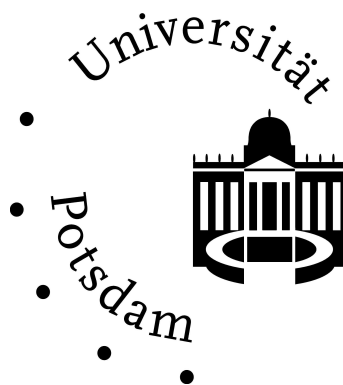# UNIVERSITÄT POTSDAM

WIRTSCHAFTS- UND SOZIALWISSENSCHAFTLICHE FAKULTÄT

VOLKSWIRTSCHAFTLICHE DISKUSSIONSBEITRÄGE

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ENDOGENOUS UNEMPLOYMENT INSURANCE AND REGIONALISATION

Diskussionsbeitrag Nr. 45

Potsdam 2001

Endogenous unemployment insurance and regionalisation

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first version: May 8, 2001
this version: December 2, 2001

This study is concerned with the impact of a regionalisation of unemployment insurance (UI) on workers´ preferences, on firms´ profits, and on efficiency. The existence and the extent of UI are endogenously derived by maximising an objective function of the UI. Three different types of regionalisation are considered which differ with respect to the area the UI objective function is related to, and with respect to the policy variable used to maximise it. It comes to light that workers are always in favour of central UI, while it depends on the type of regionalisation whether or not firms are better off with regional or with central UI. The same somewhat surprising result applies for efficiency.

Introduction

Unemployment insurance (UI) usually does not differenciate between groups of workers characterised by a different risk of becoming unemployed. This means that workers who bear a systematically low risk of becoming unemployed (involuntarily) subsidise high-risk workers. For instance, there is a considerable interregional transfer of wealth through UI in countries like Italy, Germany, or the United Kingdom which are rather heterogenous with respect to regional unemployment rates. The distorsion of migration decisions caused by this subsidy led some economists to call for a reform of UI, leading to regionally independent budgets (see e.g. Welfens, 1998, p. 293). In short, their argumentation is that the reform would improve efficiency by giving an incentive to migrate into the region where labour is relatively scarce. Then, the UI parameters would perfectly reflect the regional abundance of labour.

This study is concerned with the impact of a regionalisation of UI on workers´ expected utility, on firms´ profits, and on efficiency. In contrast to many contributions dealing with UI, the present paper endogenously derives the reason for the existence and the extent of UI by assuming an objective function to be maximised by the choice of UI parameters. For the indicated aim, the approach established by Sanner (2001) which integrates elements from labour market theory (right-to-manage approach), the theory of fiscal federalism, and migration theory with self-financing UI is extended to include the objectives pursued by UI. The framework´s complexity implies that a number of simplifying assumptions are indispensable, and that a comparison of the models is only possible if the models are calibrated.

In the following section, the basic assumptions are given, the objective function to be maximised by the choice of UI parameters is discussed, and the constraints of the maximisation problem are introduced. In section 2, the models are calibrated for a comparison of the results. The final section provides some concluding remarks.

I. ANALYTICAL FRAMEWORK

Assumptions

We employ the following assumptions and standardisations. A1 to A7 stem from Sanner (2001). They build the basic approach which is extended in this study.

A1 A federal state consists of two regions ($i \in 1, 2$) which differ only with respect to the endowment with an immobile, inelastically and costlessly supplied factor of production subsequently referred to as infrastructure, x_i. Region 1 is assumed to possess more infrastructure than region 2, $x_1 > x_2$. Regions 1 / 2 are referred to as *rich* region and *poor* region, respectively.

A2 In each region, K identical firms produce a single homogeneous good which is taken as numeraire. K is assumed to be sufficiently large that firms behave as price-takers on every market. The technology of a representative firm shall be described by the production function

$$f_i = f(n_i, x_i),$$

where n symbolises labour input. Denoting derivatives with subscripts (and omitting the subscript i for simplicity), it is assumed that $f_n > 0$, $f_x > 0$, $f_{nn} < 0$. Infrastructure enhances the productivity of labour, expressed by a

positive cross-derivative, $f_{nx} > 0$. There are no fixed costs, so that the profits of a firm can be written as

$$\pi_i = f(n_i, x_i) - n_i w_i, \tag{1}$$

where w represents the gross wage rate per unit of labour. Profit maximisation yields the inverse labour demand function:

$$f_{n_i} = w. \tag{2}$$

A3 M identical workers inelastically supply one unit of labour. They share the same concave utility function:

$$u_{i,j} = u(c_{i,j}),$$

where c stands for consumption of the homogenous good, and where the subscript j with $j \in e, u$, indicates whether a worker is employed ($j = e$) or not ($j = u$). Consumption before the deduction of eventual migration costs reads $c_{i,e} = (1 - \tau_i)w_i$ in the case of employment, where τ is the proportional UI tax rate, and $c_{i,u} = \beta_i \overline{w}_i$, with $\overline{w}$ denoting the wage level used to calculate UI benefits, and β standing for the benefit rate, in the case of unemployment. Workers maximise expected utility by choosing the region where they supply labour.

A4 Ex ante, there live one half of the total workforce in each region. Migration occurs in one direction only, i.e. from the poor to the rich region. If a worker migrates, costs corresponding with an annuity of k arise. Within both regions, workers are distributed equally over firms, sharing the same risk of unemployment. The number of workers per firm is denoted by m.

A5 All (employed and unemployed) workers are members of a trade union. The gross wage rate is subject to a bargain between one union and one firm (decentralised bargain). Firms retain control over employment (right-to-manage approach, for models with UI see e.g. Pissarides (1998)).

A6 Unions maximise the expected utility of a representative member (see e.g. Oswald, 1985, p. 163). We employ the symmetric Nash solution to the bargaining problem which maximises the product of a union´s and the corresponding firm´s payoff. Firms attain zero profits if the bargain breaks down, so that

the payoff of an agreement equals the value of the profits (Creedy and Mc-Donald, 1991, p. 350). The 'threat point' of a union is given by the situation where all of its members receive UI benefits. The payoff of a union, G, is thus the difference between the expected utility of a representative worker in the case of an agreement, and the utility of an unemployed worker (Farber, 1986, p. 1070):

$$
\begin{aligned}
G &= \frac{n}{m} u[(1-\tau)w] + \left(1 - \frac{n}{m}\right) u[\beta\overline{w}] - u[\beta\overline{w}] \\
&= \frac{n}{m} \left\{ u[(1-\tau)w] - u[\beta\overline{w}] \right\}.
\end{aligned} \tag{3}
$$

While bargaining, firms and unions take employment, wages and UI parameters as given. The Nash product to be maximised then reads

$$
\begin{aligned}
\max_{w} NP &= G \cdot \pi \\
&= \frac{n}{m} \left(u_e - u_u\right) \cdot [f(n,x) - nw].
\end{aligned} \tag{4}
$$

A7 The UI is obliged to balance its budget. Alternatively, it is assumed that the budget(s) is (are) to be balanced within each region (regional UI), or on the whole (central or federal UI).

A8 The UI authority knows the interplay between UI parameters, wages, and employment. It maximises an exogenously given objective function. It is assumed that the objective function which reflects the preferences of the society, is related either to the same, or to a higher level of territorial authority as the balancing of the budget.

Models

Since the UI has two parameters only, the contribution rate τ and the benefit rate β, A7 and A8 imply that both are determined simultaneously. If they are related to the same region(s), it doesn´t make any difference whether the contribution rate is calculated such that the budget is equilibrated, and the benefit rate serves to maximise the objective function or the other way around. Therefore, and because of assumption A8, it suffices to consider four different institutional settings:

Model I Both, the balancing of the budget, and the maximisation of the objective function take place on the central level. This means that the UI benefit rate as well as the UI tax rate are uniform across the federal state.

Model II   Regional UI authorities adjust the contribution rate such that UI revenues equal expenditures within each region. The benefit rate is uniform across both regions, and serves to maximise the objective function.

Model III   The benefit rate is adjusted regionally to equilibrate the budgets of UI, while the contribution rate is uniform across the federal state.

Model IV   UI benefits and taxes are determined on the regional level. In this case, the federal level has no function at all, so that one should rather think of two independent states, linked by migration, than of a federation.

In models II and III, regional UI authorities hold no decision-making competence. Therefore, only model IV truely describes a regionalisation of UI in a strict sense. But in the former cases also, there is no indirect transfer from the rich to the poor region through UI. To assess the effects of the different kinds of regionalising UI, the outcome of each model with regionally balanced UI budgets (II-IV) respectively is compared with the outcome of the model with centrally balanced UI budget (I).

Objectives of UI

The objectives persecuted by the UI authority need not literally be its own objectives. It may well be that the legislator or the department of employment set what the UI authority shall strive for.

Now, what are the objectives of UI? In some countries, the UI is also responsable for active labour market policy, so that the impression could arise that UI seeks to reduce unemployment. Yet, it is obvious that, with respect to this goal, the optimal policy would be to abolish UI. Without UI, wages would be the lowest in most models of the labour market, as well as presumptively in reality, causing the highest employment. The same result would come to light if the GDP was to be maximised.

The answer to the question depends on one´s view of the state. To assume that UI maximises the expected utility of workers corresponds with a positive attitude towards the state. In comparison, e.g. Brennan and Buchanan (1980) assume a "Leviathan", who seeks to enlarge himself. In the context of the present study this would mean that the UI maximises its tax revenues (and, through it, also its expenditures).

In the present study, and in our opinion more plausibly, there are two objectives which can be attached to UI. First, workers shall be protected as good as possible

against fluctuations of their income. This would suggest to choose a high replacement rate, i.e. the focus lies on the unemployed. Secondly, employment shall be enhanced, i.e. the incentive to work shall be preserved which implies that employed workers must be considerably better off than unemployed workers. An objective function which integrates both objectives and which is thus suitable to express the described trade-off is

$$Z\left(\beta_1, \beta_2, \frac{n_1}{m_1}, \frac{n_2}{m_2}\right) = \beta_1^{\frac{\rho}{2}} \cdot \beta_2^{\frac{\rho}{2}} \cdot \left(\frac{n_1}{m_1}\right)^{\frac{1-\rho}{2}} \cdot \left(\frac{n_2}{m_2}\right)^{\frac{1-\rho}{2}} \qquad \text{with } 0 < \rho < 1. \quad (5)$$

The first two arguments are the benefit rates from both regions. They stand for the well-being of the unemployed. The third and fourth argument are the employment rates in both regions. These arguments are weighted in the objective function with their exponents which sum up to unity. The exogenous parameter ρ indicates the relative weight of the goal "high compensation", while $1 - \rho$ stands for the relative weight of the goal "high employment". The objective function (5) shall be used in the following analysis to endogenise the extent of UI when the objectives of UI are related to both regions (models I-III). In model IV, the function needs modification because in that case the arguments are related to only one region. Then, the objective functions are:

$$Z_i^{IV}\left(\beta_i, \frac{n_i}{m_i}\right) = \beta_i^{\rho} \cdot \left(\frac{n_i}{m_i}\right)^{1-\rho} \qquad \forall i \in 1, 2, \quad \text{with } 0 < \rho < 1. \quad (6)$$

Constraints of the maximisation

In each model, one constraint of the maximisation problem is that of UI being self-financing. The shape of the equations depends on whether the budget is to be equilibrated regionally, or on the whole. In the former case, the revenues and expenditures of UI have to coincide within each region. The budget constraints then read

$$\tau_i n_i K w_i = \beta_i (m_i - n_i) K w_i, \quad \forall i \in 1, 2. \quad (7)$$

In the case of a uniform benefit rate (model II), $\beta_1 = \beta_2 = \beta$, and in the case of a uniform contribution rate (model III), $\tau_1 = \tau_2 = \tau$. If UI is central (Model I), the budget constraint is

$$n_1 K \tau w_1 + n_2 K \tau w_2 = (m_1 - n_1) K \beta w_1 + (m_2 - n_2) K \beta w_2. \quad (8)$$

The revenues of the UI respectively stand on the left-hand side of the equations, while the expenditures are on the right-hand side.

If the assumption that the UI aims at increasing employment shall make sense, it must recognise the impact of its parameters on wages. In other words, it is perfectly informed about the utilities of workers in the cases of employment, and of unemployment, because these enter into the wage determination by collective bargaining. Then, there is no reason why the UI should not be aware of migration responses of workers to changes of UI parameters. To know about the wage determination also implies that the UI knows the profit and the labour demand function of firms. In other words, the UI has all information necessary to choose the equilibrium that fulfills best the requirements stated in the objective function (5). Formally, this means that every equilibrium condition of the model is a constraint of the maximisation (see assumption A8).

Since we assume that firms controll employment, the realised combination of wages and employment must lay on the (inverse) labour demand function (2) in both regions. Next, the first-order condition for a maximum of the Nash product (4) must be fulfilled in both regions. Building the derivative with respect to the wage rate, and setting $w = \overline{w}$, we get

$$\frac{n_{iw_i}}{n_i} + \frac{u_{i,e_{w_i}}}{u_{i,e} - u_{i,u}} - \frac{n_i}{f(n_i, x_i) - n_i w_i} = 0, \quad \forall i \in 1, 2. \tag{9}$$

Finally, the UI takes migration responses into account. Two relationships determine the distribution of workers on regions, expressed by the number of workers per firm within each region, m_1 and m_2. First, a migration equilibrium requires that there is no incentive for workers from the poor region to move to the rich region any longer, i.e. the expected utility in the cases of migration and of remaining must be equal. If $u[(1 - \tau_1)w_1 - k] = u_{m1,e}$, $u[\beta_1 w_1 - k] = u_{m1,u}$, $u[(1 - \tau_2)w_2] = u_{2,e}$, and $u[\beta_2 w_2 - k] = u_{2,u}$, this condition corresponds with the following equation:

$$\frac{n_1}{m_1}u_{m1,e} + \frac{m_1 - n_1}{m_1}u_{m1,u} = \frac{n_2}{m_2}u_{2,e} + \frac{m_2 - n_2}{m_2}u_{2,u}, \tag{10}$$

where the fractions should be interpreted as the probabilities to become employed or unemployed in both regions, respectively. Secondly, the number of workers is given. This means that m_1 and m_2 sum up to a constant, or

$$K(m_1 + m_2) = M. \tag{11}$$

The maximisation problem of the UI consists of the objective function (5), and seven or eight constraints in the cases of central and regional UI, respectively. These are the budget constraint(s) (8) or (7), the inverse labour demand function (2) and

the first-order condition for a maximum of the Nash product (9) for each region, as well as equations (10) and (11). The Lagrangian functions for models I to IV are given in the appendix. In model IV, the function is related to the UI in region 1 only. Because in this case a change of the UI parameters in one region affects the optimal choice of parameters of the UI in the other region, the UI could set their parameters strategically. We will however abstract from such considerations and assume that each UI takes the contribution rate of the other UI as given. The corresponding function for the UI from region 2 can be obtained by exchanging the subscripts.

The equation systems which are formed by the first-order conditions of the maximisation problems stated in the appendix cannot be solved generally. However, it is possible to assume specific functions instead of the general utility and production functions, and to replace the exogenous variables by specific values. Then, the outcome of the models with regional UI can be compared with the outcome of the model with central UI which is subject of the following section.

II. Specification, and Comparison of the Models

Specification

The chosen utility function and production function read:

$$\text{utility function} \qquad u(c) = \sqrt{c},$$

$$\text{production function} \quad f(n,x) = \tfrac{1}{a}\left(nx - \tfrac{1}{2}n^2\right),$$

with a being a positive parameter. Both functions have the assumed properties, i.e. positive first derivatives, and negative second derivatives with respect to consumption and employment, respectively[1]. The cross-derivative of the production function is positive. The labour demand function can be derived by partially differentiating $f(\cdot)$, and rearranging: $n = x - aw$. The values for the exogenous parameters are given in table 1.

Table 1: parameter values

parameter	a	k	K	M	x_1	x_2
value	0.6	0.27	1	1	1	0.6

---

[1]The signs of the derivatives only follow if $x > n$ which is guaranteed by the choice of the parameters made hereafter.

Comparison of the models

With the indicated functions, and the parameter values given in table 1, the endogenous variables of the models can be found heuristically for given weights ρ of the objectives of UI. Then, the profits and expected utilities of firms and workers from both regions can be computed. A comparison of these values from the model with central UI (model I) with the corresponding values from a model with regional UI (models II-IV) shows whether or not the respective group of actors prefers central or regional UI. Apart from preferability, an efficiency criterion is used to compare the models.

Figure 1 assesses the preferability and efficiency of central vs. regional UI when there is still a uniform benefit rate which is determined on the federal level (model 1 vs. model II). The definitions and interpretations of the curves are (for figures 2 and 3 analogous definitions apply):

$$Fi \equiv \quad \pi_i^I - \pi_i^{II} \quad \begin{cases} > 0 & \text{firms from region i prefer central UI} \\ \\ < 0 & \text{firms from region i prefer regional UI} \end{cases}$$

$$\tag{12}$$

$$Wi \equiv \quad Eu_i^I - Eu_i^{II} \quad \begin{cases} > 0 & \text{workers from region i prefer central UI} \\ \\ < 0 & \text{workers from region i prefer regional UI,} \end{cases}$$

where the superscripts I and II stand for the models employed to calculate the indicated variable.

For the efficiency criterion, the total production in both regions is summed up, less the total costs of migration. Related to one firm from each region, the variable is defined as follows:

$$z \equiv f(n_1, x_1) + f(n_2, x_2) - k \left(m_1 - \frac{M}{2K} \right).$$

The number of workers per firm is $M/(2K)$ ex ante since workers are distributed evenly across all firms (see assumption A4). To find out, under which arrangement more income rests for consumption, the differences between z in the case of central UI and z in the cases of regional UI are calculated:

$$\Delta z = z^I - z^{II} \quad = \quad f^I(n_1, x_1) + f^I(n_2, x_2) \tag{13}$$
$$- \left[f^{II}(n_1, x_1) + f^{II}(n_2, x_2) \right] - k \left(m_1^I - m_1^{II} \right).$$

Again, positive values signify an advantage of central UI and negative ones that regional UI is preferable. If, for instance, the value of Δz is positive, it is *potentially* possible that all workers and firms are better off with central UI if the excess of production is distributed appropriately.

—— Figure 1 here ——

The range of ρ is limited by equation (5), and by the restriction that all endogenous variables must be non-negative. Figure 1 shows that workers from both regions are better off if UI is organised on the central level. Firms from region 2 are also in favour of central UI. Only firms from the rich region have an advantage if UI is regionalised. This advantage, however, is by far larger than the disadvantage the other agents suffer from regional UI. The latter can be concluded from the negative sign of the efficiency criterion, Δz, stating that the quantity of production which rests for consumption or profits is higher with regional UI.

Things considerably change if a uniform UI tax rate is used to maximise the objective function of the UI, while the benefit rates are adjusted according to regional unemployment rates (model III). Figure 2 shows that, if this model is compared with model I, firms from region 1 prefer central UI, whereas firms from the poor region have an advantage from regional UI. The efficiency criterion now recommends central UI. Workers from both regions are still in favour of central UI.

—— Figure 2 here ——

If regionalisation of UI means that UI benefits as well as UI taxes are determined on the regional level, firms from both regions are better off with regional UI (see figure 3). The efficiency criterion also favours regional UI. Workers from any region prefer central UI, however.

—— Figure 3 here ——

The key to an understanding of figures 1-3 lies in the responses of wages to variations of UI parameters, and in the induced migration reactions. First, the preferences of workers from the rich and from the poor region parallel each other because migration costs determine the difference in terms of income. Thus, there is no contradiction between workers´ preferences as one could suspect on the first sight. Secondly, higher UI contributions cause the bargaining parties to agree on

10

higher wages. This relation, which is not unambigous in the literature (see e.g. Layard (1982), Lockwood and Manning (1993), and, for empirical evidence, Steiner (1998)), holds for the assumed functions and parameters of this model. Therefore, a regionalisation of UI in the sense of model II, leading to lower contributions in region 1, lowers the wage rate there, which explains why firms from region 1 prefer regional UI. For region 2, the opposite holds true. Thirdly, an increase of UI benefits raises equilibrium wages, too. This result is well-known in the theoretical literature, but, nevertheless, it is difficult to find empirical evidence for it (for an overview over empirical studies on this subject see Layard, Nickell and Jackman (1991, p. 211)). This relationship means that if regionalisation takes place like in model III, the increase of benefits in region 1 causes wages to rise. Therefore, firms from region 1 are in favour of a central UI. The inverse effects occur in region 2.

In any case, the difference of the wage rate in region 1 between central and regional UI is larger than the wage rate in region 2. This can be stated by the course of F1 compared to F2 in figures 1 to 3, and is due to the effect of the induced migration responses on UI parameters. Since, with given infrastructure, profits depend on wages only, the effects on wages can be concluded from F1 and F2. Since higher wages do not only have a negative impact on profits but also on production, it is clear, why the efficiency criterion which contains the total production always favours the same organisational form of UI as firms from region 1 do.

The case of regionally determined UI contributions *and* benefits is special in that the preferences of firms from both regions are contrary to the preferences of workers. The reason is an external effect. If the benefit rate in region 1 is raised, more workers from region 2 immigrate. This effect is augmented by the induced increase of the wage rate. This means that unemployment in region 2 is reduced, and the value of the UI objective function in region 2 increases. Since the regional UI authorities mutually neglect the positive effect of a higher benefit rate on the objective function of the other UI authority, the optimal benefit rate (and, therefore, the optimal contribution rate as well) is lower than in models where the objective function is related to the federation, with equal weighting of the two objectives. Hence, wages are lower, too, leading to the preferences of firms and workers depicted in figure 3.

The trade-off occuring in model IV is typical for models of fiscal federalism. On the one hand, regions have diverging interests because they are different. In this respect, the regionalisation has an advantage since each region can determine UI parameters as it is optimal in its respective economic situation. On the other hand, the interdependence of the economic systems then leads to an external effect which causes underprovision with a public good, or, like in the present study, with social

insurance (see e.g. the contributions surveyed in Wildasin and Wilson, 1991). However, there is one fundamental difference. In those studies, the regions compete to attract the mobile tax basis by lowering the tax rates which leads to a disadvantage of the other region (see e.g. Zodrow and Mieszkowski, 1986). Here, the emigration of a part of the labour force allows to increase benefits or to lower taxes because, with given employment, less workers remain unemployed.

Figures 1-3 reveal that the preferences of firms and workers do not hinge on the weight the UI authority attaches to its objectives "employment" and "benefit rate". Yet, it has an impact on the amount of the advantage or disadvantage, a group of firms or workers has from a certain organisational form of UI.

III. Conclusions

The present study investigates the effects of three different types of regionalisation of UI on profits of firms, on the expected utility of workers, and on efficiency. A common view is that a regionalisation of social insurance would generally be to the economic disadvantage of agents from the poor region, and to the advantage of agents from the rich region, and that efficiency is always improved by it. However, our results shed a different light on the issue:

- Workers from any region prefer central UI to any of the considered forms of regional UI.

- If the UI tax rate only is determined according to regional unemployment rates, firms from the rich region prefer regional UI, and firms from the poor region prefer central UI. If the benefit rate only is regionally variable, the inverse holds true. If both parameters are determined on the regional level, both groups of firms prefer regional UI.

- The efficiency criterion favours regional UI if the regionalisation concerns the benefit rate only, or if both parameters of UI are determined on the regional level. In the case of a uniform UI tax rate, where only the benefits are adjusted regionally, efficiency is worsened by the reform.

- Neither the preferences of economic agents, nor efficiency qualitatively depend on the weighting of the two objectives of UI, to provide a high compensation for the unemployed, and to enhance employment.

It should be emphasised, however, that these results partially hinge on the employed production and utility functions, and on the specification of exogenous variables. Yet, as it is done above, the results of the analysis which contradict the common view on this issue can be traced back to plausible economic effects. In this way, the use of a formal approach contributes to a sounder understanding of the effects, a regionalisation of UI has.

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Appendix

Model I

$$
\begin{aligned}
\max_{\beta,\tau,m_i,n_i,w_i,\lambda_j} \mathcal{L}_I \;=\; & \beta^\rho \cdot \left(\frac{n_1}{m_1}\right)^{\frac{1-\rho}{2}} \cdot \left(\frac{n_2}{m_2}\right)^{\frac{1-\rho}{2}} \\
& +\lambda_1 \left[(\beta+\tau)(n_1 w_1 + n_2 w_2) - \beta(m_1 w_1 + m_2 w_2)\right] \\
& +\lambda_2 \left[f_{n_1}(n_1,x_1) - w_1\right] \\
& +\lambda_3 \left[f_{n_2}(n_2,x_2) - w_2\right] \\
& +\lambda_4 \left[\frac{n_{1w_1}}{n_1} + \frac{u_{1,e_{w_1}}}{u_{1,e}-u_{1,u}} - \frac{n_1}{f(n_1,x_1)-n_1 w_1}\right] \\
& +\lambda_5 \left[\frac{n_{2w_2}}{n_2} + \frac{u_{2,e_{w_2}}}{u_{2,e}-u_{2,u}} - \frac{n_2}{f(n_2,x_2)-n_2 w_2}\right] \\
& +\lambda_6 \left[\frac{n_1}{m_1}u_{m1,e} + \frac{m_1-n_1}{m_1}u_{m1,u} - \frac{n_2}{m_2}u_{2,e} - \frac{m_2-n_2}{m_2}u_{2,u}\right] \\
& +\lambda_7 \left[K(m_1+m_2) - M\right], \qquad \text{with } i \in 1,2 \text{ and } j \in 1,\dots 7.
\end{aligned}
\tag{14}
$$

Model II

$$
\max_{\beta,\tau_i,m_i,n_i,w_i,\lambda_j} \mathcal{L}_{II} = \beta^\rho \cdot \left(\frac{n_1}{m_1}\right)^{\frac{1-\rho}{2}} \cdot \left(\frac{n_2}{m_2}\right)^{\frac{1-\rho}{2}} \tag{15}
$$
$$
+\lambda_1 \left[(\beta + \tau_1)n_1 - \beta m_1\right]
$$
$$
+\lambda_2 \left[(\beta + \tau_2)n_2 - \beta m_2\right]
$$
$$
+\lambda_3 \left[f_{n_1}(n_1, x_1) - w_1\right]
$$
$$
+\lambda_4 \left[f_{n_2}(n_2, x_2) - w_2\right]
$$
$$
+\lambda_5 \left[\frac{n_{1w_1}}{n_1} + \frac{u_{1,e_{w_1}}}{u_{1,e} - u_{1,u}} - \frac{n_1}{f(n_1, x_1) - n_1 w_1}\right]
$$
$$
+\lambda_6 \left[\frac{n_{2w_2}}{n_2} + \frac{u_{2,e_{w_2}}}{u_{2,e} - u_{2,u}} - \frac{n_2}{f(n_2, x_2) - n_2 w_2}\right]
$$
$$
+\lambda_7 \left[\frac{n_1}{m_1}u_{m1,e} + \frac{m_1 - n_1}{m_1}u_{m1,u} - \frac{n_2}{m_2}u_{2,e} - \frac{m_2 - n_2}{m_2}u_{2,u}\right]
$$
$$
+\lambda_8 \left[K(m_1 + m_2) - M\right], \qquad \text{with } i \in 1,2 \text{ and } j \in 1,\ldots 8
$$

Model III

$$
\max_{\beta_i,\tau,m_i,n_i,w_i,\lambda_j} \mathcal{L}_{III} = \beta_1^{\frac{\rho}{2}} \cdot \beta_2^{\frac{\rho}{2}} \cdot \left(\frac{n_1}{m_1}\right)^{\frac{1-\rho}{2}} \cdot \left(\frac{n_2}{m_2}\right)^{\frac{1-\rho}{2}} \tag{16}
$$
$$
+\lambda_1 \left[(\beta_1 + \tau)n_1 - \beta_1 m_1\right]
$$
$$
+\lambda_2 \left[(\beta_2 + \tau)n_2 - \beta_2 m_2\right]
$$
$$
+\lambda_3 \left[f_{n_1}(n_1, x_1) - w_1\right]
$$
$$
+\lambda_4 \left[f_{n_2}(n_2, x_2) - w_2\right]
$$
$$
+\lambda_5 \left[\frac{n_{1w_1}}{n_1} + \frac{u_{1,e_{w_1}}}{u_{1,e} - u_{1,u}} - \frac{n_1}{f(n_1, x_1) - n_1 w_1}\right]
$$
$$
+\lambda_6 \left[\frac{n_{2w_2}}{n_2} + \frac{u_{2,e_{w_2}}}{u_{2,e} - u_{2u}} - \frac{n_2}{f(n_2, x_2) - n_2 w_2}\right]
$$
$$
+\lambda_7 \left[\frac{n_1}{m_1}u_{m1,e} + \frac{m_1 - n_1}{m_1}u_{m1,u} - \frac{n_2}{m_2}u_{2,e} - \frac{m_2 - n_2}{m_2}u_{2,u}\right]
$$
$$
+\lambda_8 \left[K(m_1 + m_2) - M\right], \qquad \text{with } i \in 1,2 \text{ and } j \in 1,\ldots 8
$$

Model IV

$$\max_{\beta_i,\tau_1,m_i,n_i,w_i,\lambda_j} \mathcal{L}^{IV} = \beta_1{}^\rho \cdot \left(\frac{n_1}{m_1}\right)^{1-\rho} \tag{17}$$

$$+\lambda_1\left[(\beta_1+\tau_1)n_1 - \beta_1 m_1\right]$$

$$+\lambda_2\left[(\beta_2+\tau_2)n_2 - \beta_2 m_2\right]$$

$$+\lambda_3\left[f_{n_1}(n_1,x_1) - w_1\right]$$

$$+\lambda_4\left[f_{n_2}(n_2,x_2) - w_2\right]$$

$$+\lambda_5\left[\frac{n_{1w_1}}{n_1} + \frac{u^e_{1w_1}}{u^e_1 - u^u_1} - \frac{n_1}{f(n_1,x_1) - n_1 w_1}\right]$$

$$+\lambda_6\left[\frac{n_{2w_2}}{n_2} + \frac{u^e_{2w_2}}{u^e_2 - u^u_2} - \frac{n_2}{f(n_2,x_2) - n_2 w_2}\right]$$

$$+\lambda_7\left[\frac{n_1}{m_1}u^{e,1}_2 + \frac{m_1-n_1}{m_1}u^{u,1}_2 - \frac{n_2}{m_2}u^e_2 - \frac{m_2-n_2}{m_2}u^u_2\right]$$

$$+\lambda_8\left[K(m_1+m_2) - M\right], \quad \text{mit } i \in 1,2 \text{ und } j \in 1,\dots 8$$
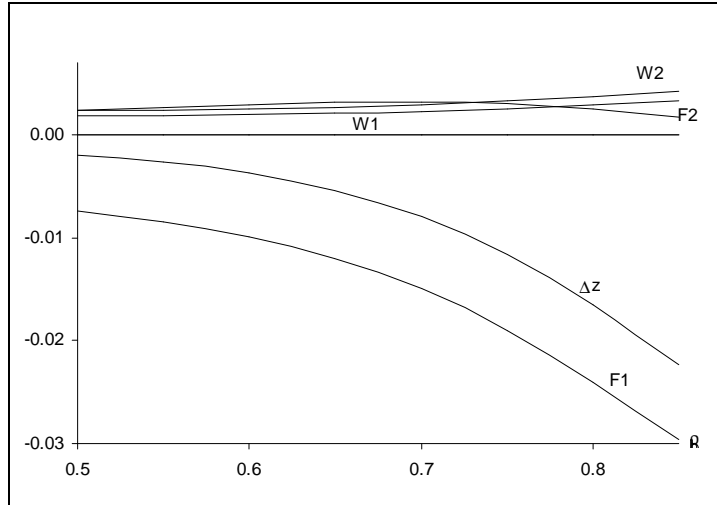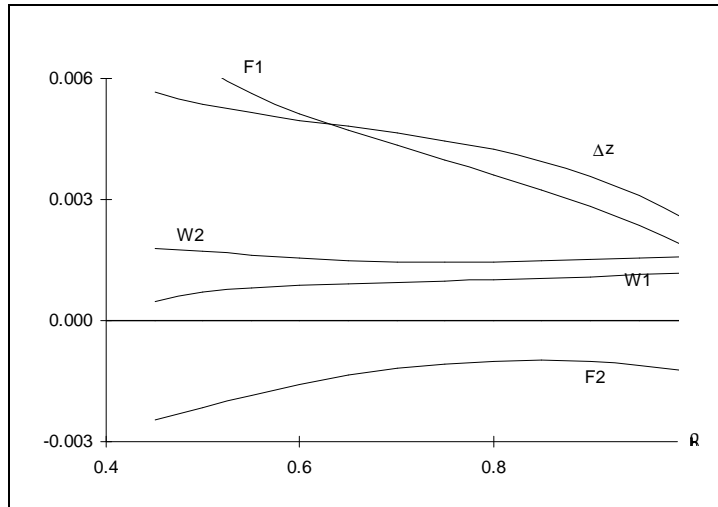

Figure 1: Comparison of model I and model II

Figure 2: Comparison of model I and model III
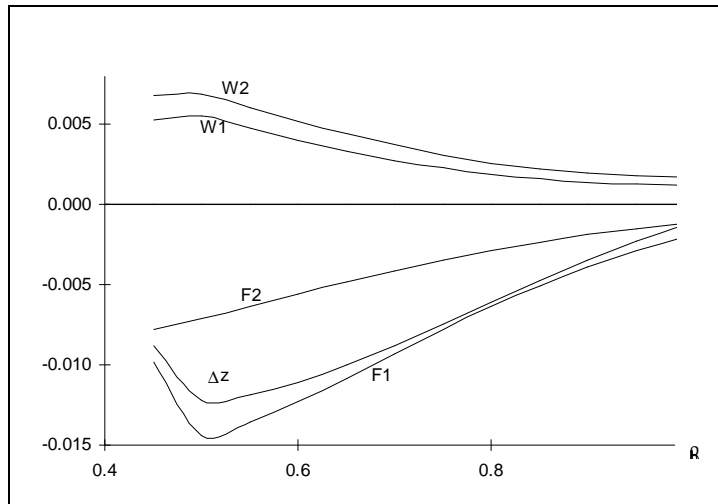

Figure 3: Comparison of model I and model IV

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