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Should unemployment insurance be centralized in a state union?

by

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Should unemployment insurance be centralized in a state union?

Unearthing a principle of efficient federation building*

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Abstract

Our study compares the efficiency of unemployment insurance programs in a state union. A centralized insurance pools the cost of unemployment which implies a collective bargaining in the countries that leads to excessively high wages and inefficient insurance. Those high wages attract workers who reduce the outsourced economic cost of unemployment. Only with perfect mobility, this opposing migration effect completely outweighs the pooling effect, and the insurance is no longer inefficient when centralized. Furthermore, we conclude that a principle of efficient federal systems might be that fiscally linked economic policies and institutions should be governed on the same federative level.

Keywords: unemployment insurance, imperfect labor markets, federal state union, centralization, migration, vertical fiscal externality

JEL codes: F22, F66, H77, J65

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1 Introduction

Should the social security systems of member states be centralized in a state union or remain in the single country's competence? In the European Union, the concept of a centralized European unemployment insurance system has often been proposed and discussed (Beblavý and Lenaerts, 2017, Andor et al., 2014). Recently, the French prime minister argued in favor of a common European unemployment insurance in order to redistribute resources from economically more successful countries to less successful ones. Typically, this debate deals with the stabilizing function of a common unemployment insurance program, where centralization serves as mutual interstate insurance against asymmetric economic shocks on the labor markets of individual member states. However, another perspective on such centralization is the allocational effects on migration and the labor market, and the ability to provide efficient insurance against the risk of unemployment.

In this paper we compare the efficiency of a centrally organized unemployment insurance program at the state union's level with the decentralized organization of individual countries. In the model, two countries form a state union where the labor force as well as the firms in both countries may relocate across state lines. The labor markets in each state are governed by collective bargaining between trade unions and firms to set gross wages. We assume 'large' trade unions and firm associations which means that the effects of the wage bargain on macroeconomic variables like the unemployment rate and the governmental insurance budget are taken into account.[1] Under both types of unemployment insurance, decentralized or centralized, the government determines the contribution rate of wages to balance the insurance budget. The governmental contribution rate is actuarially fair and unemployment fully insured if the insurance is efficient.

In our model we can show as a novel result that a centralized unemployment insurance is generically inefficient with symmetric regions. It can achieve efficiency only if workers and

[1] With firm-level bargaining, which e.g. is also a standard assumption in the search and matching literature, no such effects can be expected because a single worker or firm cannot be expected to see through the government's budget or consider the wage effect on national employment. We also choose a collective bargaining framework because it strongly eases the formal analysis and clear presentation of results. E.g. the consideration of vacancy formation or search effort would inflate the model's first-order conditions but not help to clarify the main results of the paper.

firms are completely mobile. In this case all competing effects of mobility and fiscal interdependency set each other off in the wage formation such that the government's decision is unaffected from collective bargaining. First, on the one hand trade unions have an incentive to bargain excessively high wages because the financing of the insurance is pooled such that economic costs of higher wages are shared between regions. Second, on the other hand trade unions aim at wages that are inefficiently low because they do not consider positive effects of higher wages on expected utility in the other region. Higher wages attract workers to relocate from there such that for given labor demand expected utility increases. Third, firms negotiate wages that are inefficiently high because like the trade unions they do not take account of positive effects of their decision making on the other region. With symmetric regions and full mobility these effects exactly outweigh each other. In all other cases we show that a decentralized organization of unemployment insurance is superior to a centralized organization. In the decentralized regime the contribution rate is set efficiently irrespective of firms' and workers' mobility costs, implying that full insurance against the risk of unemployment is provided. This result is obtained even for asymmetric states.[2]

Another important and novel finding is that the inefficiency of centralized unemployment insurance depends on the degree of centralization of the wage bargaining process within the state union. The pooling effect which distorts the central government's decision about unemployment insurance, even in the case of symmetric states, arises only if wage negotiations are decentralized in the states. If the labor markets were integrated, in the sense of implementing a centralized wage bargaining process, a centralized insurance program could also be efficient. This gives rise to the consideration of a more general principle of efficient implementation of collective decision-making and institutions in a federal system of states: if the budget of an institution affects collective decisions, it is efficient to establish both, the decision-making and the institution on the same federative level.

The paper proceeds as follows: section 2 reviews the relevant literature; section 3 introduces

[2]Governmental behavior in both scenarios essentially hinges on our assumption of imperfect labor markets. A change in the contribution rate affects positively the negotiated gross wage. This effect in our model is essential for all results and serves as an important difference to inter-regional models with mobile workers in integrated perfect labor markets (see Wildasin, 1991, Kolmar, 1999, Wellisch, 2000 for similar questions about the optimal allocation of redistributive governmental functions in a federal setting).

the model; section 4 determines the social optimum; section 5 discusses the behavior of the trade union, the firm association and the government in a decentralized setting; section 6 proceeds with the centralized organization of unemployment insurance; and section 7 concludes.

2 Literature review

The issue of centralizing unemployment insurance in a state union is currently discussed from two perspectives. First, it is advocated as an instrument to cushion adverse macroeconomic shocks on member states in a state union (see Dolls et al., 2018 or Moyen et al., 2019 and their discussion of the related literature). National governments pay into a common supra-national budget. If a member state is adversely affected by a rising unemployment rate, this common unemployment insurance supports the respective state with transfer payments to the national social security budget. International risk-sharing levels out the business cycle.[3]

Our paper has to be placed in a second body of literature which focuses on the efficiency of the insurance itself, asking for example to what extent insurance against the risk of unemployment can be provided in the case that a common unemployment insurance system is introduced.

In the context of collective wage bargaining on the labor market, unemployment insurance may be organized either by the government or by trade unions themselves. In the latter case, the so-called Ghent system, trade unions determine the parameters of unemployment insurance. If the government subsidizes local insurance funds, Holmlund and Lundborg (1988, 1989) show that trade unions partially externalize the cost of bargaining for higher wages to other trade unions or sectors. Then, wages and unemployment are inefficiently high. In our model we come to a similar conclusion if we interpret states as sectors. Similar to our findings, Saha and Schöb (2019) identify a fiscal externality in such centralized unemployment insurance setting. At the labor-rent maximizing wage rate, full unemployment insurance cannot be provided. However, in contrast to our paper, governmental decision making is exogenous, and no migration incentives emerge for unemployed workers, the only group with partial mobility. We in

[3]Migration could have a similar effect to such a common reinsurance if mobility is very high and workers and firms relocate instantaneously in case of a downturn. Then, workers and firms transmit part of the economic burden to other member states such that the economic shock smoothes out, too. However, relocation is usually not instantaneous such that the common reinsurance budget has the advantage of faster transmission.

turn allow for the mobility of firms and the full labor force which then reveals an interesting interplay of migration effects and the fiscal externality. Under certain conditions, wage setting as well as governmental behavior are efficient.

In a theoretical model with minimum wages, Lozachmeur (2003) shows that decentralized governments strategically set contribution rates too low. This result is driven by the full mobility of low skilled workers which provides distortive incentives for governmental contribution rate setting. A decentralized setting is also considered by Saha and Schöb (2019) who investigate unemployment insurance in a Ghent system with pure welfare migration between sectors. To prevent welfare decreasing from immigration, the sector specific unions limit the generosity of unemployment insurance. Even though similar migration effects occur in our setting, we can show that the mobility of firms and the labor force does not affect the provision of full unemployment insurance. Furthermore, in our paper we consider unemployment insurance organized by state governments, where the trade unions only engage in wage negotiations.

Horizontal inter-jurisdictional externalities are well understood in the literature on fiscal federalism (see Zodrow and Mieszkowski, 1986, Wildasin, 1991 and Dahlby, 1996, among others). To maximize social welfare, governments set inefficiently low tax rates in order to attract a mobile tax base. In our paper, similar relocation effects occur with both types of unemployment insurance and with respect to wage and contribution rate setting. The interplay of horizontal and vertical fiscal externalities, in turn, were initially and extensively elaborated by Keen and Kotsogiannis (2002). For the case of local public goods and federal tax spending, they showed that each externality drives the local tax rates in opposite directions. Under certain conditions one externality may dominate the other such that the total effect on tax rate setting is unambiguous. In our paper, similar results are obtained in the noticeably different case of centralized unemployment insurance organization. Surprisingly, all externalities cancel each other out in the special case of full mobility and symmetric regions. Then, a centralized insurance system approaches the efficient solution, i.e. full insurance against the risk of unemployment.

3 Model

A state union is characterized by the option that some competences on policy decisions of the member states can be transferred to a supranational authority. In our model this is the option to assign the policy of unemployment insurance to a centralized supranational government. The state union consists of two states, $i = 1,2$. N identical individuals live and M identical firms produce in the state union. All individuals and firms are allocated to one of the two states:

$$M = m^1 + m^2 \tag{1}$$

$$N = n^1 + n^2 \tag{2}$$

with n^i for the number of individuals and m^i for the number of firms in either state.

3.1 Labor demand

All firms located in one of the two states are organized in a regional firm association. Each firm receives π^i as equal share of the total regional profit which is given by $\Pi^i = f^i(l^i) - w^i l^i$. Each firm is owned by an entrepreneur who consumes the profit.[4] The aggregate production function $f^i(l^i)$ is assumed to be continuous, monotonically increasing and strictly concave.[5] Furthermore, $f^i(0) = 0$. Optimal regional labor demand l^i in either state is determined by the firm association which maximizes profit per firm $\pi^i = \Pi^i/m^i$ in region i for a given gross wage level w^i. This yields the first-order condition

$$\frac{\partial \pi^i}{\partial l^i} = \frac{1}{m^i}\left(\frac{\partial f^i}{\partial l^i} - w^i\right) \stackrel{!}{=} 0 \tag{3}$$

The firm association weighs the marginal product against the marginal cost of an additional unit of labor and thereby maximizes the producer surplus. Furthermore, condition (3) implies $l^i(w^i)$

[4] Therefore a firm is synonymous with the entrepreneur and, in the following, enters the welfare function of the government.

[5] Considering aggregate production and labor demand allows us to take account of firm relocation effects in the objective functions of the wage bargain and the governments. Otherwise, e.g. with firm-level profit maximization these effects would cancel out in the case of identical firms.

with $\partial l^i/\partial w^i < 0$ because $\partial^2 f^i/\partial (l^i)^2 < 0$.[6]

3.2 Labor force

Each individual is endowed with one unit of labor supplied inelastically in the state of residence. The number of individuals n^i in either state is divided into the subgroups employed l^i and unemployed u^i:

$$n^i = l^i + u^i, \quad i = 1,2 \tag{4}$$

Following Harris and Todaro (1970), the probability of being employed is defined by $\frac{l^i}{n^i}$ and the probability of being unemployed by $\frac{u^i}{n^i} = \frac{n^i - l^i}{n^i}$. Ex ante, individuals do not know their labor market status. If they are employed, they receive a net wage $\tilde{w}^i \equiv w^i\left(1-t^i\right)$, where w^i represents the gross wage and t^i denotes the contribution rate of their unemployment insurance. If the individuals are unemployed, they receive an unemployment benefit b^i. Through their income, either the net wage or benefit, individuals finance consumption. The utility they draw from consumption is represented by a monotonically increasing and strictly concave utility function $U(\cdot)$. Hence, individuals are assumed to be risk averse and in favor of insurance against the risk of unemployment. The expected utility EU^i of an individual living in either state is given by

$$EU^i = \frac{l^i}{n^i} U(\tilde{w}^i) + \frac{n^i - l^i}{n^i} U(b^i), \quad i = 1,2 \tag{5}$$

3.3 Migration

Mobile individuals and firms relocate as long as their expected utilities or profits differ between the states. Both of them move to the state in which they have a higher expected utility EU^i or a higher profit π^i. The migration equilibrium is given when expected utilities as well as profits are equalized across states. With full mobility of all individuals and firms, the migration equilibria

[6] Later on we also take mobility of firms into account: e.g. $m^i(l^i)$. It can be shown that despite of additional mobility effects in condition (3), labor demand is still optimal if the marginal product of labor equals the gross wage.

are given by

$$\pi^1 - \pi^2 = 0 \tag{6}$$

$$EU^1 - EU^2 = 0 \tag{7}$$

Now assume that a certain amount of firms m^i_{immob} and individuals n^i_{immob} in each state is immobile such that the total numbers of immobile firms and individuals in the state union are given by $M_{immob} = m^1_{immob} + m^2_{immob} \leq M$ and $N_{immob} = n^1_{immob} + n^2_{immob} \leq N$. Then, the total number of mobile firms $M_{mob} \leq M$ and mobile individuals $N_{mob} \leq N$ in the state union is given exogenously, too, while the country-specific amounts of mobile firms m^i_{mob} and individuals n^i_{mob} are endogenous. Rewriting equations (1) and (2) yields

$$M = M_{immob} + M_{mob} = m^1_{immob} + m^2_{immob} + m^1_{mob} + m^2_{mob} \tag{8}$$

$$N = N_{immob} + N_{mob} = n^1_{immob} + n^2_{immob} + n^1_{mob} + n^2_{mob} \tag{9}$$

Obviously, only the mobile firms and individuals can respond with migration to changes in the unemployment insurance of a state, i.e. the contribution rate t^i, $m^i_{mob}\left(t^i\right)$ and $n^i_{mob}\left(t^i\right)$, while the number of immobile individuals and firms is constant. In either country, the share α^i of mobile firms is the ratio of m^i_{mob} to the number of all firms m^i. Equivalently, the share β^i of mobile households is defined as the ratio of n^i_{mob} to n^i which is identical to the ratio of mobile employed persons l^i_{mob} to all employed persons l^i:[7]

$$\alpha^i = \frac{m^i_{mob}}{m^i} = 1 - \frac{m^i_{immob}}{m^i} \tag{10}$$

$$\beta^i = \frac{n^i_{mob}}{n^i} = \frac{l^i_{mob}}{l^i} = 1 - \frac{n^i_{immob}}{n^i} \tag{11}$$

The number of mobile firms m^i_{mob} in state i is determined by the migration decision of firms. Firms have an expectation that a certain share $\bar{\alpha}^i$ of profits is distributed to mobile firms: $\Pi^i_{mob} =$

[7]The share of mobile firms and households can be interpreted as an indicator of migration cost. Assume each firm and household has a willingness to pay a certain cost of moving from one state to the other. This willingness to pay differs across all individuals. Only those firms and households are mobile and do migrate whose willingness to pay is higher than the migration cost. Thus, the share of mobile firms and households is higher the lower the actual cost of migration.

$\bar{\alpha}^i\Pi^i$. This share has to be distinguished carefully from the share of mobile firms in a state, α^i. On basis of this expectation the mobile firms migrate between the states until the profit per mobile firm is equalized. Then, for $M_{immob} < M$ the mobile firms' migration equilibrium is:

$$\frac{\bar{\alpha}^1\Pi^1}{m^1_{mob}} - \frac{\bar{\alpha}^2\Pi^2}{m^2_{mob}} = 0 \tag{12}$$

The adjustment process to the steady state migration equilibrium is as follows. The share of mobile firms after the first round of migration is given by $\alpha^i = \frac{m^i_{mob}}{m^i} = \frac{m^i_{mob}}{m^i_{mob}+m^i_{immob}}$, where m^i_{immob} is exogenously given. The share of mobile firms, α^i, may differ from the expected share of profits for mobile firms: $\bar{\alpha}^i \neq \alpha^i$. Assume that $\bar{\alpha}^i > \alpha^i$ after migration. Then the expected profit per mobile firm in state i is larger than the realized profit per mobile firm:

$$\frac{\bar{\alpha}^1\Pi^1}{m^1_{mob}} > \frac{\Pi^1}{m^1}.$$

The realized per-capita profits of the mobile firms are in each round of migration equal to the average profits of all firms because all firms (mobile and immobile) are identical and receive the same per-capita profit at each stage of the adjustment process to the steady state. Hence, in our example, the expectations will be adjusted and the expected share of profits will be reduced to the share of mobile firms: $\bar{\alpha}^i = \alpha^i$. This in turn creates a disequilibrium of migration in the next round. Again, migration takes place until the migration equilibrium is reached. Eventually the migration ends up in a steady state equilibrium where $\bar{\alpha}^i = \alpha^i$ and no further adjustments of the expected profits are necessary. This is the steady state we analyze in the following.[8]

Along the same lines, the number of mobile workers n^i_{mob} in state i is determined by the migration decision of workers. Workers expect that a certain share $\bar{\beta}^i$ of employment in state i is occupied by mobile individuals: $l^i_{mob} = \bar{\beta}^i l^i$. For $N_{immob} < N$, the workers' migration equilibrium is then given by

$$\frac{\bar{\beta}^1 l^1}{n^1_{mob}} U^1(\tilde{w}^1) + \frac{n^1_{mob} - \bar{\beta}^1 l^1}{n^1_{mob}} U^1\left(b^1\right) - \frac{\bar{\beta}^2 l^2}{n^2_{mob}} U^2(\tilde{w}^2) - \frac{n^2_{mob} - \bar{\beta}^2 l^2}{n^2_{mob}} U^2\left(b^2\right) = 0 \tag{13}$$

[8] In this steady state we can treat the share of mobile firms as exogenous because in the symmetric case of states it is equal to the exogenous overall share of mobile firms in the state union.

3.4 Unemployment insurance

Unemployment insurance may be organized either regionally in each state or centrally for the whole state union. In the former case, the budget constraint reads as

$$b^i(n^i - l^i) = t^i w^i l^i, \quad i = 1,2 \tag{14}$$

where the contribution rate t^i is the policy instrument of the regional government and the unemployment benefit b^i is determined as residual from the balanced budget. The left-hand side represents the total expenditure on unemployment benefits while the right-hand side shows the tax revenues paid by the employed. In the case of a centralized budget, a uniform benefit b^c and a uniform contribution rate t^c apply to both regions. The budget constraint is given by

$$b^c\left(N - l^1 - l^2\right) = t^c\left(w^1 l^1 + w^2 l^2\right) \tag{15}$$

The central government chooses the contribution rate of unemployment insurance t^c in order to maximize social welfare.

3.5 Wage negotiations

The labor market is characterized by unemployment. This enters the model by implementing symmetric Nash bargaining about the regional gross wage w^i.[9]

It is assumed that membership in the trade union or the firm association in either country encompasses all resident individuals n^i and firms m^i. We assume that wages and employment are determined separately in each state. This means the labor market integrates both states in the sense that the labor force and firms can move between them. However, the labor market is still separated due to localized wage bargaining in each state. If the migration of individuals and relocation of firms is possible, any change of residence implies a change of membership which is non-exclusive. Both negotiating parties then consider how their wage setting affects the relocation of mobile firms $m^i_{mob}(w^i)$ and the migration of mobile households $n^i_{mob}(w^i)$. Furthermore,

[9]We assume symmetric bargaining powers in the negotiations because it eases the calculus without affecting the general results of the paper.

they consider the budgets (14) or (15) of each government, take as given the contribution rates and account for optimal labor demand.[10] The objective function of the bargaining parties is given by the logarithmized Nash-product

$$\ln B^i = \ln \pi^i + \ln EU^i, \quad i = 1,2 \tag{16}$$

Without loss of generality, outside options are normalized to zero.[11]

3.6 Social optimum and governmental regimes

In the following parts of the paper we analyze and compare decentralized and centralized governmental decisions about unemployment insurance with respect to efficiency. First, we determine the social optimum where a social planner faces the same institutional framework as the governments with decentralized or centralized unemployment insurance, i.e. he cannot abolish the wage bargaining process between trade unions and firm associations or dissolve the regional integrity of the state union. However, the planner can allocate firms and workers directly between the states and he chooses optimal consumption levels. We use this social planner allocation as a benchmark for efficiency.

Then we analyze the following two regimes of unemployment insurance. The first regime is characterized by decentralization (dc) where each government of a member state decides autonomously and independently on the state unemployment insurance program. Borders between the states are open and the economies are integrated in a common labor market where individuals and firms are partially mobile. The second regime is characterized by a centralized (c) organization with a common unemployment insurance pool for all states within the state union. The central government sets the unitary parameters of the common unemployment insurance system, accounting for open borders and the partial migration of individuals and firms.

In both regimes, each of the governments is a Stackelberg leader with respect to wage setting

[10] With a large trade union and a sizeable firm association in each state, it is reasonable to assume that both negotiators recognize the impact of their decisions on the social security budget.

[11] Positive values of the outside options could be implemented but would only add redistributive effects, which is not a focus of this paper. For reasonable outside options under open borders, it can be shown that both parties prefer to take part in negotiations.

and takes into account the effect of the contribution rate on the gross wage level. The objective of the different governments as well as the social planner is to maximize the logarithmized Nash-Bernoulli social welfare function

$$\ln V^i = \ln \pi^i + \ln EU^i, \quad i = 1,2 \tag{17}$$

The governments' objectives are in line with the welfare objectives of the social groups. In particular, they do not follow their own redistributive goals. This implies that the welfare of both social groups is equally weighted.[12]

3.7 Sequence of decisions

At the first stage, the government decides on the contribution rate which maximizes a social welfare function. All other endogenous variables are taken into account by the government, including possible responses to migration. At the second stage, the negotiators of the wage bargain take as given the contribution rate. Like the government, they contemplate the effects of their wage setting on migration and relocation. If the wage is determined, the firm association decides at the third stage what number of workers it wishes to employ in the sector. Finally, at the fourth stage, workers decide whether to migrate between countries by comparing net wages and benefits, and firms decide on their location by balancing profits. The model is solved backwards. Table 1 summarizes the sequence of decisions.

Table 1: Sequence of decisions

Stage	Decision variable		Decision maker
1	Contribution rate:	t	Governments
2	Wage level:	w	Trade union/ Firm association
3	Employment:	l	Firm association
4	Migration:	n, m	Work force and firms

[12]The welfare function exhibits the same weights for the social groups of the labor force and the firms as the bargaining function. We have checked the implications of setting different weights. An additional effect arises (the so-called misrepresentation effect, see Fenge and Friese, 2018), both in the centralized and decentralized decisions about unemployment insurance, which does not affect the comparative results of both regimes.

4 Social optimum

The social planner faces the same institutional framework of the labor market as the governments with centralized and decentralized unemployment insurance. He is restricted by collective wage bargaining and profit-maximizing labor demand, as well as the regional integrity of the state union. He maximizes social welfare by choosing the consumption levels of the employed and the unemployed via the setting of the contribution rate t^i and the benefit level b^i, and allocating firms m^i and households n^i among the member states of the state union, with $i = 1,2$. Mobility restrictions do not apply to the social planner.

In the following sub-chapters we firstly derive the optimality condition for the gross wage and then consider the social planner's decision problem. The first-order conditions give us benchmarks to evaluate the solutions of the decentralized and centralized scenarios following in chapter 5 and 6. Most importantly, in this chapter we find that the restricted social planner chooses an actuarially fair contribution rate because this equalizes the marginal utilities between the two labor market statuses and maximizes social welfare. Full insurance against the risk of unemployment is provided.[13]

4.1 Wage bargaining

The bargaining parties, both the firm association and the trade union, maximize the Nash-product (16) subject to optimal labor demand given by condition (3):

$$\max_{w^i} \ln B^i = \ln\left(\frac{f^i(l^i) - w^i l^i}{m^i}\right) + \ln\left(\frac{l^i}{n^i} U^i\left(w^i(1-t^i)\right) + \frac{n^i - l^i}{n^i} U^i\left(\frac{t^i w^i l^i}{n^i - l^i}\right)\right) \tag{18}$$

with $l^i = l^i(w^i)$ from (3). The first-order condition is given by

$$\frac{d\ln B^i}{dw^i} = \underbrace{\frac{1}{\pi^i}\pi^i_{w^i}}_{\substack{\text{labor cost}\\ \text{effect}}} + \frac{1}{EU^i}\left(\underbrace{EU^i_{\tilde{w}^i}\tilde{w}^i_{w^i}}_{\substack{\text{net wage}\\ \text{effect}}} \underbrace{+EU^i_{l^i}\frac{\partial l^i}{\partial w^i}}_{\substack{\text{status}\\ \text{effect}}} \underbrace{+EU^i_{b^i}\left(b^i_{w^i} + b^i_{l^i}\frac{\partial l^i}{\partial w^i}\right)}_{\substack{\text{total benefit effect via}\\ \text{wage and employment}}}\right) \stackrel{!}{=} 0 \tag{19}$$

[13] We have checked the behavior of an unrestricted social planner and find that he would also choose an actuarial fair contribution rate.

with $\pi^i_{w^i} = -\frac{l^i}{m^i}$, $EU^i_{\tilde{w}^i} = \frac{l^i}{n^i} U^i_{\tilde{w}^i}$, $\tilde{w}^i_{w^i} = (1-t^i)$, $EU^i_{l^i} = \frac{1}{n^i}[U(\tilde{w}^i) - U(b^i)]$, $EU^i_{b^i} = \frac{n^i - l^i}{n^i} U^i_{b^i}$, $b^i_{w^i} = t^i \frac{l^i}{n^i - l^i}$, $b^i_{l^i} = t^i \frac{w^i n^i}{(n^i - l^i)^2}$, and condition (3) already taken into account.[14] The negotiated gross wage balances the marginal benefits from a wage increase with the marginal costs.[15] While the firm association considers the direct effect of a gross wage adjustment on the unit cost of employment, the *labor cost effect*, the trade union takes three effects into account: the *net wage effect* depicts the effect on the expected utility of the employed, the *status effect* the indirect impact on expected utility via the number of households that change their labor market status due to the wage adjustment, and the *total benefit effect via wage and employment* illustrates the wage effects on the benefit level, directly as well as indirectly via an adjustment of employment.

Rewriting condition (19) and suppressing the country index yields:

$$\frac{d \ln B}{dw} = -\frac{1}{\pi}\frac{l}{m} + \frac{1}{EU}\left(\frac{l}{n} U_{\tilde{w}}(1-t) + \frac{1}{n}[U(\tilde{w}) - U(b)]\frac{\partial l}{\partial w} + U_b \frac{b}{w}\left(\frac{n-l}{n} + \frac{\partial l}{\partial w}\frac{w}{l}\right)\right) \stackrel{!}{=} 0 \tag{20}$$

Condition (20) shows that the sign of the total benefit effect depends on the unemployment ratio and the elasticity of profit-maximizing labor demand with respect to the gross wage. There are two effects of a wage adjustment on the benefit level. On the one hand, it affects the taxable base, which decreases due to a wage increase if $1 < -\frac{\partial l^i}{\partial w^i}\frac{w^i}{l^i}$, and vice versa. Lower employment outweighs the higher wage level. On the other hand, a higher wage increases the number of beneficiaries because employment decreases. Thus, expenditures increase. Accounting for both effects yields the *total benefit effect*. The total effect of a higher gross wage on the benefit level is negative, if and only if $\frac{n^i - l^i}{n^i} < -\frac{\partial l^i}{\partial w^i}\frac{w^i}{l^i}$. In the following this effect is assumed to be negative for empirical reasons.[16]

[14] The partial derivative of the variable x with respect the variable y is denoted by $x_y := \partial x / \partial y$.

[15] We exclude corner solutions by assuming that the derivative of expected utility with respect to the gross wage is positive: $\frac{\partial EU^i}{\partial w^i} = EU^i_{\tilde{w}^i}\tilde{w}^i_{w^i} + EU^i_{l^i}\frac{\partial l^i}{\partial w^i} + EU^i_{b^i}\left(b^i_{w^i} + b^i_{l^i}\frac{\partial l^i}{\partial w^i}\right) > 0$. The derivative of profit per firm with respect to the gross wage is clearly negative: $\pi^i_{w^i} = -\frac{l^i}{m^i} < 0$.

[16] The value of the elasticity of labor demand with respect to the wage level, $\frac{\partial l^i}{\partial w^i}\frac{w^i}{l^i}$, measures approximately between -0.3 and -0.8 (Hamermesh, 1993). A more recent study of Lichter et al. (2015) finds a mean value of -0.197 in a meta-regression analysis. As unemployment rates typically have lower absolute values, the sum of the benefit effects is assumed to be negative.

4.2 Unemployment insurance

The social planner maximizes the social welfare function (17) by setting the contribution rate t^i subject to condition (19) as well as the number of firms (1) and individuals (2) in the state union. He faces the following optimization problem:

$$\max_{t^i,m^i,n^i} \sum_{i=1}^{2} \ln V^i = \sum_{i=1}^{2} \left[\ln \left(\frac{f^i(l^i) - w^i l^i}{m^i} \right) + \ln \left(\frac{l^i}{n^i} U \left(w^i (1-t^i) \right) + \frac{n^i - l^i}{n^i} U \left(\frac{t^i w^i l^i}{n^i - l^i} \right) \right) \right] \quad (21)$$

with $l^i = l^i(w^i)$, $w^i = w^i(t^i)$ and $m^j = M - m^i$, for $i, j = 1,2$ and $i \neq j$. The first-order condition regarding t^i is given by

$$\begin{aligned} \frac{d \ln V^i}{dt^i} = & \underbrace{\frac{1}{EU^i} \left(EU^i_{\tilde{w}^i} \tilde{w}^i_{t^i} + EU^i_{b^i} b^i_{t^i} \right)}_{\text{insurance condition}} + \frac{1}{\pi^i} \pi^i_{w^i} \frac{\partial w^i}{\partial t^i} \\ & + \frac{1}{EU^i} \left(EU^i_{\tilde{w}^i} \tilde{w}^i_{w^i} + EU^i_{l^i} \frac{\partial l^i}{\partial w^i} + EU^i_{b^i} \left(b^i_{w^i} + b^i_{l^i} \frac{\partial l^i}{\partial w^i} \right) \right) \frac{\partial w^i}{\partial t^i} \stackrel{!}{=} 0 \end{aligned} \quad (22)$$

where $\frac{\partial w^i}{\partial t^i} = -\frac{\partial^2 \ln B^i}{\partial w^i \partial t^i} / \frac{\partial^2 \ln B^i}{\partial w^i \partial w^i} > 0$ is assumed to be positive without loss of generality,[17] and $\tilde{w}^i_{t^i} = -w^i$ and $b^i_{t^i} = \frac{w^i l^i}{n^i - l^i}$. To maximize social welfare, the social planner's contribution rate must serve two purposes. First, it directly aims for optimal intra-group redistribution within the labor force, which is denoted by the *insurance condition*. And second, it must provide optimal inter-group redistribution between the labor force and the firms which is achieved by indirectly adjusting the gross wage level via the contribution rate setting.

The first term of the *insurance condition* denotes the marginal effect on the expected utility for an employed individual and the second term for an unemployed person. Thus, by changing the value of t^i, the social planner redistributes income between employment statuses within the labor force, i.e., between employed and unemployed. Applying the envelope theorem with respect to (19) reveals that this is actually the only target the social planner aims at:

$$\frac{d \ln V^i}{dt^i} = \frac{1}{EU^i} \frac{l^i}{n^i} w^i \left(U^i_{b^i} - U^i_{\tilde{w}^i} \right) \stackrel{!}{=} 0 \quad (23)$$

The social planner determines the contribution rate so that the marginal utility of the unem-

[17] Because $\frac{\partial^2 \ln B^i}{\partial w^i \partial w^i} < 0$ must hold to ensure an interior optimum of the Nash bargain, $\frac{\partial^2 \ln B^i}{\partial w^i \partial t^i} > 0$ is assumed.

ployment benefit balances against the marginal utility loss of the net wage. The indirect effects via the wage level $w^i(t^i)$ cancel out because the planner's objective function V^i is identical to the wage Nash bargaining function B^i. Therefore, for any given value of the contribution rate t^i, the resulting wage level $w^i(t^i)$ maximizes social welfare on decision stage two and no indirect intervention by the social planner is necessary. The contribution rate can be used just to solve the problem of optimal intra-group redistribution within the labor force. In the following we say that a unemployment insurance is efficient if it balances the marginal utilities of being employed and unemployed as in first-order condition (23). This is realized at the actuarial fair contribution rate which is equal to the unemployment probability. $t^i = \frac{n^i - l^i}{n^i}$.

The first-order condition regarding the number of firms in, say state 1, m^1 is given by

$$\sum_{i=1}^{2} \frac{d \ln V^i}{dm^1} = \frac{1}{\pi^1}\left(\pi^1_{m^1} + \pi^1_{w^1}\frac{\partial w^1}{\partial m^1}\right) + \frac{1}{\pi^2}\left(\pi^2_{m^2} + \pi^2_{w^2}\frac{\partial w^2}{\partial m^2}\right)\frac{\partial m^2}{\partial m^1} \stackrel{!}{=} 0 \tag{24}$$

with $\pi^i_{m^i} = -\frac{f^i - w^i l^i}{(m^i)^2}$, and $\partial w^i / \partial m^i$ being implicitly determined via the migration equilibrium (12), $i = 1,2$. The social planner balances the marginal costs and benefits that result from a change of the number of firms in state i. With symmetric states, an efficient allocation of firms that fulfills first-order condition (24) is achieved once they are equally distributed among states: $m^1 = m^2 = \frac{1}{2}M$.

The first-order condition regarding the number of individuals, say in state 1, n^1 is given by

$$\begin{aligned}\sum_{i=1}^{2} \frac{d \ln V^i}{dn^1} = {} & \frac{1}{EU^1}\left(EU^1_{n^1} + EU^1_{b^1} b^1_{n^1}\right) + \frac{1}{EU^1} EU^1_{w^1}\frac{\partial w^1}{\partial n^1} \\ & + \frac{1}{EU^2}\left(EU^2_{n^2} + EU^2_{b^2} b^2_{n^2}\right)\frac{\partial n^2}{\partial n^1} + \frac{1}{EU^2} EU^2_{w^2}\frac{\partial w^2}{\partial n^2}\frac{\partial n^2}{\partial n^1} \stackrel{!}{=} 0\end{aligned} \tag{25}$$

with $EU^i_{n^i} = \frac{l^i}{(n^i)^2}\left(U^i(\tilde{w}^i) - U^i(b^i)\right)$, $\frac{\partial b^i}{\partial n^i} = \frac{t^i w^i l^i}{(n^i - l^i)^2}$, and $\partial w^i / \partial n^i$ being implicitly determined via the migration equilibrium (13), $i = 1,2$. A change in the number of households in state 1 affects the expected utility in both regions directly via its impact on the likelihood of unemployment as well as indirectly via the adjustment of the gross wage. Furthermore, the adjustment of the unemployment benefit level produces an indirect effect. The social planner then chooses an allocation which balances the respective costs and benefits within the state union from an

additional inhabitant in region 1. For symmetric regions an equally distributed allocation of individuals results: $n^1 = n^2 = \frac{1}{2}N$.[18]

5 Decentralized unemployment insurance

This section considers collective wage bargaining and governmental contribution rate setting within a decentralized system of unemployment insurance. The firms and the labor force actively move between states which is taken into account by the negotiating parties as well as the government. Furthermore, each state government organizes its own unemployment insurance whose budget is known to local decision makers.

At first we show that due to the mobility of firms and workers the wage bargain is now accompanied by migrational effects. We will then demonstrate that, nevertheless, the decentral governments set an efficient contribution rate because the indirect wage effects do not distort the governmental decision making.

5.1 Wage bargaining

The firm association and the trade union in both states, $i = 1,2$, negotiate the gross wage level w^i to maximize the Nash bargaining function (16) subject to optimal labor demand (3), the decentralized budget (14), and the migration equilibria (12) and (13). The maximization problem is given by

$$\max_{w^i} \ln B^i = \ln\left(\frac{f^i(l^i) - w^i l^i}{m^i}\right) + \ln\left(\frac{l^i}{n^i} U\left(w^i(1-t^i)\right) + \frac{n^i - l^i}{n^i} U\left(\frac{t^i w^i l^i}{n^i - l^i}\right)\right) \tag{26}$$

[18] The assumption of symmetry implies that firms and individuals are equally allocated between states: $m^i = \frac{1}{2}M$ and $n^i = \frac{1}{2}N$. These specific allocations are efficient as they represent valid solutions to the respective first-order conditions $d\ln V^i/dm^i = 0$ and $d\ln V^i/dn^i = 0$. For the following cases of decentralized and centralized unemployment insurance schemes, the symmetry assumption implies that the allocation of firms and individuals among the states is also socially optimal.

with $l^i = l^i(w^i)$, $m^i = m^i_{immob} + m^i_{mob}(w^i)$, $n^i = n^i_{immob} + n^i_{mob}(w^i)$. The following first-order-condition results

$$\frac{d\ln B^i}{dw^i} = \frac{1}{\pi^i}\pi^i_{w^i}\left(1 - \alpha^i \underbrace{\frac{\frac{\partial \pi^i_{mob}}{\partial m^i_{mob}}}{\frac{\partial \pi^1_{mob}}{\partial m^1_{mob}} + \frac{\partial \pi^2_{mob}}{\partial m^2_{mob}}}}_{\text{mobility-profit factor}}\right) + \frac{1}{EU^i}\left(EU^i_{\tilde{w}^i}\tilde{w}^i_{w^i} + EU^i_{l^i}\frac{\partial l^i}{\partial w^i}\right.$$

$$\left. + EU^i_{b^i}\left(b^i_{w^i} + b^i_{l^i}\frac{\partial l^i}{\partial w^i}\right)\right)\left(1 - \beta^i \underbrace{\frac{\frac{\partial EU^i_{mob}}{\partial n^i_{mob}}}{\frac{\partial EU^1_{mob}}{\partial n^1_{mob}} + \frac{\partial EU^2_{mob}}{\partial n^2_{mob}}}}_{\text{mobility-utility factor}}\right) \stackrel{!}{=} 0 \tag{27}$$

with $\frac{\partial EU^i_{mob}}{\partial n^i_{mob}} = \left[-\frac{l^i}{(n^i)^2}\left[U^i(\tilde{w}^i) - U^i(b^i)\right] - \frac{n^i - l^i}{n^i}\frac{\partial U^i}{\partial b^i}\frac{t^i w^i l^i}{(n^i - l^i)^2}\right]\frac{1}{\beta^i}$ delineating the effect of a change of the number of mobile inhabitants on their expected utility for the respective state and $\frac{\partial \pi^i_{mob}}{\partial m^i_{mob}} = -\frac{1}{\alpha^i}\frac{\Pi^i}{(m^i)^2} < 0$ describing the effect of the number of firms on profit per firm.[19]

Like the social planner, the bargaining parties in the decentralized case take into consideration all direct and indirect wage effects: the labor cost effect of the firms and the net wage, status and benefit effects of the labor force (compare condition (19)). Additionally, open borders cause migration and relocation effects such that each wage effect is accompanied by an opposing mobility effect.

For firms the strength of these mobility effects depend on two factors: firstly, the share of mobile firms, α^1, and secondly, the *mobility-profit factor*. The higher the share of mobile firms in state 1, the greater the inclination of the firm association to increase profit per firm. The mobility-profit factor then indicates in which state the level of profit per firm is affected relatively stronger by the relocation of firms. An analogous interpretation applies to the workers and the *mobility-utility factor*.

Consider the case that the incentives given by firm mobility are stronger than that of the labor force: $\alpha^i \frac{\partial \pi^i_{mob}}{\partial m^i_{mob}} / \left(\frac{\partial \pi^1_{mob}}{\partial m^1_{mob}} + \frac{\partial \pi^2_{mob}}{\partial m^2_{mob}}\right) > \beta^i \frac{\partial EU^i_{mob}}{\partial n^i_{mob}} / \left(\frac{\partial EU^1_{mob}}{\partial n^1_{mob}} + \frac{\partial EU^2_{mob}}{\partial n^2_{mob}}\right)$. How does a wage rate increase affect both negotiating parties? First, note that without migration a higher wage increases expected household utility, and lowers firms' profits. Wage bargaining leads to a gross

[19]Note that a stable relocation equilibrium requires $\partial \pi^i_{mob}/\partial m^i_{mob} < 0$, which is satisfied in both scenarios. Similarly, for the workers $\partial EU^i_{mob}/\partial n^i_{mob} < 0$ has to hold, which we assume for both scenarios.

wage where the marginal benefit of households is equal to the marginal cost of the firm. Allowing for migration reduces both the utility increase of the households and the decrease of the firms' profits. As a wage increase in a state clearly benefits the labor force and harms the firms, this incentivizes workers to migrate to this state and encourages firms to relocate to the other state. Hence, the expected utility decreases and the profit per firm increases. Since in the case considered here households are more immobile than firms, the share by which the labor force increases due to immigration is relatively lower than the share of firms that leave the state. As a consequence of migration, the expected utility of households decreases by less than the increase of profits per firm. Thus, the dampening effect of migration on the increasing expected utility of households is smaller than its impact on the decreasing profit of firms. Generally, a higher degree of immobility improves the respective bargaining position of the negotiator, which we call the *advantage of relative immobility*.

In the case of symmetric states, the absolute impact of migration on expected utility is equally strong, such that the trade union in state 1 can realize exactly one half of its intended effect on expected utility in region 1. If regions are symmetric the first-order condition (27) becomes

$$\begin{aligned}\frac{d\ln B}{dw} = &-\frac{1}{\pi}\frac{l}{m}\left(1-\alpha\frac{1}{2}\right)+\frac{1}{EU}\left(\frac{l}{n}U_{\tilde{w}}(1-t)+\frac{1}{n}[U(\tilde{w})-U(b)]\frac{\partial l}{\partial w}\right.\\ &\left.+U_b\frac{b}{w}\left(\frac{n-l}{n}+\frac{\partial l}{\partial w}\frac{w}{l}\right)\right)\left(1-\beta\frac{1}{2}\right)\overset{!}{=}0\end{aligned} \tag{28}$$

The total effect of combining the direct wage and migration effects is as follows. The marginal benefit of households due to a higher wage becomes larger than the marginal cost of firms if α is greater than β in condition (28). This implies that the optimal wage must be higher if firms are more mobile than households. Since the total beneficial effect of higher wages for households is larger than the total cost effect on firms, households receive a higher weight in the bargaining process: $1-\alpha\frac{1}{2} < 1-\beta\frac{1}{2}$. As result of wage negotiations, the gross wage will be higher due to the advantage of the relative immobility of the labor force.

If both firms and the labor force are equally mobile ($\alpha = \beta$), the bargaining position of the firm association and the trade union driven by this mobility outweigh each other as migration exerts the same relative strength on gains and losses from a wage increase. Comparing the

first-order condition (20) to condition (28) then implies that wage setting in the decentralized scenario is efficient as long as firms and the labor force have the same degree of mobility: $\alpha = \beta$. With symmetry the following proposition holds.

Proposition 1. *In symmetric states, (a) the negotiated gross wage level in each state with decentralized unemployment insurance is efficient, if firms and workers are equally mobile:* $1 \geq \alpha = \beta \geq 0$. *Furthermore, (b) firms that are more mobile than workers will produce a wage level that is higher than the efficient level:* $1 \geq \alpha > \beta \geq 0$, *and vice versa.*

Proof. See appendix. ■

5.2 Decentralized governments

Each government in the state union sets a contribution rate t^i to maximize social welfare (17) in its region, $i = 1,2$, subject to optimal wage bargaining (27), optimal labor demand (3), the decentralized budget (14) and the migration equilibria (12) and (13):

$$\max_{t^i} \ln V^i = \ln\left(\frac{f^i(l^i) - w^i l^i}{m^i}\right) + \ln\left(\frac{l^i}{n^i} U\left(w^i(1-t^i)\right) + \frac{n^i - l^i}{n^i} U\left(\frac{t^i w^i l^i}{n^i - l^i}\right)\right) \tag{29}$$

with $l^i = l^i(w^i)$, $w^i = w^i(t^i)$, $m^i = m^i_{immob} + m^i_{mob}(t^i)$ and $n^i = n^i_{immob} + n^i_{mob}(t^i)$. The decentralized government's first-order condition is given by

$$\frac{d \ln V^i}{dt^i} = \frac{1}{EU^i} \frac{l^i}{n^i} w^i \left(U^i_{b^i} - U^i_{\tilde{w}^i}\right) \left(1 - \beta^i \frac{\frac{\partial EU^i_{mob}}{\partial n^i_{mob}}}{\frac{\partial EU^1_{mob}}{\partial n^1_{mob}} + \frac{\partial EU^2_{mob}}{\partial n^2_{mob}}}\right) \stackrel{!}{=} 0 \tag{30}$$

where the envelope theorem with respect to optimal wage setting (27) is already taken into account. All indirect effects of the contribution rate via wage and employment are internalized by wage negotiations, and the bargaining objective is aligned with the government's welfare objective. Hence, the government only considers the direct effect of the contribution rate on expected utility of the household.

Migration incentives due to the contribution rate concern only the labor force. Since the household migration affects the employed and unemployed population to the same degree, the

chosen contribution rate is not distorted and efficient. The following proposition for symmetric and asymmetric states results:

Proposition 2. *The decentralized decision of the government in either state, $i = 1,2$, yields the efficient contribution rate which provides full insurance against the risk of unemployment, irrespective of firms' and households' degrees of mobility.*

Proof. Consider condition (30) with symmetric regions $(i = 1 = 2)$ and divide by $\left(1-\beta\frac{1}{2}\right)$ where $0 \leq \beta \leq 1$. For any degree of household mobility then, (30) is equivalent to the efficiency condition (23). ■

Just like the social planner, the decentralized government balances the effect of the contribution rate on the marginal utility of the unemployment benefit with the marginal loss of utility derived from the net wage. This describes optimal intra-group redistribution within the labor force, and the first-order condition (30) is equivalent to the efficient solution, condition (23).

6 Centralized unemployment insurance

The following sections consider collective wage bargaining and the government setting of the contribution rate within a centralized unemployment insurance system. While collective wage bargaining is still decentralized in each state, unemployment insurance is now determined by a single institution: the central government. This means that for both states a uniform contribution rate applies and a uniform unemployment benefit is granted. A centralized budget balances the sum of contributions and expenditures from both states. Similar to the above scenarios, all decision makers take into account the mobility of firms and the labor force, and are aware of the central government's budget.

First, we show that besides migration effects, wage negotiations are affected by a fiscal externality because unemployment insurance revenues and expenditures are pooled now. Second, we show that the central government behaves generically inefficient and does not provide full insurance because the contribution rate is used to internalize the migration and fiscal effects that arise on the wage bargaining level.

6.1 Wage bargaining

The bargaining parties in each state, $i = 1,2$, negotiate independently the gross wage rate w^i in order to maximize the local Nash bargaining function (16) subject to optimal labor demand (3), the central budget (15) and the migration equilibria (12) and (13):

$$\max_{w^i} \ln B^i = \ln\left(\frac{f^i(l^i) - w^i l^i}{m^i}\right) + \ln\left(\frac{l^i}{n^i} U\left(w^i(1-t^c)\right) + \frac{n^i - l^i}{n^i} U\left(\frac{t^c w^1 l^1 + t^c w^2 l^2}{N - l^1 - l^2}\right)\right) \quad (31)$$

with $l^i = l^i(w^i)$, $m^i = m^i_{immob} + m^i_{mob}(w^i)$, $n^i = n^i_{immob} + n^i_{mob}(w^i)$. Taking condition (3) via the envelope theorem into account, the resulting first-order condition is

$$\begin{aligned}\frac{d\ln B^i}{dw^i} = {} & \frac{1}{\pi^i}\pi^i_{w^i}\left(1 - \alpha^i \frac{\frac{\partial \pi^i_{mob}}{\partial m^i_{mob}}}{\frac{\partial \pi^1_{mob}}{\partial m^1_{mob}} + \frac{\partial \pi^2_{mob}}{\partial m^2_{mob}}}\right) + \frac{1}{EU^i}\Bigg(EU^i_{\tilde{w}^i}\tilde{w}^i_{w^i} + EU^i_{l^i}\frac{\partial l^i}{\partial w^i} \\ & \underbrace{+ EU^i_{b^c}\left(b^c_{w^i} + b^c_{l^i}\frac{\partial l^i}{\partial w^i}\right)}_{\text{benefit effect minus vertical fiscal externality}}\Bigg)\left(1 - \beta^i \frac{\frac{\partial EU^i_{mob}}{\partial n^i_{mob}}}{\frac{\partial EU^1_{mob}}{\partial n^1_{mob}} + \frac{\partial EU^2_{mob}}{\partial n^2_{mob}}}\right) \\ & \underbrace{+ \frac{1}{EU^i} EU^j_{b^c}\left(b^c_{w^i} + b^c_{l^i}\frac{\partial l^i}{\partial w^i}\right)\beta^i \frac{\frac{\partial EU^i_{mob}}{\partial n^i_{mob}}}{\frac{\partial EU^1_{mob}}{\partial n^1_{mob}} + \frac{\partial EU^2_{mob}}{\partial n^2_{mob}}}}_{\text{reversed migration due to common benefit}} \stackrel{!}{=} 0\end{aligned} \quad (32)$$

with $b^c_{w^i} = t^c \frac{l^i}{N - l^i - l^j}$, $b^c_{l^i} = t^c \frac{w^i(N - l^j) + w^j l^j}{(N - l^i - l^j)^2}$ and $\frac{\partial EU^i_{mob}}{\partial n^i_{mob}} = -\frac{l^i[U^i(\tilde{w}^i) - U^i(b^c)]}{(n^i)^2}$ and $i, j = 1,2$, $i \neq j$. Negotiators consider the same wage effects – including the indirect effects via migration – as those with decentralized unemployment insurance programs. In particular, the labor cost effect on firms and the effects on the expected utility of households are accompanied by opposing migration effects. Whether these migration effects lead to higher or lower gross wages in the bargain depends again on the relative advantage of immobility: if firms are more immobile the negotiated wage decreases, and if households are more immobile the wage increases.

However, compared to the case of decentralized unemployment insurance systems, there are two additional effects on the wage bargaining outcome. First, centralized unemployment insurance is now characterized by a common pool which gives rise to a bottom-up *vertical fiscal externality* (compare Keen and Kotsogiannis, 2002) that induces excessive wages. Note that a

higher wage in region 1 reduces employment and increases unemployment: the number of those who receive the unemployment benefit grows and the number of contributors to the insurance program diminishes. If the effect of the direct wage increase on the basis of contributions is smaller than the negative effect via lower employment (or the wage elasticity of labor demand is smaller than -1, as is assumed here) the contribution base shrinks. The higher number of the unemployed and the subsequent reduction of total contributions causes an additional burden for unemployment insurance in state 1, which leads to lower benefits. This negative benefit effect constrains the ability of the wage bargaining parties in state 1 to negotiate higher wages. However, in a framework with centralized unemployment insurance this loss of benefits as a result of higher negotiated wages is now co-financed by the payments of contributors from the other state 2. State 1 no longer has to bear the full cost of lower benefits if it increases the gross wage. Hence, the expected utility reduction of the unemployed due to a higher wage is smaller than in the case of decentralized insurance: $\left|EU^i_{b^c}\left(b^c_{w^i}+b^c_{l^i}\frac{\partial l^i}{\partial w^i}\right)\right| < \left|EU^i_{b^i}\left(b^i_{w^i}+b^i_{l^i}\frac{\partial l^i}{\partial w^i}\right)\right|$. The vertical fiscal externality is the difference of both terms. In the special case of symmetric states the loss in benefit is half the loss in the decentralized case: $EU^i_{b^c}\left(b^c_{w^i}+b^c_{l^i}\frac{\partial l^i}{\partial w^i}\right)=\frac{1}{2}EU^i_{b^i}\left(b^i_{w^i}+b^i_{l^i}\frac{\partial l^i}{\partial w^i}\right)$. Therefore, with centralized unemployment insurance the benefit effect of reducing the negotiated wage rate is not as strong as in the decentralized case. Due to this effect, the trade union will reduce the wage level but since the effect is smaller the reduction is not quite as high as under the decentralized regime. In fact, the wage rate will be too high compared to the efficient wage rate in the scenario with decentralized unemployment insurance.

Second, the migration from state 1 to state 2 has a reverse counterpart because the centralized unemployment benefit decreases in both states if the wage in state 1 increases. Due to the lower benefit, households in state 2 also migrate to state 1, again reducing the probability of employment and the expected utility in state 1. This effect is described by the product of terms in the last summand of condition (32). Vice versa the same reasoning applies to region 2. However, if both states are symmetric, migration flows cancel each other out. For symmetric

states the first-order condition (32) becomes

$$\frac{d\ln B}{dw} = -\frac{1}{\pi}\frac{l}{m}\left(1-\alpha\frac{1}{2}\right)+\frac{1}{EU}\left(\frac{l}{n}U_{\tilde{w}}(1-t)+\frac{1}{n}[U(\tilde{w})-U(b)]\frac{\partial l}{\partial w}\right)\left(1-\beta\frac{1}{2}\right) \underbrace{+\frac{1}{EU}U_b\frac{b}{w}\left(\frac{n-l}{n}+\frac{\partial l}{\partial w}\frac{w}{l}\right)\frac{1}{2}}_{\text{vertical fiscal externality}} \tag{33}$$

What remains is a vertical externality described above that leads to unduly high negotiated gross wages in each state. Wage negotiators undervalue the negative effect of higher wages on the centralized unemployment benefit insofar as its reduction is shared by other states. Hence, in contrast to decentralized unemployment insurance, the gross wage with centralized unemployment insurance is too high and generically not efficient with the exception of two special cases:

Proposition 3. *In symmetric states, the negotiated gross wage level in each state with centrally organized unemployment insurance is efficient only in two special cases: (a) the share of mobile firms and workers approaches unity,* $\alpha = \beta \to 1$ *or, (b) in the case of* $0 \leq \alpha < \beta \leq 1$*, if the advantage of greater firm immobility compared to the cost of labor is outweighed by the trade union's incentive to increase labor costs by externalizing the cost of a higher wage rate on unemployment benefits. In all other cases, the wage bargaining in the states under a centralized unemployment insurance system is not efficient.*

Proof. See appendix. ■

Assume the full immobility of firms and households, that is $\alpha = \beta = 0$, and compare condition (33) to the corresponding social planner condition (20). In this special case, the only difference between both first-order conditions consists of the effect of a wage increase on the utility derived from the common unemployment benefit b^c. The cost of a wage increase in terms of the centralized unemployment benefit is halved in comparison to the social planner solution. The total benefit effect is multiplied by $\frac{1}{2}$. This means that, in comparison to socially efficient wage setting, the costs related to a wage increase are lowered such that the negotiated wage in the centralized scenario is higher than the socially efficient wage. This additionally holds true for all degrees of firm and household mobility, satisfying $0 \leq \beta \leq \alpha < 1$.

However, the difference between the higher centralized wage level and the socially efficient

wage level, say in state 1, melts down with an increasing degree of household mobility. The gains for the trade union from the exploitation of the vertical externality decrease because mobile households in state 2 react to this policy and are induced to migrate to state 1 due to the higher local wage level. The higher the degree of mobility, the greater the exodus from state 2 to state 1. Ceteris paribus, social welfare in state 1 then decreases due to the higher number of households among which the gains from the wage increase have to be distributed. This explains why a higher reverse migration further reduces the advantage of the cost externalization arising from higher wages in a centralized unemployment insurance system. At the limit $\alpha = \beta \to 1$, the reverse migration effect completely offsets this advantage, the vertical externality dissolves and wage setting in the centralized scenario approaches the socially efficient optimum.

6.2 Central government

The central government sets the uniform contribution rate t^c. In particular, its objective is to maximize the sum of social welfare (17) of the states subject to optimal local wage bargaining (32) with centralized unemployment insurance, optimal labor demand (3), the central budget (15) and the migration equilibria (12) and (13):

$$\max_{t^c} \sum_{i=1}^{2} \ln V^i = \sum_{i=1}^{2} \left[\ln \left(\frac{f^i(l^i) - w^i l^i}{m^i} \right) + \ln \left(\frac{l^i}{n^i} U\left(w^i(1-t^c)\right) + \frac{n^i - l^i}{n^i} U\left(\frac{t^c w^1 l^1 + t^c w^2 l^2}{N - l^1 - l^2} \right) \right) \right] \tag{34}$$

with $l^i = l^i(w^i)$, $w^i = w^i(t^c)$, $m^i = m^i_{immob} + m^i_{mob}(t^c)$, $n^i = n^i_{immob} + n^i_{mob}(t^c)$, $m^j = M - m^i$ and $n^j = N - n^i$. By setting the common contribution rate, all those first-order effects of welfare-maximization in either state, say i, cancel out which run via this state's wage rate because these effects are already internalized by wage bargaining in state i (envelope theorem via (32)). The central government still must observe the direct effects of the contribution rate setting (common

insurance), the indirect effects via the wage rate in the other state j and the migration responses:

$$\sum_{i=1}^{2}\frac{d\ln V^i}{dt^c}=\sum_{\substack{i,j=1\\ i\neq j}}^{2}\Bigg[\underbrace{\frac{1}{EU^i}\left(EU^i_{\tilde{w}^i}\tilde{w}^i_{t^c}+EU^i_{b^c}b^c_{t^c}\right)\left(1-\beta^i\frac{\frac{\partial EU^i_{mob}}{\partial n^i_{mob}}}{\frac{\partial EU^1_{mob}}{\partial n^1_{mob}}+\frac{\partial EU^2_{mob}}{\partial n^2_{mob}}}\right)}_{\text{insurance in state i net of migration}}$$

$$\underbrace{+\frac{1}{EU^i}\left(EU^j_{\tilde{w}^j}\tilde{w}^j_{t^c}+EU^j_{b^c}b^c_{t^c}\right)\beta^i\frac{\frac{\partial EU^i_{mob}}{\partial n^i_{mob}}}{\frac{\partial EU^1_{mob}}{\partial n^1_{mob}}+\frac{\partial EU^2_{mob}}{\partial n^2_{mob}}}}_{\text{migration in state j due to common insurance}}\underbrace{+\frac{1}{\pi^i}\pi^j_{w^j}\frac{\partial w^j}{\partial t^c}\alpha^i\frac{\frac{\partial \pi^i_{mob}}{\partial m^i_{mob}}}{\frac{\partial \pi^1_{mob}}{\partial m^1_{mob}}+\frac{\partial \pi^2_{mob}}{\partial m^2_{mob}}}}_{\substack{\text{relocation of firms due to}\\ \text{labor cost effect in state j}}}$$

$$\underbrace{+\frac{1}{EU^i}\left(EU^j_{\tilde{w}^j}\tilde{w}^j_{w^j}+EU^j_{l^j}\frac{\partial l^j}{\partial w^j}+EU^j_{b^c}\left(b^c_{w^j}+b^c_{l^j}\frac{\partial l^j}{\partial w^j}\right)\right)\frac{\partial w^j}{\partial t^c}\beta^i\frac{\frac{\partial EU^i_{mob}}{\partial n^i_{mob}}}{\frac{\partial EU^1_{mob}}{\partial n^1_{mob}}+\frac{\partial EU^2_{mob}}{\partial n^2_{mob}}}}_{\text{migration due to net wage/status/benefit effects in state j}}$$

$$\underbrace{+\frac{1}{EU^i}EU^i_{b^c}\left(b^c_{w^j}+b^c_{l^j}\frac{\partial l^j}{\partial w^j}\right)\frac{\partial w^j}{\partial t^c}\left(1-\beta^i\frac{\frac{\partial EU^i_{mob}}{\partial n^i_{mob}}}{\frac{\partial EU^1_{mob}}{\partial n^1_{mob}}+\frac{\partial EU^2_{mob}}{\partial n^2_{mob}}}\right)}_{\text{internalization of vertical externality in state i via wage in state j net of migration}}\Bigg]\stackrel{!}{=}0 \tag{35}$$

with $b^c_{t^c}=\frac{w^i l^i+w^j l^j}{N-l^i-l^j}$ and $\tilde{w}^i_{t^c}=-w^i$. The first two summands in condition (35) show how, net of migration, the central government provides common unemployment insurance in order to optimally redistribute between the employed and the unemployed populations of each state. The remaining summands describe the government's attempts to internalize welfare-reducing distortions on the wage bargaining level: first, the externalities of the migration of firms and households; and second, the trade union's exploitation of the vertical fiscal externality. Disposing of one instrument to achieve these three goals causes the following distortions.

The central government aims at full insurance (the efficient solution) by setting fairly the contribution rate of unemployment insurance. This means incomes in both statuses on the labor market, employed and unemployed, must be equal. However, the central government can only set a common benefit level in both member states. With a common contribution rate the government cannot take full account of asymmetric state specific conditions. This effect of a common policy for asymmetric states in a state union is well-known. In a federal setting, the deadweight loss from centralization has been shown by Oates (1972). Hence, the central government cannot succeed in providing full insurance unless both states are symmetric and

have, in equilibrium, the same probability of unemployment.[20] Furthermore, the insurance, or the setting of the contribution rate to provide full insurance, is distorted by migration between the states (see first two summands in (35)). If the states are symmetric, the migration responses to the insurance effect cancel each other out.[21]

But even with symmetric states there are further distortions due to centralized decisions about unemployment insurance, preventing full insurance. Maximizing the welfare of one state (say state 1) by setting a common contribution rate must account for changes in the wage rate of the other state 2 as a result of its local wage bargaining.

First, the advantage of relative immobility distorts the wages in both states and a central government has to consider the repercussions of migration in both states on their welfare. In the decision about the common contribution rate, the central government already accounts for the effects of migration on wage bargaining in state 1 (envelope theorem). However, there are also migration externalities of both, firms and households, in state 2 which are not yet internalized. From the viewpoint of welfare in state 1, the central government addresses those migration externalities by using the common contribution rate. A higher contribution rate increases the wage in state 2 as a result of wage bargaining, and a lower contribution rate induces the opposite result. Contingent on the relative immobility of firms and households, the wage bargaining in state 2 generates higher or lower wages and the contribution rate must be adjusted accordingly. If households are more immobile than firms, $\alpha^i \frac{\partial \pi^i_{mob}}{\partial m^i_{mob}} / \left(\frac{\partial \pi^1_{mob}}{\partial m^1_{mob}} + \frac{\partial \pi^2_{mob}}{\partial m^2_{mob}} \right) > \beta^i \frac{\partial EU^i_{mob}}{\partial n^i_{mob}} / \left(\frac{\partial EU^1_{mob}}{\partial n^1_{mob}} + \frac{\partial EU^2_{mob}}{\partial n^2_{mob}} \right)$, the wage in state 2 increases due to the advantage of relative immobility. This migration externality can be internalized by the government if the contribution rate is reduced which diminishes the wage rate in state 2. In this case, the share of households that migrate to state 1 is smaller than the share of firms that leave state 1. Thus, expected utility will decrease by less than profits per firm increase so that the

[20] If a persistent subsidization and therefore ex ante redistribution is to be avoided with centralized unemployment insurance, a certain degree of symmetry is required across the participating countries. Otherwise, the insurance aspects will be diluted with distributional considerations.

[21] Note that even with two distinct contribution rates, t^1 and t^2, and benefit levels, b^1 and b^2, distortions remain in the case of a centralized unemployment insurance. The vertical fiscal externality occurs due to the common budget and not due to common contribution and benefit levels. Furthermore, the central government still had to internalize migration externalities that would arise on the wage bargaining level. With asymmetric states, even the condition for full insurance could not be achieved with country-specific instruments because the contribution rate in, say state 1, still affected the welfare of the unemployed in country 2 via the common budget.

welfare in state 1 increases with a lower contribution rate. If firms are more immobile, state 1 improves its welfare if it increases the common contribution rate. This is the internalization of the externalities of migration on welfare in state 1 which arise due to the advantage of relative immobility in state 2. The same reasoning applies when maximizing the welfare of state 2.

Second, there is the effort of the central government to internalize the vertical fiscal externality that – as we have shown – arises at the level of wage bargaining under a centralized unemployment insurance program. Due to the common budget, the trade union in state 2 negotiates a wage level that is inefficiently high such that the level of the common unemployment benefit is inefficiently low. Thereby, the welfare in state 1 is adversely affected. In order to decrease wages, the central government uses the common contribution rate. This intent is described by the last summand in condition (35). Since the common contribution rate affects the wage rate in state 2, the central government sets a lower contribution rate to decrease wages in state 2. This increases employment in state 2 and, hence, the common unemployment benefit in both states and the welfare in state 1. However, there is again an opposing migration effect because lowering the wage in state 2 and increasing the benefit raises the expected utility in state 1 and generates migration of households to state 1. This in turn reduces employment probability and expected utility so that the increase in welfare is cushioned. This restrains any impulse to lower the contribution rate by too much. The more mobile the labor force, the stronger the migration induced by a wage increase in state 2. Ceteris paribus, this migration enhances the welfare of region 1 and diminishes it in region 2. Thus, the trade union's intent to increase the wage level in state 2 is mitigated and the distortion to be internalized is weaker. Indeed, if work force mobility β^i, with $i = 1,2$, approaches unity, the gains of the trade union in region 2 from a wage increase induced by the common budget are completely offset by the welfare effects of the inflow of workers from state 1, and the vertical externality is completely outweighed.[22]

The overall incentives show that the central government sets an overly reduced contribution rate compared to the socially optimal rate due to the internalization of the vertical externality. In addition, the contribution rate may be distorted downwards or upwards depending on the relative immobility of households and firms. If the states are symmetric, the condition yielding

[22]This can be seen by substituting the first-order condition (32) into condition (35).

full insurance remains distorted by those two effects, impeding an efficient decision on the contribution rate with centralized unemployment insurance. With symmetry first-order condition (35) becomes

$$\frac{d\ln V}{dt^c} = \underbrace{\frac{1}{EU}\frac{l}{n}w\left(U_b - U_{\tilde{w}}\right)}_{\text{full insurance}} \underbrace{-\frac{1}{\pi}\frac{l}{m}\frac{\alpha-\beta}{2-\beta}\frac{\partial w}{\partial t^c}}_{\substack{\text{advantage of}\\ \text{relative immobility}}}$$
$$\underbrace{+\frac{1}{EU}U_b\frac{b^c}{w}\left(\frac{n-l}{n}+\frac{w}{l}\frac{\partial l}{\partial w}\right)\frac{1-\beta}{2-\beta}\frac{\partial w}{\partial t^c}}_{\text{internalization of vertical fiscal externality}} \stackrel{!}{=} 0 \tag{36}$$

and the following proposition holds

Proposition 4. *In symmetric states, a centrally organized unemployment insurance program is efficient in two special cases: (a) the share of mobile firms and households in the state union approaches unity, $\alpha = \beta \to 1$, or (b) in the case of $0 \leq \alpha < \beta \leq 1$, the effects of the migration externalities on the contribution rate have the same absolute strength as the effect of the vertical externality. In all other cases, the central government cannot provide full insurance against the risk of unemployment.*

Proof. See appendix. ■

The first-order condition with symmetric regions (36) shows that in order to internalize the vertical fiscal externality the central government adjusts the contribution rate less strong if the share β of mobile worker increases. In the special case that worker mobility approaches unity, $\beta \to 1$, no vertical externality occurs. Open borders and migration prevent the trade union from externalizing cost from state 2 to state 1, and no governmental intervention is required to maximize social welfare. If in addition the share of mobile firms approaches unity, then neither firms nor workers can take advantage of relative immobility. The migration externalities, which originate from wage bargaining in state 2 and adversely affect welfare in state 1, have the same relative strength such that the wage level in state 2 is not distorted and no inefficient migration of either firms or workers is induced. For $\alpha = \beta \to 1$ the common contribution rate t^c then needs to serve only a single purpose: optimal labor force insurance. First-order condition (36)

approaches the efficiency condition (23).[23]

Up to this point, we have shown that a centralized unemployment insurance system induces a vertical fiscal externality at the level of wage bargaining in the states because negotiators can partly externalize the cost of higher wages and therefore increase them above efficient levels. As a consequence, the central government attempts to internalize the vertical externality and sets the contribution rate lower than would be optimal in order to bring down excessive wages. In addition, the contribution is distorted by the advantage of relative immobility. These distorting effects arise because of the common pool character of the insurance market, which allows for the externalization of costs via the indirect effects of wages in the other state. The asymmetric federal design of a centralized unemployment insurance mixed with a decentralized wage bargaining within states is the reason for the vertical fiscal externality and the advantage of relative immobility. Both effects vanish if the symmetry of centralization (or decentralization) of institutions on all federal levels is restored. In our setting the distortion of governmental behavior can be healed by centralizing the wage negotiations in the state union. Then, the trade unions and firm associations of both states determine a common wage level for the state union. All indirect effects via wages are internalized from the viewpoint of the central government because they are taken care of in a centralized wage bargaining system. What remains is the insurance condition. With asymmetric states the central government cannot provide full insurance in both states because the employment probabilities of the labor force are still conditional on the place of residence. Therefore, unless regions merge, centralized government behavior is efficient only in the symmetric case:

Proposition 5. *In symmetric states, a centrally organized unemployment insurance system is efficient, if collective wage bargaining is also centralized and yields a common wage level for the whole state union.*

Proof. See appendix. ■

The centralization of unemployment insurance is accompanied by several distortions which

[23] Due to stability requirements the special case of $\alpha = \beta = 1$ cannot be considered. For full mobility of firms and workers the migration equilibria had either no solution or an infinite number of solutions, because with full mobility the central government was induced to set a fair contribution rate such that $\partial EU^i/\partial n^i = 0$, which is excluded. However, valid migration equilibria are defined for values of t^c around the fair contribution rate.

make it generically inefficient. A main reason for this result is the non-alignment of the levels on which decision making takes place. Decentralized wage determination and centralized contribution rate setting causes migration and fiscal externalities. Aligning the decision-making process eliminates these distortions. However, the asymmetry of states ultimately prevents the accomplishment of an efficient solution via a single governmental policy instrument.

7 Conclusion

Should unemployment insurance be centralized in a state union? This paper presents two answers. The first answer is that it depends on the degree of mobility of households and firms between the member states of the state union. Only with perfect mobility is the centralized organization of unemployment insurance efficient and equivalent to the decentralized organization in the member states. In this case migration offsets the vertical fiscal externality that arises from the pooled budget of a centralized insurance. In all other cases, if there are any costs of migration, like administrative obstacles, language barriers, cultural distinctions, etc., the decentralized insurance systems of the states are superior in terms of efficiency to centralized insurance at the union level.

The second answer is that centralized unemployment insurance is only inferior to decentralized state insurance if wage bargaining within state labor markets remains decentralized. This setting creates the vertical fiscal externality and all included migration effects that would vanish if wage bargaining took place centrally and a uniform wage were negotiated for the whole state union. In this case, centralized unemployment insurance would become efficient.

This may explain why a centralized unemployment insurance in a federal nation can be justified for reasons of efficiency if a nation's internal mobility is very high or if wage setting is also centralized with binding standard wages nationwide. At the same time, a supranational organization could be rejected on the same grounds if those conditions do not apply.

For the example of the European Union this means that national unemployment schemes in the federal member states may be efficient while a European unemployment insurance may be not for the same reasons. Thus the European Union could implement an efficient common unemployment insurance only if either impediments of migration of workers and firms would

be eliminated or at least significantly reduced, or if the member states of the EU would accept to transfer also the competence of collectively wage bargaining on the labor markets to the EU-level. This would mean a central wage bargaining determines wages on the labor markets of all member states.

This discussion gives rise to a wider perspective on efficient fiscal-federal structures of a state union. If the budget of an institution (like unemployment insurance) affects collective decision-making (like wage negotiations) then both, the decision making and the institution, should be assigned to the same federal level of a state union. Otherwise, fiscal externalities may emerge that render the policies inefficient. Thus, a principle of efficient federal systems might be that fiscally linked economic policies and institutions should be ruled on the same federative layer: centrally or decentrally. This issue is left for further investigation in our future research.

Appendix I: Proofs of propositions

Proof of Proposition 1

Part (a): Consider condition (28) and evaluate at $0 \leq \alpha = \beta \leq 1$. Dividing by $\left(1-\beta\frac{1}{2}\right)$ then yields the social planner condition (20). Part (b): Consider condition (28) and evaluate at $0 \leq \alpha < \beta \leq 1$. In comparison to the socially efficient condition (20) then, costs from a wage increase related to profit per firm are always evaluated higher than the gains for expected utility because $1-\alpha\frac{1}{2} > 1-\beta\frac{1}{2}$. Thus the negotiated wage level is lower than in the social planner's case. ■

Proof of Proposition 3

Part (a): Consider condition (33) and evaluate at $\alpha = \beta \to 1$. Dividing by $\frac{1}{2}$ then yields the efficiency condition (20). Part (b): Consider condition (33) and evaluate at $0 \leq \beta \leq \alpha < 1$ such that $1-\alpha\frac{1}{2} \leq 1-\beta\frac{1}{2}$. Dividing by $\left(1-\beta\frac{1}{2}\right)$ then shows that in the case with centrally organized unemployment insurance, the costs of a wage increase related to the benefits and the profit per firm are evaluated lower than in the social planner case. Thus, the negotiated wage level is higher than in the efficient case. Now evaluate at $0 \leq \alpha < \beta < 1$ such that $1-\alpha\frac{1}{2} > 1-\beta\frac{1}{2}$. Dividing by $\left(1-\beta\frac{1}{2}\right)$ and comparing to the socially efficient first-order condition (20) shows

that the effect of a wage adjustment on the profit per firm is evaluated at a higher level, while the effect on the unemployment benefit is evaluated at a lower one. Effects on the net wage and the labor market status are weighed equally. Then, any combination of mobility degrees $0 \leq \alpha < \beta \leq 1$, which yields a relative advantage of firm immobility whose negative effect on the negotiated wage rate outweighs the positive trade union's intent to negotiate a higher wage, implies that centralized wage bargaining is efficient. ■

Proof of Proposition 4

Part (a): Evaluate condition (36) at $\alpha = \beta \to 1$. Then, $\frac{d \ln V}{dt^c} = \frac{1}{EU} \frac{l}{n} w \left(U_{b^c} - U_{\tilde{w}}\right) \stackrel{!}{=} 0$, which is equivalent to the social planner's condition for providing unemployment insurance. Part (b): In the case of $0 \leq \alpha < \beta \leq 1$, the second term in condition (36) has the opposite sign of the third term in condition (36). Any combination of mobility degrees $0 \leq \alpha < \beta \leq 1$, which equalizes the absolute strength of both terms, implies that the central government provides full insurance against the risk of unemployment. ■

Proof of Proposition 5

Consider the maximization problem (34) of the central government and assume $w^1 = w^2$. Under the condition of symmetric objective functions in collective wage bargaining and social welfare maximization, the envelope theorem states that no indirect effect of the contribution rate on the common wage level enters the first-order condition of the central government. Then, only the government's direct effects remain. Due to different budgetary conditions, it follows directly that only in the case of symmetry the governmental first-order condition coincides with that of the constrained social planner. ■

Appendix II: Migration and relocation responses

1. Firm relocation in the decentral scenario

With decentral unemployment insurance, the relocation responses of the firms, (a) dm^i_{mob}/dl^i, (b) dm^i_{mob}/dw^i and (c) dm^i_{mob}/dt^i are obtained as follows.

The firms' relocation equilibrium is given by

$$F \equiv \frac{\bar{\alpha}^1 \Pi^1}{m^1_{mob}} - \frac{\bar{\alpha}^2 \Pi^2}{m^2_{mob}} = 0 \tag{37}$$

where $\Pi^i = (f^i(l^i) - w^i l^i)$, $l^i = l^i(w^i)$, $w^i = w^i(t^i)$ with $i = 1,2$, and $m^j_{mob} = M_{mob} - m^i_{mob}$, with $i, j = 1,2$ and $i \neq j$.

Part (a):

Taking the differentials with respect to m^i_{mob} and l^i in equation (37) yields

$$-dm^i_{mob} \sum_{i=1}^{2} \frac{\bar{\alpha}^i (f^i(l^i) - w^i l^i)}{(\alpha^i m^i)^2} + dl^i \frac{\bar{\alpha}^i \left[\frac{\partial f^i}{\partial l^i} - w^i\right] \alpha^i m^i}{(\alpha^i m^i)^2} = 0 \tag{38}$$

Assume $\bar{\alpha}^i = \alpha^i$. Then:

$$\frac{dm^i_{mob}}{dl^i} = -\frac{\frac{1}{m^i}\left(\frac{\partial f^i}{\partial l^i} - w^i\right)}{-\sum_{i=1}^{2} \frac{\Pi^i}{(m^i)^2} \frac{1}{\alpha^i}} \tag{39}$$

Part (b):

Taking the differentials with respect to m^i_{mob} and w^i in equation (37) yields

$$-dm^i_{mob} \sum_{i=1}^{2} \frac{\bar{\alpha}^i \Pi^i}{(\alpha^i m^i)^2} + dw^i \frac{\bar{\alpha}^i \left(\left[\frac{\partial f^i}{\partial l^i} - w^i\right] \frac{\partial l^i}{\partial w^i} - l^i\right) \alpha^i m^i}{(\alpha^i m^i)^2} = 0 \tag{40}$$

Assume $\bar{\alpha}^i = \alpha^i$ and apply envelope theorem w.r.t. optimal labor demand. Then:

$$\frac{dm^i_{mob}}{dw^i} = -\frac{-\frac{l^i}{m^i}}{-\sum_{i=1}^{2}\frac{\Pi^i}{(m^i)^2}\frac{1}{\alpha^i}} \tag{41}$$

Part (c):

Taking the differentials with respect to m^i_{mob} and t^i in equation (37) yields

$$-dm^i_{mob}\sum_{i=1}^{2}\frac{\bar{\alpha}^i\Pi^i}{(\alpha^i m^i)^2} + dt^i\frac{\bar{\alpha}^i\left(\left[\frac{\partial f^i}{\partial l^i} - w^i\right]\frac{\partial l^i}{\partial w^i} - l^i\right)\alpha^i m^i}{(\alpha^i m^i)^2}\frac{\partial w^i}{\partial t^i} = 0 \tag{42}$$

Assume $\bar{\alpha}^i = \alpha^i$ and apply envelope theorem w.r.t. optimal labor demand. Then:

$$\frac{dm^i_{mob}}{dt^i} = -\frac{-\frac{l^i}{m^i}}{-\sum_{i=1}^{2}\frac{\Pi^i}{(m^i)^2}\frac{1}{\alpha^i}}\frac{\partial w^i}{\partial t^i} \tag{43}$$

2. Firm relocation in the central scenario

With central unemployment insurance, the relocation responses of the firms, (a) dm^i_{mob}/dl^i, (b) dm^i_{mob}/dw^i and (c) dm^i_{mob}/dt^c are obtained as follows.

$$F \equiv \frac{\bar{\alpha}^1\Pi^1}{m^1_{mob}} - \frac{\bar{\alpha}^2\Pi^2}{m^2_{mob}} = 0 \tag{44}$$

where $\Pi^i = (f^i(l^i) - w^i l^i)$, $l^i = l^i(w^i)$, $w^i = w^i(t^c)$ with $i = 1,2$, and $m^j_{mob} = M_{mob} - m^i_{mob}$, with $i, j = 1,2$ and $i \neq j$.

Part (a):

Taking the differentials with respect to m^1_{mob} and l^1 in equation (44) yields

$$-dm^i_{mob}\sum_{i=1}^{2}\frac{\bar{\alpha}^i(f^i(l^i) - w^i l^i)}{(\alpha^i m^i)^2} + dl^i\frac{\bar{\alpha}^i\left[\frac{\partial f^i}{\partial l^i} - w^i\right]\alpha^i m^i}{(\alpha^i m^i)^2} = 0 \tag{45}$$

Assume $\bar{\alpha}^i = \alpha^i$. Then:

$$\frac{dm^i_{mob}}{dl^i} = -\frac{\frac{1}{m^i}\left(\frac{\partial f^i}{\partial l^i} - w^i\right)}{-\sum_{i=1}^{2} \frac{\Pi^i}{(m^i)^2}\frac{1}{\alpha^i}} \tag{46}$$

Part (b):

Taking the differentials with respect to m^i_{mob} and w^i in equation (44) yields

$$-dm^i_{mob}\sum_{i=1}^{2}\frac{\bar{\alpha}^i\Pi^i}{(\alpha^i m^i)^2} + dw^i\frac{\bar{\alpha}^i\left(\left[\frac{\partial f^i}{\partial l^i} - w^i\right]\frac{\partial l^i}{\partial w^i} - l^i\right)\alpha^i m^i}{(\alpha^i m^i)^2} = 0 \tag{47}$$

Assume $\bar{\alpha}^i = \alpha^i$ and apply envelope theorem w.r.t. optimal labor demand. Then:

$$\frac{dm^i_{mob}}{dw^i} = -\frac{-\frac{l^i}{m^i}}{-\sum_{i=1}^{2} \frac{\Pi^i}{(m^i)^2}\frac{1}{\alpha^i}} \tag{48}$$

Part (c):

Taking the differentials with respect to m^i_{mob} and t^c in equation (44) yields

$$\begin{aligned} &-dm^i_{mob}\sum_{i=1}^{2}\frac{\bar{\alpha}^i\Pi^i}{(\alpha^i m^i)^2} + dt^c\frac{\bar{\alpha}^i\left(\left[\frac{\partial f^i}{\partial l^i} - w^i\right]\frac{\partial l^i}{\partial w^i} - l^i\right)\alpha^i m^i}{(\alpha^i m^i)^2}\frac{\partial w^i}{\partial t^c} \\ &-dt^c\frac{\bar{\alpha}^j\left(\left[\frac{\partial f^j}{\partial l^j} - w^j\right]\frac{\partial l^j}{\partial w^j} - l^j\right)\alpha^j m^j}{(\alpha^j m^j)^2}\frac{\partial w^j}{\partial t^c} = 0 \end{aligned} \tag{49}$$

Assume $\bar{\alpha}^i = \alpha^i$ and apply envelope theorem w.r.t. optimal labor demand. Then:

$$\frac{dm^i_{mob}}{dt^c} = -\frac{-\frac{l^i}{m^i}}{-\sum_{i=1}^{2} \frac{\Pi^i}{(m^i)^2}\frac{1}{\alpha^i}}\frac{\partial w^i}{\partial t^c} + \frac{-\frac{l^j}{m^j}}{-\sum_{i=1}^{2} \frac{\Pi^i}{(m^i)^2}\frac{1}{\alpha^i}}\frac{\partial w^j}{\partial t^c} \tag{50}$$

3. Labor migration in the decentral scenario

With decentral unemployment insurance, the migration responses (a) dn^i_{mob}/dw^i and (b) dn^i_{mob}/dt^i of the work force are obtained as follows.

$$F \equiv \frac{\bar{\beta}^1 l^1}{n^1_{mob}}U^1(\tilde{w}^1) + \frac{n^1_{mob} - \bar{\beta}^1 l^1}{n^1_{mob}}U^1\left(b^1\right) - \frac{\bar{\beta}^2 l^2}{n^2_{mob}}U^2(\tilde{w}^2) - \frac{n^2_{mob} - \bar{\beta}^2 l^2}{n^2_{mob}}U^2\left(b^2\right) = 0 \tag{51}$$

where $l^i = l^i(w^i)$, $\tilde{w}^i = w^i(1-t^i)$, $b^i = \frac{t^i w^i l^i}{n^i - l^i}$, $n^i = \frac{n^i_{mob}}{\beta^i}$, with $i = 1,2$, and $n^j_{mob} = N_{mob} - n^i_{mob}$ with $i, j = 1,2$ and $i \neq j$.

Part (a):

Taking the differentials with respect to n^i_{mob} and w^i in equation (51) yields

$$
\begin{aligned}
&- dn^i_{mob} \sum_{i=1}^{2} \left[\frac{\bar{\beta}^i l^i}{(\beta^i n^i)^2} \left[U^i(\tilde{w}^i) - U^i\left(b^i\right) \right] + \frac{\beta^i n^i - \bar{\beta}^i l^i}{\beta^i n^i} \frac{\partial U^i}{\partial b^i} \frac{t^i w^i \bar{\beta}^i l^i}{(\beta^i n^i - \bar{\beta}^i l^i)^2} \right] \\
&+ dw^i \left[\frac{1}{\beta^i n^i} \bar{\beta}^i \frac{\partial l^i}{\partial w^i} \left[U^i(\tilde{w}^i) - U^i(b^i) \right] + \frac{\bar{\beta}^i l^i}{\beta^i n^i} U^i_{\tilde{w}^i}(1-t^i) \right] \\
&+ dw^i \left[\frac{\beta^i n^i - \bar{\beta}^i l^i}{\beta^i n^i} \frac{\partial U^i}{\partial b^i} \left[\frac{t^i \bar{\beta}^i l^i}{\beta^i n^i - \bar{\beta}^i l^i} + \frac{t^i w^i \beta^i n^i}{(\beta^i n^i - \bar{\beta}^i l^i)^2} \bar{\beta}^i \frac{\partial l^i}{\partial w^i} \right] \right] = 0
\end{aligned}
\tag{52}
$$

Assume $\bar{\beta}^i = \beta^i$. Then:

$$
\frac{dn^i_{mob}}{dw^i} = - \frac{\frac{1}{n^i} \frac{\partial l^i}{\partial w^i} \left[U^i(\tilde{w}^i) - U^i(b^i) \right] + \frac{l^i}{n^i} U^i_{\tilde{w}^i}(1-t^i) + \frac{n^i - l^i}{n^i} \frac{\partial U^i}{\partial b^i} \left[\frac{t^i l^i}{n^i - l^i} + \frac{t^i w^i n^i}{(n^i - l^i)^2} \frac{\partial l^i}{\partial w^i} \right]}{\sum_{i=1}^{2} \left[- \frac{l^i}{(n^i)^2} \left[U^i(\tilde{w}^i) - U^i(b^i) \right] - \frac{n^i - l^i}{n^i} U^i_{b^i} \frac{t^i w^i l^i}{(n^i - l^i)^2} \right] \frac{1}{\beta^i}}
\tag{53}
$$

Part (b):

Taking the differentials with respect to n^i_{mob} and t^i in equation (51) yields

$$
\begin{aligned}
&- dn^i_{mob} \sum_{i=1}^{2} \left[\frac{\bar{\beta}^i l^i}{(\beta^i n^i)^2} \left[U^i(\tilde{w}^i) - U^i\left(b^i\right) \right] + \frac{\beta^i n^i - \bar{\beta}^i l^i}{\beta^i n^i} U^i_{b^i} \frac{t^i w^i \bar{\beta}^i l^i}{(\beta^i n^i - \bar{\beta}^i l^i)^2} \right] \\
&+ dt^i \left[\frac{1}{\beta^i n^i} \bar{\beta}^i \frac{\partial l^i}{\partial w^i} \left[U^i(\tilde{w}^i) - U^i(b^i) \right] + \frac{\bar{\beta}^i l^i}{\beta^i n^i} U^i_{\tilde{w}^i}(1-t^i) \right] \frac{\partial w^i}{\partial t^i} \\
&+ dt^i \left[\frac{\beta^i n^i - \bar{\beta}^i l^i}{\beta^i n^i} U^i_{b^i} \left[\frac{t^i \bar{\beta}^i l^i}{\beta^i n^i - \bar{\beta}^i l^i} + \frac{t^i w^i \beta^i n^i}{(\beta^i n^i - \bar{\beta}^i l^i)^2} \bar{\beta}^i \frac{\partial l^i}{\partial w^i} \right] \right] \frac{\partial w^i}{\partial t^i} \\
&+ dt^i \left[- \frac{\bar{\beta}^i l^i}{\beta^i n^i} U^i_{\tilde{w}^i} w^i + \frac{\beta^i n^i - \bar{\beta}^i l^i}{\beta^i n^i} U^i_{b^i} \frac{w^i \bar{\beta}^i l^i}{\beta^i n^i - \bar{\beta}^i l^i} \right] = 0
\end{aligned}
\tag{54}
$$

Assume $\bar{\beta}^i = \beta^i$. Then:

$$\frac{dn^i_{mob}}{dt^i} = -\frac{\frac{1}{n^i}\frac{\partial l^i}{\partial w^i}\left[U^i(\tilde{w}^i) - U^i(b^i)\right] + \frac{l^i}{n^i}U^i_{\tilde{w}^i}(1-t^i) + \frac{n^i-l^i}{n^i}U^i_{b^i}\left[\frac{t^i l^i}{n^i-l^i} + \frac{t^i w^i n^i}{(n^i-l^i)^2}\frac{\partial l^i}{\partial w^i}\right]}{\sum_{i=1}^{2}\left[-\frac{l^i}{(n^i)^2}\left[U^i(\tilde{w}^i) - U^i(b^i)\right] - \frac{n^i-l^i}{n^i}U^i_{b^i}\frac{t^i w^i l^i}{(n^i-l^i)^2}\right]\frac{1}{\beta^i}}\frac{\partial w^i}{\partial t^i}$$
$$-\frac{-\frac{l^i}{n^i}U^i_{\tilde{w}^i}w^i + \frac{n^i-l^i}{n^i}U^i_{b^i}\frac{w^i l^i}{n^i-l^i}}{\sum_{i=1}^{2}\left[-\frac{l^i}{(n^i)^2}\left[U^i(\tilde{w}^i) - U^i(b^i)\right] - \frac{n^i-l^i}{n^i}U^i_{b^i}\frac{t^i w^i l^i}{(n^i-l^i)^2}\right]\frac{1}{\beta^i}} \tag{55}$$

4. Labor migration in the central scenario

With central unemployment insurance, the migration responses (a) dn^i_{mob}/dw^i and (b) dn^i_{mob}/dt^c of the work force are obtained as follows.

The worker's migration equilibrium is given by

$$F \equiv \frac{\bar{\beta}^1 l^1}{n^1_{mob}}U^1(\tilde{w}^1) + \frac{n^1_{mob} - \bar{\beta}^1 l^1}{n^1_{mob}}U^1(b^c) - \frac{\bar{\beta}^2 l^2}{n^2_{mob}}U^2(\tilde{w}^2) - \frac{n^2_{mob} - \bar{\beta}^2 l^2}{n^2_{mob}}U^2(b^c) = 0 \tag{56}$$

where $l^i = l^i(w^i)$, $w^i = w^i(t^c)$, $\tilde{w}^i = w^i(1-t^c)$, with $i = 1,2$, $b^c = \frac{t^c w^1 l^1 + t^c w^2 l^2}{N - l^1 - l^2}$ and $n^j_{mob} = N_{mob} - n^i_{mob}$, with $i, j = 1,2$ and $i \neq j$.

Part (a):

Taking the differentials with respect to n^i_{mob} and w^i in equation (56) yields

$$\begin{aligned}
&-dn^i_{mob}\sum_{i=1}^{2}\left[\frac{\bar{\beta}^i l^i}{(\beta^i n^i)^2}\left[U^i(\tilde{w}^i) - U^i(b^c)\right]\right] \\
&+dw^i\left[\frac{1}{\beta^i n^i}\bar{\beta}^i\frac{\partial l^i}{\partial w^i}\left[U^i(\tilde{w}^i) - U^i(b^c)\right] + \frac{\bar{\beta}^i l^i}{\beta^i n^i}U^i_{\tilde{w}^i}(1-t^c)\right] \\
&+dw^i\frac{\beta^i n^i - \bar{\beta}^i l^i}{\beta^i n^i}U^i_{b^c}\left[\frac{t^c l^i}{N - l^i - l^j} + \frac{t^c w^i(N-l^j) + t^c w^j l^j}{(N-l^i-l^j)^2}\frac{\partial l^i}{\partial w^i}\right] \\
&-dw^i\frac{\beta^j n^j - \bar{\beta}^j l^j}{\beta^j n^j}U^j_{b^c}\left[\frac{t^c l^i}{N - l^i - l^j} + \frac{t^c w^i(N-l^j) + t^c w^j l^j}{(N-l^i-l^j)^2}\frac{\partial l^i}{\partial w^i}\right] = 0
\end{aligned} \tag{57}$$

Assume $\bar{\beta}^i = \beta^i$. Then:

$$\frac{dn^i_{mob}}{dw^i} = -\frac{\frac{1}{n^i}\frac{\partial l^i}{\partial w^i}\left[U^i(\tilde{w}^i) - U^i(b^i)\right] + \frac{l^i}{n^i}U^i_{\tilde{w}^i}(1-t^c) + \frac{n^i-l^i}{n^i}U^i_{b^c}b^c_{w^i} - \frac{n^j-l^j}{n^j}U^j_{b^c}b^c_{w^i}}{\sum_{i=1}^2 -\frac{l^i}{(n^i)^2}\left[U^i(\tilde{w}^i) - U^i(b^c)\right]\frac{1}{\beta^i}} \tag{58}$$

with $b^c_{w^i} = \frac{t^c l^i}{N-l^i-l^j} + \frac{t^c w^i(N-l^j)+t^c w^j l^j}{(N-l^i-l^j)^2}\frac{\partial l^i}{\partial w^i}$.

Part (b):

Taking the differentials with respect to n^i_{mob} and t^c in (56) yields

$$\begin{aligned}
&- dn^i_{mob}\sum_{i=1}^2\left[\frac{\bar{\beta}^i l^i}{(\beta^i n^i)^2}\left[U^i(\tilde{w}^i) - U^i(b^c)\right]\right] \\
&+ dt^c\left[\frac{1}{\beta^i n^i}\bar{\beta}^i\frac{\partial l^i}{\partial w^i}\left[U^i(\tilde{w}^i) - U^i(b^c)\right] + \frac{\bar{\beta}^i l^i}{\beta^i n^i}U^i_{\tilde{w}^i}(1-t^c)\right]\frac{\partial w^i}{\partial t^c} \\
&+ dt^c\frac{\beta^i n^i - \bar{\beta}^i l^i}{\beta^i n^i}U^i_{b^c}\left[\frac{t^c l^i}{N-l^i-l^j} + \frac{t^c w^i(N-l^j)+t^c w^j l^j}{(N-l^i-l^j)^2}\frac{\partial l^i}{\partial w^i}\right]\frac{\partial w^i}{\partial t^c} \\
&- dt^c\frac{\beta^j n^j - \bar{\beta}^j l^j}{\beta^j n^j}U^j_{b^c}\left[\frac{t^c l^i}{N-l^i-l^j} + \frac{t^c w^i(N-l^j)+t^c w^j l^j}{(N-l^i-l^j)^2}\frac{\partial l^i}{\partial w^i}\right]\frac{\partial w^i}{\partial t^c} \\
&- dt^c\left[\frac{1}{\beta^j n^j}\bar{\beta}^j\frac{\partial l^j}{\partial w^j}\left[U^j(\tilde{w}^j) - U^j(b^c)\right] + \frac{\bar{\beta}^j l^j}{\beta^j n^j}U^j_{\tilde{w}^j}(1-t^c)\right]\frac{\partial w^j}{\partial t^c} \\
&- dt^c\frac{\beta^j n^j - \bar{\beta}^j l^j}{\beta^j n^j}U^j_{b^c}\left[\frac{t^c l^j}{N-l^i-l^j} + \frac{t^c w^j(N-l^i)+t^c w^i l^i}{(N-l^i-l^j)^2}\frac{\partial l^j}{\partial w^j}\right]\frac{\partial w^j}{\partial t^c} \\
&+ dt^c\frac{\beta^i n^i - \bar{\beta}^i l^i}{\beta^i n^i}U^i_{b^c}\left[\frac{t^c l^j}{N-l^i-l^j} + \frac{t^c w^j(N-l^i)+t^c w^i l^i}{(N-l^i-l^j)^2}\frac{\partial l^j}{\partial w^j}\right]\frac{\partial w^j}{\partial t^c} \\
&- dt^c\left[\frac{\bar{\beta}^i l^i}{\beta^i n^i}U^i_{\tilde{w}^i}w^i - \frac{\beta^i n^i - \bar{\beta}^i l^i}{\beta^i n^i}U^i_{b^c}\frac{w^i l^i + w^j l^j}{N-l^i-l^j}\right] \\
&+ dt^c\left[\frac{\bar{\beta}^j l^j}{\beta^j n^j}U^j_{\tilde{w}^j}w^j - \frac{\beta^j n^j - \bar{\beta}^j l^j}{\beta^j n^j}U^j_{b^c}\frac{w^i l^i + w^j l^j}{N-l^i-l^j}\right] = 0
\end{aligned} \tag{59}$$

Assume $\bar{\beta}^i = \beta^i$. Then:

$$\begin{aligned}\frac{dn^i_{mob}}{dt^c} = &- \frac{\frac{i}{n^i}\frac{\partial l^i}{\partial w^i}\left[U^i(\tilde{w}^i) - U^i(b^i)\right] + \frac{l^i}{n^i}U^i_{\tilde{w}^i}(1-t^c) + \frac{n^i-l^i}{n^i}U^i_{b^c}b^c_{w^i} - \frac{n^j-l^j}{n^j}U^j_{b^c}b^c_{w^i}}{\sum_{i=1}^2 -\frac{l^i}{(n^i)^2}\left[U^i(\tilde{w}^i) - U^i(b^c)\right]\frac{1}{\beta^i}}\frac{\partial w^i}{\partial t^c} \\ &+ \frac{\frac{1}{n^j}\frac{\partial l^j}{\partial w^j}\left[U^j(\tilde{w}^j) - U^j(b^j)\right] + \frac{l^j}{n^j}U^j_{\tilde{w}^j}(1-t^c) + \frac{n^j-l^j}{n^j}U^j_{b^c}b^c_{w^j} - \frac{n^i-l^i}{n^i}U^i_{b^c}b^c_{w^j}}{\sum_{i=1}^2 -\frac{l^i}{(n^i)^2}\left[U^i(\tilde{w}^i) - U^i(b^c)\right]\frac{1}{\beta^i}}\frac{\partial w^j}{\partial t^c} \\ &+ \frac{\frac{l^i}{n^i}U^i_{\tilde{w}^i}w^i - \frac{n^i-l^i}{n^i}U^i_{b^c}b^c_{t^c} - \frac{l^j}{n^j}U^j_{\tilde{w}^j}w^j + \frac{n^j-l^j}{n^j}U^i_{b^c}b^c_{t^c}}{\sum_{i=1}^2 -\frac{l^i}{(n^i)^2}\left[U^i(\tilde{w}^i) - U^i(b^c)\right]\frac{1}{\beta^i}}\end{aligned} \tag{60}$$

with $b^c_{t^c} = \frac{w^1 l^1 + w^2 l^2}{N - l^1 - l^2}$.

Appendix III: Derivations of key first-order-conditions

Derivation of first-order-condition (27)

The maximization problem is given by equation (26):

$$\max_{w^i} \ln B^i = \ln\left(\frac{f^i(l^i) - w^i l^i}{m^i}\right) + \ln\left(\frac{l^i}{n^i}U^i\left(w^i(1-t^i)\right) + \frac{n^i - l^i}{n^i}U^i\left(\frac{t^i w^i l^i}{n^i - l^i}\right)\right)$$

where $l^i = l^i(w^i)$, $m^i = m^i_{immob} + m^i_{mob}(w^i)$, $n^i = n^i_{immob} + n^i_{mob}(w^i)$, with $i = 1,2$. Furthermore, note that $\Pi^i = f^i(l^i) - w^i l^i$, $\pi^i = \frac{\Pi^i}{m^i}$, $EU^i = \frac{l^i}{n^i}U^i(\tilde{w}^i) + \frac{n^i - l^i}{n^i}U^i(b^i)$, $\tilde{w}^i = w^i(1-t^i)$, $b^i = \frac{t^i w^i l^i}{n^i - l^i}$, with $i = 1,2$.

Derive partially w.r.t. w^i:

$$\begin{aligned}\frac{d\ln B^i}{dw^i} = &\frac{1}{\pi^i}\frac{(\frac{\partial f^i}{\partial l^i}\frac{\partial l^i}{\partial w^i} - w\frac{\partial l^i}{\partial w^i} - l^i)m^i - \Pi^i\frac{dm^i_{mob}}{dw^i}}{(m^i)^2} \\ &+ \frac{1}{EU^i}\left(\frac{l^i}{n^i}U^i_{\tilde{w}^i}(1-t^i) + \frac{\frac{\partial l^i}{\partial w^i}n^i - l^i\frac{dn^i_{mob}}{dw^i}}{(n^i)^2}U^i(\tilde{w}^i) + \frac{(\frac{dn^i_{mob}}{dw^i} - \frac{\partial l^i}{\partial w^i})n^i - (n^i - l^i)\frac{dn^i_{mob}}{dw^i}}{(n^i)^2}U^i(b^i)\right. \\ &\left. + \frac{n^i - l^i}{n^i}U^i_{b^i}\frac{(t^i l^i + t^i w^i\frac{\partial l^i}{\partial w^i})(n^i - l^i) - t^i w^i l^i(\frac{dn^i_{mob}}{dw^i} - \frac{\partial l^i}{\partial w^i})}{(n^i - l^i)^2}\right) \stackrel{!}{=} 0\end{aligned}$$

Rearrange terms, apply envelope theorem w.r.t. optimal labor demand, and substitute implicit derivatives $\frac{dm^i_{mob}}{dw^i}$ and $\frac{dn^i_{mob}}{dw^i}$ (see appendix II):

$$\begin{aligned}\frac{d\ln B^i}{dw^i} &= \frac{1}{EU^i}\left(\frac{l^i}{n^i}U^i_{\tilde{w}^i}(1-t^i)+\frac{1}{n^i}\frac{\partial l^i}{\partial w^i}\left[U^i(\tilde{w}^i)-U^i(b^i)\right]+\frac{n^i-l^i}{n^i}U^i_{b^i}\left[\frac{t^i l^i}{n^i-l^i}+\frac{t^i w^i n^i}{(n^i-l^i)^2}\frac{\partial l^i}{\partial w^i}\right]\right)\\ &\quad-\frac{1}{EU^i}\left(\frac{l^i}{(n^i)^2}[U^i(\tilde{w}^i)-U^i(b^i)]+\frac{n^i-l^i}{n^i}U^i_{b^i}\frac{t^i w^i l^i}{(n^i-l^i)^2}\right)\\ &\quad\times\left(-\frac{\frac{l^i}{n^i}U^i_{\tilde{w}^i}(1-t^i)+\frac{1}{n^i}\frac{\partial l^i}{\partial w^i}\left[U^i(\tilde{w}^i)-U^i(b^i)\right]+\frac{n^i-l^i}{n^i}U^i_{b^i}\left[\frac{t^i l^i}{n^i-l^i}+\frac{t^i w^i n^i}{(n^i-l^i)^2}\frac{\partial l^i}{\partial w^i}\right]}{-\sum_{i=1}^2\left[\frac{l^i}{(n^i)^2}\left[U^i(\tilde{w}^i)-U^i(b^i)\right]\frac{1}{\beta^i}+\frac{n^i-l^i}{n^i}U^i_{b^i}\frac{t^i w^i l^i}{(n^i-l^i)^2}\frac{1}{\beta^i}\right]}\right)\\ &\quad-\frac{1}{\pi^i}\frac{l^i}{m^i}-\frac{1}{\pi^i}\frac{\Pi^i}{(m^i)^2}\left(-\frac{-\frac{l^i}{m^i}}{\sum_{i=1}^2\left[-\frac{\Pi^i}{(m^i)^2}\frac{1}{\alpha^i}\right]}\right)\stackrel{!}{=}0\end{aligned}$$

Rearrange and abbreviate terms to obtain equation (27):

$$\begin{aligned}\frac{d\ln B^i}{dw^i} &= \frac{1}{\pi^i}\pi^i_{w^i}\left(1-\alpha^i\frac{\frac{\partial\pi^i_{mob}}{\partial m^i_{mob}}}{\frac{\partial\pi^1_{mob}}{\partial m^1_{mob}}+\frac{\partial\pi^2_{mob}}{\partial m^2_{mob}}}\right)+\frac{1}{EU^i}\left(EU^i_{\tilde{w}^i}\tilde{w}^i_{w^i}+EU^i_{l^i}\frac{\partial l^i}{\partial w^i}+EU^i_{b^i}\left(b^i_{w^i}+b^i_{l^i}\frac{\partial l^i}{\partial w^i}\right)\right)\\ &\quad\times\left(1-\beta^i\frac{\frac{\partial EU^i_{mob}}{\partial n^i_{mob}}}{\frac{\partial EU^1_{mob}}{\partial n^1_{mob}}+\frac{\partial EU^2_{mob}}{\partial n^2_{mob}}}\right)\stackrel{!}{=}0\end{aligned}$$

with $\pi^i_{w^i}=-\frac{l^i}{m^i}$, $\frac{\partial\pi^i_{mob}}{\partial m^i_{mob}}=-\frac{\Pi^i}{(m^i)^2}\frac{1}{\alpha^i}$, $EU^i_{\tilde{w}^i}=\frac{l^i}{n^i}U^i_{\tilde{w}^i}$, $\tilde{w}^i_{w^i}=(1-t^i)$, $EU^i_{l^i}=\frac{1}{n^i}\left[U^i(\tilde{w}^i)-U^i(b^i)\right]$,
$EU^i_{b^i}=\frac{n^i-l^i}{n^i}U^i_{b^i}$, $b^i_{w^i}=\frac{t^i l^i}{n^i-l^i}$, $b^i_{l^i}=\frac{t^i w^i n^i}{(n^i-l^i)^2}$,
$\frac{\partial EU^i_{mob}}{\partial n^i_{mob}}=-\frac{l^i}{(n^i)^2}\left[U^i(\tilde{w}^i)-U^i(b^i)\right]\frac{1}{\beta^i}-\frac{n^i-l^i}{n^i}U^i_{b^i}\frac{t^i w^i l^i}{(n^i-l^i)^2}\frac{1}{\beta^i}$.

Derivation of first-order-condition (32)

The maximization problem is given by equation (31):

$$\max_{w^i}\ln B^i=\ln\left(\frac{f^i(l^i)-w^i l^i}{m^i}\right)+\ln\left(\frac{l^i}{n^i}U^i\left(w^i(1-t^c)\right)+\frac{n^i-l^i}{n^i}U^i\left(\frac{t^c w^1 l^1+t^c w^2 l^2}{N-l^1-l^2}\right)\right)$$

where $l^i=l^i(w^i)$, $m^i=m^i_{immob}+m^i_{mob}(w^i)$, $n^i=n^i_{immob}+n^i_{mob}(w^i)$ with $i=1,2$. Furthermore, note that $\Pi^i=f^i(l^i)-w^i l^i$, $\pi^i=\frac{\Pi^i}{m^i}$, $EU^i=\frac{l^i}{n^i}U^i(\tilde{w}^i)+\frac{n^i-l^i}{n^i}U^i(b^c)$, $\tilde{w}^i=w^i(1-t^c)$, with $i=1,2$, and $b^c=\frac{t^c w^i l^i+t^c w^j l^j}{N-l^i-l^j}$ with $i,j=1,2$, $i\neq j$.

Derive partially w.r.t. w^i:

$$\frac{d\ln B^i}{dw^i} = \frac{1}{\pi^i}\frac{(\frac{\partial f^i}{\partial l^i}\frac{\partial l^i}{\partial w^i} - w\frac{\partial l^i}{\partial w^i} - l^i)m^i - \Pi^i\frac{dm^i_{mob}}{dw^i}}{(m^i)^2} + \frac{1}{EU^i}\left(\frac{l^i}{n^i}U^i_{\tilde{w}^i}(1-t^c) + \frac{\frac{\partial l^i}{\partial w^i}n^i - l^i\frac{dn^i_{mob}}{dw^i}}{(n^i)^2}U^i(\tilde{w}^i)\right.$$
$$+ \frac{(\frac{dn^i_{mob}}{dw^i} - \frac{\partial l^i}{\partial w^i})n^i - (n^i - l^i)\frac{dn^i_{mob}}{dw^i}}{(n^i)^2}U^i(b^c)$$
$$\left. + \frac{n^i - l^i}{n^i}U^i_{b^c}\frac{\left(t^c l^i + t^c w^i\frac{\partial l^i}{\partial w^i}\right)\left(N - l^j - l^i\right) - t^c(w^j l^j + w^i l^i)(-\frac{\partial l^i}{\partial w^i})}{(N - l^j - l^i)^2}\right) \stackrel{!}{=} 0$$

Rearrange terms, apply envelope theorem w.r.t optimal labor demand, and substitute implicit derivatives $\frac{dm^i_{mob}}{dw^i}$ and $\frac{dn^i_{mob}}{dw^i}$ (see appendix II):

$$\frac{d\ln B^i}{dw^i} = \frac{1}{EU^i}\left(\frac{l^i}{n^i}U^i_{\tilde{w}^i}(1-t^c) + \frac{1}{n^i}\frac{\partial l^i}{\partial w^i}\left[U^i(\tilde{w}^i) - U^i(b^c)\right] + \frac{n^i - l^i}{n^i}U^i_{b^c}\left(\frac{l^i}{N - l^j - l^i}\right.\right.$$
$$\left.\left. + \frac{w^i\left(N - l^j\right) + w^j l^j}{(N - l^j - l^i)^2}\frac{\partial l^i}{\partial w^i}\right)t^c\right) - \frac{1}{EU^i}\frac{l^i}{(n^i)^2}[U^i(\tilde{w}^i) - U^i(b^c)]$$
$$\times\left[-\frac{\frac{l^i}{n^i}U^i_{\tilde{w}^i}(1-t^c) + \frac{1}{n^i}\frac{\partial l^i}{\partial w^i}\left[U^i(\tilde{w}^i) - U^i(b^c)\right] + \frac{n^i - l^i}{n^i}U^i_{b^c}\left(\frac{l^i}{N - l^j - l^i} + \frac{[w^i\left(N - l^j\right) + w^j l^j]}{(N - l^j - l^i)^2}\frac{\partial l^i}{\partial w^i}\right)t^c}{\sum_{i=1}^2\left[-\frac{l^i}{(n^i)^2}\left[U^i(\tilde{w}^i) - U^i(b^c)\right]\frac{1}{\beta^i}\right]}\right.$$
$$\left. + \frac{\frac{n^j - l^j}{n^j}U^j_{b^c}\left(\frac{l^i}{N - l^j - l^i} + \frac{[w^i\left(N - l^j\right) + w^j l^j]}{(N - l^j - l^i)^2}\frac{\partial l^i}{\partial w^i}\right)t^c}{\sum_{i=1}^2\left[-\frac{l^i}{(n^i)^2}\left[U^i(\tilde{w}^i) - U^i(b^c)\right]\frac{1}{\beta^i}\right]}\right]$$
$$- \frac{1}{\pi^i}\frac{l^i}{m^i} - \frac{1}{\pi^i}\frac{\Pi^i}{(m^i)^2}\left[-\frac{1}{\sum_{i=1}^2\left[\frac{\Pi^i}{(m^i)^2}\frac{1}{\alpha^i}\right]}\frac{l^i}{m^i}\right] \stackrel{!}{=} 0$$

Rearrange and abbreviate terms to obtain equation (32):

$$\frac{d\ln B^i}{dw^i} = \frac{1}{\pi^i}\pi^i_{w^i}\left(1 - \alpha^i\frac{\frac{\partial\pi^i_{mob}}{\partial m^i_{mob}}}{\frac{\partial\pi^1_{mob}}{\partial m^1_{mob}} + \frac{\partial\pi^2_{mob}}{\partial m^2_{mob}}}\right) + \frac{1}{EU^i}\left(EU^i_{\tilde{w}^i}\tilde{w}^i_{w^i} + EU^i_{l^i}\frac{\partial l^i}{\partial w^i} + EU^i_{b^c}\left(b^c_{w^i} + b^c_{l^i}\frac{\partial l^i}{\partial w^i}\right)\right)$$
$$\times\left(1 - \beta^i\frac{\frac{\partial EU^i_{mob}}{\partial n^i_{mob}}}{\frac{\partial EU^1_{mob}}{\partial n^1_{mob}} + \frac{\partial EU^2_{mob}}{\partial n^2_{mob}}}\right) + \frac{1}{EU^i}EU^j_{b^c}\left(b^c_{w^i} + b^c_{l^i}\frac{\partial l^i}{\partial w^i}\right)\beta^i\frac{\frac{\partial EU^i_{mob}}{\partial n^i_{mob}}}{\frac{\partial EU^1_{mob}}{\partial n^1_{mob}} + \frac{\partial EU^2_{mob}}{\partial n^2_{mob}}} \stackrel{!}{=} 0$$

where $\pi^i_{w^i} = -\frac{l^i}{m^i}$, $\frac{\partial\pi^i_{mob}}{\partial m^i_{mob}} = -\frac{\Pi^i}{(m^i)^2}\frac{1}{\alpha^i}$, $EU^i_{\tilde{w}^i} = \frac{l^i}{n^i}U^i_{\tilde{w}^i}$, $\tilde{w}^i_{w^i} = (1-t^c)$ $EU^i_{l^i} = \frac{1}{n^i}\left[U^i(\tilde{w}^i) - U^i(b^c)\right]$, $EU^i_{b^c} = \frac{n^i - l^i}{n^i}U^i_{b^c}$, with $i = 1,2$, and $b^c_{w^i} = t^c\frac{l^i}{N - l^i - l^j}$, $b^c_{l^i} = t^c\frac{w^i(N - l^j) + w^j l^j}{(N - l^i - l^j)^2}$, $\frac{\partial EU^i_{mob}}{\partial n^i_{mob}} = -\frac{l^i[U^i(\tilde{w}^i) - U^i(b^c)]}{(n^i)^2}\frac{1}{\beta^i}$ with $i, j = 1,2$, $i \neq j$.

Derivation of first-order-condition (35)

The maximization problem is given by equation (34):

$$\max_{t^c} \sum_{i=1}^{2} \ln V^i = \sum_{i=1}^{2} \left[\ln \left(\frac{f^i(l^i) - w^i l^i}{m^i} \right) + \ln \left(\frac{l^i}{n^i} U^i \left(w^i (1-t^c) \right) + \frac{n^i - l^i}{n^i} U^i \left(\frac{t^c w^1 l^1 + t^c w^2 l^2}{N - l^1 - l^2} \right) \right) \right]$$

where $l^i = l^i(w^i)$, $w^i = w^i(t^c)$, $m^i = m^i_{immob} + m^i_{mob}(t^c)$, $n^i = n^i_{immob} + n^i_{mob}(t^c)$, with $i = 1,2$, and $m^j = M - m^i$, $n^j = N - n^i$, with $i, j = 1,2$, $i \neq j$. Furthermore, $\Pi^i = f^i(l^i) - w^i l^i$, $\pi^i = \frac{\Pi^i}{m^i}$, $EU^i = \frac{l^i}{n^i} U^i(\tilde{w}^i) + \frac{n^i - l^i}{n^i} U^i(b^c)$, $\tilde{w}^i = w^i(1-t^c)$, with $i = 1,2$, and $b^c = \frac{t^c w^i l^i + t^c w^j l^j}{N - l^i - l^j}$, with $i, j = 1,2$, $i \neq j$.

Derive partially w.r.t. t^c:

$$\begin{aligned}
\sum_{i=1}^{2} \frac{d \ln V^i}{dt^c} = {} & \frac{1}{\pi^i} \left(\frac{\left[\frac{\partial f^i}{\partial l^i} \frac{\partial l^i}{\partial w^i} \frac{\partial w^i}{\partial t^c} - \frac{\partial w^i}{\partial t^c} l^i - w^i \frac{\partial l^i}{\partial w^i} \frac{\partial w^i}{\partial t^c} \right] m^i - \Pi^i \frac{dm^i_{mob}}{dt^c}}{(m^i)^2} \right) \\
& + \frac{1}{\pi^j} \left(\frac{\left[\frac{\partial f^j}{\partial l^j} \frac{\partial l^j}{\partial w^j} \frac{\partial w^j}{\partial t^c} - \frac{\partial w^j}{\partial t^c} l^j - w^j \frac{\partial l^j}{\partial w^j} \frac{\partial w^j}{\partial t^c} \right] m^j - (-1) \Pi^j \frac{dm^i_{mob}}{dt^c}}{(m^j)^2} \right) \\
& + \frac{1}{EU^i} \left(\frac{\frac{\partial l^i}{\partial w^i} \frac{\partial w^i}{\partial t^c} n^i - l^i \frac{dn^i_{mob}}{dt^c}}{(n^i)^2} U^i(\tilde{w}^i) + \frac{l^i}{n^i} U^i_{\tilde{w}^i} \left(\frac{\partial w^i}{\partial t^c} (1-t^c) - w^i \right) \right. \\
& \left. + \frac{\left(\frac{dn^i_{mob}}{dt^c} - \frac{\partial l^i}{\partial w^i} \frac{\partial w^i}{\partial t^c} \right) n^i - (n^i - l^i) \frac{dn^i_{mob}}{dt^c}}{(n^i)^2} U^i(b^c) \right) + \frac{1}{EU^i} \frac{n^i - l^i}{n^i} U^i_{b^c} \left(\frac{w^i l^i + w^j l^j}{N - l^i - l^j} \right. \\
& + \frac{t^c \left(\frac{\partial w^i}{\partial t^c} l^i + w^i \frac{\partial l^i}{\partial w^i} \frac{\partial w^i}{\partial t^c} + \frac{\partial w^j}{\partial t^c} l^j + w^j \frac{\partial l^j}{\partial w^j} \frac{\partial w^j}{\partial t^c} \right) (N - l^i - l^j)}{(N - l^i - l^j)^2} \\
& \left. - \frac{t^c \left(w^i l^i + w^j l^j \right) \left(- \frac{\partial l^i}{\partial w^i} \frac{\partial w^i}{\partial t^c} - \frac{\partial l^j}{\partial w^j} \frac{\partial w^j}{\partial t^c} \right)}{(N - l^i - l^j)^2} \right) \\
& + \frac{1}{EU^j} \left(\frac{\frac{\partial l^j}{\partial w^j} \frac{\partial w^j}{\partial t^c} n^j - l^j (-1) \frac{dn^i_{mob}}{dt^c}}{(n^j)^2} U^j(\tilde{w}^j) + \frac{l^j}{n^j} U^j_{\tilde{w}^j} \left(\frac{\partial w^j}{\partial t^c} (1-t^c) - w^j \right) \right. \\
& \left. + \frac{\left((-1) \frac{dn^i_{mob}}{dt^c} - \frac{\partial l^j}{\partial w^j} \frac{\partial w^j}{\partial t^c} \right) n^j - (n^j - l^j)(-1) \frac{dn^i_{mob}}{dt^c}}{(n^j)^2} U^j(b^c) \right) \\
& + \frac{1}{EU^j} \frac{n^j - l^j}{n^j} U^j_{b^c} \left(\frac{w^i l^i + w^j l^j}{N - l^i - l^j} + \frac{t^c \left(\frac{\partial w^i}{\partial t^c} l^i + w^i \frac{\partial l^i}{\partial w^i} \frac{\partial w^i}{\partial t^c} + \frac{\partial w^j}{\partial t^c} l^j + w^j \frac{\partial l^j}{\partial w^j} \frac{\partial w^j}{\partial t^c} \right) (N - l^i - l^j)}{(N - l^i - l^j)^2} \right. \\
& \left. - \frac{t^c \left(w^i l^i + w^j l^j \right) \left(- \frac{\partial l^i}{\partial w^i} \frac{\partial w^i}{\partial t^c} - \frac{\partial l^j}{\partial w^j} \frac{\partial w^j}{\partial t^c} \right)}{(N - l^i - l^j)^2} \right) \stackrel{!}{=} 0
\end{aligned}$$

Apply envelope theorem w.r.t. optimal labor demand, sort and rewrite terms, use abbreviations:

$$\begin{aligned}
\sum_{i=1}^{2}\frac{d\ln V^i}{dt^c} &= \frac{1}{\pi^i}\pi^i_{w^i}\frac{\partial w^i}{\partial t^c}+\frac{1}{\pi^j}\pi^j_{w^j}\frac{\partial w^j}{\partial t^c}+\frac{1}{EU^i}\left(EU^i_{l^i}\frac{\partial l^i}{\partial w^i}+EU^i_{\tilde{w}^i}\tilde{w}^i_{w^i}\right)\frac{\partial w^i}{\partial t^c}\\
&+\frac{1}{EU^j}\left(EU^j_{l^j}\frac{\partial l^j}{\partial w^j}+EU^j_{\tilde{w}^j}\tilde{w}^j_{w^j}\right)\frac{\partial w^j}{\partial t^c}+\frac{1}{EU^i}EU^i_{b^c}\left(\left[b^c_{w^j}+b^c_{l^j}\frac{\partial l^j}{\partial w^j}\right]\frac{\partial w^j}{\partial t^c}+\left[b^c_{w^i}+b^c_{l^i}\frac{\partial l^i}{\partial w^i}\right]\frac{\partial w^i}{\partial t^c}\right)\\
&+\frac{1}{EU^j}EU^j_{b^c}\left(\left[b^c_{w^j}+b^c_{l^j}\frac{\partial l^j}{\partial w^j}\right]\frac{\partial w^j}{\partial t^c}+\left[b^c_{w^i}+b^c_{l^i}\frac{\partial l^i}{\partial w^i}\right]\frac{\partial w^i}{\partial t^c}\right)\\
&+\frac{1}{EU^i}EU^i_{\tilde{w}^i}\tilde{w}^i_{t^c}+\frac{1}{EU^j}EU^j_{\tilde{w}^j}\tilde{w}^j_{t^c}+\left(\frac{1}{EU^i}EU^i_{b^c}+\frac{1}{EU^j}EU^j_{b^c}\right)b^c_{t^c}\\
&+\left(\frac{1}{\pi^i}\frac{\partial\pi^i_{mob}}{\partial m^i_{mob}}\alpha^i-\frac{1}{\pi^j}\frac{\partial\pi^j_{mob}}{\partial m^j_{mob}}\alpha^j\right)\frac{dm^i_{mob}}{dt^c}+\left(\frac{1}{EU^i}\frac{\partial EU^i_{mob}}{\partial n^i_{mob}}\beta^i-\frac{1}{EU^j}\frac{\partial EU^j_{mob}}{\partial n^j_{mob}}\beta^j\right)\frac{dn^i_{mob}}{dt^c}\overset{!}{=}0
\end{aligned}$$

where $\pi^i_{w^i}=-\frac{l^i}{m^i}$, $\frac{\partial\pi^i_{mob}}{\partial m^i_{mob}}=-\frac{\Pi^i}{(m^i)^2}\frac{1}{\alpha^i}$, $EU^i_{\tilde{w}^i}=\frac{l^i}{n^i}U^i_{\tilde{w}^i}$, $\tilde{w}^i_{w^i}=(1-t^c)$, $\tilde{w}^i_{t^c}=-w^i$, $EU^i_{l^i}=\frac{1}{n^i}\left[U^i(\tilde{w}^i)-U^i(b^c)\right]$, $EU^i_{b^c}=\frac{n^i-l^i}{n^i}U^i_{b^c}$, $\frac{\partial EU^i_{mob}}{\partial n^i_{mob}}=-\frac{l^i[U^i(\tilde{w}^i)-U^i(b^c)]}{(n^i)^2}\frac{1}{\beta^i}$, with $i=1,2$, and $b^c_{w^i}=t^c\frac{l^i}{N-l^i-l^j}$, $b^c_{l^i}=t^c\frac{w^i(N-l^j)+w^jl^j}{(N-l^i-l^j)^2}$, $b^c_{t^c}=\frac{w^il^i+w^jl^j}{N-l^i-l^j}$, with $i,j=1,2$, $i\neq j$.

Substitute implicit derivatives $\frac{dm^i_{mob}}{dt^c}$ and $\frac{dn^i_{mob}}{dt^c}$ (see appendix II):

$$\begin{aligned}
&\sum_{i=1}^{2}\frac{d\ln V^i}{dt^c}=\frac{1}{\pi^i}\pi^i_{w^i}\frac{\partial w^i}{\partial t^c}+\frac{1}{\pi^j}\pi^j_{w^j}\frac{\partial w^j}{\partial t^c}+\frac{1}{EU^i}\left(EU^i_{l^i}\frac{\partial l^i}{\partial w^i}+EU^i_{\tilde{w}^i}\tilde{w}^i_{w^i}\right)\frac{\partial w^i}{\partial t^c}\\
&+\frac{1}{EU^j}\left(EU^j_{l^j}\frac{\partial l^j}{\partial w^j}+EU^j_{\tilde{w}^j}\tilde{w}^j_{w^j}\right)\frac{\partial w^j}{\partial t^c}+\frac{1}{EU^i}EU^i_{b^c}\left(\left[b^c_{w^j}+b^c_{l^j}\frac{\partial l^j}{\partial w^j}\right]\frac{\partial w^j}{\partial t^c}+\left[b^c_{w^i}+b^c_{l^i}\frac{\partial l^i}{\partial w^i}\right]\frac{\partial w^i}{\partial t^c}\right)\\
&+\frac{1}{EU^j}EU^j_{b^c}\left(\left[b^c_{w^j}+b^c_{l^j}\frac{\partial l^j}{\partial w^j}\right]\frac{\partial w^j}{\partial t^c}+\left[b^c_{w^i}+b^c_{l^i}\frac{\partial l^i}{\partial w^i}\right]\frac{\partial w^i}{\partial t^c}\right)+\frac{1}{EU^i}EU^i_{\tilde{w}^i}\tilde{w}^i_{t^c}+\frac{1}{EU^j}EU^j_{\tilde{w}^j}\tilde{w}^j_{t^c}\\
&+\left(\frac{1}{EU^i}EU^i_{b^c}+\frac{1}{EU^j}EU^j_{b^c}\right)b^c_{t^c}+\left(\frac{1}{\pi^i}\frac{\partial\pi^i_{mob}}{\partial m^i_{mob}}\alpha^i-\frac{1}{\pi^j}\frac{\partial\pi^j_{mob}}{\partial m^j_{mob}}\alpha^j\right)\left(-\frac{\pi^i_{w^i}\frac{\partial w^i}{\partial t^c}-\pi^j_{w^j}\frac{\partial w^j}{\partial t^c}}{\sum_{i=1}^{2}\frac{d\pi^i_{mob}}{dm^i_{mob}}}\right)\\
&+\left(\frac{1}{EU^i}\frac{\partial EU^i_{mob}}{\partial n^i_{mob}}\beta^i-\frac{1}{EU^j}\frac{\partial EU^j_{mob}}{\partial n^j_{mob}}\beta^j\right)\\
&\times\left(-\frac{EU^i_{l^i}\frac{\partial l^i}{\partial w^i}+EU^i_{\tilde{w}^i}\tilde{w}^i_{w^i}+EU^i_{b^c}\left[b^c_{w^i}+b^c_{l^i}\frac{\partial l^i}{\partial w^i}\right]-EU^j_{b^c}\left[b^c_{w^i}+b^c_{l^i}\frac{\partial l^i}{\partial w^i}\right]}{\sum_{i=1}^{2}\frac{\partial EU^i_{mob}}{\partial n^i_{mob}}}\frac{\partial w^i}{\partial t^c}\right.\\
&\quad+\frac{EU^j_{l^j}\frac{\partial l^j}{\partial w^j}+EU^j_{\tilde{w}^j}\tilde{w}^j_{w^j}+EU^j_{b^c}\left[b^c_{w^j}+b^c_{l^j}\frac{\partial l^j}{\partial w^j}\right]-EU^i_{b^c}\left[b^c_{w^j}+b^c_{l^j}\frac{\partial l^j}{\partial w^j}\right]}{\sum_{i=1}^{2}\frac{\partial EU^i_{mob}}{\partial n^i_{mob}}}\frac{\partial w^j}{\partial t^c}\\
&\left.-\frac{EU^i_{\tilde{w}^i}\tilde{w}^i_{t^c}+EU^i_{b^c}b^c_{t^c}}{\sum_{i=1}^{2}\frac{\partial EU^i_{mob}}{\partial n^i_{mob}}}+\frac{EU^j_{\tilde{w}^j}\tilde{w}^j_{t^c}+EU^j_{b^c}b^c_{t^c}}{\sum_{i=1}^{2}\frac{\partial EU^i_{mob}}{\partial n^i_{mob}}}\right)\overset{!}{=}0
\end{aligned}$$

Rearrange terms and apply envelope theorem w.r.t. the wage bargaining condition (32) in the centralized scenario to obtain equation (35):

$$\sum_{i=1}^{2}\frac{d\ln V^i}{dt^c}=\sum_{\substack{i,j=1\\ i\neq j}}^{2}\Bigg[\frac{1}{EU^i}\left(EU^i_{\tilde{w}^i}\tilde{w}^i_{t^c}+EU^i_{b^c}b^c_{t^c}\right)\left(1-\beta^i\frac{\frac{\partial EU^i_{mob}}{\partial n^i_{mob}}}{\frac{\partial EU^1_{mob}}{\partial n^1_{mob}}+\frac{\partial EU^2_{mob}}{\partial n^2_{mob}}}\right)$$
$$+\frac{1}{EU^i}\left(EU^j_{\tilde{w}^j}\tilde{w}^j_{t^c}+EU^j_{b^c}b^c_{t^c}\right)\beta^i\frac{\frac{\partial EU^i_{mob}}{\partial n^i_{mob}}}{\frac{\partial EU^1_{mob}}{\partial n^1_{mob}}+\frac{\partial EU^2_{mob}}{\partial n^2_{mob}}}+\frac{1}{\pi^i}\pi^j_{w^j}\frac{\partial w^j}{\partial t^c}\alpha^i\frac{\frac{\partial \pi^i_{mob}}{\partial m^i_{mob}}}{\frac{\partial \pi^1_{mob}}{\partial m^1_{mob}}+\frac{\partial \pi^2_{mob}}{\partial m^2_{mob}}}$$
$$+\frac{1}{EU^i}\left(EU^j_{\tilde{w}^j}\tilde{w}^j_{w^j}+EU^j_{l^j}\frac{\partial l^j}{\partial w^j}+EU^j_{b^c}\left(b^c_{w^j}+b^c_{l^j}\frac{\partial l^j}{\partial w^j}\right)\right)\frac{\partial w^j}{\partial t^c}\beta^i\frac{\frac{\partial EU^i_{mob}}{\partial n^i_{mob}}}{\frac{\partial EU^1_{mob}}{\partial n^1_{mob}}+\frac{\partial EU^2_{mob}}{\partial n^2_{mob}}}$$
$$+\frac{1}{EU^i}EU^i_{b^c}\left(b^c_{w^j}+b^c_{l^j}\frac{\partial l^j}{\partial w^j}\right)\frac{\partial w^j}{\partial t^c}\left(1-\beta^i\frac{\frac{\partial EU^i_{mob}}{\partial n^i_{mob}}}{\frac{\partial EU^1_{mob}}{\partial n^1_{mob}}+\frac{\partial EU^2_{mob}}{\partial n^2_{mob}}}\right)\Bigg]\stackrel{!}{=}0$$

References

Andor, L., Dullien, S., Jara, H. X., Sutherland, H. and Gros, D. (2014). Designing a European Unemployment Insurance Scheme. Intereconomics, 49(4), 184-203.

Beblavý, M. and Lenaerts, K. (2017). Feasibility and Added Value of a European Unemployment Benefits Scheme. Centre for European Policy Studies, Brussels.

Dahlby, B. (1996). Fiscal externalities and the design of intergovernmental grants. International tax and public finance, 3(3), 397-412.

Dolls, M., Fuest, C., Neumann, D. and Peichl, A. (2018). An unemployment insurance scheme for the euro area? A comparison of different alternatives using microdata. International Tax and Public Finance, 25(1), 273-309.

Fenge, R. and Friese, M. (2018). Should Unemployment Insurance be Centralized in a State Union? CESifo Working Paper, No. 6898.

Hamermesh, D. S. (1993). Labor Demand. Princeton University Press.

Harris, J. R. and Todaro, M. P. (1970). Migration, Unemployment and Development: A Two-Sector Analysis. In: American Economic Review, 60(1), 126-142.

Holmlund, B. and Lundborg, P. (1988). Unemployment Insurance and Union Wage Setting. In: The Scandinavian Journal of Economics, 90(2), 161-172.

Holmlund, B. and Lundborg, P. (1989). Unemployment Insurance Schemes for Reducing the Natural Rate of Unemployment. In: Journal of Public Economics, 38, 1-15.

Keen, M. J. and Kotsogiannis, C. (2002). Does Federalism Lead to Excessively High Taxes? In: American Economic Review, 92(1), 363-370.

Kolmar, M. (1999). Optimale Ansiedlung sozialpolitischer Entscheidungskompetenzen in der Europäischen Union: Eine theoretische Untersuchung. Mohr Siebeck.

Lichter, A., Peichl A., and Siegloch S. (2015). The Own-Wage Elasticity of Labor Demand: A Meta-Regression Analysis. In: European Economic Review, 80, 94-119.

Lozachmeur, J.-M. (2003). Fiscal Competition, Labor Mobility, and Unemployment. In: FinanzArchiv/ Public Finance Analysis, 59(2), 212-226.

Moyen, S., Stähler, N. and Winkler, F. (2019). Optimal unemployment insurance and international risk sharing. In: European Economic Review, 115, 144-171.

Oates, W. E. (1972). Fiscal Federalism. Citeseer.

Saha, D. and Schöb, R. (2019). Unemployment Insurance in Unionized Labor Markets with Mobile Workers: Neither Ghent nor Centralized. In: Empirica, 46(2), 305-326.

Wellisch, D. (2000). Theory of Public Finance in a Federal State. Cambridge University Press.

Wildasin, D. E. (1991). Income Redistribution in a Common Labor Market. In: American Economic Review, 81(4), 757–774.

Zodrow, G. R. and Mieszkowski P. (1986). Pigou, Tiebout, Property Taxation, and the Underprovision of Local Public Goods. In: Journal of Urban Economics, 19(3), 356-370.