median of the earnings growth distribution is essentially flat at zero across the entire firm revenue growth distribution.

To a large extent, this relationship is driven by the lower tail of the earnings growth distribution. In firms with positive revenue growth, the 10th percentile is flat at around -14%, and at the bottom of the revenue growth distribution it is -27%. The gradient is 13 percentage points, as in the data.

To a lesser extent, the relationship is also driven by the right tail of the earnings growth distribution. The model captures the slight increase in the 90th percentile over the positive part of the firm revenue growth distribution, although it is less pronounced than the three to four percentage points in the data.

Overall, the model reproduces Fact 1: large earnings losses occur along the entire firm revenue growth distribution, with an incidence that is essentially constant in growing firms and rises in shrinking firms.

Wage inaction for the median worker is the result of the wage setting protocol, in which wages are only adjusted in the case of certain events: relevant outside offers or productivity shocks violating participation constraints. The former are important to generate the upper tail of the earnings growth distribution. At the bottom of the revenue growth distribution, gains for workers are mostly generated through outside offers that lead to job-to-job transitions. This is because these firms tend to be hit by negative productivity shocks in the recent past and thus of low productivity, so that most outside offers are from better firms. At the top of the revenue growth distribution, job-to-job transitions still play a role, but since these firms tend to be of high productivity, outside offers are more often used as a threat to negotiate up wages within an existing match. For the lower tail of the earnings growth distribution exogenous separations, endogenous separations, and firm demanded renegotiations leading to wage losses are the relevant margins. We now differentiate between the role of the extensive and intensive margin, and how they are driven by firm- and worker-level shocks.

5.2 The Extensive Margin: Separations

Figure 6 shows the model counterpart to Figure 2, the evidence behind Fact 2: the likelihood of experiencing unemployment spells of varying lengths in year t, together with the underlying data.

The first panel shows the share of workers with no unemployment in year t. As in the data, this share is fairly stable across growing firms, at around 91%, and falls the more a firm's revenue goes down. Between growing firms and the most strongly shrinking firms the unemployment incidence rises from roughly 9% to 15%, reproducing the gradient in unemployment risk.

The remaining three panels show how this larger probability of experiencing unemployment spells is distributed across different unemployment durations. As in the data, workers starting in shrinking firms are more likely to experience unemployment spells both of short and of longer duration, and the pattern of unemployment risk along the firm distribution mirrors the gradient in large earnings losses from Fact 1.

Overall, the model reproduces Fact 2: transitions to unemployment are observed along the entire firm revenue growth distribution, with an incidence that is essentially constant in growing firms and rises in shrinking firms.

In firms with positive revenue growth there are essentially no endogenous separations caused by firm productivity shocks and only a few caused by worker productivity shocks, and the model captures those transitions as exogenous separations. In total, around 93% of all separations to unemployment in the model are exogenous.

Endogenous separations are, on the other hand, important to generate the gradient in the separation probability in the bottom half of the firm revenue growth distribution. Out of all endogenous separations, almost half are triggered by a firm-level productivity shock, just under two fifths by a worker productivity shock, and a little over one tenth

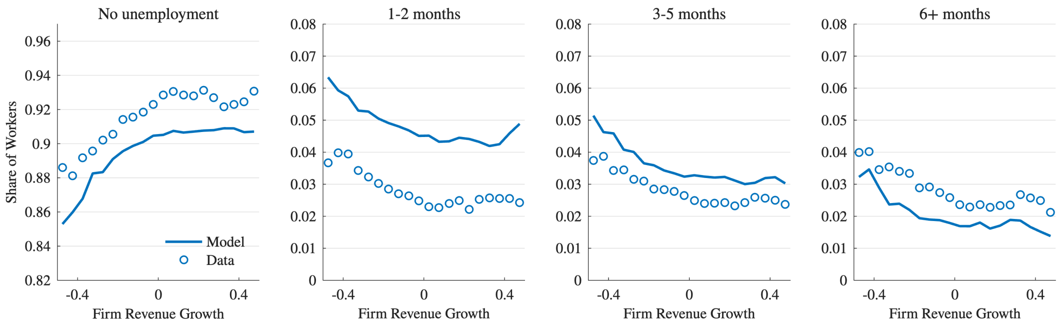

Figure 6: Unemployment Propensities by Firm Revenue Growth – Model and Data

Notes: Each panel shows the likelihood of experiencing an unemployment spell of the indicated duration, conditional on the revenue growth of the firm at which workers are employed in the initial year. Lines are model simulated moments, circles are the corresponding data moments of Figure 2.

by a simultaneous shock to both firm and worker productivities. The relative importance of firm versus worker shocks changes dramatically along the revenue distribution, as depicted in Figure 7. Towards the bottom of the revenue growth distribution, the share of separations driven by firm productivity shocks strongly increases as lower firm productivity makes fewer matches feasible. However, endogenous separations driven by worker productivity shocks are also increasing towards the bottom of the firm revenue growth distribution. Firms in that range tend to be of low productivity, such that it also becomes more likely for worker productivity shocks to trigger an endogenous separation. Hence, endogenous separations rise through this channel in strongly shrinking firms, even if a firm shock is not the final determinant of the separation.[35]

5.3 The Intensive Margin: Wage Renegotiations

Figure 8 shows the model counterpart to Figure 3, the evidence behind Fact 3: the earnings growth of stayers along the firm revenue growth distribution, together with the underlying data. Consistent with the data, and because the largest losses are driven by separations, the distribution of stayers' earnings growth is more compressed than the unconditional one depicted in Figure 5.

There is a positive relation between revenue growth and earnings growth for the stayer sample as well: on average, earnings growth is around 6 percentage points higher at the top of the firm revenue growth distribution than at the bottom, against three percentage points in the data. Again, this is mostly driven by the tails of the earnings growth distribution. While the median is slightly increasing along the firm distribution, the increase is much stronger for both the 10th and the 90th percentile.

[35] A portion of the gradient in the model is caused by a varying share of exogenous separations. Firms experiencing more exogenous separations are more likely to have falling revenues because they have fewer workers.

Figure 7: Reasons for Endogenous Separations – Model

Notes: This figure splits up model generated endogenous separations into those driven by worker productivity shocks, firm productivity shocks, or both. As in the data, workers are observed at a single firm in the base year with measurable earnings and firm revenue growth, and each worker contributes at most one separation per year, the first one that occurs. The shares therefore do not aggregate exactly to those reported in the text, which are based on all endogenous separations in the model.

The 10th percentile ranges from around -8% in growing firms to around -15% in the most strongly shrinking firms. The gradient of the 90th percentile is steeper than in the data because at the bottom of the revenue growth distribution the model tends to generate job-to-job transitions rather than gains through renegotiation after outside offers.

Overall, the model reproduces Fact 3: for stayers, large earnings losses are more likely in shrinking firms and large earnings gains more likely in growing firms, while both are observed along the entire firm revenue growth distribution.

In the model, the 10th percentile of earnings growth remains negative across the entire growing half of the firm revenue growth distribution. This happens when a worker experiences a large negative productivity shock and the employing firm consequently demands a renegotiation. This highlights the role of worker productivity shocks in generating losses even in growing firms, where a firm shock alone rarely does.

Quantitatively, out of all firm demanded renegotiations, just under 60% are triggered by a worker productivity shock, a little over 30% by a firm-level productivity shock, and over 10% by a simultaneous shock to both firm and worker productivities. Figure 9 shows how important firm and worker productivity shocks are along the firm revenue growth distribution in causing large earnings losses for stayers. Specifically, we consider stayers with large earnings losses of 10% or more. This is an annual outcome, and may be the consequence of several renegotiations following different types of shocks. We consider all

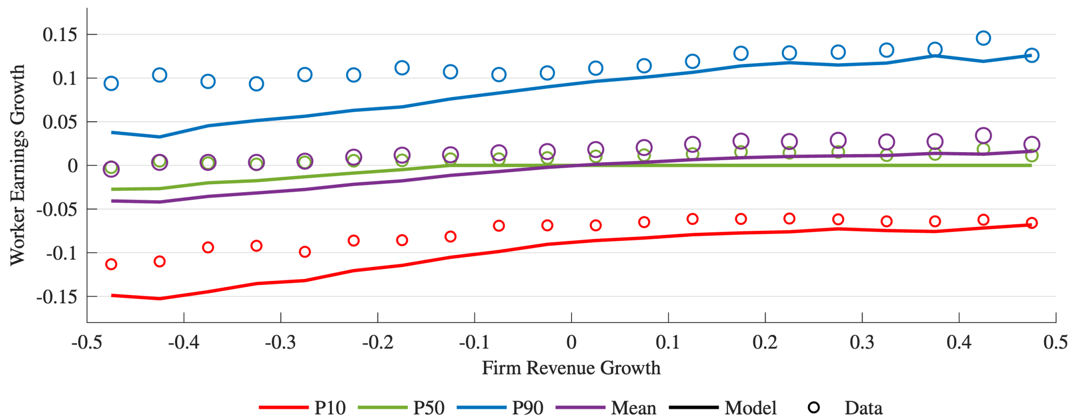

Figure 8: Worker Earnings Growth of Stayers by Firm Revenue Growth – Model and Data

Notes: This figure shows moments of the annual earnings growth distribution for workers staying at the same firm, conditional on the revenue growth of the firm. Lines are model simulated moments, circles are the corresponding data moments of Figure 3.

Figure 9: Reasons for Large Downward Wage Renegotiations – Model

Notes: This figure shows which share of stayers experiences earnings losses larger than 10%, by firm revenue growth group. It decomposes which share is driven by firm vs. worker productivity shocks. We consider downward wage renegotiations in year $t-1$ and t. If a worker experiences multiple renegotiations for different reasons, we count them with a weight equal to one over the number of renegotiations the worker experiences.

downward wage renegotiations workers experience in base year and second year, leading to the large year-on-year earnings loss.

Large earnings losses for stayers are more than twice as likely at the bottom as in the top revenue growth groups. As in the unconditional case, the slope is much steeper in the bottom half of the revenue growth distribution. This gradient is largely driven by the differential probability of renegotiations after negative firm productivity shocks. At the bottom of the revenue growth distribution, firm and worker productivity shocks are of roughly equal importance in causing renegotiations. At the top, worker productivity shocks clearly dominate.

Because downward renegotiations outweigh endogenous separations in number, firm-level shocks account for roughly one third of the losses driven by productivity shocks, our headline result.

6 Insuring Workers Against Earnings Risk

With risk-averse workers, there is space for the government to provide insurance against the earnings losses documented above. We evaluate three policies that reflect distinct approaches to this problem: unemployment benefits and progressive taxes, which insure workers directly, and layoff taxes, which aim to preserve jobs at the firm. All three interact with the equilibrium allocation of heterogeneous workers to heterogeneous firms, but in different ways: the two worker-side policies trade insurance off against allocation, whereas layoff taxes need not.

6.1 Policy Experiments

In all cases, the exercise we are implementing is the following. Across a range of values for unemployment benefits, layoff taxes, and tax progressivities, we compute the stationary equilibrium given a tax policy. We balance the budget by adjusting the level parameter of the income tax function.

6.2 Unemployment Insurance

The first policy we consider is a change in the unemployment benefits. In terms of flow utility, higher benefits are beneficial for the unemployed, however, the negative general equilibrium effects outweigh this direct benefit for the majority of the workers.

The upper left panel of Figure 10 shows how the unemployment rate varies with the unemployment benefit. A higher unemployment benefit leads to a much higher unemployment rate.[36] The direct effect of higher unemployment benefits is that workers dislike unemployment less, so some matches that were feasible in the baseline economy become infeasible. Higher benefits also discourage the search effort of the unemployed, shown in the bottom left panel, both directly and because the pool of unemployed shifts towards lower productivity workers, who search less.

[36] Around the calibrated benefit level, the elasticity of the unemployment rate with respect to the benefit is 2.3. This is higher than micro estimates of the response of unemployment duration to benefit levels (Schmieder and Von Wachter 2016), which hold job creation fixed, but much lower than the elasticities implied by matching models calibrated to reproduce the cyclical volatility of unemployment (Christoffel and Kuester 2009; Costain and Reiter 2008).

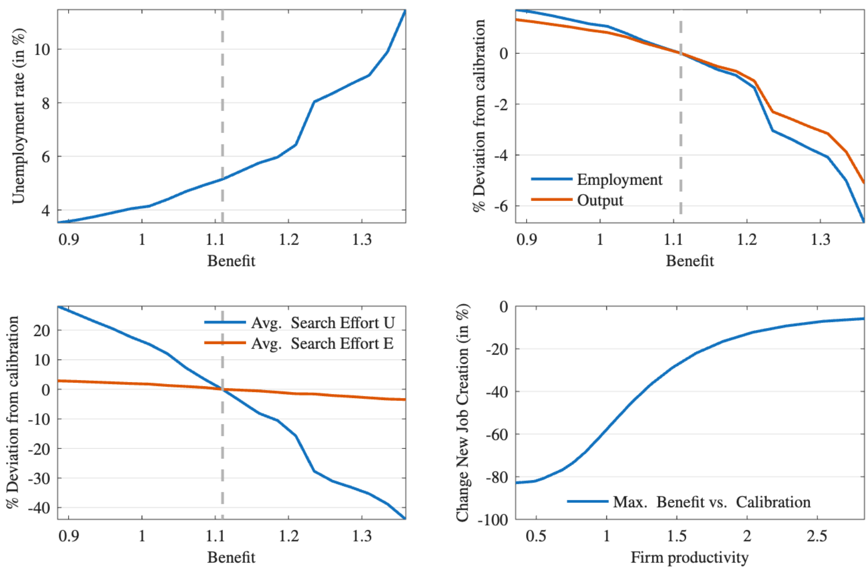

Figure 10: Policy Evaluation – Varying the Unemployment Benefit

Notes: This figure shows the unemployment rate, employment and output, and search effort across a range of unemployment benefit levels from 40% to 62% of the average monthly wage in the baseline economy (dashed line = calibrated value, 50%). It also shows how new job creation by firm type varies in the highest benefit scenario relative to the calibration.

Although firms are not directly affected by the policy itself, they still react strongly in general equilibrium. The bottom right panel shows how new job creation by firm type differs in the equilibrium with the highest considered unemployment benefit relative to the calibration: job creation drops across the entire firm productivity distribution, most at relatively unproductive firms, as firms face workers with an improved outside option and must pay higher starting wages.

On aggregate, both total employment and output fall in response to higher unemployment benefits, as shown in the upper right panel. There is less job creation, slowing reallocation of workers towards better firms, and taxes have to rise because there are more unemployed receiving benefits and fewer employed to tax.

The model implies a heterogeneous optimal benefit level across worker types: the lowest-productivity unemployed are better off at every benefit level considered up to somewhat above the calibrated value, whereas for higher-productivity unemployed the adverse equilibrium effects dominate almost immediately, with losses from reduced job creation and higher taxes growing sharply in productivity.

6.3 Layoff Taxes

Given the adverse equilibrium effects of unemployment benefits, an alternative policy is a layoff tax, a lump sum paid by firms on endogenous separations, aimed at preserving matches that would otherwise be destroyed. The typical argument in favor of a layoff tax is that it corrects a fiscal externality: firms and workers, when deciding whether to separate, do not take into account that the unemployment benefit received by the worker has to be financed. Theoretically, the effect on equilibrium unemployment is ambiguous, and quantitatively the literature finds both positive and negative effects on employment.

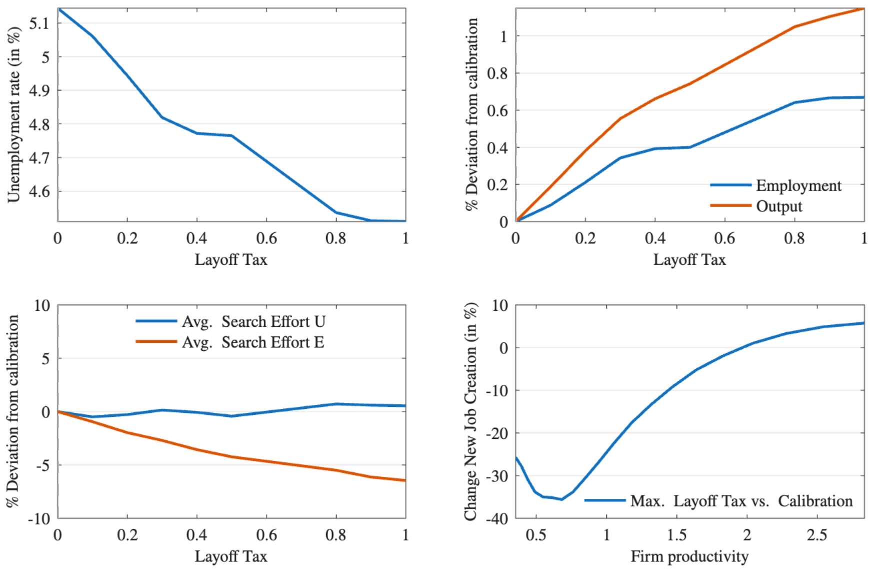

Figure 11: Policy Evaluation – Varying a Layoff Tax

Notes: This figure shows the unemployment rate, employment and output, and search effort across a range of layoff tax levels (dashed line = calibrated value). It also shows how new job creation by firm type varies in the highest layoff tax scenario relative to the calibration without layoff tax.

Figure 11 shows how the equilibrium changes with positive layoff taxes. In our framework, the unemployment rate falls slightly and aggregate employment goes up. Key to this result is how job creation adjusts across heterogeneous firms. Recall from the previous section that endogenous separations are much more likely in firms with negative productivity shocks, or generally low levels of productivity. Hence, new job creation by those firms is most strongly negatively affected. In equilibrium, high productivity firms face less competition from less productive firms, such that their job creation goes in fact up. Search effort of workers changes only modestly, so that the equilibrium allocation of workers to firms improves and output rises even more than employment. The layoff taxes considered here remain modest, up to around 46% of the average monthly wage in the baseline economy,[37] and the gains are already concave: the fall in the unemployment rate

[37] Separation decisions in our model are discrete, which makes the equilibrium difficult to compute at higher layoff taxes. Not all points on the grid converge, including some in the interior of the range shown. We have verified our results in a variant that smooths the separation decision around the threshold; it converges over a wider range and yields the same picture. We report the discrete version, which is the one used in the calibration.

over the second half of this range is only about two thirds as large as over the first half, and the gain in output only about half as large. This is the sense in which layoff taxes escape the insurance–allocation trade-off facing the other two policies: because the disincentive to hire falls unevenly across firms, preserving marginal matches at unproductive firms goes together with, rather than against, a better allocation of workers to firms.

Unlike higher unemployment benefits, the layoff tax does not divide workers: no worker type is worse off than without it, and the gains increase in worker productivity, as high-productivity workers benefit most from the improved allocation and faster job finding. These gains flatten out at the same low tax levels, so our results speak to modest layoff taxes rather than large ones.

6.4 Progressive Taxation

Next we consider changes in the degree of tax progressivity. Unlike the previous two policies that were mostly targeted towards reducing very large earnings losses through unemployment, progressive taxes reduce after-tax inequality and earnings changes across the entire distribution.

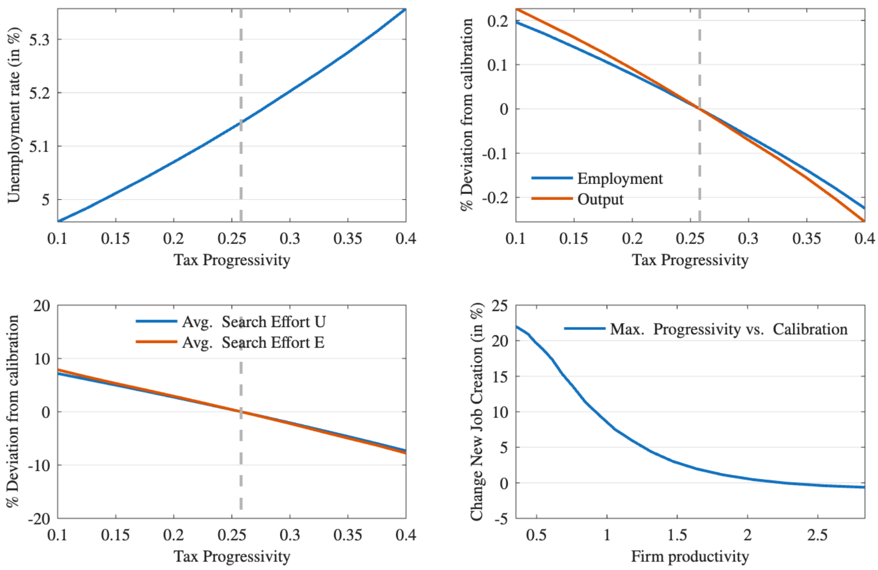

Figure 12: Policy Evaluation – Varying Tax Progressivity

Notes: This figure shows the unemployment rate, employment and output, and search effort across a range of tax progressivities (dashed line = calibrated value). It also shows how new job creation by firm type varies in the highest progressivity scenario relative to the calibration.

Progressive taxation has been extensively studied in incomplete-markets models with exogenous income, where the trade-off is between insurance and disincentives to labor supply, skill investment, and capital accumulation.[38] In our framework, the benefits in reducing consumption inequality and fluctuations are similar, but the set of distortions is quite different.

Equilibria across a range of tax progressivities are shown in Figure 12. More progressive taxes reduce search effort of households, and in contrast to higher unemployment benefits they do so for both unemployed and employed workers. With more progressive taxes, tax payments are lower at the bottom of the wage distribution and higher at the top, reducing the benefit from moving up the job ladder. Hence, employment is falling, but output is falling even more strongly, as the reallocation of employed towards better firms is slowed down, resulting in a higher degree of misallocation. This effect is amplified by less job creation by the most productive firms.

The model implies a heterogeneous optimal degree of progressivity across worker types: the lowest-productivity workers are better off at every level of progressivity we consider, whereas the highest-productivity workers prefer the least progressivity, with the calibrated value lying close to the point where preferences switch sign.

7 Conclusion

This paper studies how firm shocks shape worker earnings dynamics, combining Danish matched employer-employee data with an equilibrium search model with worker- and firm-level productivity shocks. Large earnings losses are common in shrinking firms, but occur throughout the firm revenue growth distribution — since a firm shock cannot explain losses in growing firms, these must come from worker-level shocks instead. Disciplined by this logic, the model attributes roughly a third of the losses driven by productivity shocks to firm shocks. Our findings locate the pass-through documented in the literature following Guiso et al. (2005): it operates through separations and large downward renegotiations, leaving the median worker's earnings largely insulated from firm shocks.

We use the model to evaluate unemployment insurance, progressive taxation, and layoff taxes. All three face a trade-off between insurance and the equilibrium allocation of workers to firms, but layoff taxes are distinctive: because their disincentive to hire falls disproportionately on unproductive firms, they can improve worker-firm allocation even as they preserve marginal matches — a force absent from policies that operate through worker-side incentives alone.

[38] See e.g. Heathcote et al. (2017) for skill investment choices; and Boar and Midrigan (2022) and Ferriere, Grübener, Navarro, and Vardishvili (2023) for savings decisions, among many others.

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Appendix: For Online Publication Only

A Data Appendix

A.1 Overview of Data Sources

For the empirical investigation we combine data from several Danish registry data sets provided by Statistics Denmark.

BFL. The main data source on earnings and employment in this paper is the BFL (*Beskæftigelse for Lønmodtagere*). We use information on employment spells within each month from 2008 until 2016. For each of these spells we observe earnings, hours, and the start and end date of the spell. Also, for each individual there is an identifier based on the anonymized social security number, which can be used to link this individual to other data sets. Similarly, for each firm there is an identifier that also can be used to match the data to other data sets. It also contains information on occupation, industry, and location.

BEF. The BEF (*Befolkningen*) data set contains information on demographics, which can be merged with the BFL data. A control variable we use from this data source is an individual's sex.

IDAP. Another individual-level data set is IDAP (*Integreret Database for Arbejdsmarkedsforskning - Persondata*) from the Integrated Database for Labor Market Research. From this data set we take variables on individuals' age and labor market experience.

UDDA. The UDDA (*Uddannelser*) database contains information on individuals' education.

FIKS. The main source for firm revenue information is the FIKS (*Firmaernes køb og salg*) database. This data set includes information on firms' purchases and sales from value added tax data. In addition to the purchase and sales numbers it contains information on the frequency at which a firm settles its VAT accounts. For the largest firms this is done at monthly frequency; for smaller firms it is done at quarterly or half-yearly frequency.

FIRM. The FIRM (*Generel firmastatistik*) database contains general information on firms. From this database we take information on firm-level employment and information on the source of firm-level accounting data in the FIRE database (see below).

FIRE. FIRE (*Regnskabsstatistikken*) is the database for firm-level accounting information, a complementary source of information on firm revenues. Non-imputed revenue information is available only for a much smaller set of firms than what is available in the FIKS data, so we use FIKS as our main source for revenues.

A.2 Marginal Earnings and Revenue Growth Distributions

While in the main text we focus on the joint distribution of worker earnings growth and firm revenue growth, in this section we show the respective marginal distributions, with properties similar to those reported in the literature.

A.2.1 Worker Earnings Growth Distribution

The worker earnings growth distribution in Denmark exhibits the same key features as those extensively documented in recent literature for a wide range of countries. Figure A.1 shows the histogram of the annual worker earnings growth distribution, benchmarked against a normal distribution with the same mean and variance. This is similar to the well-known Figure 1 from Guvenen et al. (2021), which uses U.S. Social Security data to investigate higher order moments of the earnings growth distribution. The key feature of the Danish earnings growth distribution is excess kurtosis, with a kurtosis of 12 for growth rates between -2 and 2, compared to 3 for a normal distribution. Compared to a normal distribution there is much more mass concentrated around zero, implying that the majority of workers experience very small earnings changes in any given year. There is, however, also a substantial mass of workers with very large earnings changes. The 10th percentile of the distribution is an earnings loss of 23%; the 90th percentile is an earnings gain of 25%.[39]

Figure A.1 uses the growth rates of raw earnings. Table A.1 shows statistics of the distribution of annual earnings growth, both for raw earnings and residualized earnings after taking out education, gender, location, industry, and occupation. Residualizing earnings changes the statistics only in a quantitatively minor way. Similarly, restricting the earnings growth to be between -2 and 2 does not affect the statistics in a meaningful way.

A.2.2 Firm Revenue Growth Distribution

The firm revenue growth distribution also exhibits strong deviations from normality, in line with the literature (Jaimovich et al. 2025; Salgado et al. 2025). Table A.2 shows statistics of the firm revenue growth distribution, based on both the value added tax data (FIKS) and the accounting data (FIRE). Further, it shows the statistics unweighted and employment weighted as well as trimmed.

[39] In contrast to the findings reported in Guvenen et al. (2021), the distribution of earnings changes in the Danish data is essentially symmetric. The skewness of the earnings growth distribution exhibits the same cyclical patterns as reported for U.S. data in Guvenen et al. (2014), with negative skewness during the Great Recession years and positive skewness post-2010. This is in line with the findings in Leth-Petersen and Sæverud (2022), which reports positive skewness in booms and negative skewness in recessions also in a longer time series of Danish data.

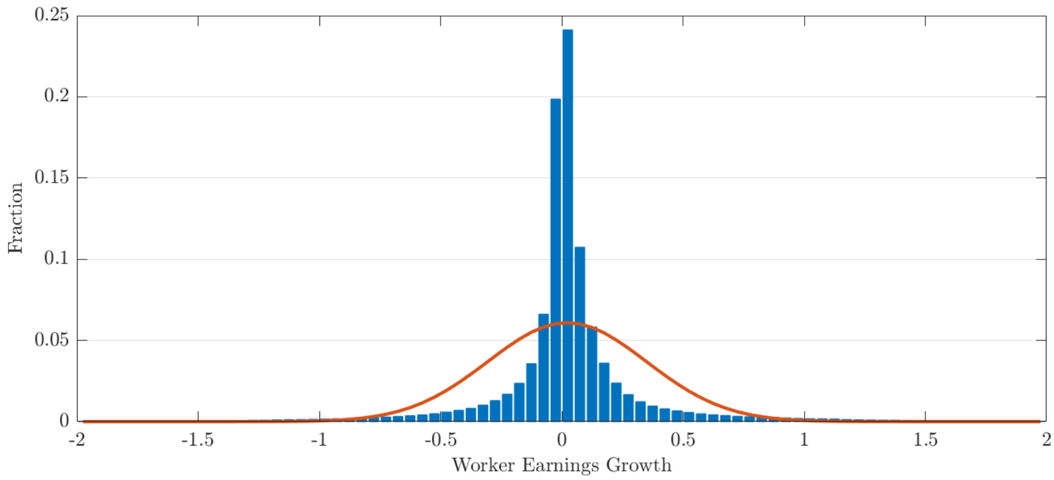

Figure A.1: Annual Earnings Growth Distribution

Notes: This figure shows the annual earnings growth distribution for the entire sample. The red line compares a normal distribution with the same mean and standard deviation.

Table A.1: The Annual Earnings Growth Distribution

	Mean	SD	Skewness	Kurtosis	P10	P50	P90
Raw earnings	0.02	0.34	0.08	13.70	-0.23	0.01	0.25
Raw earnings [-2,2]	0.02	0.33	0.12	12.16	-0.23	0.01	0.25
Res. earnings [-2,2]	0.02	0.31	0.15	12.26	-0.23	0.01	0.25

Notes: Table A.1 shows statistics of the annual earnings growth distribution using raw earnings, raw earnings for earnings changes restricted between -2 and 2, and for residualized earnings with changes also restricted between -2 and 2.

Table A.2: The Annual Revenue Growth Distribution

	Mean	SD	Skewness	Kurtosis	P10	P50	P90
FIKS	-0.04	0.80	-0.19	12.75	-0.81	-0.02	0.63
FIKS (emp. weighted)	-0.00	0.56	1.37	53.23	-0.36	0.00	0.30
FIKS [-2,2]	-0.03	0.56	-0.04	5.20	-0.71	-0.02	0.56
FIKS (emp. weighted) [-2,2]	-0.00	0.36	-0.36	10.54	-0.34	0.00	0.29
FIKS (also in FIRE) [-2,2]	-0.02	0.35	-0.13	7.93	-0.39	-0.01	0.33
FIRE	-0.02	0.36	-0.50	24.22	-0.35	-0.00	0.29
FIRE (emp. weighted)	0.00	0.27	-1.54	68.40	-0.23	0.00	0.21
FIRE [-2,2]	-0.02	0.32	-0.14	9.07	-0.35	-0.00	0.29
FIRE (emp. weighted) [-2,2]	0.00	0.24	-0.37	14.70	-0.23	0.00	0.21
FIRE (also in FIKS) [-2,2]	-0.02	0.32	-0.11	8.78	-0.35	-0.00	0.29

Notes: Table A.2 shows statistics of the annual firm revenue growth distribution.

The firm revenue growth distribution has more extreme outliers than the worker earnings growth distribution such that trimming the data has a larger effect on the statistics. Revenue growth is more dispersed in the FIKS data, as it covers many more (smaller) firms. When restricting the set of firms to those available in both datasets the results are quite similar.

A.3 Joint Worker-Firm Outcomes: Robustness

In the main text we report moments of the joint distribution of worker earnings growth and firm revenue growth in order to inform the model about how important common firm shocks are as drivers of large earnings changes. Here, we investigate the robustness of these patterns with respect to alternative firm growth measures, the business cycle, firm size, and industry. We also decompose earnings growth into hours and wage growth.

A.3.1 Alternative Firm Growth Measures

The main measure of firm performance used in the paper is revenue growth with revenue based on value added tax data. An alternative measure of revenue is available from the FIRE database. The revenue measure in this dataset is only available for a subset of firms from a survey they reply to using accounting records or from tax data. For a large fraction of especially smaller firms there is only revenue imputed by Statistics Denmark available. We restrict the sample to firms with non-imputed data. Figure A.2 replicates Figure 1 from the main text based on the alternative revenue measure. The key patterns remain the same: on average, earnings growth of workers is increasing in the revenue growth of their firms, and the average is mostly driven by a larger fraction of very large losses in shrinking firms. The gradient in the 10th percentile of the earnings growth distribution by firm growth is stronger based on the alternative revenue measure.

Next, instead of using revenue growth as measure of firm performance we use value added growth, both based on value added tax data (sales net of purchases) and accounting data. The results are reported in Figures A.3 and A.4. The increasing pattern of percentiles of the worker earnings growth distribution by firm value added growth is slightly weaker than by revenue growth, but still present according to both measures and more pronounced for the bottom of the earnings growth distribution.

A.3.2 Business Cycle

While our focus is on the relationship between firm shocks and earnings growth of workers and we investigate this in a stationary model, it is well documented in the literature that the pass-through from firm shocks to wages differs by state of the business cycle (Azzalini 2023; Chan et al. 2025).

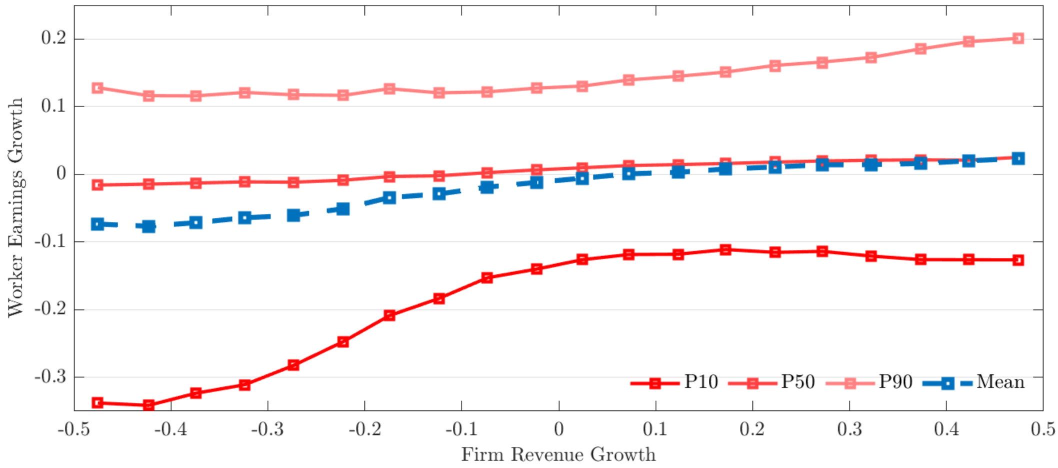

Figure A.2: Worker Earnings Growth by Firm Revenue Growth – Alternative Revenue Measure

Notes: This figure shows moments of the annual earnings growth distribution, conditional on the revenue growth of the firm at which workers are employed in the initial year. The data for revenue is taken from accounting information (FIRE) rather than value added tax data (FIKS), as in the main text, covering a smaller sample of firms.

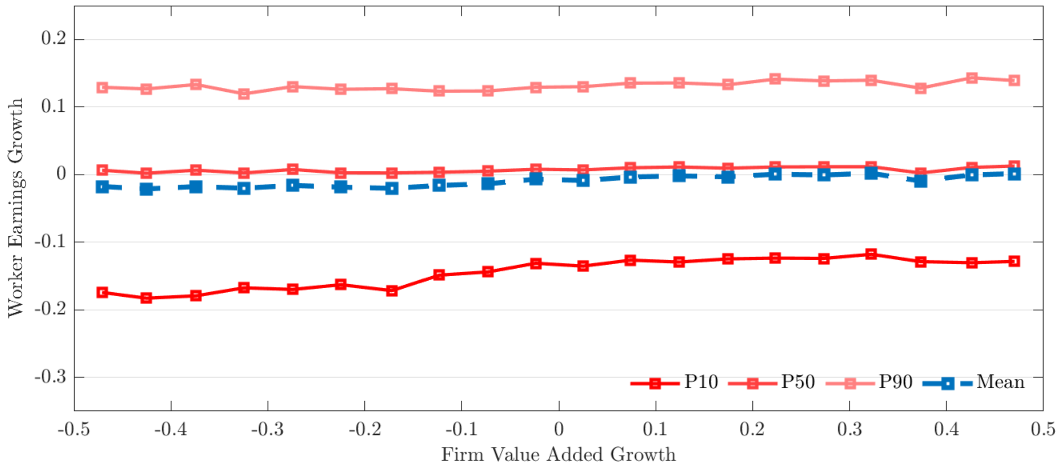

Figure A.3: Worker Earnings Growth by Firm Value Added Growth (FIKS)

Notes: This figure shows moments of the annual earnings growth distribution, conditional on the value added growth of the firm at which workers are employed in the initial year. Value added growth data is from FIKS.

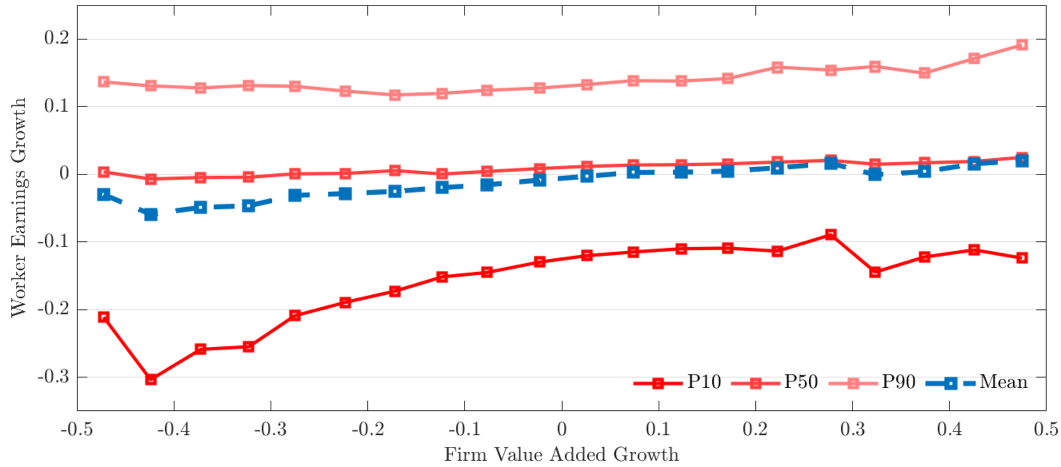

Figure A.4: Worker Earnings Growth by Firm Value Added Growth (FIRE)

Notes: This figure shows moments of the annual earnings growth distribution, conditional on the value added growth of the firm at which workers are employed in the initial year. Value added growth data is from FIRE.

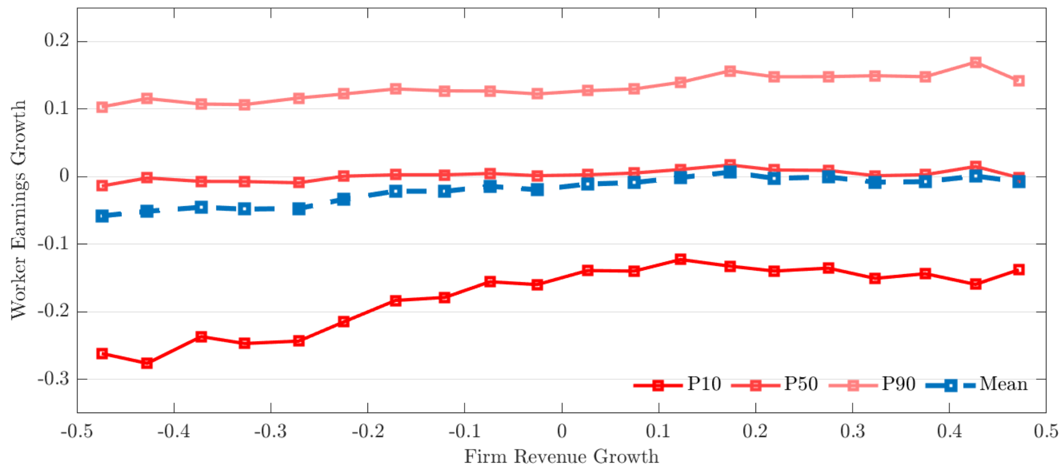

Figure A.5: Worker Earnings Growth by Firm Revenue Growth – Recession

Notes: This figure shows moments of the annual earnings growth distribution, conditional on the revenue growth of the firm at which workers are employed in the initial year. The sample is restricted to base years 2008 to 2010.

Figures A.5 and A.6 split the sample into base years 2008-2010 vs. 2013-2015, i.e. recession and expansion samples. We omit 2011 and 2012, which do not fall clearly into either phase, and 2016, since computing earnings growth requires the following year. While large earnings losses are generally more common during the recession years, the key relationship between firm revenue growth and the left tail of the worker earnings growth distribution is clearly present in both samples.

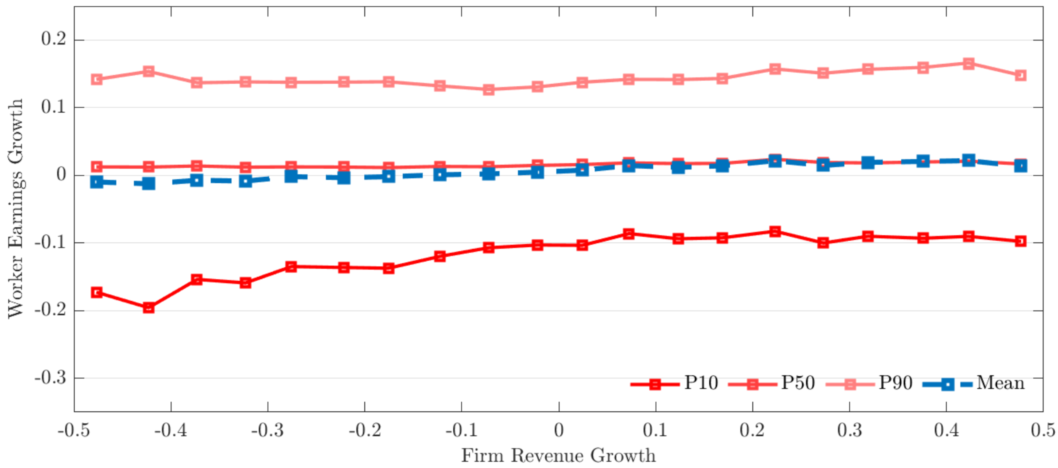

Figure A.6: Worker Earnings Growth by Firm Revenue Growth – Expansion

Notes: This figure shows moments of the annual earnings growth distribution, conditional on the revenue growth of the firm at which workers are employed in the initial year. The sample is restricted to base years 2013 to 2015.

A.3.3 Firm Size

Systematic differences in firm behavior are also well documented across firms of different sizes (Clymo and Rozsypal 2025; Gertler and Gilchrist 1994). Further, there may be a concern that there is a purely mechanical relationship between workers leaving small firms and large revenue drops of these firms (even if that feature is present in data and model alike).

Figures A.7 and A.8 show the moments of the worker earnings growth distribution by firm revenue growth separately for small and large firms (less than vs. at least 50 employees). Along the firm revenue growth distribution, the 10th percentile of the earnings growth distribution of workers increases by around 25 percentage points in the small firm sample, but also by almost 10 percentage points in the large firm sample.

A.3.4 Industry

In this section, we investigate the relationship between firm revenue growth and worker earnings growth by industry. The purpose is twofold. First, one may conjecture that some of the relationship between firm performance and worker outcomes is driven by industry-specific rather than firm-specific shocks. Indeed, Carlsson et al. (2016) and Souchier (2023) document a larger pass-through from sector-specific than from firm-specific shocks to wages in Swedish and French data, respectively. Second, while Denmark has generally a flexible labor market where it is easy to lay off workers and also to cut wages, there are some sectoral differences in the labor market flexibility. Overall, Denmark has moved from fully centralized bargaining in 1980 to a combination of sectoral and firm-level bargaining

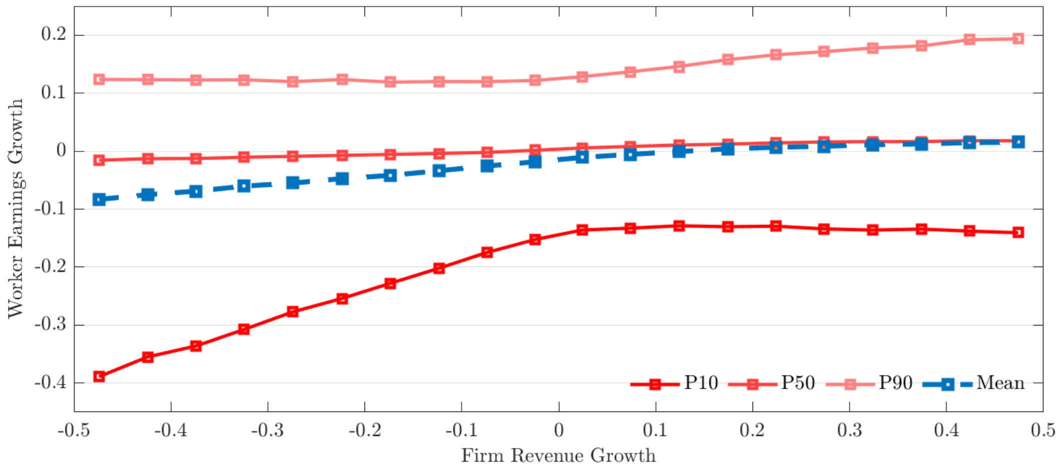

Figure A.7: Worker Earnings Growth by Firm Revenue Growth – Small Firms

Notes: This figure shows moments of the annual earnings growth distribution, conditional on the revenue growth of the firm at which workers are employed in the initial year. The sample is restricted to small firms.

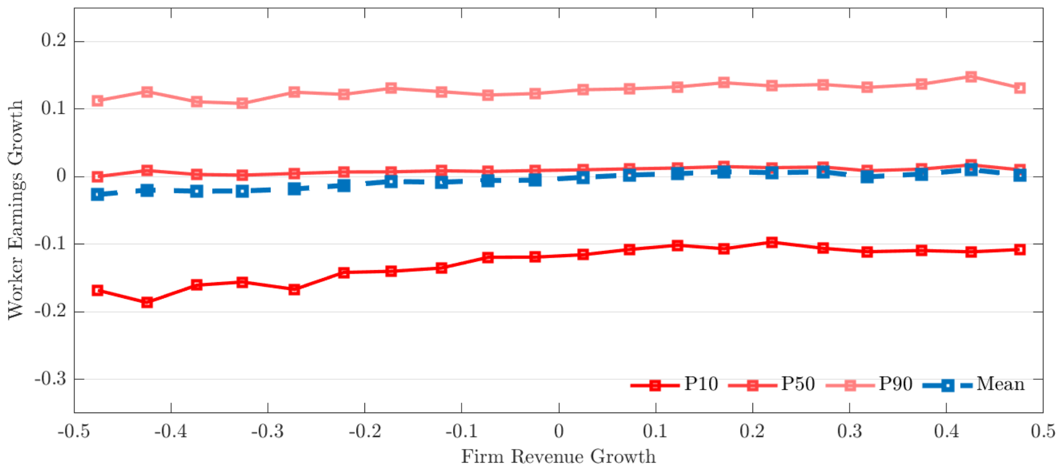

Figure A.8: Worker Earnings Growth by Firm Revenue Growth – Large Firms

Notes: This figure shows moments of the annual earnings growth distribution, conditional on the revenue growth of the firm at which workers are employed in the initial year. The sample is restricted to large firms.

in 2018 (Bhuller, Moene, Mogstad, and Vestad 2022). Two sectors where individual-level bargaining is more common than in others are manufacturing and retail (Larsen and Ilsøe 2022).

Figures A.9 and A.10 depict the worker earnings growth distribution of stayers by firm revenue growth restricted to manufacturing and wholesale and retail trade, respectively. As expected, the gradients by firm revenue growth are larger within these sectors than for the overall sample.

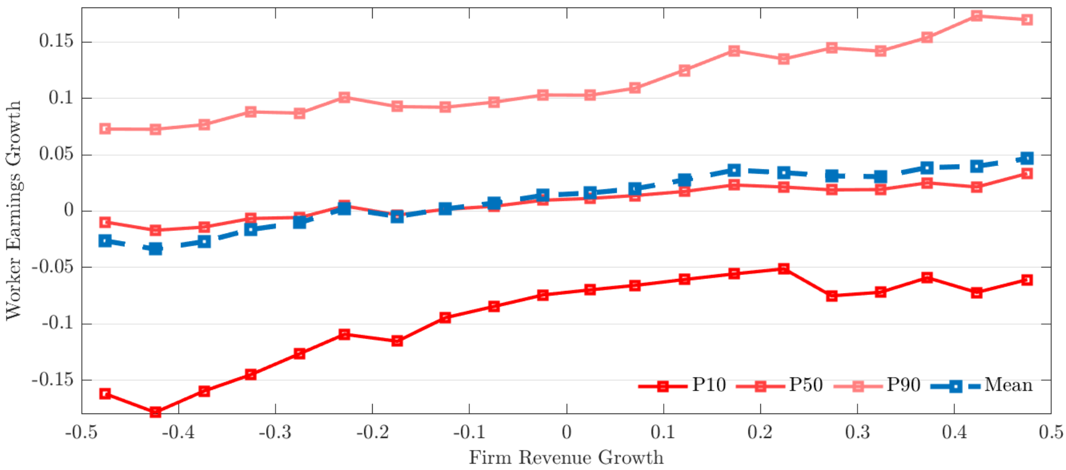

Figure A.9: Worker Earnings Growth by Firm Revenue Growth – Stayers in Manufacturing

Notes: This figure shows moments of the annual earnings growth distribution for workers staying at the same firm, conditional on the revenue growth of the firm. The sample is restricted to manufacturing.

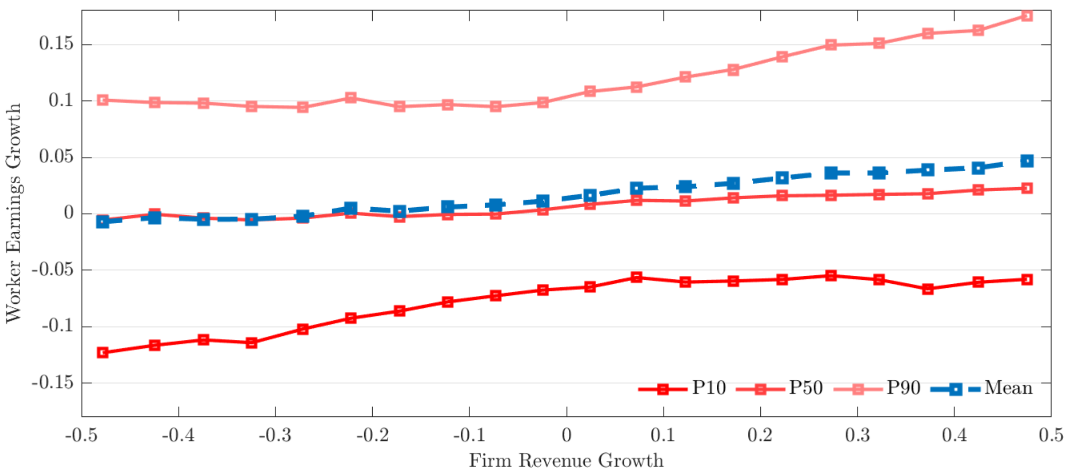

Figure A.10: Worker Earnings Growth by Firm Revenue Growth – Stayers in Wholesale/Retail

Notes: This figure shows moments of the annual earnings growth distribution for workers staying at the same firm, conditional on the revenue growth of the firm. The sample is restricted to wholesale and retail trade.

A.3.5 Hours and Wages

Wage dynamics by firm revenue growth. In addition to earnings, we also observe hours worked. As our measure of hours, we use an hours variable, where missing and implausible values have already been imputed by Statistics Denmark. We prefer this hours measure over raw reported hours because with the latter the sample is very different from our stayer sample, such that the hours and wage change figures would not combine to the

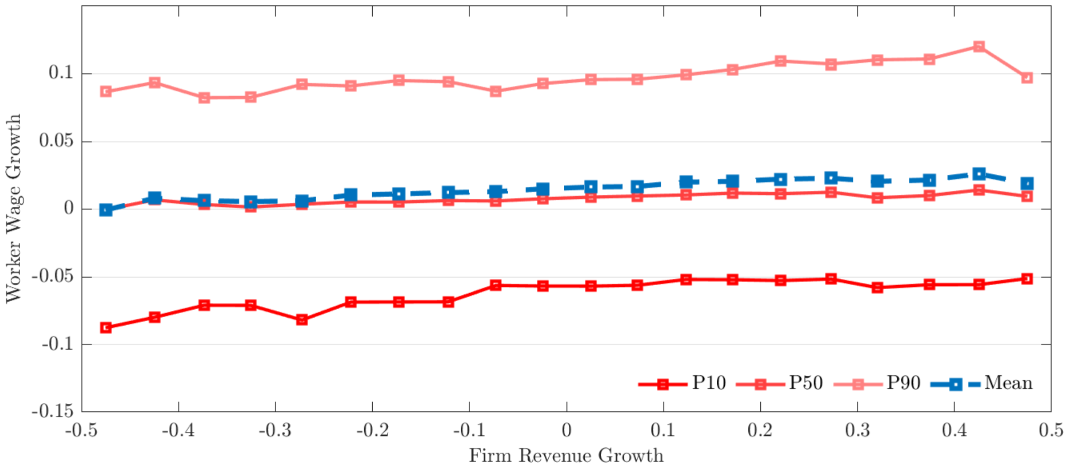

Figure A.11: Worker Wage Growth of Stayers by Firm Revenue Growth

Notes: This figure shows moments of the hourly wage growth distribution for workers staying at the same firm, conditional on the revenue growth of the firm.

total earnings of stayers figure. With this hours measure we will not capture if employer and employee decide to vary hours worked over time within the contract to obtain the right average hours worked, without adjusting contractual reported hours. However, if there was a change in contractual hours, which is arguably the relevant margin for earnings dynamics, this would be captured.

With the measure of hours, we can compute hourly wages by dividing income by hours. Moments of the hourly wage growth distribution for stayers by firm revenue growth are shown in Figure A.11. A sizable part of the earnings changes of stayers is driven by wage changes, and there is a relation between wage changes and firm revenue growth as there is for earnings.

Hours dynamics by firm revenue growth. Finally, we plot the same type of figure for hours growth in Figure A.12. We see a similar pattern, with larger hours drops more likely in shrinking firms and larger hours rises more likely in growing firms. However, overall the variability in hours is lower than the variability in wages, so that movements in the latter are more important for understanding earnings dynamics.[40]

A.3.6 Longer Horizon

A potential concern with the measures presented in the main part of the paper is that one-year changes might reflect transitory phenomena. To alleviate that concern, we present

[40]Within the pass-through literature, Bell, Bloom, and Blundell (2022) shows using UK data that only roughly a quarter of the average effect of firm-level shocks on weekly wages is driven by hours.

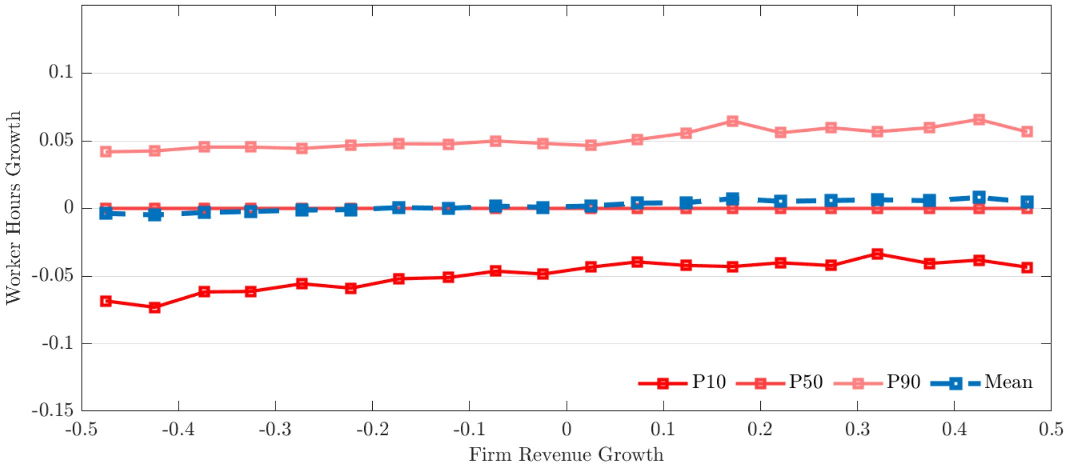

Figure A.12: Worker Hours Growth of Stayers by Firm Revenue Growth

Notes: This figure shows moments of the hours growth distribution for workers staying at the same firm, conditional on the revenue growth of the firm.

in this section results based on three year growth rates, which capture more persistent shocks.[41]

Figure A.13 shows statistics of the three year worker earnings growth distribution by three year firm revenue growth distribution. Overall, there is more dispersion in the worker earnings growth distribution. The 10th percentile of the earnings growth distribution is shifted downwards relative to Figure 1, based on one year growth rates. However, the gradient in firm revenue growth is similar.

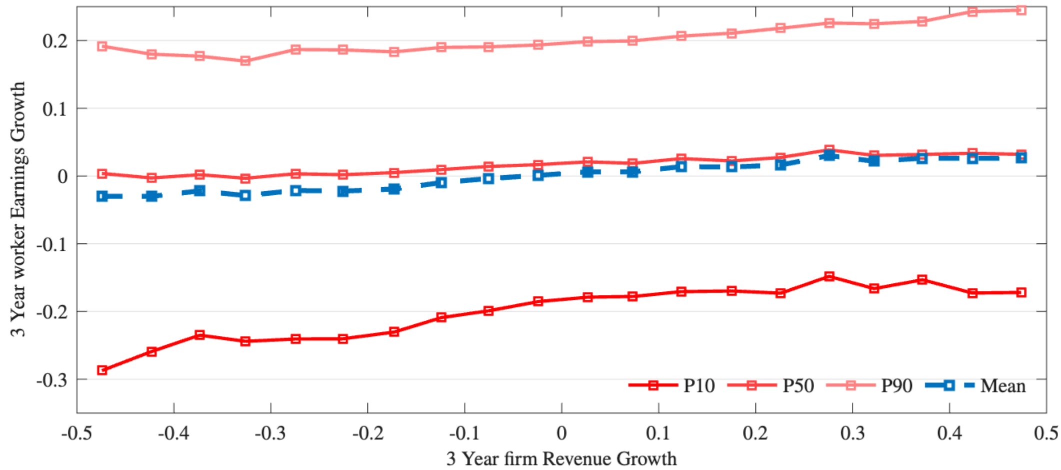

Figure A.13: 3 Year Worker Earnings Growth by Firm Revenue Growth

Notes: This figure shows moments of the three year earnings growth distribution, conditional on the three year revenue growth of the firm at which workers are employed in the initial year.

[41] See Appendix B in Guvenen et al. (2021) for a derivation of how transitory and permanent shocks contribute to moments of the growth distribution at varying horizons.

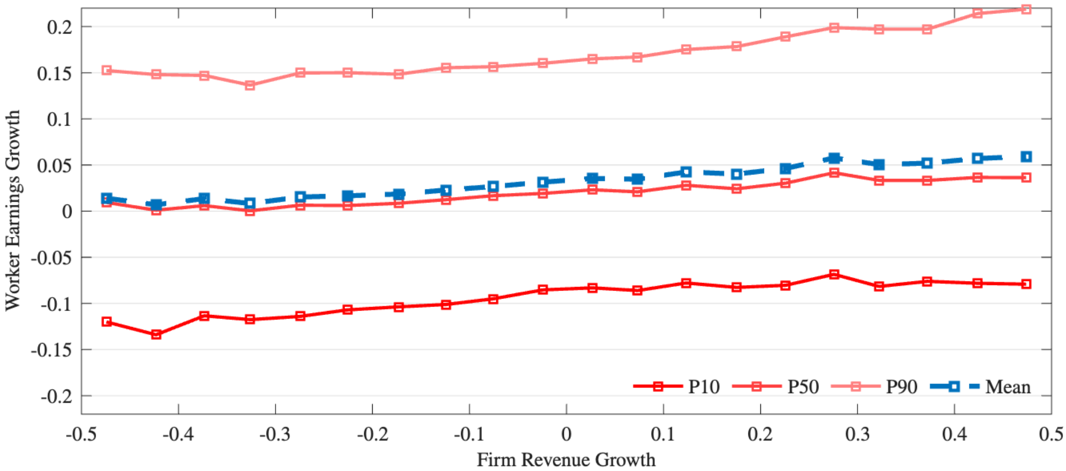

Figure A.14: 3 Year Worker Earnings Growth of Stayers by Firm Revenue Growth

Notes: This figure shows moments of the three year annual earnings growth distribution for workers staying at the same firm, conditional on the three year revenue growth of the firm.

Interpretation of the three year growth rates is complicated by the fact that we do not condition on where the workers are employed (or unemployed) from the second year onwards. Hence, after starting out in a certain firm they have completed multiple labor market transitions. Therefore, in Figure A.14 we also show the results for three year stayers, which are continuously employed at the same firm. As in our benchmark, the earnings growth distribution is naturally more compressed than when including non-stayers, but the key pattern of the probability of large losses (gains) going down (up) in firm revenue remains present.

B Model Appendix

B.1 More Details on the Model

B.1.1 Search Effort First Order Conditions

We first derive the first-order condition for the search effort of an unemployed worker:

$$\begin{aligned} c'_{w,U}\left(s\left(x'\right)\right) = \beta \Lambda'_{U}\left(s\left(x'\right)\right)\lambda\left(\theta\right) \times \\ \Bigg\{ - U\left(x'\right) + \int_{\tilde{y}} \left(1 - A_U\left(x', \tilde{y}\right)\right) U\left(x'\right) \frac{\mu_y\left(\tilde{y}\right)}{v} d\tilde{y} \\ + \int_{\tilde{y}} A_U\left(x', \tilde{y}\right) W\left(x', \tilde{y}, w^{\text{init}}\left(x', \tilde{y}\right)\right) \frac{\mu_y\left(\tilde{y}\right)}{v} d\tilde{y} \Bigg\}. \end{aligned} \tag{23}$$

Search effort is costly, and with a convex cost function increasingly so the higher search effort becomes. Higher search effort, however, increases the chances of leaving unemployment and getting on the job ladder. The marginal cost and the marginal gain have to be equalized.

The first order condition for an employed searcher reads as follows:

$$\begin{aligned}
& c'_{w,E}\left(s\left(x',y',w\right)\right)=\beta\Lambda'_{E}\left(s\left(x',y',w\right)\right)\lambda\left(\theta\right)\times \\
& \left\{\int_{\tilde{y}}A_{E}\left(x',y',\tilde{y}\right)W\left(x',\tilde{y},\bar{w}_{y}\left(x',y'\right)\right)\frac{\mu_{y}\left(\tilde{y}\right)}{v}d\tilde{y}\right. \\
& +\int_{\tilde{y}}A_{O}\left(x',y',w,\tilde{y}\right)W\left(x',y',\bar{w}_{y}\left(x',\tilde{y}\right)\right)\frac{\mu_{y}\left(\tilde{y}\right)}{v}d\tilde{y} \\
& -\int_{\tilde{y}}\left[A_{E}\left(x',y',\tilde{y}\right)+A_{O}\left(x',y',w,\tilde{y}\right)\right] \\
& \left.\times\min\left\{\max\left\{W\left(x',y',w\right),U\left(x'\right)\right\},W\left(x',y',\bar{w}_{y}\left(x',y'\right)\right)\right\}\frac{\mu_{y}\left(\tilde{y}\right)}{v}d\tilde{y}\right\}.
\end{aligned} \tag{24}$$

The increasingly higher cost of more search effort is traded off against the gains from increasing wages through more outside offers and the resulting job-to-job transitions and renegotiations.

B.1.2 Distributions

Distribution of vacant jobs. This section completes the laws of motion of Section 3.5 in the main text by describing the mass of vacant jobs $\mu_y(y)$.

$$\begin{aligned}
\mu_{y}\left(y'\right)= & \underbrace{\int_{y}\left(1-\delta\left(x^{\mathrm{med}}\right)\right)v^{\mathrm{N}}\left(y\right)\phi_{f}\left(y\right)Fp\left(y'\mid y\right)dy}_{\text{Newly created jobs}} \\
& +\left(1-\delta\left(x^{\mathrm{med}}\right)\right)\int_{y}\left\{\underbrace{\left(1-\lambda_{f}\right)}_{\text{Not filled: no meeting}}+\lambda_{f}\left\{\underbrace{p_{U}\int_{x}\left(1-A_{U}\left(x,y\right)\right)\frac{L_{U}\left(x\right)}{L_{U}}dx}_{\text{Not filled: meeting with unemployed}}\right.\right. \\
& \left.\left.+\underbrace{\left(1-p_{U}\right)\int_{\tilde{y}}\int_{x}\int_{w}\left(1-A_{E}\left(x,\tilde{y},y\right)\right)\frac{L_{E}\left(x,\tilde{y},w\right)}{L_{E}}dwdxd\tilde{y}}_{\text{Not filled: meeting with employed}}\right\}\right\}p\left(y'\mid y\right)\mu_{y}\left(y\right)dy \\
& +\underbrace{\left\{\int_{y}\int_{x}\int_{\tilde{y}}\int_{w}\left(1-\delta\left(x^{\mathrm{med}}\right)\right)\lambda_{E}\left(s\left(x,y,w\right),\theta\right)A_{E}\left(x,y,\tilde{y}\right)\times\frac{\mu_{y}\left(\tilde{y}\right)}{v}\psi^{S}\left(x,y,w\right)p\left(y'\mid y\right)dwd\tilde{y}dxdy\right\}}_{\text{Newly vacant due to job-to-job transition}} \\
& +\underbrace{\left\{\int_{y^{-}}\int_{x^{-}}\int_{y}\int_{x}\left(1-\delta\left(x^{\mathrm{med}}\right)\right)\left(1-\delta\left(x^{-}\right)\right)\left(1-A_{S}\left(x,y\right)\right)\tilde{\psi}\left(x^{-},y^{-}\right)\times p\left(y'\mid y\right)p\left(x\mid x^{-}\right)p\left(y\mid y^{-}\right)dxdydx^{-}dy^{-}\right\}}_{\text{Newly vacant due to endogenous separation}}.
\end{aligned} \tag{25}$$

The distribution of vacant jobs can be computed as the sum of three components: newly created jobs, vacant jobs that were not filled in the past, and filled jobs that became vacant. Newly created jobs are denoted with $v^{\mathrm{N}}(y)$ and are given by the job creation condition in equation (8) in the main text. New jobs are created at the beginning of the period, so they can be exogenously destroyed. New job creation is weighted with the total mass of firms F and the exogenous distribution of firms across productivities $\phi_f(y)$. Also, between the production stage and the search and matching stage productivity shocks take place.

A vacant job may remain vacant for three reasons. First, it may not meet any worker. Second, it may meet an unemployed worker, but productivities are such that no match is created. Third, it may meet an employed worker, but productivities are such that there is no job-to-job transition.

A filled job may become vacant for two reasons. First, the worker may move to another firm through a job-to-job transition. Starting from the distribution of matches at the search stage, a worker may meet a vacant job and do a job-to-job transition. Then, the firm will have a vacant job. Until the search stage of the next period, however, this job can be exogenously destroyed and is subject to the firm productivity shock. Second, there can be an endogenous separation. Starting from the distribution of matches at the production stage, jobs can be exogenously destroyed. In that case they do not enter the distribution of vacant jobs. Those matches that survive exogenous destruction shocks are subject to productivity shocks. After these realize, there may be endogenous separations. However, the vacant jobs can only be refilled at the search stage of the next period, so that they are subject to exogenous destruction and productivity shocks again before entering the distribution of vacant jobs.

B.2 Equilibrium Definition

A stationary equilibrium consists of value functions for unemployment $U(x)$, employment $W(x,y,w)$, vacant jobs $V(y)$, and filled jobs $J(x,y,w)$, acceptance rules for match creation $A_U(x,y)$, endogenous separations $A_S(x,y)$, job-to-job transitions $A_E(x,y,\tilde{y})$, and renegotiations after outside offers $A_O(x,y,w,\tilde{y})$, search policies of unemployed workers $s(x)$, search policies of employed workers $s(x,y,w)$, job creation policies of firms $v^{\mathrm{N}}(y)$, wage policies $\underline{w}_x(x,y)$, $\bar{w}_y(x,y)$, $w^{\mathrm{init}}(x,y)$, a government policy $b, T(\cdot)$, and distributions of matches at the production stage $\psi(x,y,w)$, $\tilde{\psi}(x,y)$, at the search stage $\psi^S(x,y,w)$, $\tilde{\psi}^S(x,y)$, of unemployed $\mu_x(x)$, and of vacant jobs $\mu_y(y)$, such that

1. Value functions satisfy equations (5), (6), (7), and (9),
2. Acceptance rules are optimal given value functions,
3. Search policies are optimal, satisfying equations (23) and (24),

4. Job creation is optimal, satisfying equation (8),
5. Wages satisfy equations (4), (10), and (11),
6. Distributions are stationary, satisfying equations (12), (13), (14), and (25),
7. The government budget clears.

B.3 Numerical Algorithm

We use the following algorithm to compute the stationary equilibrium of the model, given a government policy.

1. Guess value functions and distributions of matches, unemployed, and vacant jobs.
2. Compute implied aggregate labor market variables.
3. Compute wage policies given value functions.
4. Compute acceptance rules.
5. Compute search effort policies given value functions and distributions.
6. Compute new value functions and deviations from guesses.
7. Compute new distributions and deviations from guesses.
8. If errors between guessed and computed value functions and distributions are small enough, stop. Otherwise, update value functions and distributions and restart from step 2.