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Equilibrium effects of payroll tax reductions and optimal policy design ☆

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ABSTRACT

We quantify the unintended effects of a low-wage payroll tax reduction using an equilibrium search model featuring bargaining, worker and firm productivity heterogeneity, labor taxes, and a minimum wage. The decentralized economy is inefficient due to search externalities and labor market policies. We estimate the model using French data and find that a significant reduction in low-wage payroll taxes in 1995 leads to an overall improvement in economic efficiency by increasing employment and correcting existing policy distortions that disincentivize labor force participation. However, the tax reduction, by increasing labor force participation among low-productivity workers and vacancy postings by low-productivity firms, results in negative but minor spillover and reallocation effects due to congestion. We find that the optimal policy mix is a lower minimum wage and lower payroll taxes compared to the policies in place in the early 1990s.

1. Introduction

Payroll tax reductions for low-wage work and minimum wages are commonly used policy instruments to increase the employment of low-wage workers and combat income inequality. Recent empirical literature suggests that their impacts may extend beyond their intended targets. Unintended consequences of the policies include worker reallocation across firms and spillover effects on the labor market outcomes of those not directly impacted. For example, Dustmann et al. (2022) find that the German minimum wage improves firms' quality in terms of size and pay, leading workers to "upgrade" to higher-quality employers. Azmat (2019) finds that a UK tax credit for low-income families affects the wages of non-eligible workers, and Saez et al. (2019) find spillover effects of a Swedish tax cut for young workers.

In this paper, we focus on payroll tax reductions in the presence of a minimum wage in labor markets with search frictions. We ask the following research questions. First, to what extent do low-wage payroll tax reductions lead to reallocation and spillover effects in labor market equilibrium and what is the overall effect on economic efficiency? Second, what is the optimal policy mix when considering both labor taxes and minimum wages?

To answer these questions, we consider a Diamond–Mortensen–Pissarides (DMP) style search and matching model in which workers and firms are respectively different in their productivity, search in the labor market to form bilateral matches, and face labor taxes and a minimum wage. Workers choose whether to participate in the labor market by weighing the cost against the returns of job search; the returns of job search depend on which jobs, or matches, are potentially acceptable. Analogously, firms choose to post vacancies by weighing the cost of vacancy-posting against the expected profit. Since workers and firms do not internalize the congestion and thick-market externalities they impose on others in the labor market (see Hosios, 1990), the labor market participation and vacancy posting decisions are potentially inefficient.

In our model, policies such as a low-wage payroll tax reduction and or a minimum wage reduction affect not only low-productivity workers that the policies target, but also those who are not directly targeted. If a policy increases the labor force participation of low-productivity workers, it creates congestion in the labor market and can potentially lower the job-finding rate of all workers. We refer to this as the spillover effect. If low-productivity firms choose to post more vacancies as a

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result of a policy, workers are more likely to encounter and work in these firms, resulting in a potential decrease in the average output per job. We refer to this as the reallocation effect. Spillover and reallocation effects have implications for economic efficiency. Increased labor force participation by low-productivity workers and increased vacancy-posting by low-productivity firms can increase labor market inefficiency because the (negative) congestion externality these workers and firms exert by participating in the frictional labor market is likely to outweigh the (positive) thick market externality (see Shimer and Smith, 2001).

We use our model to study the effects of a major low-wage payroll tax reduction in France in the 1990s. The combination of a high minimum wage and high taxes for low-wage jobs creates a high floor on labor costs, making it difficult for low-productivity workers to find jobs. This was the case in France in the early 1990s when the government implemented a series of low-wage payroll tax reductions in response to an acute employment problem.[1] We estimate our model based on French social security records data prior to the payroll tax reduction. We exclude public sector workers and workers in professional and executive occupations and focus on the broadly defined low-skilled workers. Central to our quantitative analysis are the parameters governing the productivity distributions of workers and firms and the production technology. Identifying these parameters requires the knowledge of the ranks of workers and firms in the respective productivity distributions, which our employer–employee linked data allows us to estimate. Given this ranking, we use the simulated method of moments to estimate model parameters. Our model not only replicates aggregate labor market statistics such as the unemployment and vacancy rates but also differences in wage, employment, and the job-finding rate across different worker and firm ranks. In addition, the aggregate employment effect of the payroll tax reduction as estimated by the model is in line with reduced form evidence (Crépon and Desplatz, 2003), and the distributional effects are consistent with our observations based on post-reform data.

Based on our estimated model, we find that the payroll tax reduction increases employment by 2.08% and increases output by 1.14%. A decomposition exercise indicates that most of the increase in employment and output is due to an increase in labor force participation by low-productivity workers. This is because the payroll tax reduction expands the set of viable matches for these workers and increases the returns to job search. Increased participation of low-productivity workers leads to a negative but small spillover effect: workers in the bottom quartile of the productivity distribution contribute to a 1.26% increase in aggregate output, while those in the top three quartiles contribute to a 0.11% decrease in aggregate output. There is also a negative but small reallocation effect because the tax reduction leads to an increase in vacancies posted by low-productivity firms. The average output per job decreases by 0.17% in all worker productivity quartiles.

Despite the negative spillover and reallocation effects, we find that the payroll tax reduction achieves a 1.11% increase in economic efficiency. This suggests that the labor market policies in France in the early 1990s generate significant economic inefficiency, motivating us to conduct an exercise of optimal design of the two policy instruments. We find the efficiency-maximizing policy mix to be a lower minimum wage and lower payroll taxes compared to the policies that were in place in the early 1990s. The optimal policy mix helps correct labor market inefficiencies due to search externalities without disincentivizing labor force participation by low-productivity workers.

[1] We provide details of this policy in Appendix A.3.

Related literature. It has long been recognized that in search models with bargaining (i.e., DMP models), workers and firms do not internalize the congestion and thick-market externalities they impose on others. This can lead to inefficient labor market outcomes (Hosios, 1990), and labor market policies can potentially correct these inefficiencies. Flinn (2006) shows that a minimum wage policy can be welfare-improving if workers' bargaining power is too low compared with their associated matching function elasticity. Chéron et al. (2008) incorporate training investment in a DMP model calibrated to the French economy in the same period as our study. They find that low-wage payroll subsidies enhance welfare more than a reduction in the minimum wage.

Different from Flinn (2006) and Chéron et al. (2008), we consider ex-ante heterogeneous workers and firms in terms of productivity and the labor force participation decision of workers. In a frictional market with ex-ante heterogeneous agents, Shimer and Smith (2001) show that the decentralized equilibrium is always inefficient because high-productivity agents search too little and low-productivity agents search too much. This suggests that there is more potential for labor market policies to improve efficiency. Our model builds on recent works by Lise et al. (2016) and Bagger and Lentz (2019), which introduce two-sided ex-ante productivity heterogeneity into a DMP model with counteroffers.[2] We extend their models by considering labor taxes and a minimum wage.

More generally, this paper joins a growing literature that studies the quantitative effects of labor market policies using equilibrium job-search models. Shephard (2017), Wilemme (2021), and Bagger et al. (2018) use DMP-style models to study the effects of tax policies. Shephard (2017) studies the tax credit reform in the UK. While his model includes workers that differ in their value of home production, there is no difference in terms of worker productivity, a central component of our analysis. Wilemme (2021) studies optimal taxation to correct mismatches. Bagger et al. (2018) study the effects of marginal tax rates on job-to-job mobility in Denmark. They consider a model in which labor markets are segregated by workers' productivity. Others in this literature consider competitive search equilibrium models (Bagger et al., 2021) or wage-posting models (Bloemer et al., 2018; Engbom and Moser, 2021).

Finally, our paper complements the empirical literature that shows that targeted policy reforms can result in spillovers that affect the distributions of workers and firms. See Rothstein (2008), Leigh (2010), and Azmat (2019) regarding tax credit policies, Crépon and Desplatz (2003) and Saez et al. (2019) regarding payroll tax reductions, and Dustmann et al. (2022) for the minimum wage. We complement these papers by quantifying the spillover or reallocation effects in an equilibrium framework and testing for the optimal policy design while considering these unintended effects.

Organization. The rest of the paper is organized as follows. In Section 2, we discuss the institutional background and present evidence on labor market mobility in France. In Section 3, we present the equilibrium search model. We explain our data, estimation strategy and results in Section 4. In Section 5, we simulate and analyze the first major low-wage payroll tax reduction in France. In Section 6, we study the optimal payroll taxation and the minimum wage. Finally, we conclude in Section 7.

2. Institutional background and descriptive statistics on the French labor market

2.1. Payroll tax reductions

After the Second World War, the French government organized the construction of a generous social security system financed through

[2] See Dey and Flinn (2005) and Cahuc et al. (2006) for bargaining models with counteroffers.

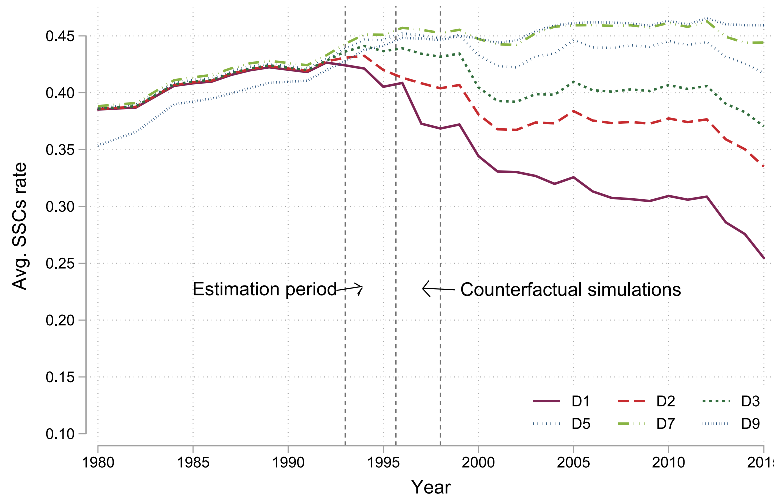

Fig. 1. Evolution of Social Security Contributions (SSCs) Rate by Wage Deciles (1980–2015). Notes: Average SSC rate is the ratio of the average total social security contributions (employer and employee) to the average labor cost in six deciles of the labor cost distribution.
Source: DADS 1980–2015. Full-time workers only. Data provided by Bozio et al. (2016). Each line represents a wage decile (e.g. D1 = the first decile). "Estimation period" (January 1993 to August 1995) is the period based on which we estimate our equilibrium model (see Section 4). "Counterfactual simulations" refer to the period from September 1995 to December 1997. We simulate the effects of the employer SSC implemented in September 1995 using our equilibrium model and compare the results to data from the "counterfactual simulations" period.

contributions levied on earnings. More precisely, employers pay contributions on contractual (or posted) earnings and withhold employee contributions from these earnings. In this paper, we focus exclusively on policies that vary employer social security contributions as they have been subject to significant revisions and play a key role in shaping the labor cost of low-wage earners. Indeed, the French minimum wage, first introduced in 1950, is defined in terms of the contractual wage, which is net of employer SSCs. This implies that employer SSCs cannot be shifted to employees and are, therefore, mechanically incident on employers at the minimum wage. In Appendix A, we provide further details on institutional background.

In the early 1990s, social security contributions (SSCs) in France represented around 45% of the labor cost for almost all workers, including those with low wages. Meanwhile, the French unemployment rate rose from 8% in 1990 to about 11% in 1994. The high unemployment rate has often been attributed to the policy combination of a high statutory minimum wage and high employer SSCs. In a political context where the minimum wage cannot easily be reduced, reducing employer SSCs for low-wage earners is an appealing solution to lower their costs. The first major reduction in employer SSCs for low-wage jobs, which we refer to as the payroll tax reduction, was implemented in September 1995.[3] As can be seen from Fig. 1, the reductions in 1995 resulted in a divergence of SSC rates among different types of workers, with workers hired at lower labor costs facing significantly lower SSC rates. Reductions in employer SSCs were maintained and even extended between 1995 and 2020, with the largest reductions occurring in 1998, 2005, 2013, and 2019. Over this entire period, the combination of a high minimum wage and large payroll tax reductions for low incomes has been the favored policy mix to maintain high net wages while limiting labor costs in the French economy.

2.2. Job mobility in the French labor market

In this subsection, we summarize empirical evidence to show that the French labor market features a high degree of job mobility, including occupational mobility across different skill levels. The evidence suggests that workers of different occupations and/or skill levels often compete for similar jobs so a labor market policy that specifically targets one group of workers can have potential unintended effects on other workers.[4]

First, although job mobility is more limited in France than in the United States (Picart, 2008), it is a prominent feature in the French labor market, especially for younger and lower-skilled workers. Around 10% of salaried workers experience at least one transition (to another employer or to unemployment) each year (Amossé et al., 2011), and 30% of unskilled workers change employers each year (Amossé, 2003). Second, a large fraction of employees experience occupational mobility. Specifically, about 30% of job-to-job transitions are accompanied by a change in occupation and 20% by a change in industry (Dubost and Tranchant, 2019).[5] This is in part because workers search for jobs across a wide range of occupations.[6] In addition, unemployment is often followed by downward mobility among both low-skilled occupations such as clerks or skilled blue-collar workers and high-skilled ones such as technicians, intermediate managers, and executives (see Chapoulie, 2000; Bianco et al., 2020). The evidence suggests that workers of different occupations and/or skill levels often compete for similar jobs.

Third, there are considerable discrepancies between the jobs that unemployed individuals initially sought and those they eventually ended up accepting. This outcome would not arise in a theoretical framework where search is purely directed. Lizé et al. (2009) present results from a survey of about 10,000 registered job seekers in France and find that a striking 73% of workers do not end up in the kind of job they initially sought. While around half of job-seekers move to jobs requiring similar skill levels as the jobs they were looking

[3] Small reductions were already implemented in 1993, but they were very limited both in terms of magnitude and affected wage brackets.

[4] We believe that job search is neither completely random (with all workers applying to all job offers) nor completely directed (with a given worker applying only to a specific type of job). Establishing which of these two archetypal modeling assumptions is the more appropriate approach is beyond the scope of the paper. In ongoing work, Lentz et al. (2023) estimate the level of directedness in the Danish labor market.

[5] Occupational mobility has also been rising over time. See Kambourov and Manovskii (2008) for the United States and Lalé (2012) for France.

[6] Amossé et al. (2011) document outcomes of displaced individuals four years after exiting a firm in the early 2000s and find that while 63% remain in the same broad occupational rank, 24% move on to a higher- and 13% to a lower-rank occupation, respectively.

for, a quarter move to higher-level jobs and a quarter to lower-level jobs. Transitions to jobs requiring fewer skills than anticipated are more frequent among highly skilled workers but also prominent among unskilled workers (Lizé et al., 2009, Table 7). Motivated by the evidence presented above, we next turn to an equilibrium random-search model with heterogeneous workers and firms and use it to quantify the potential unintended effects of labor market policies such as a low-wage payroll tax reduction.

3. Model

3.1. Environment

We consider a Diamond–Mortensen–Pissarides (DMP) style search and matching model with heterogeneous individuals and firms, labor taxes, and a minimum wage. Time is continuous, and agents live infinitely. There is a continuum of risk-neutral individuals, unable to save or borrow, and derive utility from consumption. We normalize the population of individuals to a unit measure and index them by x according to the rank of their productivity level, so that x is uniformly distributed on the interval $[0,1]$. Non-employed individuals can choose to participate in the labor force by searching for jobs at a flow search cost q. The group of non-employed, therefore, consists of both unemployed jobseekers and non-participants. The search cost captures the difference between the discomfort of search and the stigma of not looking for a job. Employed workers search on-the-job at zero cost.[7] The difference between on- and off-the-job search is captured by the difference in search intensity. Without loss of generality, we normalize search intensity to 1 for unemployed workers and let employed workers' search intensity be s_1, a parameter to be estimated.[8] Employed workers supply an indivisible unit of labor. Let $e(x)$ and $u(x)$ the fraction of employed and unemployed workers among type-x workers, with the fraction of non-participants being $1-e(x)-u(x)$.

There is a continuum of firms that also differ in productivity. We index firms by y according to the rank of their productivity level, so that y is uniformly distributed on the interval $[0,1]$. Firms choose the number of vacancies $v(y) \geq 0$ they post subject to a vacancy-posting cost.

Workers and firms are brought together pairwise via a DMP aggregate meeting technology. That is, meetings between workers and firms are one-to-one, and the meeting rate depends on the aggregate search intensity ($\xi = \int_0^1 \left[e(x) + s_1 u(x)\right] dx$) and the aggregate measure of vacancies ($V = \int_0^1 v(y)\, dy$). We assume that the meeting technology displays constant returns to scale such that the flow measure of contacts between workers and firms is

$$M(\xi, V) = m_0 \xi^{m_1} V^{1-m_1}. \tag{1}$$

For convenience, we define $\kappa(\xi,V) \equiv \frac{M(\xi,V)}{\xi V}$ so that $\kappa(\xi,V)V$ is the contact rate of an unemployed worker and $\kappa(\xi,V)\xi$ is the contact rate of a vacancy.

If worker x and firm y form a match, they produce flow output $f(x,y)$ with $f_x(x,y) > 0$ and $f_y(x,y) > 0$ for all x and y. The worker receives net wage w while the firm collects flow revenue $f(x,y)$ and pays the labor cost.[9] Although the DMP assumption implies that the meeting rate per unit of search intensity is the same for all individuals, the rate at which a match is formed varies. A match is viable if the worker–firm pair can find a wage that is mutually agreeable and greater than the minimum wage. In the subsequent subsections, we describe match formation and wage determination in detail and explain which combinations of workers and firm types can form viable matches together.

Wage is determined via bargaining between the worker and the firm. We assume that workers in the same firm have the same bargaining power $\alpha(y)$, but it can vary across firms. This reflects collective bargaining that commonly takes place in France at the firm level. To hire a worker at net wage w, firms have to bear labor cost $w + T(w)$, where $T(w)$ is the labor tax, the sum of employer and employee social security contributions (SSCs). We assume that $T(\cdot)$ is differentiable and $T'(w) > 0$ for all w. This accommodates a wide range of tax functions, including ones with non-monotone marginal tax rates. We also consider a wage floor on net wages, w_{min}, calculated by subtracting employee SSCs from the statutory minimum gross wage. Since both $T(w)$ and w_{min} remain constant in a steady state equilibrium, the assumption that taxes nominally fall on employers is without loss of generality.

Non-employed workers receive net income $b(x)$ regardless of their job search decision, where $b'(x) \geq 0$. We interpret $b(x)$ as the sum of non-employment transfers. In practice, the most important component concerns unemployment benefits are linked to previous wages. For tractability, we assume that non-employment incomes depend solely on x so that individuals' job search decisions are time-invariant.[10] The measure of filled jobs, or matches, of type (x,y) is given by $h(x,y)$ such that $e(x) = \int_0^1 h(x,y)\, dy$. A match may be destroyed exogenously at rate δ, or endogenously if a worker transitions to another job. Finally, we assume that all agents have a common subjective discount rate r.

3.2. Meetings involving unemployed individuals

When an unemployed worker meets a recruiting firm, they decide whether or not to form a match and bargain over the net-of-tax match surplus subject to the minimum wage to determine the wage. Specifically, the match surplus over which the worker–firm pair bargain is given by

$$S(w,x,y) = W_e(w,x,y) - W_{ne}(x) + J_f(w,x,y) - J_u(y) \tag{2}$$

where $W_e(w,x,y)$ and $J_f(w,x,y)$ are, respectively, the present values of the worker and the firm if a matched is formed at wage w. The worker's outside option is the value of non-employment $W_{ne}(x)$. The firm's outside option is the value of an unfilled position $J_u(y)$. Given that $T'(w) > 0$, the net surplus shrinks with higher wages.

In the absence of the minimum wage, the match surplus is split with each party receiving a proportion of the surplus according to their bargaining power.[11] The wage bargaining outcome ϕ must satisfy the following system:

$$\begin{cases} W_e(\phi,x,y) - W_{ne}(x) = \alpha(y)\, S(\phi,x,y) \\ S(\phi,x,y) \geq 0. \end{cases} \tag{3}$$

For any match (x,y), Proposition 1 states that the value of the match to the worker increases with the wage level while the value to the firm decreases in w. Section 3.4 provides the associated value functions.

[7] On-the-job search can be seen as passive search: While unemployed workers have to search actively to meet potential employers, employed workers face a positive meeting rate without explicit efforts.

[8] Alternatively, the deviation of s_1 from 1 can be interpreted as a difference in search efficiency between employed and unemployed workers.

[9] The fact that match output only depends on the individual and firm involved in the match implies that there is no complementarity between different workers within a firm. This is commonly assumed in the literature to keep models tractable. As we explain in Section 4.1, we exclude workers who mainly work in professional and executive positions from our empirical analysis, making the assumption of no complementarity more plausible.

[10] We implicitly assume that payroll-tax reductions do not affect non-employment incomes. The rule for calculating non-employment income may change if a policy change affects tax revenue. However, as we discuss in Appendix A, the link between SSCs and benefits is weak. In particular, the payroll tax reduction we study is not accompanied by modifications to benefit entitlements for workers.

[11] The proportional bargaining scheme simplifies our problem by ensuring a unique bargaining solution even if the marginal tax rate is non-monotone. See Appendix B for a discussion on Nash bargaining and proportional bargaining.

Proposition 1. *$W_e(w,x,y)$ monotonically increases in w while $J_f(w,x,y)$ monotonically decreases in w for all x and y.*

Proof. See Appendix C.1. □

The worker–firm pair (x,y) may fail to find a bargaining solution ϕ. This happens if the worker's outside option $W_{ne}(x)$ is so high that the wage that makes the worker indifferent between accepting or rejecting the job results in a negative surplus. We show that if ϕ exists, it must be unique (Appendix C.2). If the bargaining solution ϕ exists, the worker–firm pair proceeds to compare ϕ to the minimum wage w_{min}. As in Flinn (2006), we assume that, if $\phi \geq w_{min}$, a match is immediately realized at wage ϕ; otherwise (if $\phi < w_{min}$), a match is only realized if forming the match at w_{min} makes both the worker and the firm weakly better-off.[12] Formally, we define match viability as follows.

Definition 1. A match is viable if ϕ that solves Eq. (3) exists and either of the following holds: (1) $\phi \geq w_{min}$, or (2) $\phi < w_{min}$, $W_e(w_{min},x,y) - W_{ne}(x) \geq 0$ and $J_f(w_{min},x,y) - J_u(y) \geq 0$.

Let $\mathcal{A}_u(x) \subseteq [0,1]$ be the subset of firms with whom worker x can form a viable match, such that

$$\mathcal{A}_u(x) = \{y \in [0,1] : (x,y) \text{ is viable}\}. \tag{4}$$

If match (x,y) is viable, the out-of-unemployment wage for worker x is $\phi_u(x,y) = \max\{\phi, w_{min}\}$. Proposition 1 implies workers in matches such that $\phi < w_{min}$ receive strictly more than $\alpha(y)$ of the match surplus. Thus, the minimum wage effectively shifts the match surplus toward workers.

3.3. Meetings involving employed workers

When an employed worker is approached by another firm, we follow Dey and Flinn (2005) and Cahuc et al. (2006) in assuming that the poaching firm engages in a second price auction with the incumbent firm. This is followed by a wage negotiation between the worker and the highest bidder of the auction. Let $\bar{\phi}(x,y)$ be the maximum wage that firm y can pay to worker x, such that $J_f(\bar{\phi}(x,y),x,y) = J_u(y)$. Assume that worker x is currently employed at firm $y_0 \in \mathcal{A}_u(x)$. An auction takes place if the poaching firm y_1 can pay at least the minimum wage, i.e. $\bar{\phi}(x,y_1) \geq w_{min}$.

For any two bidding firms y and y', firm y outbids y' if and only if the maximum value that the worker x can attain in firm y is higher, i.e. $W_e(\bar{\phi}(x,y),x,y) \geq W_e(\bar{\phi}(x,y'),x,y')$. If the incumbent firm y_0 outbids the poaching firm y_1, the worker remains in y_0; she renegotiates her wage with y_0 if y_1 could have made the worker better-off compared to the worker's current state (i.e., $W_e(\bar{\phi}(x,y_1),x,y_1) \geq W_e(w_0,x,y_0)$, where w_0 is the worker's current wage). If, instead, y_1 outbids y_0, the worker moves to the poaching firm and bargains with it.

The surplus that an employed worker x and the winning firm y divide in wage bargaining is

$$S_e(w,x,y,y') = W_e(w,x,y) - W_e(\bar{\phi}(x,y'),x,y') + J_f(w,x,y) - J_u(y) \tag{5}$$

where $W_e(\bar{\phi}(x,y'),x,y')$ is the employed worker's outside option. As before, we apply proportional bargaining so that the bargained wage ϕ must solve the following system:

$$\begin{cases} W_e(\phi,x,y) - W_e(\bar{\phi}(x,y'),x,y') = \alpha(y)\, S_e(\phi,x,y,y') \\ S_e(\phi,x,y,y') \geq 0 \end{cases} \tag{6}$$

If a wage ϕ satisfying Eq. (6) exists, and if $\phi \geq w_{min}$ or $J_f(w_{min},x,y) \geq J_u(y)$, the match (x,y) is formed at wage $\phi_e(x,y',y) = \max\{\phi, w_{min}\}$, where y' is referred to as the "reference firm." Let $\mathcal{A}_e(x,y_0)$ be the subset of firms that can poach worker x from firm y, such that

$$\mathcal{A}_e(x,y_0) = \left\{y \in [0,1] : W_e(\bar{\phi}(x,y),x,y) > W_e(\bar{\phi}(x,y_0),x,y_0)\right\}. \tag{7}$$

3.4. Value functions

A non-employed worker can either stay out of the labor force or participate by searching for jobs. The value of non-employment, W_{ne}, is defined as follows:

$$rW_{ne}(x) = \max_{s\in\{0,1\}} \left\{ b(x) + s \left[\kappa(\xi,V) \int_{y'\in\mathcal{A}_u(x)} v(y') \times \left[W_e(\phi_u(x,y'),x,y') - W_{ne}(x)\right] dy' - q \right] \right\}. \tag{8}$$

Recall that $\kappa(\xi,V)V$ is the rate at which an unemployed worker meets a vacancy.[13] The policy function $s(x)$ denotes the optimal job search decision of a non-employed worker. $s(x)=1$ indicates unemployment and $s(x)=0$ indicates non-participation.[14]

The value of employment is defined as follows:

$$\begin{aligned} &[r+\delta+s_1\kappa(\xi,V)V]W_e(w,x,y) = w + \delta W_{ne}(x) \\ &+s_1\kappa(\xi,V)\int_{y'\in\mathcal{A}_e(x,y)} W_e(\phi_e(x,y,y'),x,y')v(y')dy' \\ &+s_1\kappa(\xi,V)\int_{y'\in[0,1]\setminus\mathcal{A}_e(x,y)} W_e(\max\{w,\phi_e(x,y',y)\},x,y)v(y')dy' \end{aligned} \tag{9}$$

An employed worker may be exogenously separated from her employer y at rate δ. She may also meet a vacancy at rate $s_1\kappa(\xi,V)V$, which she can either accept or reject. If the worker makes a job-to-job transition to the poaching firm $y' \in \mathcal{A}_e(x,y)$, she receives the new wage $\phi_e(x,y,y')$ from y'. If the worker stays with her employer y, she renegotiates her wage only if it can be increased, so that the wage can be expressed as $\max\{w,\phi_e(x,y',y)\}$.

The value of a filled position to a firm is defined as follows:

$$\begin{aligned} &[r+\delta+s_1\kappa(\xi,V)V]J_f(w,x,y) = f(x,y) - w - T(w) + \delta J_u(y) \\ &+s_1\kappa(\xi,V)J_u(y)\int_{y'\in\mathcal{A}_e(x,y)} v(y')dy' \\ &+s_1\kappa(\xi,V)\int_{y'\in[0,1]\setminus\mathcal{A}_e(x,y)} J_f(\max\{\phi_e(x,y',y),w\},x,y)v(y')dy' \end{aligned} \tag{10}$$

The firm collects the match output $f(x,y)$ and pays the labor cost $w+T(w)$. It faces separation if there is an exogenous shock or if the worker is poached by another firm, and it may be compelled to offer a higher wage if the worker meets a firm that can trigger a wage renegotiation.

3.5. Vacancy creation

A firm is the collection of jobs, filled and unfilled, of productivity y. Following Lise and Robin (2017), we assume that each firm buys the advertising of vacancies from job placement agencies.[15] In equilibrium, the free entry of vacancies ensures firms have no expected profits from opening further vacancies. Specifically, we assume that the marginal cost of posting v vacancies of type y is $c'(v,y)$, which is strictly increasing in v. This is consistent with the typical assumption of convex costs and guarantees a non-degenerate distribution of vacancies. The present value of an unfilled position to a firm is defined as follows:

[12] In the case that $\phi < w_{min}$, setting the wage at w_{min} may give the worker more than 100% of the match surplus. Thus, even if the match surplus is positive at w_{min}, the firm may not agree to a match because its share of the surplus is negative.

[13] It would be possible to include transitions between participation and non-participation. However, in equilibrium, we would need to add preference shocks to generate such transitions, which would increase the computation burden. Note that our model accounts for changes in participation as a result of changes in the steady state, for example after the change in social security contributions.

[14] We can rule out mixed strategies because each worker type x is atomless and thus the search decision $s(x)$ does not influence the contact rate.

[15] There is free entry of job placement agencies such that they make zero profits from selling advertisements in equilibrium.

$$rJ_u(y) = -c'(v,y) + \kappa(\xi,V)\int_{x\in\mathcal{B}_u(y)} J_f(\phi_u(x,y),x,y)u(x)dx \tag{11}$$
$$+s_1\kappa(\xi,V)\iint_{(x,y')\in\mathcal{B}_e(y)} J_f(\phi_e(x,y,y'),x,y)h(x,y')dy'dx.$$

The firm meets an unemployed worker at rate $\kappa(\xi,V)\int u(x)\,dx$ and meets an employed worker at rate $\kappa(\xi,V)\int s_1 e(x)\,dx$. $\mathcal{B}_u(y) = \{x : s(x)=1 \text{ and } y\in\mathcal{A}_u(x)\}$ is the set of unemployed workers with whom firm y can form a viable match, and $\mathcal{B}_e(y) = \{(x,y') : s(x)=1 \text{ and } y\in\mathcal{A}_e(x,y')\}$ is the set of matches from which firm y can successfully poach a worker. If $\mathcal{B}_u(y)\neq\emptyset$ or $\mathcal{B}_e(y)\neq\emptyset$, firm y posts a positive measure of vacancies such that $J_u(y)=0$. In equilibrium, the free-entry condition yields

$$c'(v,y) = \kappa(\xi,V)\int_{x\in\mathcal{B}_u(y)} J_f(\phi_u(x,y),x,y)u(x)dx \tag{12}$$
$$+s_1\kappa(\xi,V)\iint_{(x,y')\in\mathcal{B}_e(y)} J_f(\phi_e(x,y,y'),x,y)h(x,y')dy'dx,$$

and any job opening that does not result in a match or any filled position that loses its employee ceases to exist and has no continuation value.

3.6. Steady state equilibrium

In a steady state equilibrium, the distribution of individuals across labor force states and firms, characterized by $\{u(\cdot),h(\cdot,\cdot)\}$, is stationary. For workers who do not participate in the labor market ($s(x)=0$), $h(x,y)=0$ and $u(x)=0$; for labor market participants, the steady-state levels of $h(x,y)$ and $u(x)$ are determined by equating inflows with outflows. We have the following steady-state conditions for all x such that $s(x)=1$ and all y such that $v(y)>0$:

$$u(x) = \frac{\delta}{\delta+\kappa(\xi,V)\int_{y'\in\mathcal{A}_u(x)} v(y')dy'}, \tag{13}$$

$$h(x,y) = \frac{v(y)\kappa(\xi,V)\left[u(x)+s_1\int_{(x,y')\in\mathcal{B}_e(y)} h(x,y')dy'\right]}{\delta+s_1\kappa(\xi,V)\int_{y'\in\mathcal{A}_e(x,y)} v(y')dy'}. \tag{14}$$

Stationarity of $\{u(\cdot),h(\cdot,\cdot)\}$ ensures that the wage distribution is also stationary. We relegate the details to Appendix C.3.

Definition 2. A steady state equilibrium is a collection of optimal decisions and distributions $\{s(\cdot),\mathcal{A}_u(\cdot),\mathcal{A}_e(\cdot,\cdot),v(\cdot),u(\cdot),h(\cdot,\cdot)\}$ such that

1. $s(x)$ maximizes the value of non-employment (Eq. (8)) for all $x\in[0,1]$;
2. $\mathcal{A}_u(x)$ is defined by Eq. (4) for all $x\in[0,1]$;
3. $\mathcal{A}_e(x,y)$ is defined by Eq. (7) for all $x\in[0,1]$ and $y\in[0,1]$;
4. $v(y)$ satisfies Eq. (12);
5. $u(x)$ and $h(x,y)$ satisfy Eqs. (13) and (14) for all $x\in[0,1]$ and $y\in[0,1]$.

Due to the presence of sorting in equilibrium and the fact that utility is not perfectly transferable between workers and firms, solving for the steady-state equilibrium analytically is not feasible.[16] In Appendix D, we describe the numerical solution algorithm.

3.7. Inefficiency and policy impacts

Inefficiency in the decentralized economy. The extent of entry into markets with search frictions is often inefficient; our model is no exception. In our model, when workers and firms make labor force participation and vacancy posting decisions, they do not internalize the congestion and thick-market externalities they impose on others in the labor market. Congestion externality refers to the fact that one's entry lowers the matching probability for those on the same side of the labor market. Thick-market externality refers to the fact that one's entry increases the matching probability for those on the opposite side of the market. When workers and firms are respectively ex-ante identical, the Hosios condition ensures constraint efficiency by setting the bargaining power equal to the elasticity of the aggregate matching function (Mortensen, 1982; Hosios, 1990).

Our model is more complex than the one (Hosios, 1990) considers in the following aspects. First, we consider not only the vacancy posting decision of firms but also the labor force participation decision of workers who are heterogeneous in market productivity. Albrecht et al. (2009) show that the Hosios condition leads to too much labor force participation and vacancy creation in such a framework. Second, we consider two-sided productivity heterogeneity. Shimer and Smith (2001) show that the decentralized economy with heterogeneous productivity and uniform bargaining power is inefficient because highly productive agents search too little and low productivity agents search too much. In our model, the bargaining power is allowed to differ across firms. Given this, a Hosios-type condition would involve different firms having different powering powers. Third, the presence of labor market policies affects the efficiency of the decentralized labor market. On one hand, labor market policies can lead to additional inefficiency as they distort participation and vacancy-posting decisions of workers and firms. On the other hand, the policies can potentially mitigate the inefficiency that arises from search frictions. For example, a high minimum wage or high taxes on low-wage jobs can discourage low-productivity workers and firms from searching too much.

Direct policy impacts. While payroll taxes and minimum wages do not change the fact that workers prefer matching with more productive firms (Appendix C.4), they directly impact wages and match viability. As we explain in Appendix C.5, we can characterize the set of viable matches with a reservation firm-type policy, $\underline{y}(x)$, which defines the least productive firm with which worker x is willing to form a match. This threshold is akin to the reservation wage decision in the sequential search literature (McCall, 1970). A payroll tax reduction for low-wage jobs or a reduction of the minimum wage leads to lower $\underline{y}(x)$, particularly for low-x workers, and lower reservation firm types allow for more matching possibilities for low-y firms. As a result, such a policy reform may increase the returns to search for low-x workers and low-y firms, leading to greater labor force participation and vacancy posting by these agents.

Spillover and reallocation effects. Payroll taxes and minimum wages also have indirect impacts such that even those who are not directly impacted can be affected. We define the spillover effect as the unintended effect of a policy on untargeted workers due to changes in the targeted workers' labor supply decisions. If a policy increases labor force participation of low-x workers, it lowers the rate at which all job seekers contact vacancies, causing a spillover effect on relatively high-x workers. The reallocation effect refers to the fact that a policy reform leads to workers' reallocation to different firms due to a change in vacancy distribution. If low-y firms choose to post more vacancies as a result of a policy, workers of all productivity types are more likely to encounter low-productivity firms; they may also lower their reservation firm type because the distribution of vacancies becomes more right-skewed.

Spillover and reallocation effects have implications for economic efficiency. If the increased labor force participation or vacancy posting comes from low-x workers or low-y firms, the (negative) congestion externality from their participation in the frictional labor market is likely to outweigh the (positive) thick market externality due to their low productivity levels. The magnitude of these effects depends on the extent of heterogeneity among workers and firms, as well as the level of complementarity in the production technology. If there is

[16] The inability to solve the model analytically is common in the search literature allowing for sorting, see e.g. Lise et al. (2016) or Bagger and Lentz (2019).

a significant dispersion in the productivity distributions of workers and firms, and if they are highly complementarity in the production technology, the costs associated with congestion externality imposed on high-productivity workers and firms would be substantial.

4. Estimation strategy and results

We estimate the model via the simulated method of moments based on data prior to the implementation of the payroll tax reduction that we analyze in the next section.[17] We begin this section by describing the data we use for estimation and sample selection criteria (Section 4.1). Our primary data source is the French social security data, a linked employer-employment dataset. The estimation strategy requires us to compute moments that are conditional on worker and firm ranks in their respective productivity distributions. We discuss the ranking method in Section 4.2 and parametrization and identification in Section 4.3. We present estimation results and model fit in Sections 4.4 and 4.5.

4.1. Data

Our main data source is the "Declarations Annuelles de Donnees Sociales" (DADS), French social security data maintained by the French National Statistical Institute (INSEE). In order to obtain more complete employment biographies of sample individuals, we merge two raw datasets provided by INSEE, panel DADS and panel tous salaries. These datasets are available to us from 1988 to 2010 and cover French salaried workers born in October of even-numbered years (from 2002 onwards, everyone born in October).

Our data contains information about each job spell, including firm identifier, start and end date, region, occupation, and part-time/full-time status. We convert the spell-based DADS raw data into a monthly panel dataset (see Appendix E.2). The data also reports "net taxable yearly earnings" for each job, from which we compute employee and employer SSCs using the tax simulator TAXIPP.[18] To keep the model tractable, we ignore the modest variations in SSCs across industries and regions and model SSC as a function of earnings only. To this aim, we fit a linear spline to the relationship between SSC simulated with TAXIPP and the net wage (see Table E.2).

Since one of the goals of this paper is to analyze the reduction in employer SSCs ("payroll tax") implemented in September 1995, we estimate the steady state model mainly based on the preceding period, January 1993–August 1995. The SSCs and the minimum wage remained relatively stable in this baseline period (see Appendix A). However, as we explain later, we use a more extended sample period (1988–2010) to identify time-invariant worker and firm productivity.

Our sample contains prime-age men aged 25–64 because their labor force participation decisions are less likely to be influenced by lifecycle events such as education, fertility, and retirement, which we do not account for in our model. While younger adults (age 18–24) are more likely to hold low-wage jobs and more directly impacted by the payroll tax reduction, our age selection allows us to capture 70% of low-wage employment (wage below 1.1 times the minimum wage) among adult men. Another reason for excluding younger adults is that many of them hold apprenticeship contracts; these contracts only cover workers below age 25 and are exempt from the minimum wage.

We further restrict our sample to those primarily working full-time, private-sector, non-executive jobs (see Appendix E.1 for descriptive statistics). Let us detail the reasons behind these restrictions. First, we choose to exclude part-time jobs from our model and quantitative analyses because part-time workers account for only less than 1/5th of total employment. In addition, the hours information is absent from the DADS data before 1993 (and subject to errors in the years 1993 and 1994), preventing us from correctly recovering hourly wages from annual earnings and hours worked in these years.

Second, in our model, the aggregate meeting technology $M(\xi, V)$ implies that all workers and firms are in potential competition in the search and matching process. Moreover, we do not consider the potential productive complementarity between high- and low-skilled workers. As we take the model to data, we exclude workers in the public sector, professionals or those in executive roles to make our sample of workers more homogeneous than the sample in the raw data.[19]

The transition rate from unemployment to employment is an important statistic to be matched in our estimation strategy. However, the DADS data contains only employment spells of salaried employees; individuals who become jobless or self-employed are absent from the data, creating "gap spells" that potentially correspond to unemployment, non-participation, or self-employment. While any gap spell may end in employment, the transition rate into employment varies by the nature of the gap spell. To correctly compute the transition rate from unemployment to employment, we use data from the French labor force survey "Enquete Emploi" (EE) to predict individuals' status during these "gap spells." Appendix E.3 provides details on this imputation procedure.

4.2. Ranking workers and firms

The estimation strategy that we pursue (Section 4.3) requires us to assign workers and firms to productivity bins according to their ranks in the respective productivity distributions in the model as well as the data. However, we only observe wages and labor market stocks and flows in our data, all of which are joint outcomes of the underlying productivity distributions of workers and firms. In order to recover the productivity ranks, we estimate worker and firm fixed effects based on an AKM regression model ***a la*** Abowd et al. (1999). Specifically, we estimate the following model

$$\ln\left(w_{it}\right) = \psi_{J(i,t)} + \alpha_i + \lambda_t + \mathbf{x}_{it}'\beta + \epsilon_{it}$$

where $\psi_{J(i,t)}$ is the fixed effect of firm $J(i,t)$, the employer of worker i in year t. α_i is the individual fixed effect and λ_t is the year fixed effect. $\mathbf{x}_{it}$ include the linear, quadratic, and cubit terms of age. w_{it} is worker i's hourly wage in year t. The AKM model is estimated based on data from 1993 to 2010, a time window that encompasses our baseline period, 1993 to 1995. Enlarging the sampling window is necessary to obtain a large enough connected set of workers and firms, which is key to this type of regression model.[20]

In computing moments based on simulated data from our model, we rely on the true productivity levels of workers and firms rather than estimated fixed effects. We can do so because the estimated AKM fixed effects based on the simulated dataset highly correlate with the true types of the simulated workers and firms: The rank correlation between AKM worker fixed effects and true worker types is indeed 0.96 and the rank correlation between AKM firm fixed effects and

[17] In Section 5.2, we also show results obtained when we estimate the model using only post-reform data and policies and then examine the effect of undoing the tax reduction.

[18] The tax simulator TAXIPP (Jelloul et al., 2018), developed by the Institut des Politiques Publiques, combines the official tax tables with available information on hours worked, occupation, sector, and region of work to simulate the precise level of SSCs for different individuals.

[19] The excluded occupations include professors, engineers, business managers, artists, etc. Admittedly, despite these restrictions, our sample still contains workers in a variety of occupations. Further restricting the sample is unattractive as it would cause difficulties in ranking workers and firms (ranking is a part of our estimation strategy). In Section 2.2, we describe occupational mobility in France.

[20] We start in 1993 because hours of work are missing before. We have also performed robustness checks excluding the reform period (hence using only the post-reform years). Additional details are provided in Appendix F.

true firm types is 0.82.[21] The following factors contribute to the high rank-correlation between true types of AKM fixed effects, especially that for workers. First, match wages strongly increase in x because the estimated non-employment benefit $b(x)$ increases in x. This makes the slope of the non-employment value $W_{ne}(x)$ even steeper, contributing to the fact that higher-x workers have a higher outside option when bargaining with firms as a non-employed worker. This higher out-of-nonemployment wage also leads to higher wages when employed. As a result, higher-x workers receive higher wages within a given firm, which translate into higher worker fixed effects. Second, the fact that the estimated bargaining power of workers is high is helpful. As Cahuc et al. (2006) explain, with a high bargaining power of workers, the bargained wage increases with both worker and firm types. Given this property, the estimated ranks based on AKM fixed effects are consistent with the true ranks of workers and firms, which further contribute to the positive rank correlation between the AKM fixed effects and true worker and firm types. See Appendix F.1 for a discussion of alternative firm ranking statistics.

Thus, ranking simulated workers and firms based on their true types rather than their estimated fixed effects makes little quantitative difference, but it avoids raising significantly computational costs.[22]

4.3. Parametrization and identification

We briefly discuss our choice of moments for the SMM. Although the parameters are jointly identified in the SMM procedure, we offer insights on which parameters mostly impact each of the targeted moments.

4.3.1. Productivity distributions

Given worker and firm types, x and y, we assume their respective productivity levels are $\mathfrak{h}(x)$ and $\mathfrak{p}(y)$. $\mathfrak{h}(x)$ follows a log-Normal distribution such that $x = \Phi_x(\ln \mathfrak{h})$, where Φ_x is the cumulative distribution function of the Normal distribution $N(0, \sigma_x)$. The parametrization assumption allows us to identify worker productivity levels even for low-x workers who choose not to participate in job search and are never employed. $\mathfrak{p}(y)$ follows a standard Pareto distribution with parameter σ_y such that $y = \Phi_y(\mathfrak{p}) = 1 - \left(\frac{1}{\mathfrak{p}}\right)^{\sigma_y}$. In the numerical implementation, we discretize the support of x and y with evenly spaced grids.

The parameters σ_x and σ_y govern, respectively, worker and firm productivity dispersions. To identify these parameters, we group workers and firms into bins according to their productivity ranks (see Section 4.2). We target median wages by the worker and firm bins.[23] In addition, we target moments of the unconditional wage distribution including wage deciles and the share of workers with jobs paying within specific wage intervals that are relevant for the SSCs and tax treatment (i.e., below and above $1.3\, w_{min}$). The larger the dispersion in worker and firm productivities, the larger the wage dispersion would be, ceteris paribus.

[21] The rank correlations are calculated based on a simulated sample such that the ratio between the number of individuals and firms is the same as those in the data.

[22] Ranking simulated workers and firms using fixed effects requires estimating an AKM model on the simulated dataset at each iteration of the SMM estimation procedure, which is computationally unfeasible given our resources.

[23] Note that we do not estimate the mean productivity levels because our data do not offer separate identification of worker and firm productivity levels. Nevertheless, this is without loss of generality because we estimate the productivity dispersion parameters, the bargaining power, and the total factor productivity.

4.3.2. Production function

We specify a match production function that exhibits constant elasticity of substitution (CES) between individual and firm productivity levels:

$$f(x,y) = \begin{cases} f_0 \left[\frac{1}{2}\mathfrak{h}(x)^\gamma + \frac{1}{2}\mathfrak{p}(y)^\gamma\right]^{1/\gamma} & \text{if } \gamma \neq 0 \\ f_0 \mathfrak{h}(x)^{\frac{1}{2}} \mathfrak{p}(y)^{\frac{1}{2}} & \text{if } \gamma = 0 \end{cases} \tag{15}$$

with $f_0 > 0$ and $\gamma \leq 1$. f_0 is the total factor productivity and can be identified from the average wage level as reflected in wage decile moments. γ governs the degree of complementarity between individuals and firms. If $\gamma = 1$, worker and firm productivities are perfect substitutes. A lower value of γ indicates a greater degree of production complementarity between worker and firm productivities. γ influences the shape of the "reservation firm type" function $\underline{y}(\cdot)$, and thus the set of firms with which workers of different types will match (see Appendix C.5).[24] Workers with a lower $\underline{y}(x)$ have a larger set of viable matches, allowing them to find jobs at a faster rate. Therefore, γ influences how job-finding rates vary across workers of different productivity ranks. To identify γ, we use job-finding rates conditional on worker productivity bins.

4.3.3. Vacancy posting cost

We consider the following cost function

$$c'(v,y) = c_0 \mathfrak{p}(y)^{c_1} v \tag{16}$$

with $c_0 > 0$ and $c_1 \geq 0$. We use the vacancy rate, defined as the number of vacancies divided by the sum of vacancies and jobs, to discipline c_0. Our data for the vacancy rate is based on the number of vacancies in the non-public and non-agricultural sectors reported by the Employment Orientation Board from 2003 to 2010.[25] The rate is calculated according to the European definition of a vacancy as a job to be filled immediately or at short notice and for which there is an active search for candidates (Conseil d'Orientation pour l'Emploi, 2013). The exponent parameter c_1 influences the vacancy distribution across firms; a greater value suppresses vacancy-posting by highly productive firms relative to less productive firms. The vacancy distribution, in turn, affects the employment distribution across firms. Since we do not have firm-level vacancy data, we rely on employment shares by firm bins to identify c_1.

4.3.4. Bargaining power

Recall that we assume the bargaining power depends on firm productivity y (see Section 3.1). We parametrize workers' bargaining power as follows:

$$\alpha(y) = \frac{1}{\exp\left(-\left(\alpha_0 + \alpha_1 y\right)\right) + 1}, \tag{17}$$

with $\alpha_0, \alpha_1 \in (-\infty, \infty)$. That is, $\alpha_0 + \alpha_1 y$ is the logit transformation of $\alpha(y)$, which ranges from 0 to 1 for each y. $\alpha(y)$ influences the level of their starting wages out of unemployment relative to the maximum wage they receive in the same firm after subsequent negotiations. A low bargaining power leads to larger within-firm-bin wage dispersion as a result of a relatively low wage when coming out of unemployment and more rapid wage increases when workers receive outside offers. Exploiting the within-firm wage growth to identify bargaining powers is common in the literature (for example, see Postel-Vinay and Robin,

[24] If $\gamma = 1$ (perfect substitutes), the lowest firm productivity that is required for a firm to offer wage w_{min} decreases linearly in worker productivity. As γ decreases, the set of viable matches for low-productivity workers shrinks relative to that for high-productivity workers.

[25] The question on vacancies was introduced to the ACEMO questionnaire (Activité et conditions d'emploi de la main-d'œuvre) in 2003 and is not available before then.

2002b; Bagger and Lentz, 2019). The parameters α_0 and α_1 can therefore be identified from the comparison between starting wages out of unemployment and later wages by firm bins. As moments in estimation, we use the median out-of-unemployment wage by firm bins and the median of all wages by firm bins.

4.3.5. Non-employment benefit

We parametrize the non-employment benefit function $b(x)$ to be a linear function such that

$$b(x) = b_0 + b_1 \mathfrak{h}(x) \tag{18}$$

and estimate the parameters b_0 and b_1 by targeting the average benefit level in each worker bin. To estimate data on non-employment incomes, we use the legal rules regarding unemployment benefits and social welfare entitlements during our sample period. Legal entitlements depend on past earnings, which we observe in DADS. We provide details on our procedure in Appendix E.5.

4.3.6. Other parameters

In the aggregate matching function (Eq. (1)), the scale parameter m_0 determines the speed at which the unemployed find jobs. A higher m_0 would shorten unemployment durations and result in a lower level of unemployment across all worker types. Thus, the unemployment rate, defined as the fraction of unemployed workers among labor force participants, disciplines the parameter m_0. We set m_1 to 0.5 as in Lise et al. (2016) and Lise and Robin (2017).[26]

The search cost q discourages non-employed individuals from searching for a job. Since non-employed individuals who do not search are classified as non-participants, the labor force participation rate helps identify q. We take the official unemployment and labor force participation rates of French men aged 25–49 computed by INSEE as our target moments because DADS only contains employment spells.[27] The parameter s_1 influences the job-to-job transition rate relative to the unemployment-to-job transition rate; we therefore use the ratio of these rates as a moment for estimation.[28] Finally, we set the monthly discount rate r to 0.43%, corresponding to an annual discount rate of 5%.

4.4. Estimation results

Table 1 shows results from SMM estimation. The estimated value of the parameter γ is −0.029, indicating that workers and firms are complementary in production with an elasticity of substitution close to one. This level of production complementarity falls in the range of estimates in the literature.[29] In Section 5.1, we discuss the level of sorting in the steady state model and the effect of payroll tax reforms on sorting.

The estimated search cost q is 555 € per month or 61% of the minimum wage. The estimated value of c_1 is 14.21, suggesting that the marginal cost of posting vacancies is substantially higher in highly productive firms compared to less productive ones. The parameters m_0 and s_1 imply that, on average, it takes 3.4 months for an unemployed worker to get a job offer, and 4.4 months for an employed worker.[30]

Table 1
Parameter estimates.

Parameter	Value	S.E.[a]
Production function and productivity distributions:		
f_0	2618.89	6.87
γ	−0.029	0.004
σ_x	0.309	0.003
σ_y	5.277	0.170
Search cost and meeting technology:		
q	555.17	24.67
c_0 (10^3)	242.16	11.29
c_1	14.21	0.33
s_1	0.774	0.01
m_0	2.205	0.08
Non-employment benefit:		
b_0	563.94	6.98
b_1	514.70	5.67
Bargaining power:		
α_0	0.207	0.01
α_1	0.221	0.03

[a] Standard errors are estimated by bootstrap with 30 iterations.

The estimated values of α_0 and α_1 suggest that there is workers' bargaining power increases only modestly with firm productivity. Workers' bargaining power is 0.55 in the least productive firm and 0.6 in the most productive firm. On average, these values are higher than those estimated by Cahuc et al. (2006), who also use French data over a similar period. Since dispersion in wages is the main source of identification for bargaining power in both Cahuc et al. (2006) and this paper, the discrepancy in the estimated value might be in part because we explicitly model taxation. The wage moments that we use for estimation are computed based on net wages both in the data and in our model. The extent of wage dispersion in net wages is different from that in gross wages due to the non-linear labor taxes. The exogenous separation rate δ is calibrated directly based on the transition rate from employment to unemployment observed in the DADS data. We calibrate the separation rate δ to 0.021 per month.[31]

4.5. Model fit

Despite a parsimonious parametrization with only 13 estimated parameters, our model can fit the 61 targeted moments well. Our model performs well in terms of aggregate moments (see Table 2) and the unconditional wage distributions (see Fig. 2(e)). In both the DADS data and data simulated from our model, we group workers and firms into eight equal-sized bins according to the estimated AKM fixed effects (in the DADS data) or actual types (in the simulated data). The model captures the hump shape in employment share across firm bins (except in the 7th bin, see Fig. 2(a)). Fig. 2(b) shows that the model not only matches the wage dispersion across firm bins but also the within-firm-bin difference between out-of-unemployment wages and unconditional

[26] Lise and Robin (2017) explain that, without data on the costs of vacancy creation, it is not possible to separately identify the elasticity parameter in the aggregate matching function from the vacancy cost function. Our model is similar to theirs and we also estimate the vacancy cost function without having direct data.

[27] The rates are reported by INSEE and computed based on the French Labor Force Survey according to the International Labour Organization's (ILO) definitions.

[28] We measure the job-to-job transition rate as the fraction of workers who change jobs from month to month among those who are employed in both months. The unemployment-to-employment transition rate is the fraction of unemployed workers who are not unemployed the following month.

[29] Bagger and Lentz (2019) find the value to be around −7 based on a model estimated to the Danish data. Lise et al. (2016) use data from the United States. They find the value of the complementarity parameter to be close to 1 for the high school sample but −0.9 for the college sample.

[30] Postel-Vinay and Robin (2002b) find lower job offer arrival rates: on average every 6–8 months for unemployed workers and every 11 months for employed workers. A key difference between our model and theirs is that they assume that all job offers are acceptable to unemployed workers (i.e., the job offer arrival rate is equivalent to the job-finding rate). This is not the case in our model and the reservation wage of the unemployed depends on the worker type. Thus, the job offer arrival rate is higher than the job-finding rate.

[31] The transition rate is computed as the fraction of employed workers who become unemployed in the following month conditional on remaining in the labor force (employed or unemployed). Employment includes all jobs that can be observed in the DADS data.

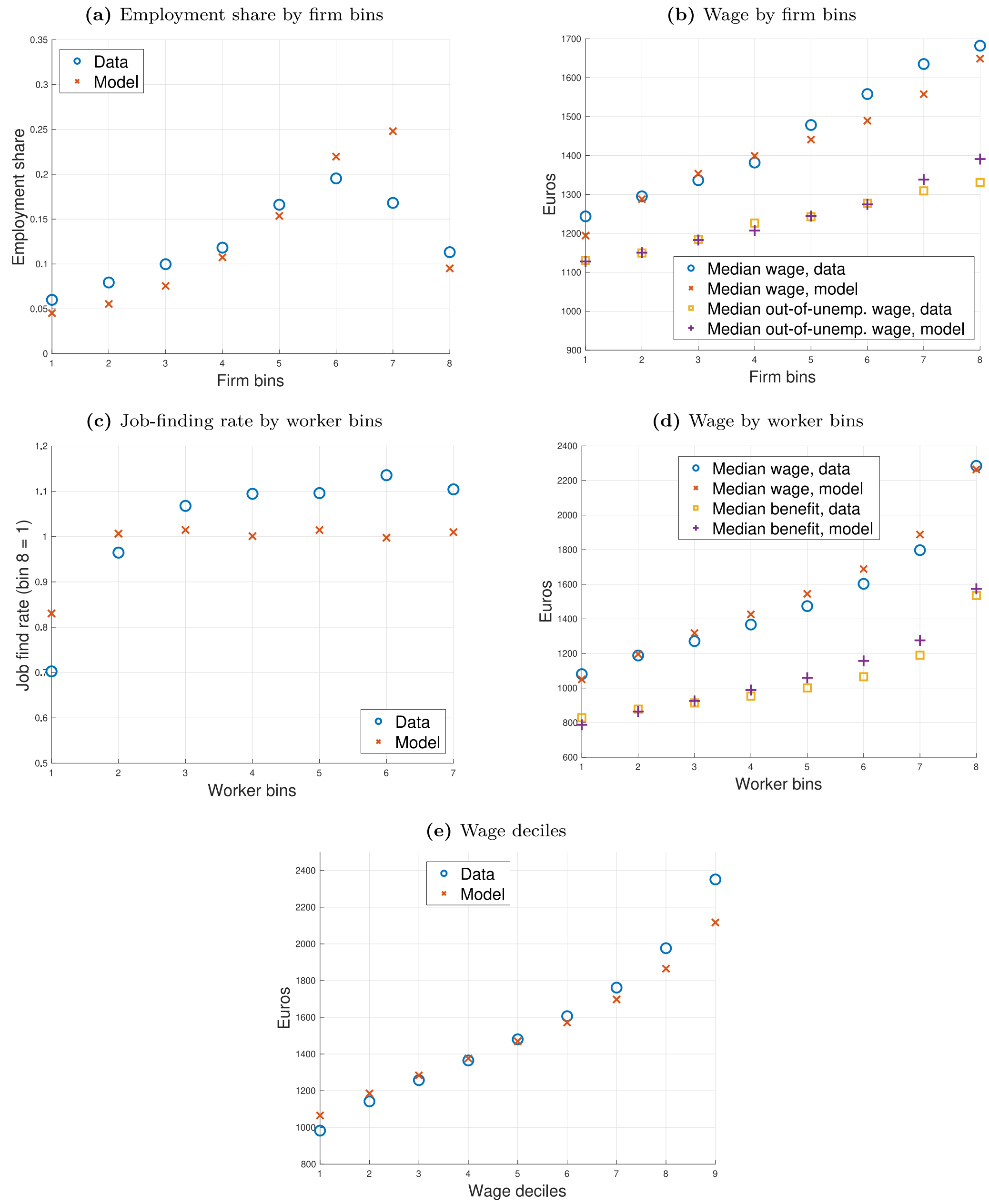

Fig. 2. Model fit. Notes: For "data" moments, worker and firm bins are based on estimated fixed effects from AKM regressions; a higher bin corresponds to higher fixed effects (which positively correlate with productivity based on our model). For "model" moments, the bins are based on actual productivity ranks.

Table 2
Model fit.

Moment	Data	Model
Labor force participation rate	0.958	0.960
Unemployment rate	0.077	0.078
Vacancy rate	0.011	0.015
Job-to-job vs. unemp-to-job	0.187	0.131
Frac. empl. workers with wage $\leq 1.3w_{min}$	0.237	0.220

See Fig. 2 for the model fit of additional targeted moments.

wages. We also replicate the pattern that the job-finding rate is lower among the lowest ranked workers (Fig. 2(c)) and closely matches the wage dispersion and benefit dispersion across worker bins (Fig. 2(d)).

5. Equilibrium effects of payroll tax reductions

In this section, we use our model to simulate the first large employer SSC (i.e. payroll tax) reduction in France was implemented in September 1995, the so-called *Ristourne Juppe*, to quantify its spillover and reallocation effects. The tax reduction was the most generous for minimum wage earners, reaching 18% of the gross wage for these workers. It phases out linearly in wage until 1.33 times the minimum wage. In our analysis, since payroll taxes nominally fall on employers, a payroll tax change is equivalent to a corresponding change in the tax schedule $T(\cdot)$ while holding constant w_{min}, the floor on net wage. We simulate data from our steady-state model under the two tax schedules prevailing in the baseline period (January 1993 to August 1995) and after the payroll tax reduction was implemented (January to December

Table 3
Simulated aggregate effects of payroll tax reform.

	(1) Both vacancy and partic. adjustments	(2) No adjustment	(3) Only vacancy adjustment	(4) Only partic. adjustment
Employment	2.18%	0.19%	0.28%	2.10%
Total output	1.14%	0.10%	0.11%	1.16%
Output per job	−1.01%	−0.09%	−0.17%	−0.93%
LF participation	2.08%	0.00%	0.00%	2.08%
Vacancies	2.72%	0.00%	2.87%	0.00%
Job finding rate	1.11%	2.16%	3.34%	0.07%

Notes: values in the table show percentage changes from the baseline due to the payroll tax reform. Column (1) shows equilibrium effects; Column (2) shows the effects when both vacancy $v(y)$ and labor force participation $s(x)$ are held at the baseline levels; Columns (3) and (4) show the effects when only $v(y)$ or $s(x)$ is allowed to adjust. See Section 5 for details. Output of a job filled by worker x in firm y is $f(x, y)$.

1997) while fixing the model parameters and the minimum wage at their values in the baseline period.[32]

5.1. Results

Column 1 of Table 3 shows the aggregate equilibrium effects of the payroll tax reduction. The tax reduction leads to an increase in employment and output increases despite a lower output per job. Labor supply and demand both increase: labor force participation increases by 2.1% while the number of vacancies increases by 2.7%. As vacancies increase slightly more than labor force participation in percentage terms, the equilibrium job-finding rate is 1.1% higher.

The payroll tax reduction also has a modest effect on the sorting between heterogeneous workers and firms. We measure sorting using indices common in the literature (Chiappori et al., 2021): odds ratio and correlation.[33] In the pre-reform baseline economy, sorting is weakly negative: the odds ratio measure is −0.0096 and the correlation measure is −0.0024. This is because the high minimum wage combined with high labor taxes makes matches between low-productivity workers and firms unviable. The tax reduction results in less negative sorting: the odds ratio becomes −0.0062 and the correlation becomes −0.0015. The level of sorting in our baseline model and the effect of the payroll tax reduction are consistent with the data. Godechot et al. (2023) find that the level of sorting was low in the 1990s in France and has since increased.[34] The low-wage tax reduction allows low-productivity workers to match with low-productivity firms, which increases the level of sorting in the model.

To disentangle the effects of labor supply and demand adjustments, we conduct counterfactual simulations of the payroll tax reform by shutting down adjustments in labor force participation $s(\cdot)$ and vacancy posting $v(\cdot)$. When neither labor force participation nor vacancy posting is allowed to adjust, the reduction in payroll taxes only affects the set of viable matches between job seekers and vacancies. This direct effect of the policy change is shown in column 2 of Table 3. Lower payroll taxes reduce labor costs in low-wage matches, allowing low-productivity workers and firms to form more viable matches. Since the direct effect only acts on workers who already participate in the labor market, the increases in employment and output are modest at 0.19% and 0.10%, respectively.

Column 3 of Table 3 shows the effect of labor demand adjustment. Specifically, we allow firms to change their vacancy posting in response to the tax reform while assuming that workers' labor force participation decisions remain unchanged. The increase in the number of vacancies concentrates among low-productivity firms, while high-productivity firms slightly reduce theirs (Fig. 3(a)). The shift of the vacancy distribution toward low-productivity firms leads to a reduction in the average output per job by 0.17%. Aggregate output only increases modestly by 0.11% even though employment increases by 0.28%.

The effect of labor supply adjustment shown in Column 4 is by far the most significant. In this scenario, we allow for changes in workers' labor force participation but not in firms' vacancy posting decisions. The increase in labor force participation in response to the tax reduction also concentrates among low-productivity workers, as our model indicates that only low-x workers are non-participants in the baseline economy. The payroll tax reduction allows for more viable match opportunities for previous non-participants, increasing their expected returns to job search. As a result, the policy attracts the marginal non-participants into the labor force. The payroll tax reduction leads to a 2.08% increase in labor force participation, resulting in significant increases in employment (2.10%) and output (1.16%).

The fact that only low-productivity firms and workers increase their labor demand and supply gives rise to reallocation and spillover effects (see Section 3.7). To see this, we show the effects of the tax reduction by worker productivity quartiles in Figs. 3(b) to 3(d), in which we use different scales for the first and top three quartiles. The bars labeled "Both adj." represent the equilibrium effect on each quartile. "No adj." shows the direct effect of the payroll tax reduction, while "Only vac. adj." and "Only part. adj." show the effects when only vacancy posting and labor force participation are allowed to adjust, respectively.

Focusing on the vacancy adjustments, Fig. 3(a) shows that the low-wage payroll tax reduction leads to more vacancies in low-productivity firms and fewer in high-productivity firms. Such vacancy adjustments lead to a negative reallocation effect as workers are more likely to match with low-productivity firms. The negative reallocation effect can be observed from the drop in the average output per job in all productivity quartiles by around 0.1% (see Fig. 3(d)). This effect echoes the finding in Dustmann et al. (2022) that a higher minimum wage leads to a positive reallocation. The small decrease in the average output per job is offset by a modest increase in employment in all quartiles (see Fig. 3(b)), resulting in little effect on total output in any quartile (see Fig. 3(c)).

Turning to adjustments in labor force participation, the increased labor force participation by low-productivity workers leads to a negative spillover effect. Specifically, both employment and output per job among workers in the top three quartiles fall (Figs. 3(b) and 3(d)), resulting in a fall in total output from these workers (Fig. 3(c)). The fall in their employment rate is due to the fact that low-productivity workers congest the labor market. That is, the higher labor force participation of low-productivity workers leads to an increase in the aggregate search intensity ξ, which lowers the contact rate for all unemployed workers $\kappa(\xi, V)V$. The fall in the average output per job is due to workers' willingness to match with less productive firms as they lower the job acceptance threshold $\underline{y}(x)$. The fact that workers and firms are complementary in production amplifies the negative spillover effect.

[32] Between 1995 and 1997, there was also a slight increase in the SSC rates for higher-paying jobs. We also include this feature in our simulation. See Fig. 1 for changes in the payroll tax schedule. The parameters of the tax function after the policy change are shown in Column (2) of Table E.2.

[33] See Appendix H for the calculation of these indices. A positive sign of both indices indicates positive assortative matching. The odds ratio index has a range $(-\infty, \infty)$, whereas the correlation index has a range $[-1, 1]$.

[34] According to their paper, in the 1990s, the level of sorting estimated from a 5-year AKM regression appears to be negative.

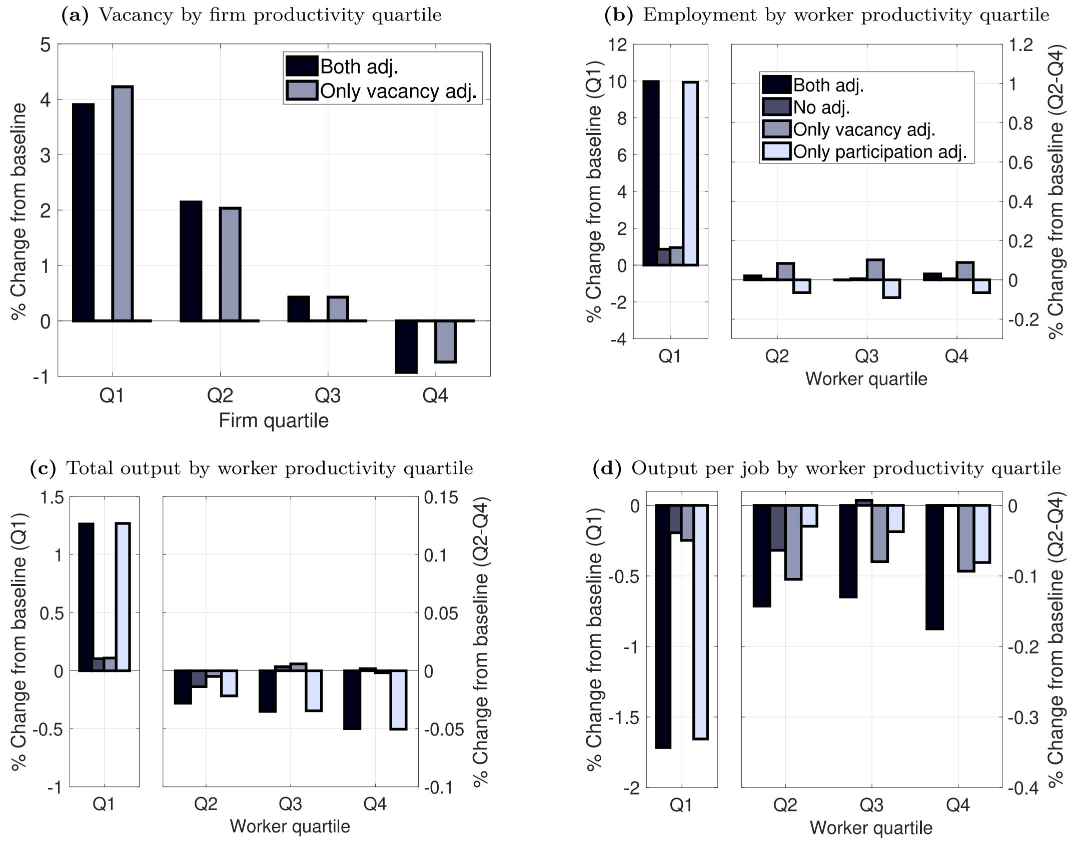

Fig. 3. Simulated distributional effects of payroll tax reform. Notes: The figures show the equilibrium effects of the payroll tax reduction by firm or worker productivity quartiles. "Both adj." refers to equilibrium effects allowing for adjustments in both labor force participation and vacancy-posting. "No adj." refers to the direct effects of the tax reduction, holding labor force participation and vacancy-posting decisions unchanged from the baseline model. "Only vacancy adj." and "Only participation adj." refer to, respectively, the effects of the tax reduction when only vacancy-posting or labor force participation is allowed to adjust.

In equilibrium (shown by "Both adj." bars), the bottom quartile of workers contributes to a 1.26% increase in total output. However, workers in the top three quartiles contribute to a 0.11% *decrease* in total output (Fig. 3(c)). That is, workers in the top three quartiles offset the output gain of the bottom quartile by 9% even though the payroll tax reduction does not directly impact them. In sum, the increased labor force participation of low-productivity workers substantially increases aggregate output, and the negative spillover and reallocation effects are modest.

5.2. Discussion and robustness checks

Our finding that the payroll tax reform leads to higher aggregate employment and vacancy is in line with Crépon and Desplatz (2003), who find evidence that firms substitute high-skilled labor for low-skilled labor in response to the policy change. However, without using the lens of a structural model, it is difficult to empirically estimate the causal effect of the tax reform on more productive workers and firms that the reform does not directly impact.

Our findings that the tax reform skews employment and vacancy distributions toward low-productivity workers and firms are consistent with the observed changes in employment distribution in the aftermath of the tax reform. In Appendix I, we compare the observed employment distribution by worker- and firm-productivity ranks in the baseline and post-reform periods. We find that low-productivity workers and low-productivity firms account for a more significant share of employment in the post-reform period compared to the baseline period. These results confirm that the broad model predictions regarding the reform's effects are supported by the data.

One potential concern is that contemporaneous with the tax reform, there may be changes in the macroeconomic environment such that the results from our policy simulation based on the baseline model are no longer valid in the post-reform era. In Appendix J.1, we re-estimate the model using the post-reform period (1997) and simulate the effect of removing the tax reform. We show that the effects of removing the tax reform have opposite signs but are in absolute values similar to the effects of the tax reform, suggesting the robustness of the results.

Another concern is that our model does not capture the potential complementarity between workers of different productivity levels in the production function. If high- and low-x workers are complements within a firm, an increase in low-x workers may increase the marginal productivity of high-x workers. We already exclude workers who are professionals and executives from our baseline sample; our results apply to workers of similar qualifications, and our model cannot speak to the effects on highly skilled workers. In Appendix J.2, we consider a more restricted sample of workers that are more homogeneous in terms of their occupation. We show that aggregate and distributional effects based on this sample are similar to those found using the baseline sample. The tax reduction's spillover effect on highly productive workers' output is still present, even though it is smaller than the baseline model.

Finally, we note that we do not model human or physical capital investment decisions by workers and firms. These investment decisions may respond to changes in labor market policies and alter the underlying productivity distributions of workers and firms in the long run. However, the shift in the vacancy distribution due to the payroll tax reduction in our model can be viewed as a shift toward lower capital intensity firms, giving rise to more "bad jobs" relative to "good jobs."[35] The increased participation of low-productivity workers also lowers the

[35] Postel-Vinay and Robin (2002a) show that, in a model like ours, the distribution of firm productivity can be endogenously generated by assuming

average worker productivity, which can be viewed as a deterioration in the average human capital of the workforce. In addition, changes in payroll taxation or the minimum wage could also affect the underlying distributions of individual and firm productivity levels ($\mathfrak{h}(x)$ and $\mathfrak{p}(y)$). For example, a low-wage payroll tax reduction may discourage young individuals from accumulating human capital. We leave such considerations for future work.

6. Welfare analyses

6.1. Government budget and welfare criteria

To make different policy regimes comparable, we assume that the government keeps a balanced budget. That is, tax revenues are first used to finance non-employment benefit payments ($b(x)$ in the model), and the remaining revenue is redistributed to the entire population as a flow lump-sum transfer (or tax if negative) D, where

$$D = \int T(w)\, g(w, x, y)\, dw dx dy - \int b(x)(1 - e(x))\, dx, \tag{19}$$

where $g(w, x, y)$ is the measure of type-x workers matched with type-y firms with wage w with $\int g(w, x, y)\, dw = h(x, y)$. $1 - e(x)$ is the non-employment rate among workers of type-x.

Since individuals in our model are risk-neutral, D does not influence any decisions or equilibrium outcomes. As we explain in Appendix A.2, social security contributions are only loosely linked to various types of social security benefits, so assuming a lump-sum transfer is a plausible simplification. The utilitarian social welfare function $\mathcal{W}$ is as follows:

$$\mathcal{W} = \int \omega_e(w, x, y) g(w, x, y)\, dw dx dy + \int \omega_{ne}(x)(1 - e(x))\, dx, \tag{20}$$

where $\omega_e(w, x, y)$ is individual welfare of employed workers, defined as

$$\omega_e(w, x, y) = rW_e(w, x, y) + D, \tag{21}$$

and $\omega_{ne}(x)$ is the individual welfare of non-employed workers, which can be similarly defined by replacing $W_e(w, x, y)$ with $W_{ne}(x)$ in Eq. (21). The social welfare criterion only considers workers' value because firms make zero profit ex-ante due to the free entry condition. Nevertheless, labor market policies impact firms' vacancy-posting decisions, which in turn affect workers' value of employment and non-employment.

6.2. Inefficiency in the baseline economy and payroll tax reduction

As we discuss in Section 3.7, the decentralized economy in our baseline model features inefficiency due to both search externalities and labor market policies. In this subsection, we first consider the extent to which we can improve economic efficiency by changing the bargaining power function while keeping the labor market policies unchanged.[36] This exercise allows us to quantify the welfare loss due to search externalities in the presence of baseline labor market policies. We then compare the welfare effect of the payroll tax reduction studied in Section 5 to that of the optimal bargaining power function.

Specifically, we choose parameters of the bargaining power function (α_0 and α_1 in Eq. (17)) to maximize economic efficiency. Fig. 4(a) (line "Optimal, baseline policy") plots the optimal bargaining power function for workers: Compared to the baseline, the optimal bargaining power function is higher for all firm types. We also find that changing the bargaining power function to the optimal one leads to a 0.17% increase in economic efficiency.

The lower bargaining power of workers leads to lower wages and labor costs in equilibrium. Fig. 5(a) (line "Baseline policy, optimal α") shows that the 10th percentile of the labor cost distribution in the model with optimal bargaining power function is 2.7% lower than that in the baseline model. The difference is smaller at higher percentiles because higher wages (and labor costs) are mainly determined by counteroffers. The lower bargaining power of workers also incentivizes firms to post more vacancies (Fig. 5(b)). As a result, compared to the baseline model, the employment rate in the counterfactual economy with the optimal bargaining power function is 0.64% higher. It is important to note that workers' participation in the labor market does not increase because they have lower bargaining power.

The optimal bargaining power function has only a modest effect on economic efficiency compared to the payroll tax reduction studied in Section 5 (which increases economic efficiency by 1.11%). While the tax reduction does not lower labor costs (Fig. 5(a)) or increase vacancy posting (Fig. 5(b)) as much as optimizing the bargaining power function, it allows for a greater number of viable matches, drawing non-participants into the labor force and resulting in over 2% increase in employment. Results in this subsection indicate that while search externalities are a source of inefficiency in the baseline economy, the baseline labor market policies generate more significant economic inefficiency which the payroll tax reduction helps correct. Next, we turn to the optimal design of labor market policies.

6.3. Optimal design of minimum wage and payroll taxation

In this subsection, we consider the optimal design of labor market policies to maximize social welfare assuming a fundamental policy reform is possible. To examine the extent to which the economic efficiency in the government-free economy can be improved, we consider a counterfactual government-free (no taxes and no minimum wages) economy with an optimal bargaining power function (henceforth, optimal-α economy). We then consider three optimal policy design exercises: (i.) optimal minimum wage while payroll taxes are set to zero ($T(w) = 0$ for all w), (ii.) optimal payroll taxation while the minimum wage is set to zero, and (iii.) optimal policy mix with both minimum wage and payroll taxation.

Fig. 4(a) shows that the optimal worker bargaining power is higher than the one in the baseline economy in all firms, but especially in low-productivity firms. This suggests that firms in the government-free economy (with baseline bargaining powers) post too many vacancies. In the optimal-α economy, firms' bargaining power increases in firm type y (i.e., workers' bargaining power decreases in y). The lower bargaining power of less productive firms disincentivizes their vacancy posting. This result is in line with Shimer and Smith (2001).

The higher workers' bargaining power in the optimal-α economy significantly increases the labor cost at the lower end of the distribution (Fig. 6(a)).[37] As a result, the optimal-α economy features lower vacancy posting compared to the government-free economy, which implies a lower total vacancy-posting cost. Overall, moving from the government-free economy to the optimal-α economy leads to a welfare gain of 0.37% (Table 4).

Next, we turn to the optimal policy design exercises. Recall that we balance the government's budget constraint via a lump sum transfer or tax. See Section 6.1. In the optimal payroll taxation and optimal policy mix exercises, we parametrize the tax function $T(w)$ as follows:

$$T(w) = \left(\frac{w}{\lambda}\right)^{\frac{1}{1-\tau}} - \lambda w, \quad \text{with } \tau < 1, 0 < \lambda \leq 1, \tag{22}$$

where w is the net wage and $T(w)$ is the total labor tax such that $[w + T(w)]$ is the labor cost. A greater value of τ indicates stronger tax progressivity: the tax schedule is progressive (i.e. the average tax rate

that firms make capital investment decisions. See also Acemoglu (1999). Hence, firm types can be interpreted as a measure of firms' capital intensity.

[36] Setting bargaining powers optimally is similar to the wage-setting mechanism in Lehmann et al. (2011). They consider a static model with search frictions in which wages are chosen to maximize economic efficiency in the absence of taxes ("*lassez-faire* economy").

[37] Labor costs at higher percentiles are less affected by the higher workers' bargaining power because these labor costs arise as a result of counteroffers.

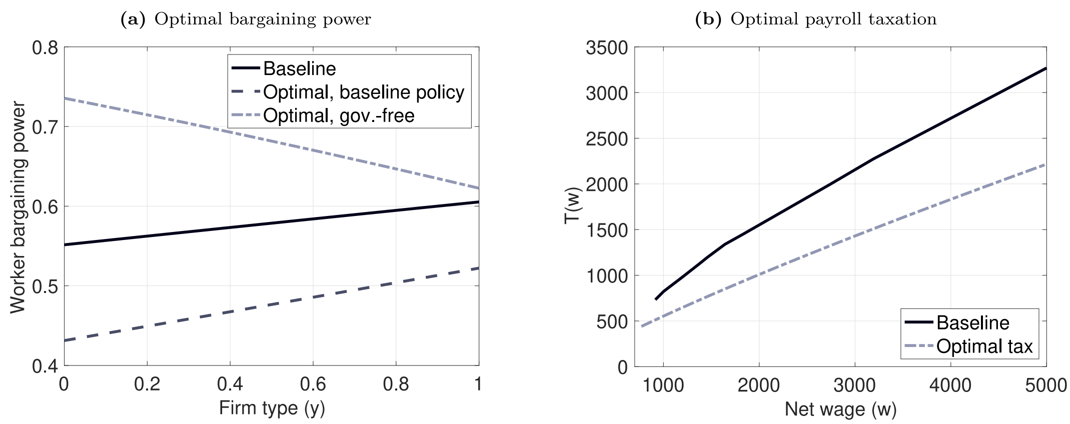

Fig. 4. Optimal bargaining power and optimal payroll taxation. *Panel (a) notes:* "Optimal, baseline policy" refers to the optimal bargaining power function given the baseline labor market policies. "Optimal, gov.-free" refers to the optimal bargaining power functions without payroll taxation or minimum wage. *Panel (b) notes:* "Optimal tax" refers to the optimal payroll tax schedule in the optimal policy mix. See Section 6.3 for details.

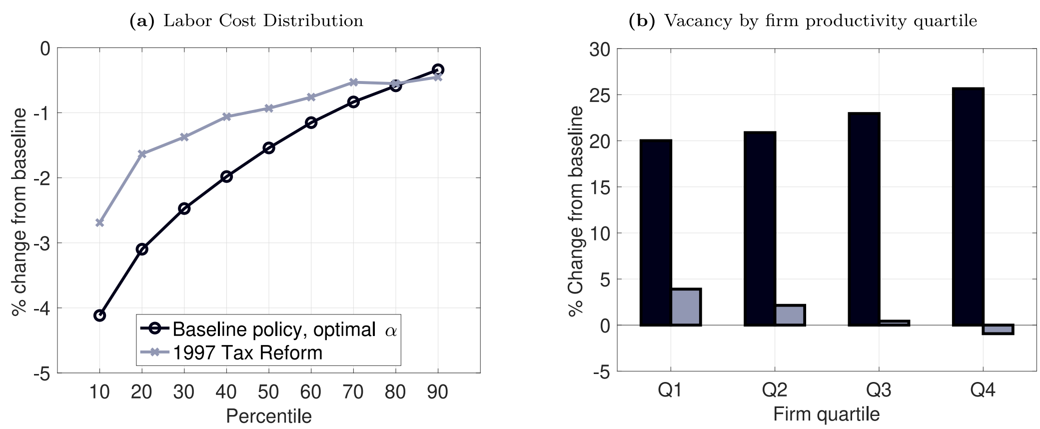

Fig. 5. Payroll tax reduction vs. Optimal bargaining power. *Panel (a) notes:* x-axis is the percentile of the equilibrium labor cost distribution. "Baseline policy, optimal α" refers to the economy with optimal bargaining power function and baseline labor market policies. "1997 Tax Reform" refers to the economy with baseline parameters and minimum wage but payroll taxation in 1997 (post-reform economy). *Panel (b) notes:* Darker bars (left in each group) represent the economy with optimal bargaining power function and baseline labor market policies. Lighter bars (right in each group) represent the economy with payroll tax reform.

$\frac{T(w)}{w}$ increases in w) if $\tau > 0$, and regressive if $\tau < 0$.[38] We use the social welfare criterion described in Eq. (20) as the policymaker's objective function. Table 4 summarizes the policy parameters and welfare gains.

In the absence of payroll taxation, the optimal minimum wage is 1254 euros per month in terms of the net monthly wage, 37.5% higher than the net minimum wage of 912 euros in France in the early 1990s. In the early 1990s, the labor cost of hiring a minimum wage worker is significantly higher than the minimum wage itself due to high payroll taxes. In the optimal minimum wage scenario, there is no payroll taxation. Thus, there is more room to increase the minimum wage without harming match viability and labor force participation. Nonetheless, the optimal minimum wage can only improve welfare by 0.11% because it cannot sufficiently raise labor costs without discouraging labor force participation and harming economic efficiency. While an even higher minimum wage can increase labor costs at the lower end of the distribution, mimicking the effect of the optimal bargaining power function (see Fig. 6(a)), it would also reduce the number of viable matches for low-productivity workers and result in a lower labor force participation rate.

The optimal payroll tax schedule, on the other hand, is more effective at improving economic efficiency. It achieves a welfare gain of 0.39% from the government-free economy, similar to the gain from changing the bargaining power function to the optimal one. Adding the minimum wage to the optimal policy mix only slightly increases the welfare gain to 0.40%, and the minimum wage in the optimal policy mix is 766 euros, significantly lower than that in the optimal minimum wage scenario. Fig. 4(b) shows the payroll tax schedule in the optimal policy mix. Compared to the government-free economy, payroll taxation in the optimal policy mix increases labor costs at the lower end of the distribution (Fig. 6(a)), which in turn suppresses vacancy posting (Fig. 6(b)). Nevertheless, with a modest minimum wage, the optimal policy mix does not set an inhibitive labor cost floor, sustaining a high labor force participation rate.

Table 4
Optimal policy parameters and welfare gains.

	w_{min}	λ	τ	Welfare gain (%)
Optimal bargaining power	–	–	–	0.37
Optimal min. wage	1254	–	–	0.11
Optimal payroll tax	–	0.591	−0.054	0.39
Optimal policy mix	766	0.556	−0.069	0.40

Notes: λ and τ are parameters of the tax function (see Eq. (22)). Welfare gain is the percentage difference from the government-free economy. See Section 6.3 for details. The labor force participation rate is 100% in all scenarios.

[38] In practice, we further restrict τ and λ to values such that $T'(w) > 0$ for all potential wages in equilibrium. For each λ, this restriction sets a lower bound on τ.

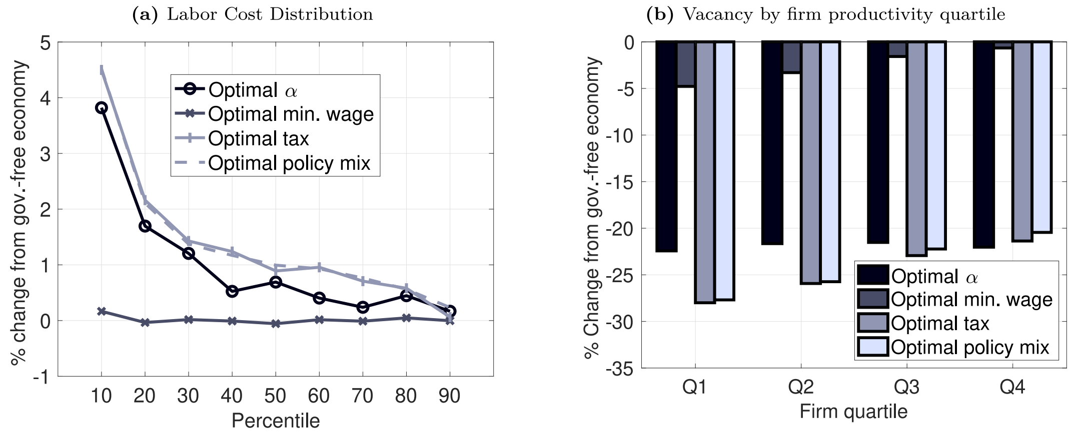

Fig. 6. Distributional effects of optimal policies. Notes: The figures plot the percentage change from the government-free economy with baseline bargaining power function. Optimal-α refers to the counterfactual government-free economy with optimal bargaining power function.

7. Conclusion

Recent empirical literature documents that targeted tax reductions or minimum wages have unintended spillover and reallocation effects on workers not directly targeted by the policies. This paper quantifies these unintended policy effects in an equilibrium search model with bargaining and sheds light on the optimal policy design. We build a DMP model with random search, endogenous labor force participation, and bargaining. Workers and firms are heterogeneous in productivity and face labor taxes and a minimum wage. We estimate our model based on French social security data and use it to analyze a major low-wage payroll tax reduction implemented in France at the end of 1995.

We find that the payroll tax reduction increases employment and output. Most of the effect is due to the increased labor force participation of low-productivity workers because the tax reduction expands the set of viable matches for these workers, increasing the returns to search. The increased participation of low-productivity workers causes a negative spillover effect that decreases the job-finding rate for workers who are more productive and not directly impacted by the policy. The tax reduction also skews the vacancy distribution toward less productive firms, causing a negative reallocation effect as workers are more likely to match with less productive firms, decreasing the average output per job.

Quantitatively, we find the spillover and reallocation effects are modest, and the tax reduction yields an overall increase in economic efficiency as it draws non-participants into the labor force. We determine that the policy mix that maximizes efficiency consists of a lower minimum wage and lower payroll taxes compared to the policies that were in place in France in the early 1990s. The optimal policy mix addresses labor market inefficiencies caused by search externalities without discouraging low-productivity workers from participating in the labor force.

CRediT authorship contribution statement

Thomas Breda: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Luke Haywood:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Haomin Wang:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Table A.1
Earnings concepts.

	Employer SSC	Employee SSC	Income tax
Labor cost	Included	Included	Included
Gross wage	Not Included	Included	Included
Net wage	Not Included	Not Included	Included
Disposable income	Not included	Not included	Not included

Appendix A. Institutional background

A.1. Earnings concepts

In France, two main types of taxes are levied on labor income: social security contributions (SSCs) and income taxes. SSCs are levied on both employers and employees, the larger part being the employer one. Income taxes are paid by households on both labor and capital incomes. Various earnings concepts involve different combinations of SSCs and income taxes. These are summarized in Table A.1. Labor cost is the total cost of employing a worker, including employer and employee SSCs and the income tax. The gross wage corresponds to the labor cost net of employer SSCs, but includes employee SSCs and income taxes.[39] The net wage is equal to the gross wage minus employee SSCs. Finally, to obtain disposable labor income, income tax is subtracted from the net wage.

In the equilibrium model introduced in Section 3, wages refer to net wages. The statutory minimum wage is a wage floor for gross wages. In our quantitative analyses, we subtract employee SSCs from the statutory minimum wage to obtain the minimum net wage w_{min}. We ignore the effects of SSC changes on income taxes for two reasons. First, to compute the income taxes for a given worker, one needs to make assumptions about the level of household earnings, its composition (labor and capital income) and how household members share the tax burden, which is not observable in administrative data. Second, the income tax is modest compared to SSCs (representing only around 10% of the total tax wedge on labor earnings), especially around the minimum wage (individuals working full-time, living alone and without capital income start paying the income tax when their earnings exceed 1.2 times the minimum wage).

[39] The term “gross” may appear inappropriate as this concept does not include employer SSCs. It is nevertheless the most commonly used term (salaire brut in France, Bruttoverdienst in Germany, gross earnings in the U.K.).

A.2. Tax-benefit linkage

As contributions are only loosely linked to benefits, we treat SSCs as labor taxes. Revenues from SSCs are mainly used to finance health insurance, child care benefits, unemployment insurance and pension programs. There is no direct link between health or childcare contributions and the actual benefits these contributions provide, implying that these contributions, which correspond to approximately one-third of total contributions, can be considered as taxes. The contributions funding unemployment insurance and pension schemes are partly linked to entitlements, but the link is not systematical (see Bozio et al. (2017) for details). Most importantly, the payroll tax reduction reforms we study in the paper only change contributions and are not linked to changes in entitlements. They can therefore be considered as pure tax reforms.

A.3. Minimum wage and payroll tax reductions

The statutory minimum wage in France is expressed as a minimum gross wage, meaning that it is net of employer SSCs but gross of employee SSCs. As a result, an employer SSC reduction is different from an employee SSC reduction around the minimum wage; in the short-run, the former lowers the labor cost of a minimum-wage worker whereas the latter increases the minimum-wage worker's net wage without lowering the labor cost. Since the French policymakers are interested in reducing labor costs for low-wage workers, they implemented a series of reductions in employer SSCs since the late 1990s, which we also refer to as payroll tax reductions.

Besides low-wage payroll tax reductions, an alternative approach to limit labor costs while protecting net wages is to remove or reduce the minimum wage while offering a tax credit directly to low-wage workers. This policy mix is more prevalent in Anglo-Saxon countries. For example, the U.S. and the U.K. both have a low minimum wage and such a tax credit: the EITC in the U.S. and the WFTC in the U.K. The main advantage of these systems is that the tax credits can depend on workers' other sources of income and family situations, so they can be well-targeted to actual working-poor individuals. The main drawback is that the economic incidence is uncertain, since the employer may capture part of the credits intended to boost workers' pay. Existing evidence suggests that this effect is indeed large (Rothstein, 2008; Azmat, 2019). To avoid this consequence, and because reducing the statutory minimum might be politically unpopular, France does not adopt this approach and instead maintains a high minimum wage while limiting payroll taxes. Although low-wage payroll tax reductions do not allow precise targeting of working-poor individuals, it has the strong advantage of perfectly controlling both the minimum net wage and the minimum labor cost.

Fig. A.1 provides an overview of the early payroll tax reductions in France (see Jelloul et al. (2018)). As shown in the figure, the first modest reductions took place from July 1993 to August 1995 with reductions in SSCs payments of 5% of the gross wage for individuals earning up to 1.1 times the minimum wage, 2.5% for individuals earning between 1.1 and 1.2 times the minimum wage and no reductions for anyone earning more than 1.3 times the minimum wage.

The first large payroll tax reduction was implemented in September 1995 (the so-called *Ristourne Juppe*). The value of SSC reductions was made more generous, reaching 18% of the gross wage for minimum wage earners, with a linear phase-out for individuals earning more than 1.33 times the minimum wage. One of the main goals of this paper is to simulate the equilibrium effects of this reduction. Further large SSC reductions followed in the early 2000s. However, they were introduced jointly with the reduction of the working time to 35 h a week, making these difficult to analyze independently. Thus, we choose to focus on the SSC reductions that were implemented in the mid-1990s in line with most of the previous literature.[40]

[40] For further institutional details, see Bunel and L'Horty (2012) and André et al. (2015).

Appendix B. Nash bargaining

Suppose that an unemployed worker and a firm engage in Nash bargaining. We follow the notation defined in Section 3, and write $\alpha(y)$ as α and $\alpha_{Nash}(y)$ as α_{Nash} for brevity. The Nash bargaining problem is

$$\phi_u^{Nash}(x,y) = \arg\max_w [W_e(w,x,y) - W_{ne}(x)]^{\alpha_{Nash}} \times [J_f(w,x,y) - J_u(y)]^{(1-\alpha_{Nash})}, \quad (23)$$

where α_{Nash} is the Nash bargaining power of workers. The first order condition is

$$W_e(w,x,y) - W_{ne}(x) = -\frac{\alpha_{Nash}}{1-\alpha_{Nash}} \frac{\partial W_e(w,x,y)/\partial w}{\partial J_f(w,x,y)/\partial w} \left[J_f(w,x,y) - J_u(y)\right]. \quad (24)$$

Without taxes, utility is perfectly transferable between the worker and the firm with $\frac{\partial W_e/\partial w}{\partial J_f/\partial w} = -1$. Whenever $\alpha_{Nash} = \alpha$, the wage under Nash bargaining coincides with the wage under proportional bargaining.[41] With labor taxes, bargained wages diverge.

We now derive $\frac{\partial W_e(w,x,y)}{\partial w}$ and $\frac{\partial J_f(w,x,y)}{\partial w}$ using results derived in Appendix C: (i) workers make job-to-job transitions only to more productive firms, $\mathcal{A}_e(x,y) = \{y' \in [0,1] : y' > y\}$; (ii) employed workers only renegotiate their wage with their current employer if they meet a vacancy from an outside firm $y' \geq y_0(w,x,y)$. Taking partial derivatives of Eqs. (9) and (10) with respect to w gives

$$[r+\delta+s_1\kappa V]\frac{\partial W_e(w,x,y)}{\partial w} = 1 + s_1\kappa \frac{\partial\left[\int_{y_0(w,x,y)}^{y} W_e(\phi_e(x,y',y),x,y)v(y')dy'\right]}{\partial w} + s_1\kappa \frac{\partial\left[\int_0^{y_0(w,x,y)} W_e(w,x,y)v(y')dy'\right]}{\partial w} \quad (25)$$

and

$$\left(r+\delta+s_1\kappa V\right)\frac{\partial J_f(w,x,y)}{\partial w} = -1 - \frac{dT(w)}{dw} + s_1\kappa \frac{\partial\left[\int_{y_0(w,x,y)}^{y} J_f(\phi_e(x,y',y),x,y)v(y')dy'\right]}{\partial w} + s_1\kappa \frac{\partial\left[\int_0^{y_0(w,x,y)} J_f(w,x,y)v(y')dy'\right]}{\partial w}. \quad (26)$$

Applying the Leibniz integral rule and noting that $\phi_e\left(x, y_0(w,x,y), y\right) = w$, we get

$$\frac{\partial W_e(w,x,y)}{\partial w} = \frac{1}{r+\delta+s_1\kappa\int_{y_0(w,x,y)}^{y_h} v(y')dy'} \quad (27)$$

and

$$-\frac{\partial J_f(w,x,y)}{\partial w} = \frac{1+\frac{dT(w)}{dw}}{r+\delta+s_1\kappa\int_{y_0(w,x,y)}^{y_h} v(y')dy'} \quad (28)$$

Substitute the partial derivations in Eq. (24) using the above, we have

$$\frac{W_e(w,x,y) - W_u(x)}{J_f(w,x,y) - J_u(y)} = \frac{\alpha_{Nash}}{\left[1-\alpha_{Nash}\right]} \frac{1}{\left[1+\frac{dT(w)}{dw}\right]} \quad (29)$$

which states that, under Nash bargaining, the match surplus is split according to the Nash bargaining power and the marginal tax rate. If the marginal tax rate is continuously increasing in w, the Nash wage is unique. However, the tax schedule that we study has a decreasing marginal tax rate, and thus the uniqueness of the Nash wage is not guaranteed. This creates theoretical and numerical challenges to solving the model. Therefore, we opt for the simpler proportional bargaining scheme.

[41] l'Haridon et al. (2013) and Jacquet et al. (2014) also present this result.

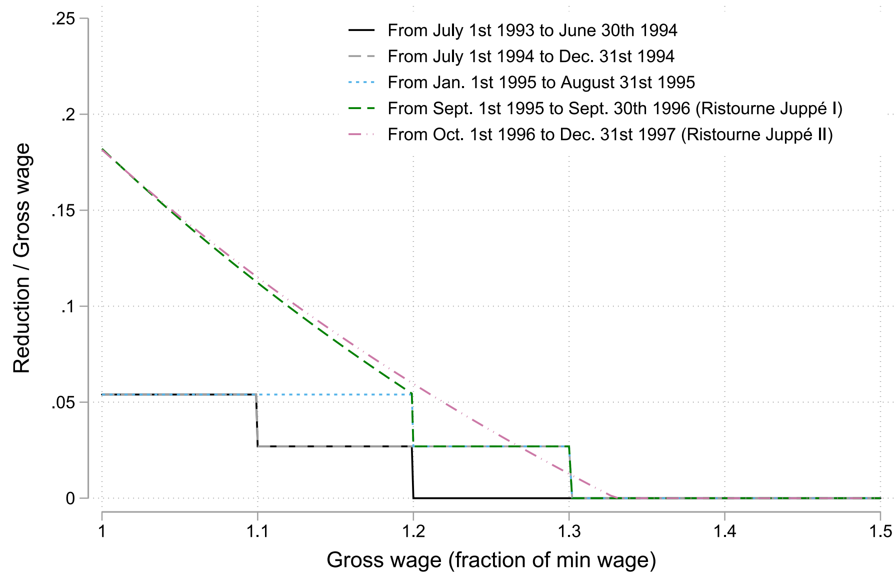

Fig. A.1. Social security reductions. Notes: The figure shows the successive schemes of reduction of SSCs that were put in place by the French government from 1993 (first reduction) to the end of 1997.
Source: Tax simulator TAXIPP (Jelloul et al., 2018).

The choice of the bargaining scheme affects the estimates of the bargaining power parameters and their interpretation. When $\alpha_{Nash} = \alpha$, the Nash wage ϕ_u^{Nash} must be smaller than the proportionally bargained wage ϕ_u because $\frac{1}{\left[1+\frac{dT(w)}{dw}\right]} \leq 1$. This implies that all else equal, the estimated bargaining power under proportional bargaining must be smaller than under Nash bargaining. The intuition is that, with Nash bargaining, workers realize that higher wages increase the tax burden. They partially compensate firms for this effect. In proportional bargaining, the two parties remain ignorant about how the tax burden comes about.

Appendix C. Theory appendix for equilibrium results

C.1. Monotonicity of value functions

Here, we prove Proposition 1. To see that the value of employment $W_e(w,x,y)$ monotonically increases in wage w, observe that the operator $\mathcal{T}_e$ in

$$\begin{aligned}\mathcal{T}_e W_e(w,x,y) = {} & \frac{w+\delta W_{ne}(x)}{[r+\delta+s_1\kappa(\xi,V)V]} \\ & + \frac{s_1\kappa(\xi,V)}{[r+\delta+s_1\kappa(\xi,V)V]}\int_{y'\in\mathcal{A}_e(x,y)} W_e(\phi_e(x,y,y'),x,y')v(y')dy' \\ & + \frac{s_1\kappa(\xi,V)}{[r+\delta+s_1\kappa(\xi,V)V]}\int_{y'\in[0,1]\setminus\mathcal{A}_e(x,y)} W_e(\max\left\{w,\phi_e(x,y',y)\right\},x,y)v(y')dy'\end{aligned} \tag{30}$$

is a contraction. The unique solution to $W_e(w,x,y) = \mathcal{T}_e W_e(w,x,y)$ solves the value function of employed workers in Eq. (9). Given that $\frac{w+\delta W_{ne}(x)}{[r+\delta+s_1\kappa(\xi,V)V]}$ monotonically increases in w, $W_e(w,x,y)$ must be monotonically increasing in w as well.

Next, to see that the value of a filled position $J_f(w,x,y)$ monotonically decreases in wage w, observe that the operator $\mathcal{T}_f$ in

$$\begin{aligned}\mathcal{T}_f J_f(w,x,y) = {} & \frac{f(x,y)-w-T(w)+\delta J_u(y)}{[r+\delta+s_1\kappa(\xi,V)V]} \\ & + \frac{s_1\kappa(\xi,V)}{[r+\delta+s_1\kappa(\xi,V)V]} J_u(y)\int_{y'\in\mathcal{A}_e(x,y)} v(y')dy' \\ & + \frac{s_1\kappa(\xi,V)}{[r+\delta+s_1\kappa(\xi,V)V]}\int_{y'\in[0,1]\setminus\mathcal{A}_e(x,y)} J_f(\max\left\{\phi_e(x,y',y),w\right\},x,y)v(y')dy'\end{aligned} \tag{31}$$

is a contraction. The unique solution to $J_f(w,x,y) = \mathcal{T}_f J_f(w,x,y)$ solves the value function of employed workers in Eq. (10). By assumption, $T'(w) > 0$ for all w (see Section 3.1). Thus, $\frac{f(x,y)-w-T(w)+\delta J_u(y)}{[r+\delta+s_1\kappa(\xi,V)V]}$ is monotonically decreasing in w and so is $J_f(w,x,y)$.

C.2. Uniqueness of the bargaining solution

Since the surplus sharing equation in Eq. (2) can be written as

$$W_e(w,x,y) - W_{ne}(x) = \frac{\alpha(y)}{1-\alpha(y)}[J_f(w,x,y) - J_u(y)], \tag{32}$$

Proposition 1 implies that $\frac{W_e(w,x,y)-W_{ne}(x)}{J_f(w,x,y)-J_u(y)}$ monotonically increases with w. Since a bargaining solution ϕ must satisfy $\frac{W_e(\phi,x,y)-W_{ne}(x)}{J_f(\phi,x,y)-J_u(y)} = \frac{\alpha(y)}{1-\alpha(y)}$, monotonicity of $\frac{W_e(w,x,y)-W_{ne}(x)}{J_f(w,x,y)-J_u(y)}$ in wage implies that the bargaining solution must be unique.

C.3. Steady state wage distribution

Wages are fully determined by worker and firm types, x and y, and workers' "reference" in wage bargaining (y' or non-employment). Given the steady state conditions for the distribution of unemployment and matches (Eqs. (13) and (14)), the wage distribution is stationary as long as the conditional distribution of y' on (x,y) is stationary for each type of viable match (x,y).

Let $G(y'|x,y)$ represent the fraction of type (x,y) matches such that the worker's reference firm type is y' or lower. Let $y' = -1$ denote the case that the worker's outside option is non-employment. For a viable match (x,y) and for $y' \geq \underline{y}(x)$, equating inflow into and outflow from $G(y'|x,y)h(x,y)$ gives us

$$\begin{aligned} & v(y)\kappa(\xi,V)\left[u(x) + s_1\int_0^{y'} h(x,y'')dy''\right] \\ & = G(y'|x,y)h(x,y)\left[\delta + s_1\kappa(\xi,V)\int_{y'}^1 v(y'')dy''\right]. \end{aligned} \tag{33}$$

For a viable match (x,y) and a reference value given by $y' = -1$, the equal flow equation is

$$v(y)\kappa(\xi,V)u(x) = G(y'|x,y)h(x,y)\left[\delta + s_1\kappa(\xi,V)\int_{\underline{y}(x)}^1 v(y'')dy''\right]. \tag{34}$$

C.4. Job-to-Job transitions

In this section, we show that employed workers make job-to-job transitions to more productive firms and that, for each (w,x,y), there exists a threshold firm type $y_0(w, x, y)$ such that a wage renegotiation is triggered by firm $y' > y_0(w, x, y)$. In an auction for an employed worker x, the firm that can offer a higher $W_e(\bar{\phi}(x, y), x, y)$ succeeds. Thus, workers prefer more productive firms if and only if $\frac{dW_e(\bar{\phi}(x,y),x,y)}{dy} \geq 0$. Recall that $\bar{\phi}(x, y)$ is the maximum wage in match (x, y) such that $J_f\left(\bar{\phi}(x, y), x, y\right) = J_u(y)$. In the next Proposition, we show that the maximum potential wage $\bar{\phi}$ is increasing in worker and firm productivity.

Proposition 2. *Given the assumptions that $f_x(x, y) > 0$ and $f_y(x, y) > 0$ for all x and y and $T'(w) \geq 0$ for all w, we have $\bar{\phi}_x(x, y) > 0$ and $\bar{\phi}_y(x, y) > 0$ for all x and y.*

Proof. Given $J_f(\bar{\phi}(x, y), x, y) = J_u(y)$ and the free-entry condition, we have $J_f(\bar{\phi}(x, y), x, y) = 0$. Therefore, it must be the case that

$$\bar{\phi}(x, y) + T(\bar{\phi}(x, y)) = f(x, y). \tag{35}$$

Taking the derivative of Eq. (35) with respect to y and rearranging, we have

$$\frac{\partial \bar{\phi}(x, y)}{\partial y} = \frac{\frac{\partial f(x,y)}{\partial y}}{1 + T'(\bar{\phi}(x, y))}.$$

By assumption, $\frac{\partial f(x,y)}{\partial y} > 0$ and $T'(\bar{\phi}(x, y)) \geq 0$. Therefore, $\frac{\partial \bar{\phi}(x,y)}{\partial y} > 0$. Similarly, we can show that $\frac{\partial \bar{\phi}(x,y)}{\partial x} > 0$. □

In other words, more productive firms can offer higher wages conditional on the worker type. Together with the fact that W_e increases in wage (Proposition 1), we know that $\frac{\partial W_e(\bar{\phi}(x,y),x,y)}{\partial w} \frac{\partial \bar{\phi}}{\partial y} \geq 0$.

It remains to be shown that the option value of matching with a more productive firm is higher, that is, $\frac{\partial W_e(w,x,y)}{\partial y} \geq 0$ at $w = \bar{\phi}(x, y)$. Substituting w with $\bar{\phi}(x, y)$, we can rewrite the value function in Eq. (9) as

$$\begin{aligned} &[r + \delta + s_1 \kappa(\xi, V) V] W_e(\bar{\phi}(x, y), x, y) = \bar{\phi}(x, y) + \delta W_{ne}(x) \\ &+ s_1 \kappa(\xi, V) \int_0^1 \max\left\{W_e(\bar{\phi}(x, y), x, y), W_e(\phi_e(x, y, y'), x, y')\right\} v(y') dy' \end{aligned} \tag{36}$$

At the maximum potential wage, workers do not renegotiate their wages as long as they stay with their current employer. Thus, when an employed worker meets a vacancy from a poaching firm, she either remains with her current employer at the same wage, or makes a job-to-job transition. By the contraction mapping theorem, the value function $W_e(\bar{\phi}(x, y), x, y)$ must be increasing in the third argument since $\bar{\phi}(x, y)$ is increasing in y. Therefore, we have

$$\frac{dW_e(\bar{\phi}(x, y), x, y)}{dy} = \frac{\partial W_e(\bar{\phi}(x, y), x, y)}{\partial w} \frac{\partial \bar{\phi}(x, y)}{\partial y} + \frac{\partial W_e(\bar{\phi}(x, y), x, y)}{\partial y} \geq 0.$$

In addition, because $\bar{\phi}(x, y)$ increases in y, the outbidding firm in an auction is also able to offer at least the minimum wage if the losing firm can form a viable match with the worker. This implies that matches between an employed worker and an outbidding firm are always viable and employed workers make job-to-job transitions only toward more productive firms. We can then conveniently express the set of firms that can poach worker x from firm y, $\mathcal{A}_e(x, y)$, as

$$\mathcal{A}_e(x, y) = \left\{y' \in [0, 1] : y' > y\right\}. \tag{37}$$

Finally, Proposition 1 implies that there exist a threshold firm type $y_0(w, x, y)$ such that for any $y' \geq y_0(w, x, y)$, $W_e(\bar{\phi}(x, y'), x, y') \geq W_e(w, x, y)$. In summary, given a match (x, y) and a poaching firm y', there are three possible scenarios. If $y' > y$, the worker makes a job-to-job transition to firm y'. If $y_0(w, x, y) < y' \leq y$, the worker remains in firm y but renegotiates her wage. If $y' \leq y_0(w, x, y)$, the match remains at the same wage w.

C.5. Reservation firm-type and policy impacts

Results from Appendix C.4 suggest that a match with a more productive firm can always yield a higher surplus. Thus, the set of viable matches for a worker of type x, $\mathcal{A}_u(x)$, can be fully characterized by a threshold $\underline{y}(x) \in [0, 1]$ such that $\mathcal{A}_u(x) = \left\{y \geq \underline{y}(x)\right\}$. The threshold $\underline{y}(x)$ arises from two constraints. The first constraint is related to the minimum wage. We use $y_{min}(x)$ to denote the lowest firm type y that can offer at least w_{min} to a worker x and characterize $y_{min}(x)$ in the next Proposition.

Proposition 3. *For any $y \in \mathcal{A}_u(x)$, we have $y \geq y_{min}(x)$ where $y_{min}(x) = \arg\min_{y \in [0,1]} \left\{y : f(x, y) \geq w_{min} + T(w_{min})\right\}$.*

Proof. In equilibrium, $J_u(y) = 0$. By Definition 1, we have $J_f(\phi_u(x, y), x, y) \geq 0$ for any $y \in \mathcal{A}_u(x)$. Given this, the value function of a filled position (Eq. (10)) implies that $f(x, y) \geq w_{min} + T(w_{min}) \geq 0$. □

Thus, a higher minimum wage or a higher tax at the minimum wage shrinks the set $\mathcal{A}_u(x)$ by making matches with low-productivity firms unviable. This is likely to affect low-productivity workers more strongly because the condition $f(x, y) \geq w_{min} + T(w_{min}) \geq 0$ is more likely to bind for them.

The second constraint stems from the match viability condition that the net match surplus must be positive (Definition 1). We use $y_u(x)$ to denote the lowest y satisfying the system of equations in Eq. (3) given x. A higher tax shrinks the set $\mathcal{A}_u(x)$ because it lowers the value of employment relative to the value of non-employment, which results from the fact that non-employment income $b(x)$ is not taxed. Since the difference between the value of employment and the value of non-employment increases with firm type, the constraint is more likely to bind for matches involving low-productivity firms.

In combination, the above two constraints define the least productive firm with which worker x can form a viable match. That is, $\underline{y}(x) = \max\left\{y_{min}(x), y_u(x)\right\}$.

Appendix D. Numerical solution of steady state equilibrium

Solving for the steady state equilibrium requires knowledge of the value functions of workers and firms because the net match surplus varies as a function of how the surplus is shared. Below, we describe the iterative numerical algorithm that solves for the fixed point. We discretize the supports of x and y with evenly spaced grids between 0.01 and 0.99 with 100 and 50 grid points, respectively. We also discretize the space of w with 100 grid points. We make an initial guess for the values W_e, W_{ne}, J_f and the distributions u, h on each grid point and the total measure of vacancies V. With inputs W_e, W_{ne}, J_f, u, h, and V, each iteration proceeds as follows:

1. Given u, and h, compute the aggregate search intensity $\xi = \sum u(x) + s_1 \sum \sum h(x, y)$.
2. Given W_e, W_{ne}, J_f, solve for the set of viable matches, Ω, such that

   $\Omega = \{(x, y) : \exists w$ s.t. $w \geq w_{min}$ and $W_e(w, x, y) - W_{ne}(x) \geq 0$ and $J_f(w, x, y) \geq 0\}$.

3. For each $(x, y) \in \Omega$, solve the following equation for the bargained wage ϕ:

   $$W_e(\phi, x, y) - W_{ne}(x) = \frac{\alpha(y)}{1 - \alpha(y)} J_f(\phi, x, y).$$

   Save the match wage $\phi_u(x, y) = \max\left\{w_{min}, \phi\right\}$. Then, find $\bar{\phi}(x, y)$ such that $J_f(\bar{\phi}(x, y), x, y) = 0$. For each (x, y', y) such that $(x, y) \in \Omega$ and $(x, y') \in \Omega$, solve the following equation for the bargained wage ϕ:

$$W_e(\phi, x, y') - W_e(\bar{\phi}(x,y), x, y) = \frac{\alpha(y)}{1-\alpha(y)} J_f(\phi, x, y').$$

Save the match wage $\phi_e(x, y', y) = \max\{w_{min}, \phi\}$.

4. Let $mobility(x, y', y) = 1$ if worker x would make a job-to-job transition from firm y to y'. That is, $mobility(x, y', y) = 1$ if either of the following criteria is satisfied.
   (a) $(x,y) \in \Omega$, $(x,y') \in \Omega$, $\phi_e(x,y',y) \leq \bar{\phi}(x,y')$, and $W_e(\bar{\phi}(x,y'), x, y') - W_e(\bar{\phi}(x,y), x, y) \geq 0$.
   (b) $(x,y) \notin \Omega$ but $(x,y') \in \Omega$.
5. Given $v(\cdot)$, solve for the search decision $s(x)$ for all x, such that
$$s(x) = \arg\max_{s\in\{0,1\}} \left\{ b(x) - sq + s\kappa \int_{y'\in\mathcal{A}_u(x)} [W_e(\max\{w_{min}, \phi_u(x,y')\}, x, y') - W_{ne}(x)]v(y')dy' \right\},$$
where $\kappa = \frac{M(\xi,V)}{\xi V}$ and $\mathcal{A}_u(x) = \{y : (x,y) \in \Omega\}$. Update $u(\cdot)$, ξ, and κ.
6. Update $v(\cdot)$ using Eq. (12) with $\mathcal{B}_u(y) = \{x : (x,y) \in \Omega\}$ and $\mathcal{B}_e(y) = \{(x,y') : mobility(x,y,y') = 1\}$. Update κ.
7. Update value functions W_{ne}, W_e, J_f using Eqs. (8), (9), and (10).
8. Update the unemployment distribution $u(\cdot)$ using Eq. (13) and the match distribution $h(\cdot,\cdot)$ using Eq. (14).
9. Evaluate the criterion function and compare the value with the pre-set tolerance level. The algorithm continues until the tolerance level is met.

Appendix E. Data appendix

E.1. Sample selection

Table E.1 compares summary statistics of workers before and after sample selection based on the primary type of employment. Specifically, we consider workers primarily employed in full-time, private-sector, non-executive jobs. That is, an individual is "primarily employed in full-time, private-sector, non-executive jobs" if he holds such jobs as the primary job for at least 50% of the time throughout his entire observed employment biography. Note that the sample selection takes place at the individual level instead of the job level. Individuals selected into our sample may occasionally hold jobs that are not full-time, private-sector, and non-executive. Moreover, since we exclude executive occupations, the median and mean wages are lower after the sample selection.

Table E.1
Summary statistics of sample workers.

Variable	(1) Non-sample	(2) Sample
# unique individuals	112,244	301,155
% Full-time	0.813	0.904
% Private sector	0.625	0.915
% Non-executive	0.595	0.936
% Sample	0.229	0.856
Wage, 25th percentile	39.95	40.38
Wage, 50th percentile	62.13	50.13
Wage, 75th percentile	95.27	63.15
Mean wage	74.42	54.08

Notes: "Non-sample" and "sample" are both drawn from the merged DADS dataset restricted to men aged 25–64 in the years 1993–1995. "Sample" is restricted to individuals that satisfy the sample selection criteria described in Section 4.1 and Appendix E.1; "Non-sample" contains those not in "sample." "% Full-time", "% Private sector", "% Non-executive" are, respectively, the fractions of employment that are full-time, in the private sector, and in non-executive occupations. "% Sample" is the fraction of employment that satisfies all three requirements. Wage is the gross daily wage in euros.

E.2. Procedures to convert spell data into monthly data

The raw data is spell-based; there is one observation per individual-job-year. We take the following steps to convert the raw data into a monthly data set.

Correcting missing spell-dates. Around 0.5% of employment spells contain missing start and end dates; the spell duration is available for over 99.998% of the spells. We infer the spell start and end dates using spell duration and the employment spells in the surrounding years. Let $spell(i, Y, j)$ denote an employment spell of worker i in year Y and firm j. Suppose we observe $spell(i, Y, j)$ with missing start and end dates, and we also observe $spell(i, Y+1, j)$ that starts on the first day of year $Y+1$, and we do not observe $spell(i, Y-1, j)$. In this case, the end date of $spell(i, Y, j)$ is the last day of year Y, and the start date is derived from the spell duration. In all other cases, we assume that the spell start date is day 1 of the spell year, and the end date is derived from spell duration. In the extremely rare cases that the spell duration is missing, we assume that the spell lasts for the entire year.

Correcting overlapping spells. Multiple spells of the same worker at the same or different firms may overlap. About 40% of the individuals have overlapping jobs. In these cases, we need to identify a main job and define a wage. During the time window the two jobs overlap, we assume that the main job is the one that is full-time, private sector, and non-executive. If both or neither jobs satisfy these criteria, the main job is identified by a higher wage. Wages from overlapping jobs are only summed if they are in the same firm. Lastly, continuous employment spells within the same firm in a given year are concatenated and the wage is defined as the average wage over the concatenated spell.

Correcting whole-year gaps. For years 1994, 2003, and 2005 many individuals are missing for the entire year but are observed in the preceding or the following years; we refer to this as a whole-year gap. Over the period between 1991 and 2008, whole-year gaps occur in 1.4% of sample individuals' biographies. In 1994, 2003 and 2005, the occurrences are 10.3%, 3.0% and 1.4% respectively. A potential reason for the whole-year gaps may be missing data for these individuals in the three years. To correct this problem, we replace the whole year gaps with employment spells if the worker is employed on the day before and after the gap year in the same firm. We take the average wages in the surrounding years as the wage for the new employment spells. Overall, 86.6% of whole-year gaps in the three years can be corrected using this technique.

Transforming spell data to monthly data. In the monthly data, there is one observation per individual-month. If an individual has several job spells in a given month, we use the one that occupies the largest fraction of the month.

E.3. Imputing labor force status in employment history

We use the French labor force survey (Enquete Emploi, hereafter EE), to impute the status of an individual in a gap spell in the DADS. Within the EE, we label unemployment, self-employment and non-participation spells as "non-working", with the indicator nw; these would appear as gap spells in the DADS. The aim is to identify the probability that a non-working spell is an unemployment spell using individual and job characteristics that are available in both the EE and the DADS.

The first step is to select an EE sample to resemble the sample in DADS. This entails restricting the sample to men aged 25–64 and dropping individuals who are not employed prior to and following a nw spell. The latter restriction is related to the data structure in the DADS panel, in which a gap spell can only be observed if it is sandwiched by two employment spells. We also drop nw spells that last for more than 3 years. We then estimate the likelihood of unemployment among

Table E.2
Tax function parameters.

	(1) Baseline	(2) 1997
p_0	−229.25	−916.72
p_1	1.050	1.676
p_2	0.799	0.915
p_3	0.821	0.841
p_4	0.842	0.882
p_5	0.778	0.840
p_6	0.585	0.639
p_7	0.601	0.625
p_8	0.601	0.608
p_9	0.615	0.606
p_{10}	0.551	0.676

Notes: The table shows the parameters of various tax functions used in this paper. All tax functions are linear spline functions with 9 nodes. Specifically, the tax function takes the form: $T(w) = \sum_{k=1}^{10} P_k(w)$, where $P_1(w) = p_0 + p_1 \cdot w$ if $w \leq w_1$; $P_k(w) = P_{k-1}(w_{k-1}) + p_k \cdot (w - w_{k-1})$ if $w_{k-1} < w \leq w_k$ for each $k = 2, \ldots, 9$; and $P_{10} = P_9(w_9) + p_{10} \cdot (w - w_9)$ if $w > w_9$. The nodes $w_1, \ldots, w_9$ are respectively 1.1, 1.3, 1.5, 1.6, 1.8, 2.0, 2.5, 3.0, and 3.5 times the minimum wage in the baseline period.

Table E.3
Values of the policy parameters $\tilde{f}$ and $\tilde{m}$ for simulating non-employment benefits. Values are nominal. Values prior to 2001 have been converted from French Francs (FF) to Euro (€) using the conversion rule of 1 € = 6.55957FF.

Date effective	$\tilde{f}$	$\tilde{m}$	Date effective	$\tilde{f}$	$\tilde{m}$
7/1/10	11.17 €	27.25 €	7/1/00	9.56 €	23.32 €
7/1/09	11.04 €	26.93 €	7/1/99	9.38 €	22.86 €
7/1/08	10.93 €	26.66 €	7/1/98	9.26 €	22.58 €
7/1/07	10.66 €	26.01 €	7/1/97	9.09 €	22.16 €
7/1/06	10.46 €	25.51 €	7/1/96	8.90 €	21.68 €
7/1/05	10.25 €	25.01 €	7/1/95	8.68 €	21.17 €
7/1/04	10.25 €	25.01 €	7/1/94	8.43 €	20.39 €
7/1/03	10.15 €	24.76 €	7/1/92	8.26 €	19.97 €
7/1/02	9.94 €	24.24 €	7/1/91	8.04 €	19.45 €
7/1/01	9.79 €	23.88 €	10/1/90	7.87 €	19.02 €

nw spells. We use information on the individual's age, the duration of the nw spell, and the following information of the employment spell following the nw spell: socio-professional status, industry, and an indicator for private or public sector. We denote this information by Ω_s. Using a Probit model, we estimate $P(u_s|nw_s, \Omega_s)$, where $u_s = 1$ indicates unemployment. The final step is to impute the unemployment status for gap spells in DADS. Based on analogous data, we construct Ω_s^{DADS} for each spell s and compute the predicted likelihood that s is an unemployment spell using the estimated predictor from EE, $\hat{P}(u_s|nw_s, \Omega_s^{DADS})$. We draw the unemployment status of each nw spell from the distribution given by the predicted likelihood.

We test our imputation method by imputing the unemployment status of non-employment spells in the EE data. We can correctly identify 68.99% of non-employment spells as unemployment or other non-employment; this is an improvement over a purely random assignment of the unemployment status.

E.4. Payroll tax schedules

We obtain our tax function $T(w)$ by fitting a linear spline to the relationship between simulated SSCs and the net wage. Table E.2 shows the parameters of the fitted tax function in the baseline period (January 1993 to August 1995) and the post-reform period (1997). All wages and taxes are expressed in 2010 Euro.

E.5. Computing non-employment benefits

Since non-employment incomes are not directly observed in the *DADS* data, we compute them based on rules governing unemployment benefits and social welfare in France. Unemployment benefits, denoted by $\tilde{b}$, depend on the average daily gross wage $\tilde{w}$ in the year preceding the unemployment spell. Specifically, $\tilde{w}$ is equal to total gross earnings divided by the number of days worked in that year. $\tilde{b}$ can then be calculated as a function of a series of observed policy parameters $\tilde{f}$, $\tilde{m}$, $\tilde{s}_0$, $\tilde{s}_1$, and $\tilde{s}_2$ as follows:

1. First, compute $\tilde{b}_0(\tilde{w}) = \max\left\{\tilde{f} + \tilde{s}_0\tilde{w}, \tilde{s}_1\tilde{w}\right\}$.
2. Then, compute $\tilde{b}_1(\tilde{w}) = \max\left\{\tilde{b}_0(\tilde{w}), \tilde{m}\right\}$.
3. If $\tilde{b}_1(\tilde{w}) = \tilde{m}$, we have $\tilde{b} = \tilde{m}$. Otherwise, $\tilde{b} = \min\left\{\tilde{b}_0(\tilde{w}), \tilde{s}_2\tilde{w}\right\}$.

Table E.3 shows the evolution of $\tilde{f}$ and $\tilde{m}$ over the relevant period. The values of $\tilde{s}_0$, $\tilde{s}_1$, and $\tilde{s}_2$ are fixed over the entire sample period from 1991 to 2008, $\tilde{s}_0 = 40.4\%$, $\tilde{s}_1 = 57.4\%$, and $\tilde{s}_2 = 75\%$. We compute unemployment benefits for each worker according to the algorithm above. We then average $\tilde{b}$ per worker bin x. b_0 and b_1 are finally determined from the regression

$$\tilde{b} = b_0 + b_1\mathfrak{h}(x) \tag{38}$$

Note that workers are eligible to receive unemployment benefits for two years (during which they are supposed to be looking for a job but in practice, there is little monitoring of this conditionality). After this period, benefits are reduced to a fixed social minimum that we do not model.

Appendix F. Ranking

The AKM regression is an empirical method to estimate the fixed effects of workers and firms, which are proxies for their respective productivity levels. The fixed effects can be identified on a network of workers and firms that are connected over time as workers move across firms. To estimate the AKM model, we first identify the largest connected set in our data. As described in Section 4.1, our data from the *DADS* contains only a 1/24 (1/12 in some years) sample of the population of workers in France. Given the relatively low frequency of job-to-job mobility, we require a longer panel to construct a reasonably large connected set, based on which we can estimate our AKM model. For this reason, we use all years that the *DADS* data is available to us, from 1993 to 2010.

Our final sample, based on which we compute data targets used for the simulated method of moments estimation, contains individuals that both satisfy our sample selection criteria laid out in Section 4.1 and have an estimated fixed effect. In computing data targets that are based on firm rank, we only consider firms that have an estimated AKM firm effect. In computing data targets that are not based on firm rank, we include all firms.

Tables F.1 and F.2 compare summary statistics of ranked and unranked workers and firms. We can estimate AKM fixed effects for a large fraction of workers and the majority of firms. Over half of the individuals who satisfy our sample selection criteria in the baseline period have an estimated worker fixed effect. About 80% of firms (that is, establishments) in our data in the baseline period have an estimated firm fixed effect, accounting for 91% of total employment. Moreover, workers and firms that have an estimated AKM fixed effect are similar in terms of their wage distribution to those without an AKM fixed effect. This reassures us regarding the representativeness of our final sample.

As a robustness check, we estimate individual and firm ranking using either only the "pre-reform" DADS data from 1993 to 1995 or only the "post-reform" DADS data from 1996 to 2010. Using only the pre-reform period severely reduces the number of individuals and firms that can be ranked to less than 6%. In addition, due to the limited number of job-to-job transitions available during a short three-year panels, the correlation between the firm (worker) effects estimated with AKM models for the sub-period 1993–2010 and those estimated on the whole period 1993–2010 is only 39% (80.3%). This has pushed us to discard this alternative rankings based only on the pre-reform period.

Using only the post-reform period (1996–2010) however provides much more satisfactory results. In that case, the post-reform time

Table F.1
Summary statistics of ranked workers.

Variable	(1) Ranked	(2) Unranked
# unique individuals	153,263	147,892
Wage, 25th percentile	39.60	41.57
Wage, 50th percentile	48.93	51.82
Wage, 75th percentile	61.54	65.32
Mean wage	52.81	55.84

Notes: "Ranked" contains individuals who satisfy our sample selection criteria and have an estimated AKM fixed effect; this is the sample based on which we compute our moments for baseline estimation. "Unranked" contains individuals who satisfy our sample selection criteria but do not have an estimated AKM fixed effect because they are not part of the largest connected set. The sample is based on the panel data from the DADS, 1993–1995. Wage is the gross daily wage in euros. See Appendix F for details.

Table F.2
Summary statistics of firms.

Variable	(1) Ranked	(2) Unranked
# unique firms	173,745	48,539
Employment Share	0.913	0.087
Wage, 25th percentile	40.64	37.24
Wage, 50th percentile	52.15	48.60
Wage, 75th percentile	69.69	67.05
Mean wage	60.04	56.98

Notes: "Ranked" and "Unranked" refer to, respectively, firms that have an estimated AKM fixed effect and firms that do not. The sample is based on the panel data from the DADS, 1993–1995. Wage is the gross daily wage in euros. See Appendix F for details.

spam is large enough to get reliable AKM firm effects. The correlation between the firm (worker) effects estimated with AKM models for the sub-period 1996–2010 and those estimated on the whole period 1993–2010 is indeed 96.9% (99.4%). Using the post-reform period, we also estimate firm effects (worker effects) for 92.7% of the firms (96.1% of the workers) for which we can estimate AKM firm effects (AKM worker effects) on the whole sample (1993–2010). To conclude, using the post-reform period to rank workers and firms leads to very similar results to those obtained with the whole sample.

F.1. Alternative firm ranking statistics

The high correlations between AKM fix effects and true worker and firm types are also the reason we choose to use AKM fixed effects for ranking workers and firms over other statistics. One potential firm-level statistic that is consistent with firm productivity based on our model is the maximum possible within-firm wage. However, the estimated maximum possible wage is imprecise for firms with a small number of wage observations, and the majority of firms are small. Even in the dataset with the entire population of salaried workers in France, only less than 30% of firms have 10 or more employees per year on average. Moreover, based on data simulated from our model, the correlation between the maximum within-firm wage and the true firm type is less than 0.4. Other firm-level statistics such as the poaching index (Bagger and Lentz, 2019) are also in practice ineffective in correctly ranking firms in data simulated from our model.

Appendix G. Simulation method

For each set of parameters, we solve the equilibrium model and generate a simulated panel dataset. The simulated data is based on one cohort of 100,000 individuals and 2000 firms whose productivity is drawn from discretized worker and firm productivity distributions, respectively. We consider a discrete-time version of our model by aggregating it to the monthly level. We assume that all individuals are non-employed initially. Individuals and firms make decisions regarding job search, vacancy posting, wage determination, and match formation and separation according to the equilibrium solution of the model. We record individuals' labor market outcomes, including labor force participation, employment, and the firm identifier of the employer in each period. We simulate these labor market outcomes for 480 months in total. Since the initial distribution is different from the steady state distribution and the convergence to the steady state distribution is not instantaneous due to labor market frictions, we discard the first 444 months of the simulated data and keep only the last 36 months. The reason for keeping 36 months of simulated data is that it is the duration of the sample window based on which we compute our moments in the *DADS* data.

Appendix H. Sorting indices

To measure sorting between heterogeneous workers and firms in our model, we first split workers (firms) into two groups, above-median and below-median, based on their type. Then, we calculate the employment distribution across the four types of matches as follows:

Worker\Firm	Above-median	Below-median
Above-median	π_a	π_b
Below-median	π_c	π_d

For example, π_a is the fraction of job matches in the steady state that are formed between above-median workers and above-median firms. We have $\pi_a + \pi_b + \pi_c + \pi_c = 1$. The odds ratio index is defined as

$$I_o(pi_a, pi_b, pi_c, pi_d) = \log\left(\frac{\pi_a \pi_d}{\pi_b \pi_c}\right),$$

and the correlation index is defined as

$$I_c(pi_a, pi_b, pi_c, pi_d) = \frac{\pi_a \pi_d - \pi_b \pi_c}{\sqrt{(\pi_a + \pi_b)(\pi_c + \pi_d)(\pi_a + \pi_c)(\pi_b + \pi_d)}}.$$

See Chiappori et al. (2021) for a detailed discussion of the properties of these indices.

Appendix I. Employment distribution before and after payroll tax reform

In this Appendix, we show changes in the observed employment distribution after the low-wage payroll tax reduction in France implemented at the end of 1995. See Section 4.1 and Appendix E for details on the data and sample. Specifically, we compare the baseline period (January 1993 to August 1995) to the post-reform period (January to December 1997) and examine the changes in employment distribution across worker or firm productivity ranks defined by AKM fixed effects (see Section 4.2).

As shown in Table I.1, the post-reform employment distribution is more skewed toward less productive workers and firms. Workers in the bottom quartile experience a 6% increase in the employment rate while the top quartile experiences a drop in the employment rate of similar magnitude. Similarly, the share of employment in the bottom quartile of firms increases by 10% while the share of employment in the top quartile decreases.

We do not interpret these changes as the causal effects of the payroll tax reform because we do not control for contemporaneous changes in other policies such as the minimum wage and in the macroeconomic environment. Nevertheless, the observed changes in employment distribution are consistent with our simulation results from the model (Section 5.1). In particular, we find that, due to the reform, the vacancy distribution becomes more skewed toward less productive firms and the employment rate increases significantly only among low-productivity workers.

Table I.1
Post-reform employment distribution.

(a) Employment rate by worker productivity			
Worker productivity quartiles	Baseline (1993–1995)	Post-Reform (1997)	Change from baseline
Q1	0.669	0.710	6.13%
Q2	0.745	0.782	4.97%
Q3	0.800	0.819	2.37%
Q4	0.861	0.812	−5.69%
(b) Employment share by firm productivity			
Firm productivity quartiles	Baseline (1993–1995)	Post-Reform (1997)	Change from baseline
Q1	0.124	0.137	10.48%
Q2	0.209	0.227	8.61%
Q3	0.359	0.357	−0.56%
Q4	0.308	0.279	−9.42%

Notes: Worker and firm productivity quartiles are based on AKM fixed effects. Employment rate is the ratio between employed workers and the population, and employment share is the share of employment in each firm quartile.

Table J.1
Estimated parameter values.

Parameter	(1) Post-reform sample	(2) Restricted sample
Production function and productivity distributions:		
f_0	2623.31	2489.59[a]
γ	−0.034	−0.035
σ_x	0.328[a]	0.252[a]
σ_y	4.920	6.728[a]
Search cost and meeting technology:		
q	513.43	470.63[a]
c_0 (10^3)	298.72[a]	306.31[a]
c_1	12.94[a]	16.17[a]
s_1	0.874[a]	0.801
m_0	2.311	2.961[a]
Non-employment benefit:		
b_0	554.51	610.40[a]
b_1	530.632[a]	320.62[a]
Bargaining power:		
α_0	0.205	0.199
$\alpha 1$	0.273	0.317[a]

Notes: See Table 1 for estimated parameter values and standard errors in the baseline model. See Appendix J.1 for the estimation based on the "Post-reform sample" and J.2 for the estimation based on the "Restricted sample."
[a] Statistically different from the baseline values at the 95% confidence level.

Appendix J. Robustness checks

J.1. Estimation and results based on post-reform data

In this section, we estimate the model based on data and policies in 1997, which is after the payroll tax reform we consider in Section 5. We then feed the pre-reform payroll tax schedule to the estimated model to compute the effects of *removing* the payroll tax reform that was implemented at the end of 1995. Column (1) of Table J.1 shows the parameter estimates based on the post-reform data. While most of the parameters are statistically different from those estimated using the pre-reform data (Table 1), the differences are nevertheless not large enough to alter the implications of the model qualitatively. The differences can be due to changes in the underlying macroeconomic environment other than payroll taxation and minimum wage policies between 1995 and 1997. Table J.3 shows the aggregate effects of removing the payroll tax reform; the values are of similar magnitude but opposite signs as those in Table 3 Column (1). Table J.2 shows the model fit, and Fig. J.2 shows the simulated distributional effects of removing the tax reform.

Table J.2
Model fit: Post-reform sample.

Moment	Data	Model
Labor force participation rate	0.956	0.960
Unemp. rate	0.083	0.082
Vacancy rate	0.011	0.012
Job-to-Job vs. unemp-to-job rate	0.285	0.142
Wage distribution relative to w_{min}:		
$Pr(w \leq 1.05w_{min})$	0.116	0.050
$Pr(1.05w_{min} < w \leq 1.3w_{min})$	0.183	0.224
$Pr(1.3w_{min} < w \leq 1.6w_{min})$	0.258	0.219
$Pr(1.6w_{min} < w \leq 2.5w_{min})$	0.353	0.456

See Fig. J.1 for the model fit of additional targeted moments.
Notes: see Appendix J.1 for details.

Table J.3
Simulated aggregate effects of removing the payroll tax reform in 1997.

Employment	−2.17%
Total output	−1.21%
Output per job	0.99%
Consumption	−1.17%
LF participation	−2.08%
Vacancies	−1.86%
Job finding rate	−0.55%
Lump-sum transfer	−2.76%

Notes: values in the table show percentage changes from the post-reform environment due to the removal of the payroll tax reform.

Table J.4
Model fit: Further restricted sample.

Moment	Data	Model
Labor force participation rate	0.958	0.960
Unemp. rate	0.077	0.080
Vacancy rate	0.011	0.011
Job-to-Job vs. unemp-to-job rate	0.203	0.135
Wage distribution relative to w_{min}:		
$Pr(w \leq 1.05w_{min})$	0.112	0.048
$Pr(1.05w_{min} < w \leq 1.3w_{min})$	0.190	0.232
$Pr(1.3w_{min} < w \leq 1.6w_{min})$	0.300	0.250
$Pr(1.6w_{min} < w \leq 2.5w_{min})$	0.355	0.443

See Fig. J.3 for the model fit of additional targeted moments.
Notes: see Appendix J.2 for details.

J.2. Estimation and results based on a more restricted sample of workers

In this section, we estimate the model based on a subsample of the data used for the baseline estimation (see Section 4.1). Our baseline sample includes individuals in three occupational categories: (i) intermediate professionals (professions intermediaries), which is an intermediate category between managers or executives and employees, (ii) employees (employes), including non-manual workers who are not professional or manager, and (iii) laborers (ouvriers), or manual workers. Here, we consider a sample with only employees and laborers (categories ii and iii).

Column (2) of Table J.1 shows the estimated parameter values; Table J.4 and Fig. J.3 shows the fit of the model. Because there is less worker heterogeneity in the restricted sample, the estimated dispersions of worker and firm productivity distributions are smaller compared to those from the baseline model.

Table J.5 show the aggregate effects of the payroll tax reform; the values in the table closely match those from the baseline sample (Table 3). Fig. J.4 shows the distributional effects of the payroll tax reform on the restricted sample, which are again comparable to those from the baseline sample (Fig. 3).

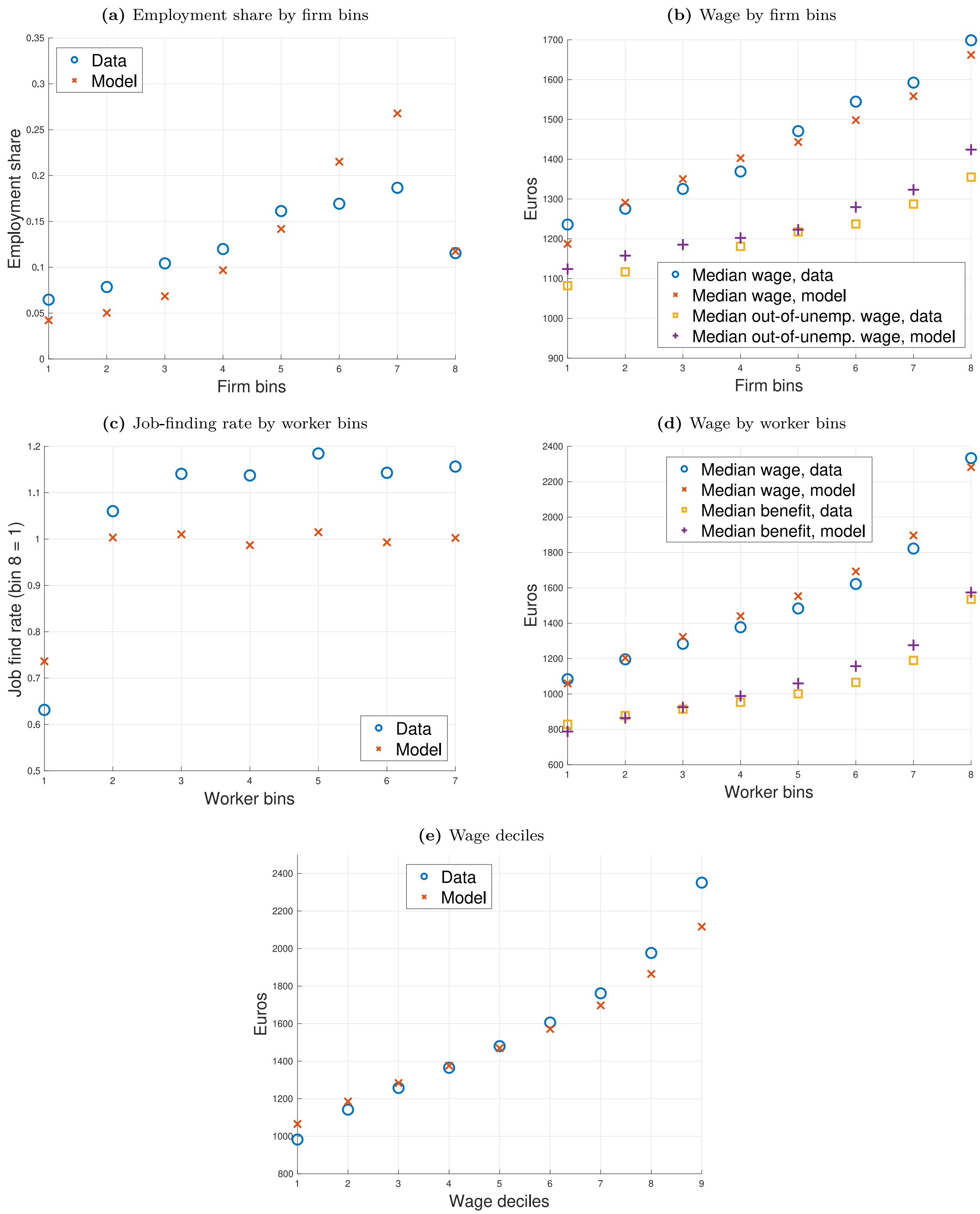

Fig. J.1. Model fit, continued. Notes: see Appendix J.1 for details.

The tax reduction's unintended spillover effect on output from relatively productive workers is present, but smaller in magnitude compared to the baseline model. In particular, the bottom quartile of workers in the restricted sample contribute to a 1.39% increase in total output, but workers in the top three quartiles contribute to a 0.09% decrease in total output. Whereas the more productive workers offset the output gain of the bottom quartile by 9% in the baseline model, the offset here is 6%.

Data availability

The data that has been used is confidential.

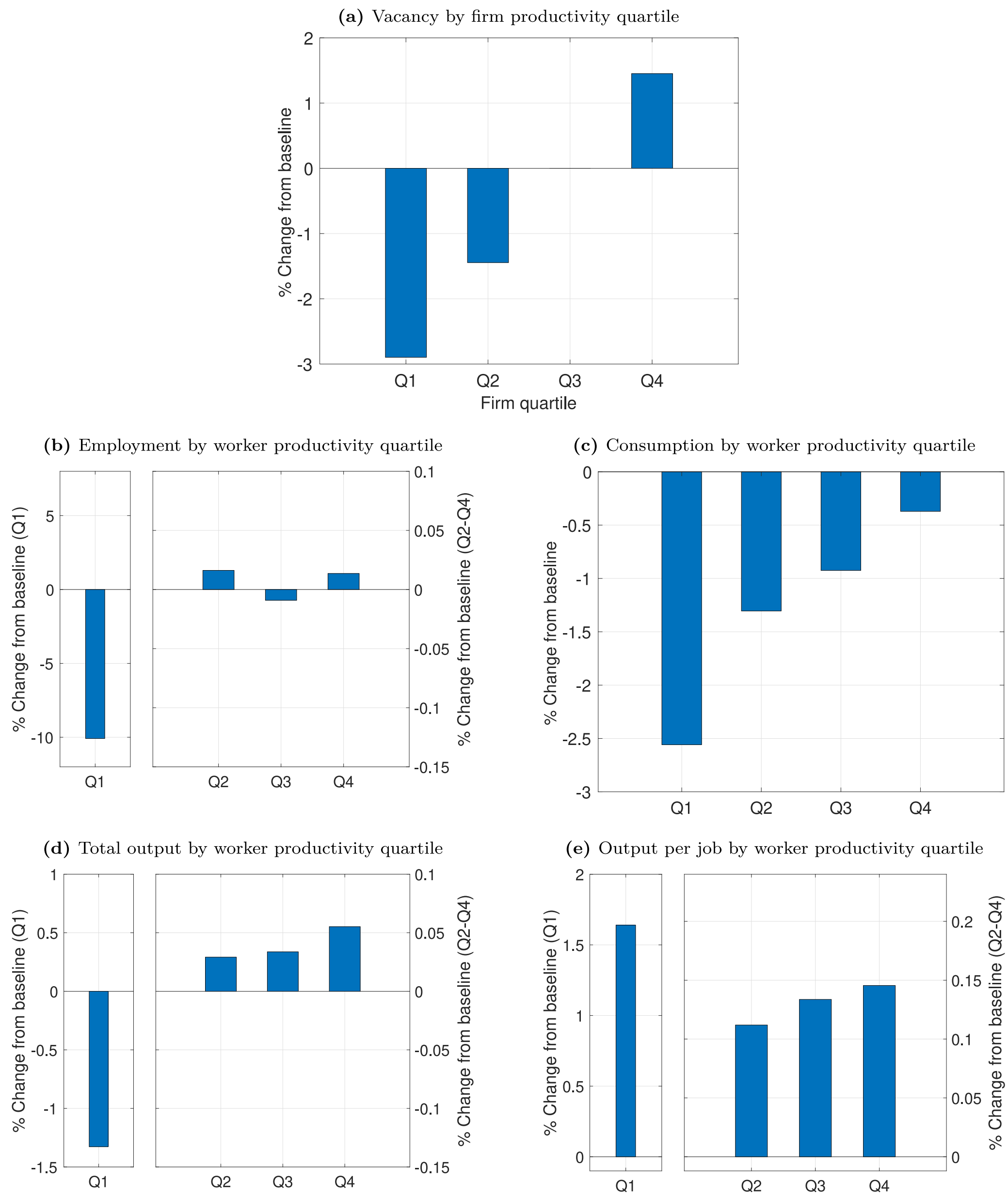

Fig. J.2. Simulated distributional effects of removing the payroll tax reform in 1997.

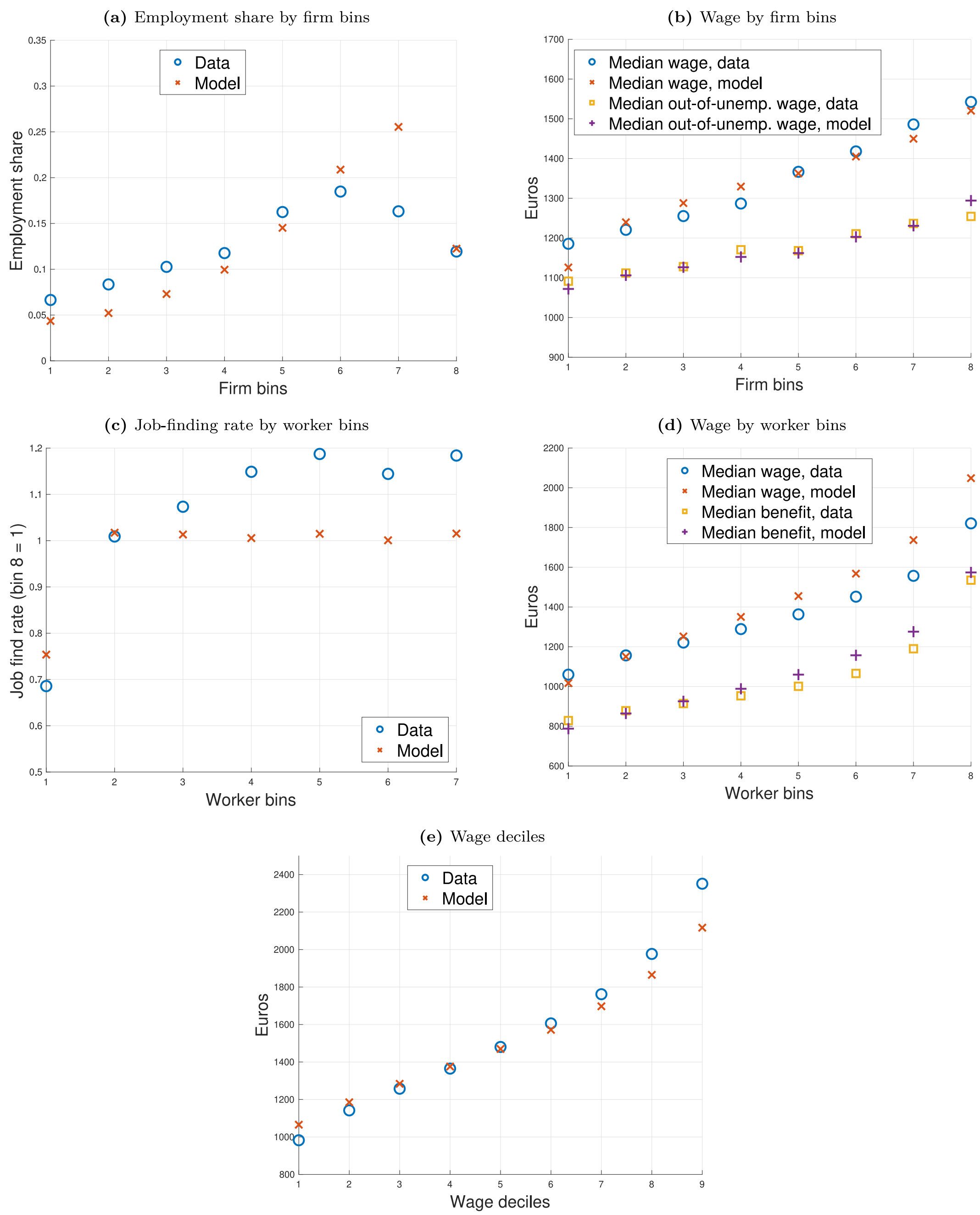

Fig. J.3. Model fit: Further restricted sample. Notes: see Appendix J.2 for details.

Table J.5
Simulated aggregate effects of payroll tax reform based on restricted sample.

Employment	2.26%
Total output	1.29%
Output per job	−0.95%
Consumption	1.23%
LF participation	2.08%
Vacancies	2.88%
Job finding rate	1.82%
Lump-sum transfer	1.12%

Notes: values in the table show percentage changes from the post-reform environment due to the removal of the payroll tax reform.

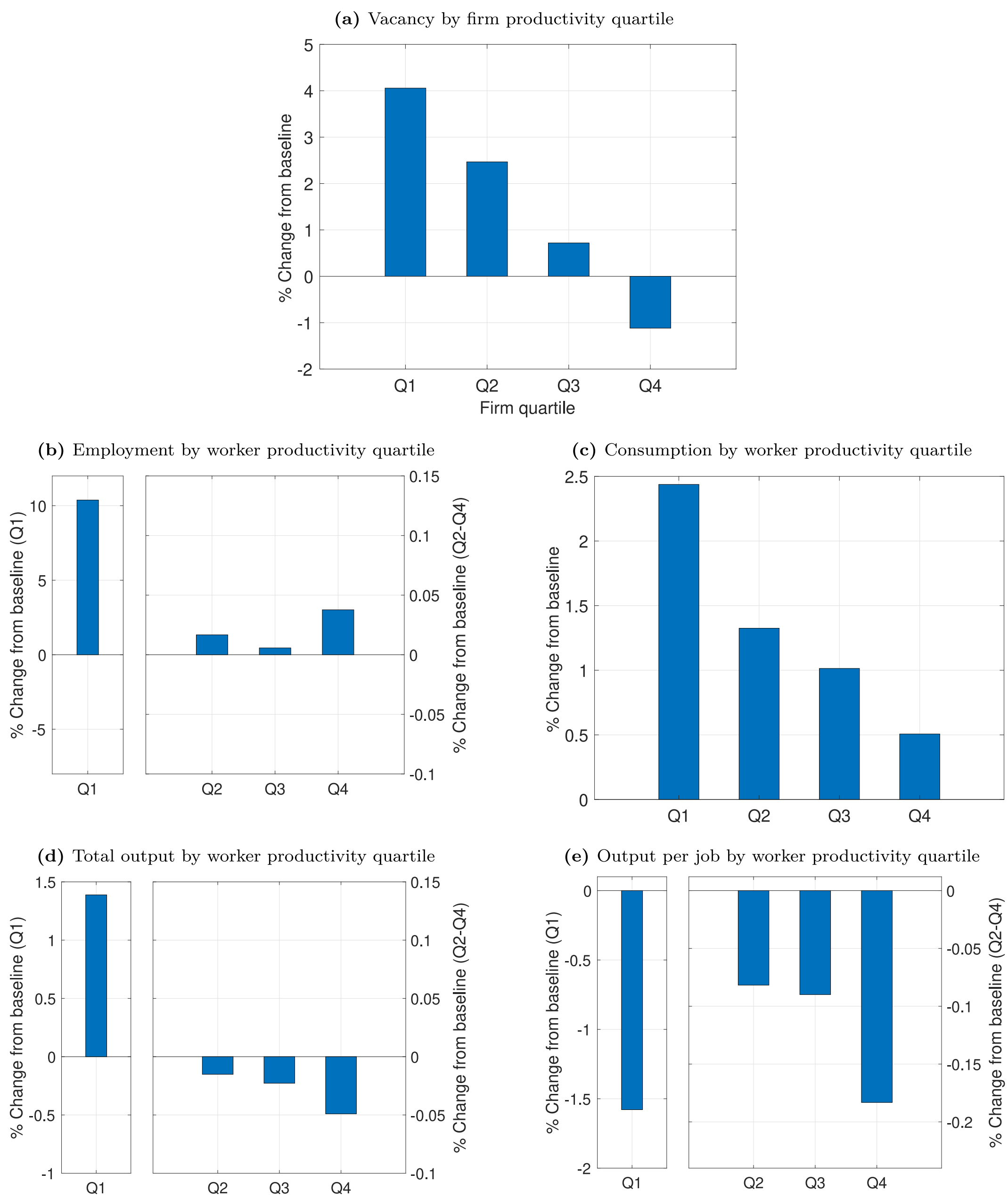

Fig. J.4. Simulated distributional effects of payroll tax reform based on restricted sample.

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