The Pitfalls of Regional Education Policy

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Abstract

In this paper we analyse if education subsidies to students in poor areas are an effective tool of regional policy. We show that this policy can miss its objectives and actually hurt instead of help the recipient area. The reason is that geographical mobility increases with the personal skill level. Education subsidies induce individuals to invest more heavily in human capital. At the end of the education period they might have crossed some threshold level of qualification beyond which emigration to the economic centre pays off. Regional policies then result in a brain drain that is harmful to those remaining in the periphery. Education subsidies are a more promising policy instrument the lower is mobility and the better the access to financial markets. Moreover, policymakers can avoid the potential pitfalls of this policy by focussing subsidies on low skilled workers.

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1) Introduction

Many federal governments conduct regional policies, i.e. they try to attract economic activity to peripheral regions. The fear is that without corrective policy interventions internal economic disparities are magnified over time that run opposite to the political preference for a balanced or "harmonic" development of all regions. Economic theory underpins this anxiety through approaches like endogenous growth theory or new economic geography, which imply that market mechanisms might not render regional convergence, but rather reinforce inequalities.

In recent years economists have developed strong interest in regional policy. This includes empirical evaluation studies (e.g. Midelfart-Knarvik/Overman, 2002; Ederveen/de Groot/Nahuis, 2002; Boldrin/Canova, 2001) as well as work on its theoretical foundations (e.g. Ottaviano/Thisse, 2002; Baldwin et al., 2003; Pflueger/Suedekum, 2004). Another issue concerns the effectiveness of different instruments of regional policy [1]. The present paper contributes to this debate by analysing the effectiveness of education subsidies as a tool for achieving regional economic cohesion.

Subsidies to higher education are a salient feature of most developed countries. For the most part these subsidies are justified without any reference to regional policy (see e.g. De Fraja, 2001). But regional objectives also play a role in education policy, particularly in such countries with extreme internal disparities like Italy or Germany. For example, as a means of providing regional aid, universities or other educational institu-

[1] Classical tools of regional policy are infrastructure investments or direct subsidies to firms in lagging regions. Some authors have argued that these instruments run the danger of being ineffective, in some cases even counterproductive for achieving spatial economic cohesion. Baldwin et al. (2003: ch.17), Martin (1999) and Martin/Rogers (1995) analyse the spatial effects of traffic infrastructure investments. They show that an improvement of interregional traffic networks between core and periphery can actually hurt the lagging areas, because it may fuel the relocation of mobile businesses towards the developed centres, since transportation costs decrease and the demand from the periphery can easier be satisfied through exports (see also Faini, 1983). Ottaviano (2003) argues that some forms of direct subsidies to firms have no effects on firm location if they do not outweigh agglomeration rents. Dupont/Martin (2003) demonstrate that even if industry location is affected by subsidies, this might still have perverse effects on the spatial income distribution if firm owners live in the central regions. A comparable analysis about the effectiveness of education subsidies as a regional policy tool has not been provided so far.

tions are often founded or specifically supported in peripheral regions. Individuals may also be targeted more directly.[2] In the recognition of the importance of human capital as a key ingredient for regional growth, both local and federal governments put emphasis on supporting education of students and young workers living in poor areas. For example, Coniglio/Prota (2003) describe a policy, where students from a Mezzogiorno region (Basilicata) receive generous subsidies when enrolling in postgraduate education. The programme is administered by local authorities and (co-)financed by the Italian federal government and the European Union. Similar policies are in place in Germany. Since reunification, East German states have received massive transfers from the West. A considerable part of these transfers was conditional ("Aufbau Ost"-programme). Local governments were restricted to use the funds according to the priorities set by the federal government, which also involved education subsidies. Another example is the active labour market policy of the German Federal Employment Agency, which has a strong regional component and provides various forms of tuition-free courses for young workers in East Germany (Vollkommer, 2004). On top of that, local governments have spent at least parts of the unconditional transfers from the federal state on education subsidies (e.g. for coverage of learning-related expenses etc.)[3].

The aim of this paper is to analyse if education subsidies to students in poor areas are an effective vehicle for sponsoring regional convergence. We develop a two-region OLG-model with heterogeneous agents and endogenous education and residence choice. The technology is characterized by localized scale effects, so that an endogenous force exists

[2] These policies are particularly relevant, because below we will model an education subsidy that is paid directly to students in poor regions.

[3] Regional policy is also a major concern for the European Union (roughly one third of the annual budget), which spends a considerable fraction of the structural funds on education measures. The individuals from the European regions will not receive education subsidies directly from Brussels. Yet, the European cohesion policy is relevant for this paper insofar, as the EU co-finances programmes initiated and administrated by the single regions ("bottom-up approach") that also include direct subsidies to students, e.g. the Basilicata programme described above.

that pushes for the spatial agglomeration of economic activity in the larger region[4]. The core region, which is initially richer (and larger) than the peripheral area, pays a wage premium and thereby attracts immigrants. This wage premium is rising with the personal skill level (see Moeller/Haas, 2003 for recent empirical evidence on this), but the geographical mobility costs are identical for all workers. Chiswick (2000) has shown how constant out-of-pocket mobility costs generate a positive self-selection of migrants in such a human capital model of migration[5]. Now consider the role of education subsidies that are paid to students in the poor region. The subsidy increases human capital formation and thereby can have a positive effect on wages. But there is also a second effect. At the end of the study period, individuals can have acquired enough skills in order to cross some threshold level beyond which migration to the economic centre pays off. The induced emigration negatively affects wages of those workers who stay in the periphery. If this effect dominates, the regional policy intervention has missed its objective to promote a catching-up of the periphery.

We discuss under which circumstances education subsidies appear to be a promising policy instrument, and under which they are not. We show that they are less likely to work the stronger the initial disparity between the central and the peripheral region and the more responsive are individuals in their location decision. Moreover, we analyse the role of capital market imperfections and find that access to financial markets strengthens

[4] Localized increasing returns or agglomeration mechanisms are the cause of endogenous divergence tendencies. These are a major concern of policymakers at the federal level and motivate regional policy interventions to begin with. Architects of regional policy arrangements seem to be convinced that this specification of the production process is an appropriate description of reality: "Historical experience suggests […] that in the absence of countervailing policies, the overall impact [of more economic integration] on peripheral regions could be negative. Transport costs and economies of scale would tend to favor a shift in economic activity away from less developed regions, especially if they were at the periphery of the Community, to the highly developed areas at its center." (Delors Report, 1989).

[5] Recent empirical evidence strongly supports the view that internal migrants who are mobile across regions tend to be high skilled (see e.g. Giannetti, 2001 for Italy; Hunt, 2000 for Germany; Mauro/Spilimbergo, 1999 for Spain). Self-selection has also been studied with other migration models, e.g. the Roy-model, where the relative income inequality of source and destination area determines the skill composition of migrants (Borjas, 1987; Borjas/Bronars/Trejo, 1992).

the case that education subsidies are a successful instrument of regional policy. We also show that policymakers can avoid the potential pitfall of this policy by taking the induced migration incentives into account. For example, this can be done by paying ability-dependent subsidies and focussing the policy on the relatively low skilled workers.

Our analysis is related to the brain drain argument from the older development literature (e.g. Bhagwati, 1976). Haque/Kim (1995) show how brain drain can distort the incentives for governments in developing countries to provide higher education[6]. Justman/Thisse (1997) point out that, due to high skilled labor mobility, the public benefits of human capital investments do not necessarily accrue where they are funded. There can thus be a case for federal instead of local funding of universities. Bound et al. (2001) emphasise this by showing that there is only a weak link between the local production and the local stock of university graduates in the United States, suggesting that many students migrate at the end of the education period. This agrees with the case study of Coniglio/Prota (2003), who also find a high migration propensity among the recipients of an education subsidy. In contrast to the existing literature, our model incorporates the (unwanted sponsoring of the) brain drain into a framework with fully endogenous migration and education choices and a technology exhibiting increasing returns. Moreover, we derive policy conclusions from a new angle. We do not analyse jurisdictional competition in education provision with mobile human capital (as Poutvaara, 2000), or at the implications of high skilled labor migration for local public finance (as Justman/Thisse, 1997). We rather look at a government whose objective is more regional equality. Note, however, that we adopt a purely *positive* point of view. We do not ask the *normative* question whether there *should be* a more equal spatial resource allocation (as Ottaviano/Thisse, 2002). We only analyse if education subsidies

[6] Differentiating the higher education sector, Poutvaara (2004) argues that governments might have an incentive to support country-specific rather than internationally compatible skills (e.g., lawyers instead of computer scientists).

are effective for achieving the self-defined political goal, and we point to potential pitfalls that policymakers in reality might not be fully aware of.

The rest of this paper is organized as follows. We introduce our model structure in section 2. After having described the equilibrium in section 3, we derive the spatial implications of education subsidies in section 4. We discuss some extensions of our model in section 5 and provide a conclusion in section 6.

2) The Model

2.1. Consumers

Consider a peripheral region (labelled ´region 1´) that is populated by two generations of heterogeneous agents, similar to the setup in Haque/Kim (1995). For simplicity we abstract both from output and population growth and assume that a new generation of size L_1 is born in each period. Young and old individuals are endowed with one unit of non-leisure time. The young can invest in human capital by devoting time to education. Investments pay off in the old age period by expanding the available effective time budget that is then only used for working. There are no direct costs of education, but only opportunity costs for foregone earnings. The learning productivity differs across individuals depending on innate ability. As a means of regional policy, education in region 1 is subsidized by drawing on tax revenue that is generated in the central region, labelled ´region 2´. At first we assume that there are no financial markets, so that human capital investments are the only means for consumption smoothing. In section 5 we also analyze the case of perfect capital markets. Individuals are tied to their location of birth during young age, but it is possible to emigrate after the first period and to spend the second lifetime period in the economic centre. Migration imposes costs that do not depend on the personal ability level. For simplicity, we work with a logarithmic utility function with a time discount rate $0<\beta<1$. Lifetime utility is given by

$$U_{t,t+1}^{i,1s} = \log c_{t,t}^{i,1s} + \beta \log c_{t,t+1}^{i,1s} \quad , \tag{1}$$

where $c_{t,t+1}^{i,1s}$ denotes consumption of individual i born at time t in region 1 and residing in region $s = \{1,2\}$ in the old age period t+1. The budget constraints are

$$c_{t,t}^{i,1s} = w_{1,t}\left(1-(1-\delta)\ell_t^{i,1s}\right) \tag{2}$$

$$c_{t,t+1}^{i,1s} = w_{s,t+1}(1+\eta^i \ell_t^{i,1s}) - m_{1s} \tag{3}$$

$w_{1,t}$ and $w_{s,t+1}$ denote the after-tax wages per effective labor unit devoted to work in the respective region and time period. For the moment we take the unit wage of the central region, $w_{2,t+1}$, as exogenously given[7]. This assumption will also be relaxed in section 5. The education subsidy is proportional to the time fraction devoted to schooling ($\ell_t^{i,1s}$) and is measured as a constant rate $0<\delta<1$ of the unit wage $w_{1,t}$.[8] The parameter η^i denotes the learning efficiency of individual i, and m_{1s} are the mobility costs that arise only in case of emigration after the first lifetime period, i.e.

$$m_{1s} = \begin{cases} 0 & if\ s=1 \\ m>0 & if\ s=2 \end{cases} \tag{4}$$

An individual simultaneously decides on education and old age residence location at the beginning of period t under perfect foresight. Utility maximization with respect to $\ell_t^{i,1s}$ yields the following first-order-condition

[7] Since income is taxed only in the centre, gross and net unit wages in the periphery do not differ. The gross unit wage in region 2 is assumed to be sufficiently high to ensure a higher net unit wage, which is an incentive for migration to the economic centre. That is to say, we assume that the federal government balances the expenditure for the education subsidy to the periphery with the tax revenue generated in the centre, with $w_{2,t+1} \gg w_{1,t+1}$.

[8] We do not specify which institution decides on the subsidy rate δ. It could be the federal government by means of a conditional transfer, but it might also be a local government that draws on unconditional funds from the rich region. In reality, both types of education policy occur.

$$\frac{c_{t,t+1}^{i,1s}}{c_{t,t}^{i,1s}} = \frac{\beta \cdot \eta^i \cdot w_{s,t+1}}{w_{1,t}\left(1-\delta\right)} \quad . \tag{5}$$

Together with the budget constraints (2) and (3) the optimal education choice is

$$0 \le \ell_t^{i*,1s} = \frac{\beta}{\left(1+\beta\right)\left(1-\delta\right)} + \frac{(m_{1s}/w_{s,t+1})-1}{\eta^i(1+\beta)} \le 1 \ , \tag{6}$$

Education demand increases with personal ability η^i. The education subsidy δ induces individuals to devote more time to schooling. Interestingly, individuals who plan to emigrate after period t (m_{1s}=m) demand more education than people who are going to remain in the same region in t+1 (m_{1s}=0)[9].

By substituting (6) into the budget constraints (2) and (3) we can compute the optimal consumption paths for given residence choice. An individual who remains in region 1 during t+1 has the following consumption profile

$$c_{t,t}^{i,11} = w_{1,t}\left(\frac{1+\eta^i-\delta}{\eta^i(1+\beta)}\right) \tag{7}$$

$$c_{t,t+1}^{i,11} = \beta w_{1,t+1}\left(\frac{1+\eta^i-\delta}{(1+\beta)(1-\delta)}\right)$$

If she spends her second lifetime period in region 2 the consumption path is

$$c_{t,t}^{i,12} = w_{1,t}\left(\frac{1+\eta^i-\delta-(1-\delta)\,m/w_{2,t+1}}{\eta^i(1+\beta)}\right) \tag{8}$$

$$c_{t,t+1}^{i,12} = \beta w_{2,t+1}\left(\frac{1+\eta^i-\delta-(1-\delta)\,m/w_{2,t+1}}{(1+\beta)(1-\delta)}\right),$$

Using (7) and (8) in (1), we can derive lifetime utility of individual i for the case that she remains in her original location ($U_{t,t+1}^{i,11}$), and for the case of emigration ($U_{t,t+1}^{i,12}$).

[9] The anticipation of future emigration already induces a higher education demand today, which is an argument close to Stark/Helmenstein/Prskawetz (1997).

$$U_{t,t+1}^{i,11} = \log\left(\left[1+\eta^i - \delta\right]^{1+\beta} w_{1,t+1}{}^{\beta}\, \mathrm{K}_t^i\right) \tag{9}$$

$$U_{t,t+1}^{i,12} = \log\left(\left[1+\eta^i - \delta - (1-\delta)\, m/w_{2,t+1}\right]^{1+\beta} w_{2,t+1}{}^{\beta}\, \mathrm{K}_t^i\right)$$

where $\mathrm{K}_t^i = w_{1,t}\left(\frac{1}{\eta^i(1+\beta)}\right)\left(\frac{\beta}{(1+\beta)(1-\delta)}\right)^{\beta}$.

Equalizing $U_{t,t+1}^{i,11}$ and $U_{t,t+1}^{i,12}$ yields ability level $\tilde{\eta}_{t,t+1}^{i}$ where an individual is indifferent between migrating and remaining in region 1 for given net unit wage rates,

$$\tilde{\eta}_{t,t+1}^i = (1-\delta)\left(\frac{m/w_{2,t+1}}{1-\omega_{t+1}} - 1\right) \tag{10}$$

where $\omega_{t+1} = \left(w_{1,t+1}/w_{2,t+1}\right)^{\beta/(1+\beta)}$ <1 is a measure of the relative unit wage in the periphery. Individuals with ability below $\tilde{\eta}_{t,t+1}^i$ derive higher lifetime utility from remaining in the location of birth ($U_{t,t+1}^{i,11} > U_{t,t+1}^{i,12}$), whereas individuals with $\eta^i > \tilde{\eta}_{t,t+1}^i$ are better off spending their second lifetime period in region 2. Thus, (10) can be understood as the *cut-off ability level* beyond which migration to the centre is more attractive than staying in the periphery.

We assume that ability η^i is uniformly distributed across the L_1 members of a generation in the range $[1,k]$, with $k>1$. The least talented individual (indexed i=0) can not expand her effective labor units through education, whereas the average learning efficiency is 1+k/2. The fraction of L_1 that is going to remain in region 1 is then given by

$$\mu_{t,t+1} = \frac{\left(\tilde{\eta}_{t,t+1}^i - 1\right)}{k - 1} = \frac{1}{k - 1}\left(\frac{m(1-\delta)}{w_{2,t+1}(1-\omega_{t+1})} + \delta - 2\right) \tag{11}$$

If $\mu_{t,t+1}$<0 or $\mu_{t,t+1}$>1, the model predicts a corner solution with an entire generation emigrating from or, respectively, remaining in the region of birth.

2.2. Labor supply

Let $S_{1,t}$ denote total labor supply in region 1 at time t, which consists of the effective labor units offered by the two generations. Using (6), (10) and (11), we have

$$S_{1,t} = \int_{i=0}^{\mu_{t,t+1} L_1} (1-\ell_t^{i*,11})\, d\eta^i + \int_{i=\mu_{t,t+1} L_1}^{L_1} (1-\ell_t^{i*,12})\, d\eta^i + \int_{i=0}^{\mu_{t-1,t} L_1} (1+\eta^i \ell_{t-1}^{i*,11})\, d\eta^i \qquad (12)$$

The first (second) term denotes labor supply of the young agents who are going to stay in (leave) region 1 after the study period. The third term is the labor supply of the old generation residing in region 1.

2.3. Production

We now turn to the production side of this economy. In order to take serious the fear of policymakers concerning endogenous divergence tendencies in an integrated economic area (cf. footnote 4), we assume that there are localized increasing returns to scale in production. Various arguments for this have been discussed in the literature, dating back to the agglomeration mechanisms described by Alfred Marshall (1890).

In order to use the simplest possible form we assume a direct externality such that unit wages in region 1, $w_{1,t}$, are increasing in effective regional labor supply $S_{1,t}$. This can be due to a production technology where one effective labor unit is transformed into A units of output Y. The productivity parameter A is external to firms and depends endogenously on $S_{1,t}$. The market for Y is characterised by perfect competition and free tradability. We therefore have price equalization across regions, and we use the price p^Y as the numeráire and normalize it to one. The zero profit condition for the perfectly competitive industry then commands that the equilibrium wage per effective labor unit must equal the productivity parameter $A(S_{1,t})$.

$$w_{1,t} = A(S_{1,t}) \qquad \text{with } dA(.)/dS_{1,t} > 0 \qquad (13)$$

Note that (13) is consistent with different specifications of an increasing returns technology and can be understood as a reduced form of an equilibrium wage equation that would result from more complicated production processes. For example, an expression qualitatively similar to (13) would also be obtained in a Chamberlinian setup with product differentiation, monopolistic competition and endogenous market size effects á la Dixit/Stiglitz (1977), Krugman (1980, 1991) and Ethier (1982). These models use market-mediated linkage effects and pecuniary externalities through. For our argument the precise mechanism for increasing returns is not crucial. It is only essential that migration affects wages positively in the destination region and negatively in the source region.

3) Equilibrium

We have derived the fraction $\mu_{t,t+1}$ of each generation that remains in the peripheral region 1 after the first lifetime period in equation (11). In steady state this equilibrium condition can be rewritten as

$$w_1(\mu) = w_2\left[1 - \frac{m\cdot(1-\delta)}{w_2\cdot\left(\mu(k-1)+2-\delta\right)}\right]^{\frac{1+\beta}{\beta}} \tag{14}$$

Using (12), steady state labor supply S_1 is given by

$$S_1(\mu) = L_1\left(1+\mu\right) + \frac{L_1}{k-1}\left[\int_1^{\tilde{\eta}^i}\left(\ell^{i*,11}\cdot(\eta^i-1)\,d\eta^i\right) - \int_{\tilde{\eta}^i}^{k}\left(\ell^{i*,12}\right)d\eta^i\right] \tag{15}$$

Substituting (6) and (11) into (15) and solving out the integrals leads to

$$S_1(\mu) = L_1\left(1+\mu+\frac{\Delta(\mu)}{(k-1)(1+\beta)}\right) \tag{16}$$

Details of this derivation and the definition of $\Delta(\mu)$ are deferred to appendix 1. Using (13) and (16), the second equilibrium condition that comes from the product market side is given by

$$w_1(\mu) = A\left(S_1(\mu)\right) \tag{17}$$

General equilibrium in this economy is obtained when both (14) and (17) are simultaneously satisfied. Due to the involved non-linearity of the two conditions, we can not compute closed-form solutions for the endogenous variables w_1 and μ. Throughout the paper we will focus on those constellation where a unique and stable interior equilibrium with $0 < \mu^* < 1$ and $w_1^* > 0$ exists. In the remainder of this section we will derive and graphically illustrate the crucial properties of this steady state solution. After this characterization we will analyse the effects of an increase in the education subsidy rate δ. At first, it is important to note

Lemma 1:
The two equilibrium conditions $w_1(\mu)$, given by (14) and (17), are both increasing in μ in the relevant range with $0 < \mu^* < 1$ and $w_1^* > 0$.

Proof: See Appendix 1.

Labor supply S_1 (and thus the unit wage w_1) is increasing in μ for several reasons that can be followed in (15): Because the pure population mass is larger (the first term), because more returns to education accrue to region 1 the fewer people leave (the second term), and because fewer opportunity costs arise for the education of individuals whose private and social returns to education will be realized in the other region (the third term). The intuition for the result that (14) is increasing in μ is that, ceteris paribus, fewer people will want to leave region 1 after the first period the higher is the unit wage w_1 relative to the given value w_2.

Put bluntly, equations (14) and (17) form a cumulative causation mechanism where people leave region 1 if wages are low and wages are low if people leave. The only break in this downward spiral is the presence of mobility costs. Graphically, the two equilibrium conditions can be illustrated as upward-sloping curves in the w_1/μ-space.

The locus V_0V_1 in figure 1 represents the consumers´ optimal residence choice described in (14). The locus R_0R_1 represents the technological relation (17) and depicts the product market equilibrium wage w_1 as a function of labor supply $S_1(\mu)$.

Figure 1 here

For existence and uniqueness of an interior equilibrium we need that the two curves cross precisely once in the relevant range. The stability of equilibrium requires that the curve V_0V_1 is steeper than R_0R_1. This can be seen by considering briefly the adjustment processes outside the steady state: for points above (below) the R_0R_1 schedule, w_1 is too high (low) for any given value of μ. Using the zero profit condition described in section 2.3., the wage must realign until it is consistent with the equilibrium locus R_0R_1. This determines the phase arrows in the vertical direction. Similarly, for points to the right (left) of V_0V_1, μ is too high (low) for any given wage w_1. Individuals can still increase lifetime utility by changing locations and migration will occur until μ is consistent with V_0V_1. This determines the horizontal phase arrows. As long as V_0V_1 is steeper than R_0R_1 the system converges back to (μ*, w_1*) in case of a random perturbation [10]. In appendix 2 we further explore the conditions for the existence, uniqueness and stability of equilibrium.

4) The effect of regional education policy

In this section we will analyse the comparative statics of an increase in the education subsidy rate δ, starting from an initial interior equilibrium (w_1*, μ*). The immediate impact of $\delta\uparrow$ is that *all* L_1 individuals increase their demand for education, regardless of

[10] In the other case where R_0R_1 is steeper than V_0V_1 the system is characterized by a point stability of the steady state. The system would be driven towards a corner solution when a random disturbance occurs, with either full or no emigration.

where they are going to live in the old age period[11]. This has implications both for labor supply and for the equilibrium residence choice.

An increase of δ firstly implies that the curve V_0V_1 is shifted upwards and to the left. At any level of w_1, μ is now lower and a larger fraction (1-μ) of a generation L_1 crosses the threshold level of qualification beyond which emigration to region 2 yields a higher lifetime utility. The intuition is that an individual will devote more time to schooling when receiving a higher education subsidy and thus she will embody a higher number of effective labor units during old age. Therefore, she has a stronger incentive to move to region 2 that offers a higher net unit wage.

The second effect of an increase in δ is that the product market equilibrium curve R_0R_1 rotates around some interior value of μ and becomes steeper. The rotation point can be found by setting the expression $\partial S_1(\mu)/\partial\delta$ equal to zero and then solving for μ. It turns out to be $\tilde{\mu} = \left(\sqrt{2k-1}-1\right)\big/\left(k-1\right)$ with $0<\tilde{\mu}<1$ and $d\tilde{\mu}/dk<0$. The increase of δ has no effect on the R_0R_1-curve if $\mu=\tilde{\mu}$. For any value of μ below (above) $\tilde{\mu}$ the respective w_1* on the R_0R_1-curve is lower (higher) after the policy intervention δ↑. The intuition for the rotation is that the effect of more education on labor supply is ambiguous and depends on the initial value of μ*. If initially a large fraction μ* remains in region 1, the consolidated impact of education subsidies on effective labor supply is positive. The time used for education by the young is overcompensated by the returns during old age. This latter effect weakens the lower μ*. If the returns to education are largely realized in region 2 in the old steady state, an increase in education demand of the young generation results in lower overall labor supply S_1 and thus a lower product market equilib-

[11] From evaluating (6) it can be seen that $\partial\ell^{i,11}/\partial\delta = \partial\ell^{i,12}/\partial\delta$, i.e. the effect of an increase in subsidies on the optimal learning time does itself not depend on the residence choice for the second time period. In the case with perfect capital markets (analysed in section 5), it will not be the case that all individuals change their education demand after the increase in δ.

rium wage. More formally, the effects of the policy shock δ↑ on the two curves V_0V_1 and R_0R_1 are summarized in lemma 2.

Lemma 2:
As δ increases, the points V_0 and V_1 shift up and thus the schedule V_0V_1 shifts upwards and to the left. The R_0R_1-curve rotates around the point $\tilde{\mu} = \left(\sqrt{2k-1}-1\right) \big/ \left(k-1\right)$, with $0 < \tilde{\mu} < 1$. The point R_0 shifts down, the point R_1 shifts up.

Proof: See Appendix 3.

Given that both schedules change, a decomposition of the total effect is helpful. First consider only the shift of the V_0V_1-curve with an unchanged R_0R_1-schedule. This represents the effect of more education on optimal residence choice, neglecting the endogenous repercussion on wages. This shift alone leads to a momentary configuration $\left(\mu', w_1'\right)$ with lower values of μ and w_1 compared to the initial steady state equilibrium. The second effect, the rotation of R_0R_1, amplifies the first if $\mu' < \tilde{\mu}$, because the R_0R_1-curve rotates downwards in this range. Comparing the old and the new steady state, the latter must be associated with more emigration (lower μ) and lower unit wages w_1. This case is graphically illustrated in figure 2. Prior to the regional policy intervention the equilibrium is at point A. Taking the shift of V_0V_1 alone, the momentary configuration is at point A′. Since $\mu' < \tilde{\mu}$, the “bad news” for region 1 are amplified. The new equilibrium is at point B with lower values of μ* and w_1*. In other words, the policy harms the recipient region not only because more people will leave. Additionally, since emigration is strong initially, the induced education of the young has a negative overall effect on regional labor supply and – consequently – on wages.

Figure 2 here

If $\mu' > \tilde{\mu}$, the upward rotation of R_0R_1 is counteracting the shift of V_0V_1. Since a sufficiently high fraction of each generation stays in region 1 in the initial steady state, the increased human capital accumulation following the higher education subsidy positively affects labour supply. This increase translates into rising product market equilibrium wages. The strength of the effect depends on the properties of the external productivity function $A(S_1)$. The weaker the increasing returns to scale in production, the smaller will be the rotation of the R_0R_1-curve.

It is possible that the effect of the rotating R_0R_1-curve dominates the effect of the shift in the V_0V_1-curve, in which case the increase in the education subsidy δ will lead to a higher unit wage w_1* and (possibly) even to less emigration (μ*↑) in equilibrium[12]. This possibility requires that the R_0R_1-curve rotates relatively strongly upwards and that the shift of the V_0V_1-curve is modest[13]. In terms of the involved parameters, this is more likely (i) the more responsive product market equilibrium wages with respect to changes in labour supply (the higher $dA(S_1)/dS_1$), (ii) the more unequal the innate ability distribution in each generation (the higher k), since this decreases the rotation point $\tilde{\mu}$, (iii) the lower w_2 and the higher m, since this leads to a higher μ', and (iv) the higher the initial equilibrium value μ*.

In sum, education subsidies to poor regions can be a counterproductive policy tool to achieve economic cohesion, although the instrument does not fail in all cases. It is less

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[12] To see this, consider now the rotation of R_0R_1 in isolation, i.e. with an unchanged V_0V_1-schedule. If the rotation point $\tilde{\mu}$ lies above (below) the initial steady state μ*, then the momentary configuration (μ′, w_1′) will be associated with lower (higher) unit wages compared to (μ*,w_1*). This illustrates that even without considering the effects of education subsidies on optimal residence choice (V_0V_1), the education policy can miss its objectives if the consolidated impact on labor supply is negative. How strongly wages will change depends on the strength of the rotation of R_0R_1, i.e. on the strength of the scale economies. The shift of V_0V_1 will then unambiguously reduce w_1 and μ compared to the momentary configuration. Comparing the old and the new steady state, an increase in the unit wage w_1* is consistent both with a higher and a lower value of μ*, since the R_0R_1-curve has become steeper.

[13] In order to maintain the property of stability of equilibrium the R_0R_1 should remain flatter than V_0V_1 even after the policy intervention. Nevertheless, the possibility of $\partial w_1^*/\partial\delta>0$ exists.

likely to be a successful instrument the poorer the recipient area is initially and the stronger and more responsive the incentives for emigration. This illustrates the crucial importance of factor mobility for the potential pitfalls of regional education policy. If labour is immobile (or if it does not have a sufficient incentive to migrate), the returns to education will be realized in the recipient area. But with mobile factors this policy can also result in an unwanted sponsoring of the brain drain harming those who remain in the peripheral region.

For the remainder of this section we focus on the case where an increase in δ is associated with lower equilibrium values of w_1^* and μ* (the case illustrated in figure 2). The drop in w_1 implies that every individual who remains in region 1 will receive a lower remuneration per effective labor unit. However, the education subsidy also induces more investments in human capital. Total consumption and welfare must therefore not necessarily fall also. To see this, consider the (approximated) marginal change in utility following an increase in δ, given that the respective individual will remain in region 1 during old age.

$$\frac{\partial U^{i,11}}{\partial \delta} \approx \frac{\partial c_y^{i,11}}{\partial \delta} + \beta \cdot \frac{\partial c_o^{i,11}}{\partial \delta} \tag{18}$$

$c_y^{i,11}$ and $c_o^{i,11}$ denote the steady state consumption level during young and old age, respectively. Using (7) this can be rewritten as

$$\frac{\partial U^{i,11}}{\partial \delta} \approx \frac{\beta^2 \cdot \eta^i \cdot \overline{w}_{1,o}}{(1+\beta)\cdot(1-\delta)^2} - \frac{\overline{w}_{1,y}}{(1+\beta)\cdot \eta^i} \tag{19}$$

$\overline{w}_{1,y}$ and $\overline{w}_{1,o}$ are the equilibrium values of the unit wage during young (old) age, with $\overline{w}_{1,y} > \overline{w}_{1,o}$ for the case with $\partial w_1 * / \partial \delta < 0$. This expression is smaller than/equal to/greater than zero if the innate ability η^i of the (non-migrating) individual i is smaller than/equal to/greater than the following critical level

$$\tilde{\eta}^{i}_{Welfare} = \frac{\sqrt{\overline{w}_{1,y}\left(1-2\delta+\delta^{2}\right)}}{\beta\cdot\sqrt{\overline{w}_{1,o}}} > 0 \qquad (20)$$

This implies that the regional policy intervention δ↑ is particularly harmful for the least skilled (i.e. the poorest) individuals among those who stay in the peripheral region, as they are more likely to perceive a decrease in welfare. Since these workers invest only little in human capital, they will also not strongly increase education demand because of the subsidy. They are predominantly affected by the decreasing unit wages. The relatively skilled workers among those who remain in the periphery can perceive an increase in welfare. This is so, because they invest more heavily in human capital after the subsidy and they consequently have a higher income during old age. Nonetheless, these workers are also faced with a lower *remuneration per labor unit* after the regional policy intervention.

The members of a generation L_1 can thus be distinguished into four groups, in descending order with respect to personal ability η^i: (i) those who emigrate to region 2 after the first lifetime period before and after the increase in δ, (ii) those who would have remained in region 1 without δ↑, but who now emigrate, (iii) those who stay in region 1 and who are better off[14], and (iv) those who stay in region 1 and are worse off after the regional policy intervention.

5) Extensions

In this section we discuss three extensions of the model. In 5.1 we look at the case where the government is able to differentiate the education subsidy among individuals. In 5.2 we discuss the role of capital market imperfections and in 5.3 we explicitly take

[14] For this group one could argue that regional policy has succeeded. However, if w_1 falls the policy intervention leads to a stronger agglomeration wage premium for equally skilled individuals in the centre. This development is also not fully in accordance with the intentions of regional policy, which is typically evaluated in terms of the relative income position of the periphery. This is especially so if the unit wage in the centre (w_2) is endogenous and increases with more immigration (see section 5.3.).

into account wage formation in the central region, i.e. we endogenize the formerly exogenous parameter w_2.

5.1. Differentiated subsidies

One way to avoid the possible pitfall of regional education policy that was described in the last section is to differentiate the subsidy among the recipients. From (10) it follows that all individuals are going to leave region 1 whose ability level is greater than $\hat{\eta}^i = \left(\frac{m / w_2}{1-\omega} - 1 \right)$, even when they receive no education subsidy. Given its policy objective, the federal authority has no interest in subsidizing individuals who will emigrate anyway[15]. If the government aims at maximizing the income level of the peripheral region 1, all individuals with ability η^i below $\hat{\eta}^i$ should receive a subsidy δ_i such that emigration is just prevented. Manipulating (10), we can show that this is the case if

$$\delta_i = \left(1 - \eta^i \Big/ \left(\frac{m / w_2}{1-\omega} - 1 \right) \right). \tag{21}$$

The least talented individuals should receive the highest subsidy and subsidization should fade out with higher ability. Policymakers can avoid the brain drain problem by focussing education subsidies on the relatively low skilled workers in the peripheral area, since they are more distant to emigration.

A policy implication like this obviously sounds peculiar, since it advises governments to allocate resources to less productive uses. However, equation (21) is primarily meant to illustrate a general point: Policymakers who are preoccupied with the (potentially unconvincing) political goal to sponsor the catching-up of the periphery can do so without inducing brain drain. There are other, less peculiar ways to achieve this. For example, a

[15] If feasible, the Commission could even consider to levy a ´negative education subsidy´ on the most talented individuals, i.e. to charge tuition fees. Such proposals have occurred in the literature, e.g. in form of Bhagwati's "brain drain tax" (see Bhagwati, 1976), but will not be discussed further in this paper.

straightforward alternative is to offer education loans to individuals that are only turned into pure subsidies if the individuals choose to remain in region 1 during old age. This would shift up the cut-off ability level of emigration and contribute to regional convergence between the two regions. Another possible solution with similar effects is a direct wage subsidy to skilled workers who are willing to locate in the economic periphery.

5.2. Perfect capital markets

So far we have assumed that capital markets are missing and human capital investments are the only means for consumption smoothing. Now we look at the situation where individuals can invest in a secure asset b_t during young age that pays off in the second lifetime period with a real interest rate r. Individual i faces the following intertemporal budget constraint (assuming again an undifferentiated subsidy δ)

$$c_{t,t}^{i,1s} + \frac{c_{t,t+1}^{i,1s}}{1+r} = w_{1,t}(1-(1-\delta)\ell_t^{i,1s}) + \frac{w_{s,t+1}(1+\eta^i \cdot \ell_t^{i,1s}) - m_{1s}}{1+r} \tag{22}$$

Maximizing (1) subject to (22) with respect to young age consumption, old age consumption and learning time yields the standard Euler equation $c_{t,t+1}^{i,1s} = \beta(1+r)c_{t,t}^{i,1s}$ and the following first order condition that is linear in the ability parameter η^i.

$$w_{1,t}(1-\delta) - \frac{w_{s,t+1} \cdot \eta^i}{1+r} = 0 \tag{23}$$

As shown also by de Gregorio and Kim (1994), the presence of perfect capital markets allows agents to completely specialize in human capital accumulation or working during young age, depending on personal ability. Specifically, the education decision of agent i is given by

$$\ell_t^{i,1s}* = \begin{cases} 1 & \quad if \quad \eta^i > \tilde{\eta}_{stud}^i = \left[(1+r)(1-\delta)\,w_{1,t}\right] / w_{s,t+1} \\ 0 & \quad \quad \eta^i \le \tilde{\eta}_{stud}^i = \left[(1+r)(1-\delta)\,w_{1,t}\right] / w_{s,t+1} \end{cases} \tag{24}$$

The individual at the margin, with $\eta^i = \tilde{\eta}^i_{stud}$, is indifferent between becoming educated or not. More talented young agents will use their entire time budget for studying. Less able young agents will only work. More people will choose to become educated the higher the subsidy δ, the lower the return on bonds r, the lower the unit wage during young age and the higher during old age. Note that, although mobility costs m_{1s} do not show up directly in (24), they influence the education decision of agent i via the old age residence choice s={1,2} that enters through unit wage in the second period, $w_{s,t+1}$.

The location decision can be computed by using the Euler equation. The equilibrium consumption path is given by

$$c_{t,t}^{i,1s}* = \frac{1}{1+\beta}\left[w_{1,t}(1-(1-\delta)\ell_t^{i,1s}*) + \frac{w_{s,t+1}(1+\eta^i \cdot \ell_t^{i,1s}*) - m_{1s}}{1+r} \right] \quad (25)$$

$$c_{t,t+1}^{i,1s}* = \frac{\beta}{1+\beta}\left[(1+r)\left(w_{1,t}(1-(1-\delta)\ell_t^{i,1s}*) \right) + w_{s,t+1}(1+\eta^i \cdot \ell_t^{i,1s}*) - m_{1s} \right]$$

Focussing first on those who do not study ($\ell_t^{i,1s}* = 0$), their consumption stream no longer depends on ability. Liftetime utility as a function of residence location s is given by

$$U_{\ell*=0}^{i,1s} = \frac{(1+(1+r)\beta^2)}{(1+r)(1+\beta)} \cdot \log\left((1+r)w_{1,t} + w_{s,t+1} - m_{1s} \right) \quad (26)$$

Their location decision is determined solely by the term $w_{s,t+1} - m_{1s}$. If $m > w_{2,t+1} - w_{1,t+1}$, all non-students would stay in region 1, otherwise all would leave.

For students ($\ell_t^{i,1s}* = 1$), equation (25) shows that lifetime utility in case of non-migration and migration is, respectively, given by

$$U_{\ell*=1}^{i,11} = \log\left(\left((1+r)\delta w_{1,t} + (1+\eta^i) w_{1,t+1} \right)^{1+\beta} \cdot K \right) \quad (27)$$

$$U_{\ell*=1}^{i,12} = \log\left(\left((1+r)\delta w_{1,t} + (1+\eta^i) w_{2,t+1} - m \right)^{1+\beta} \cdot K \right)$$

where $K = \left(\beta(1+r)\right)^{\beta} \cdot \left((1+\beta)(1+r)\right)^{\beta-1}$. Equating $U_{\ell^*=1}^{i,11}$ and $U_{\ell^*=1}^{i,12}$ yields the critical ability level for migration in the case of perfect capital markets

$$\tilde{\eta}_{mig}^{i} = \frac{m}{w_{2,t+1} - w_{1,t+1}} - 1 \qquad (28)$$

which is increasing in m and $w_{1,t+1}$, decreasing in $w_{2,t+1}$ and – in contrast to (10) – independent of δ. In the case where all non-students leave region 1 after the first period ($m < w_{2,t+1} - w_{1,t+1}$), equation (28) implies that also all students would leave. The more interesting and relevant case is thus when all non-students and the group of students with ability $\eta^{i} < \tilde{\eta}_{mig}^{i}$ remain in region 1, which requires $m > w_{2,t+1} - w_{1,t+1}$ and $\tilde{\eta}_{stud}^{i} < \tilde{\eta}_{mig}^{i}$.

Focussing on this case, (24) and (28) indicate that an increase in the subsidy δ affects only education, but not residence choice. An increase in δ shifts down $\tilde{\eta}_{stud}^{i}$ and induces more individuals who formerly chose to work during young age to specialize in human capital formation. At the same time, $\tilde{\eta}_{mig}^{i}$ remains constant (at first instant) and the returns to education accrue in the peripheral region 1. This will have a positive effect on labor supply and unit wages w_1, thereby shifting up $\tilde{\eta}_{mig}^{i}$ in a secondary round and increasing w_1 even further.

Hence, without credit market imperfections the education subsidy is more likely to be an effective policy instrument, since access to capital markets allows individuals to separate education and residence choice. Without the possibility to specialize, every individual will invest some time in education and the subsidy δ will also affect the incentives for emigration out of the lagging area. With perfect capital markets and with mobility costs that are substantial enough to induce at least some educated individuals to stay in region 1 during old age ($\tilde{\eta}^i_{stud} < \tilde{\eta}^i_{mig}$), a higher subsidy δ provides no secondary migration incentives, but only increases the incentive to become educated.

5.3. Endogenising the central region

Finally, we explicitly consider wage formation in the economic centre. Consumer behaviour and goods production are assumed to be identical to region 1, and we again focus on the case with missing capital markets. Effectively, the (gross) equilibrium unit wage in the centre (W_2) is a function of *regional* labor supply, i.e.

$$W_2 = A(S_2) \qquad \text{with } A'(S_2) > 0 \tag{29}$$

An analysis of regional policy naturally requires an initial real disparity between the areas. Equation (29) suggests that this has to be due to a larger effective labor supply in region 2 (i.e. a larger size and/or higher learning abilities of each new born generation L_2). Since income in region 2 is taxed in order to finance the education subsidies, L_2 must be *sufficiently* larger than L_1.

We can apply the consumer problem described in section 2.1., taking into account that education is not subsidized and there are no migration incentives. The optimal education choice $\ell^{i*,22}$ can be computed as

$$\ell^{i*,22} = \frac{\beta}{1+\beta} - \frac{1}{\eta^i(1+\beta)} \quad .$$

Total effective labor supply in region 2, S_2, is given by

$$S_2 = 2L_2 + \int_{i=0}^{L_2} \ell^{i*,22}(\eta^i - 1) + (1-\mu)L_1 + \int_{i=\mu L_1}^{L_1} \eta^i \ell^{i*,12} \, , \tag{30}$$

which is an increasing function of the immigrant population $(1-\mu)L_1$. Effectively all that changes in this generalized model is that W_2 will no longer be independent of μ, as labor supply and thus unit wages in region 2 increase endogenously with emigration from region 1[16]. This has implications for the optimal location decision of individuals from region 1. The actual cut-off ability level beyond which emigration starts is lower than implied by (10), where the endogenous impact on W_2 has been neglected. The cumulative causation spiral described above is accentuated if wage formation in the core region is endogenous. The true amount of equilibrium migration has been understated in section 4, but the central insights with respect to the spatial effects of higher education subsidies remain qualitatively unchanged.

6) Conclusion

In this paper we have shown that paying education subsidies to students in poor regions can be a counterproductive instrument of regional policy. Under certain circumstances the actual effect of this policy can be more high skilled labor emigration and stronger regional disparities rather than a catching-up of the poor areas. This is more likely the stronger the recipient area is lagging behind the economic centre and the more responsive are individuals in their location decisions. If the education subsidy induces a brain drain, those individuals who remain in the peripheral region are faced with falling wages. The poorest and least able workers within the recipient area lose out most heavily. The negative consequences for the periphery are amplified if wage formation in the centre is endogenous and wages increase with immigration.

Two policy suggestions can be derived from our model. Firstly, we have shown that the described "pitfall" of regional education subsidies requires capital market imperfections. With perfect capital markets, agents can separate education and location decisions, and an education subsidy does not increase emigration incentives. This underlines the im-

[16] Note that the average skill level in the core region is also likely to increase, since the migrants from region 1 are taken from the top of the skill distribution. Put differently, human capital is going where the local stock of human capital is already large, which is in line with observations from the endogenous growth literature (e.g. Moretti, 2004).

portance of strengthening the access to capital markets in economically under-developed regions, as this improves the effectiveness of education subsidies as a regional policy tool. Secondly, even if capital markets remain imperfect, policymakers can avoid the pitfalls of education subsidies by acknowledging the induced secondary migration incentives, and by adapting the subsidization practice accordingly. One possible way to do this is to make subsidies ability-dependent and focus the subsidies on the workers with low ability.

<u>Appendix 1</u>: Proof of Lemma 1

Using the equilibrium condition (14), an interior solution requires that $w_1(\mu) > 0$ for any $\mu \in [0,1]$, which is the case if $w_2/m > (1-\delta)/(\mu(k-1)+2-\delta)$. Considering $\mu = 0$, the equation reduces to

$$w_1(\mu = 0) = w_2\left[1 - \frac{m(1-\delta)}{w_2(2-\delta)}\right]^{\frac{1+\beta}{\beta}} \tag{A1}$$

Similarly, with $\mu = 1$ we have

$$w_1(\mu = 1) = w_2\left[1 - \frac{m(1-\delta)}{w_2(1+k-\delta)}\right]^{\frac{1+\beta}{\beta}} \tag{A2}$$

Using (A1), this implies the parameter restriction

$$\frac{w_2}{m} > \frac{1-\delta}{2-\delta} \tag{A3}$$

that warrants $w_1(\mu) > 0$ for any $\mu \in [0,1]$. Provided (A3) holds, it must also be true that $w_1(\mu = 1) > w_1(\mu = 0) > 0$. More generally, we have

$$\frac{\partial w_1}{\partial \mu} = \frac{1+\beta}{\beta}\cdot\left[1 - \frac{(1-\delta)\,m/w_2}{\mu(k-1)+2-\delta}\right]^{1/\beta}\cdot\left[\frac{(k-1)\cdot m\cdot(1-\delta)}{\left((k-1)\cdot\mu+2-\delta\right)^2}\right] > 0 \tag{A4}$$

Hence, equation (14) is upward sloping in μ.
Turning to the product market equilibrium condition, we first evaluate steady state labor supply $S_1(\mu)$. By substituting (6) and (11) in (15) we can write this as

$$S_1 = L_1(1+\mu) + \frac{L_1}{k-1}\left[\begin{array}{c}\displaystyle\int_1^{\tilde{\eta}^i}\left(\frac{\beta\eta^i}{(1+\beta)(1-\delta)}\right)d\eta^i + \int_1^{\tilde{\eta}^i}\left(\frac{1}{(1+\beta)\eta^i}\right)d\eta^i - \int_1^{\tilde{\eta}^i}\left(\frac{1}{(1+\beta)}\right)d\eta^i \\ \displaystyle -\int_1^{k}\left(\frac{\beta}{(1+\beta)(1-\delta)}\right)d\eta^i + \int_{\tilde{\eta}^i}^{k}\left(\frac{1-m/w_2}{\eta^i(1+\beta)}\right)d\eta^i\end{array}\right]$$

Solving the integrals and rearranging terms we have

$$S_1 = L_1(1+\mu) + \frac{L_1}{k-1}\left[\frac{\beta}{(1+\beta)(1-\delta)}\left(\frac{(\tilde{\eta}^i)^2}{2} - k + \frac{1}{2}\right) + \frac{\log(k) - \tilde{\eta}^i + 1}{1+\beta} - \frac{m/w_2}{1+\beta}\left(\log(k) - \log(\tilde{\eta}^i)\right)\right]$$

Using the fact that $\tilde{\eta}^i = \mu(k-1)+1$ this simplifies to

$$S_1(\mu) = L_1\left(1+\mu+\frac{\Delta(\mu)}{(k-1)(1+\beta)}\right), \tag{A5}$$

with

$$\Delta(\mu) = Log(k)\left(1-\frac{m}{w_2}\right)+\frac{m}{w_2}\left(Log\left[1+(k-1)\mu\right]\right)+\frac{\beta(k-1)\left(\mu((k-1)\mu+2)-2\right)}{2(1-\delta)}-(k-1)\mu$$

Considering the cases with $\mu=1$ and $\mu=0$, respectively, we can show that

$$S_1(\mu=0)=\frac{L_1}{(1+\beta)}\left(\frac{1-\delta(1+\beta)}{(1-\delta)}+\frac{\left(1-m/w_2\right)\cdot Log(k)}{(k-1)}\right)>0 \tag{A6}$$

$$S_1(\mu=1)=\frac{L_1}{2(1+\beta)}\left(2+\frac{\beta(3+k-4\delta)}{(1-\delta)}+\frac{2Log(k)}{(k-1)}\right)>S_1(\mu=0)>0 \tag{A7}$$

The sign of (A6) follows from the fact that also in case of full emigration the education demand of the most talented individual from the young generation, $\ell^{i*,12}(\eta^i=k)$, given by (6), can at most be equal to one. Steady state labor supply is monotonously increasing in μ

$$\frac{\partial S_1}{\partial \mu}=\frac{L_1\left(m(1-\delta)+\beta w_2(1+(k-1)\mu)\cdot(2-\delta+(k-1)\mu)\right)}{w_2\cdot(1+\beta)\cdot(1-\delta)\cdot(1+(k-1)\mu)}>0 \tag{A8}$$

Thus, by (13) we have

$$\frac{\partial w_1(\mu)}{\partial \mu}=\frac{dA\left(S_1(\mu)\right)}{dS_1}\cdot\frac{\partial S_1}{\partial \mu}>0\,. \tag{A9}$$

which proves that equation (17) is also monotonously increasing in μ. □

<u>Appendix 2:</u> Steady state equilibrium

In appendix 1 we have shown that with the parameter restriction (A3) the points V_0, V_1, R_0 and R_1 in figure 1 are all strictly positive, and that $V_1 > V_0$, $R_1 > R_0$. Furthermore, both the V_0V_1- and the R_0R_1-curve are monotonously increasing in μ.
An interior equilibrium exists and is unique if the two curves V_0V_1 and R_0R_1 cross precisely once in the relevant range. It will turn out to be useful to impose a quite strong requirement on the two equilibrium loci that guarantees the uniqueness of equilibrium, namely that both curves are strictly concave. Note that this is just a sufficient, but not a necessary condition for uniqueness.

Concavity of the V_0V_1 curve

Turning first to the V_0V_1-curve, equation (14), it is possible to show that

$$\frac{\partial^2 w_1}{\partial \mu^2} = \left[\frac{K_1 \cdot K_2}{(K_3)^3 \cdot K_4} \right] \cdot \Psi \tag{A10}$$

where

$$K_1 = \left[1 - \frac{m \cdot (1-\delta)}{w_2 \cdot \left(\mu(k-1) + 2 - \delta \right)} \right]^{\frac{1}{\beta}} > 0 \qquad \text{by (A3)}$$

$$K_2 = (k-1)^2 \cdot m \cdot (1+\beta) \cdot \left(1-\delta\right) > 0$$

$$K_3 = \left((k-1)\mu + 2 - \delta \right) > 0$$

$$K_4 = \beta^2 \left(w_2 \left((k-1)\mu + 2 - \delta \right) - m\left(1-\delta\right) \right) > 0 \quad \text{by (A3)}$$

$$\Psi = m \cdot (1+2\beta) \cdot (1-\delta) - 2\beta \cdot w_2 \cdot \left(\mu(k-1) + 2 - \delta \right) \tag{A11}$$

The term in the parentheses is unambiguously positive and the sign of (A10) is determined only by the sign of Ψ. The V_0V_1-curve is strictly concave (convex) if Ψ is negative (positive). We will restrict the exogenous parameters such that the V_0V_1-curve is concave. Expression Ψ from (A11) is negative if

$$\frac{w_2}{m} > \frac{1+2\beta}{2\beta} \cdot \left[\frac{1-\delta}{2-\delta} \right] \tag{A12}$$

Note than $\left(1+2\beta\right)/2\beta > 1$, since 0<β<1. Hence, the parameter restriction (A12) is stricter than the previous restriction on (w_2/m) given in (A3).

Concavity of the R_0R_1 curve

Turning to the R_0R_1-curve, the second order derivative of (17) is given by

$$\frac{\partial^2 w_1(\mu)}{\partial\mu^2} = \frac{dA\left(S_1(\mu)\right)}{dS_1}\cdot\frac{\partial^2 S_1}{\partial\mu^2} + \frac{d^2 A\left(S_1(\mu)\right)}{d(S_1)^2}\cdot\frac{\partial S_1}{\partial\mu} \tag{A13}$$

The sign of (A13) is determined by the properties of the labor supply function $S_1(\mu)$ and the properties of the external productivity function $A(S_1)$. In (A8) we have shown that $\partial S_1(\mu)/\partial\mu > 0$. The second order derivative is given by

$$\frac{\partial^2 S_1(\mu)}{\partial\mu^2} = \frac{(k-1)L_1}{(1+\beta)}\cdot\left(\frac{\beta}{1-\delta} - \frac{m}{w_2\left(1+(k-1)\mu\right)^2}\right) \tag{A14}$$

The sign of (A14) is ambiguous, depending on the term in the parentheses. However, even if $S_1(\mu)$ is convex, the R_0R_1-curve can still be concave if $d^2 A(S_1)/\partial S_1^2$ is sufficiently negative, i.e. if the degree of concavity of $A(S_1)$ is sufficiently strong. We need

$$\left|\frac{d^2 A\left(S_1(\mu)\right)}{d(S_1)^2}\right| > \left(\frac{dA\left(S_1(\mu)\right)}{dS_1}\cdot\frac{\partial^2 S_1}{\partial\mu^2}\right)\Big/\left(\frac{\partial S_1}{\partial\mu}\right) \tag{A15}$$

for concavity, which is automatically satisfied if $S_1(\mu)$ is concave. We will assume that the properties of the exogenous functional form of $A(S_1)$ are such that (A15) always holds, also if $\partial^2 S_1(\mu)/\partial\mu^2 > 0$. Economically, this restriction can be interpreted such that the external productivity function $A(S_1)$ is only weakly increasing in labor supply S_1. In other words, the increasing returns in production must not be too pervasive. Given empirical evidence, e.g. Hamermesh (1993), this seems to be a plausible assumption.

Existence and stability of an interior equilibrium

With increasing, concave curves in figure 1, existence and stability of an interior equilibrium are established if the points on the axes are such that $V_0<R_0$ and $V_1>R_1$.
As can be seen in equations (A1) and (A6), the expression for the point R_0 depends on the size of each new born generation L_1 (through $S_1(\mu=0)$), whereas the point V_0 does not. By an appropriate choice of L_1 (L_1 sufficiently high) the condition $V_0<R_0$ can therefore be met. The point V_1 is located above R_1 if the V_0V_1-curve is sufficiently steeper than the R_0R_1-curve. The slope of the R_0R_1-curve depends crucially on the properties of the external productivity function $A(S_1)$. If increasing returns to scale are only weak, which we have deemed to be plausible above, the product market equilibrium wage $w_1(\mu)$ will be only weakly increasing in μ and effectively $V_1>R_1$.

To sum up, some parameter restrictions and assumptions on the properties of the exogenous functional form of $A(S_1)$ are necessary to focus on the tractable case of an interior, unique and stable equilibrium, leaving aside the otherwise prohibitively complex taxonomy of corner solutions or multiple equilibria.

<u>Appendix 3:</u> Proof of Lemma 2

Differentiating steady state labor supply (A2) at the point μ=0 yields

$$\frac{\partial S_1(\mu=0)}{\partial\delta}=-\frac{\beta L_1}{(1+\beta)(1-\delta)^2}<0 \qquad \text{(A16)}$$

Similarly, at μ=1 we have

$$\frac{\partial S_1(\mu=1)}{\partial\delta}=\frac{(k-1)\beta L_1}{2(1+\beta)(1-\delta)^2}>0 \qquad \text{(A17)}$$

The shifts of R_0 and R_1 are determined by $\partial w_1/\partial\delta=\left(dA(S_1)/dS_1\right)\cdot\left(\partial S_1/\partial\delta\right)$, and thus the point R_0 shifts down and R_1 shifts up. The magnitude specifically depends on $dA(S_1)/dS_1$. The weaker the external productivity function is increasing in S_1, the smaller will be the shifts.

The analytical expressions for the points V_0 and V_1 are given by (A1) and (A2), respectively. Differentiating with respect to δ we obtain

$$\frac{\partial V_0}{\partial\delta}=\frac{(1+\beta)m}{\beta(2-\delta)^2}\left[1-\frac{m(1-\delta)}{w_2(2-\delta)}\right]^{1/\beta}>0 \qquad \text{(A18)}$$

$$\frac{\partial V_1}{\partial\delta}=\frac{(1+\beta)\cdot k\cdot m}{\beta(k+1-\delta)^2}\left[1-\frac{m\cdot(1-\delta)}{w_2(k+1-\delta)}\right]^{1/\beta}>0\,. \qquad \text{(A19)}$$

Both points V_0 and V_1 shift up as δ increases. One can show that the shifts are stronger the higher w_2, and the lower β. The comparative statics of (A18) and (A19) with respect to m are ambiguous. With an even stricter parameter restriction on w_2/m than (A12), namely $w_2/m>\left[(1+\beta)/\beta\right]\cdot\left[(1-\delta)/(2-\delta)\right]$, we find that the shifts described in (A18) and (A19) are stronger the higher m.

The rotation point of the R_0R_1 curve $\tilde{\mu}$ is found by computing

$$\frac{\partial S_1\left(\mu(\bullet)\right)}{\partial\delta}=\frac{\beta\cdot L_1\cdot\left(\mu\left(2+(k-1)\mu\right)-2\right)}{2\cdot(1+\beta)\cdot(1-\delta)^2} \qquad \text{(A20)}$$

Setting (A20) equal to zero yields as solutions $\tilde{\mu}=\left(\pm\sqrt{2k-1}-1\right)\big/\left(k-1\right)$, from which only the first lies in the feasible range $0<\tilde{\mu}<1$. □

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*Figure 1: The determination of μ**

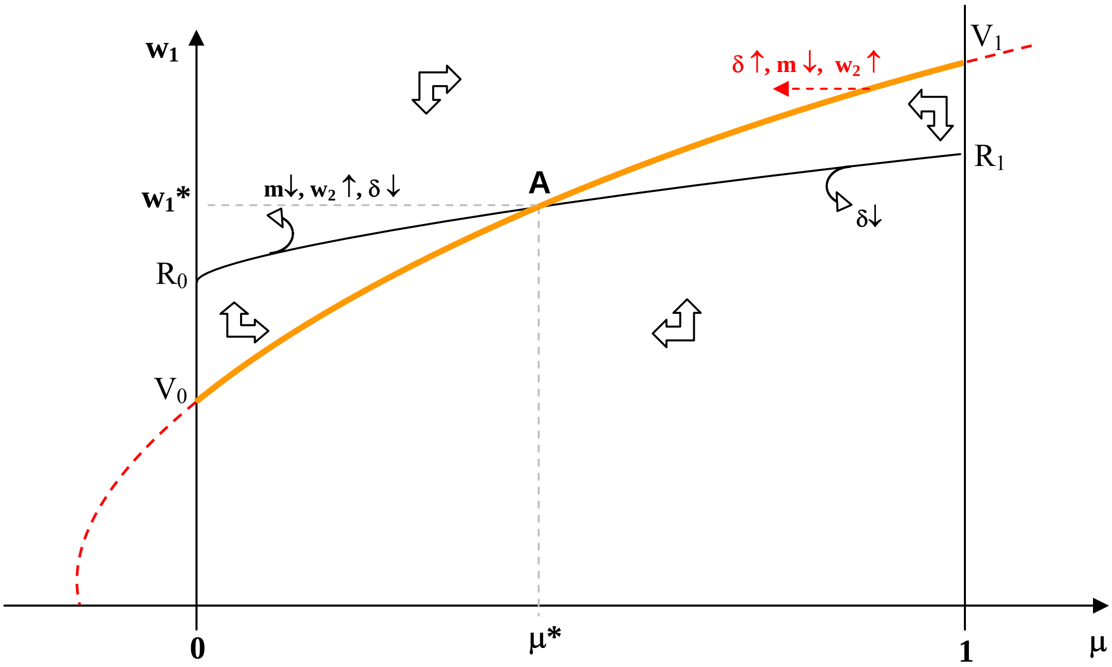

Figure 2: An increase in the education subsidy δ