The Bologna process: how student mobility affects multi-cultural skills and educational quality

Lydia Mechtenberg · Roland Strausz

Abstract We analyze the two goals behind the European Bologna process of increasing student mobility: enabling graduates to develop multi-cultural skills and increasing the quality of universities. We isolate three effects: (1) a competition effect that raises quality, (2) a free-rider effect that lowers quality, and (3) a composition effect that influences the relative strengths of the two previous effects. The effects lead to a trade-off between the two goals. Full mobility may be optimal only when externalities are high. In this case, student mobility yields inefficiently high educational quality. For moderate externalities, partial mobility is optimal and yields an inefficiently low quality of education.

Keywords Student mobility · Quality of education · Multi-cultural skills · Bologna process

JEL Classification D61 · H77 · I28

1 Introduction

The so-called Bologna process belongs to those European policy processes that have attracted considerable public attention. Its intention is to harmonize the diverse European university systems and, thereby, achieve a higher degree of comparability. It is hoped that more comparable university systems lead to higher student mobility. Thus,

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the Bologna process can be understood as a process of increasing student mobility. For two reasons, student mobility is seen as key in increasing the productivity of the highly educated. First, student mobility across countries exposes students directly to the different European cultures and helps them to develop their multi-cultural skills. These skills are seen as indispensable in a European Union that strives for full economic integration while preserving the diversity of its cultures.[1] Second, increasing student mobility is hoped to kindle a competition between countries to attract the most able students. Since university education in Europe is mostly publicly funded, the dimension in which such competition takes place is quality.[2] Hence, it is hoped that higher mobility raises university quality. This would increase the productivity of graduates further.

This paper analyzes the two rationales behind the Bologna process to increase student mobility: enabling graduates to develop their multi-cultural skills and increasing quality competition between universities. We study how these two goals can be achieved and how far they are compatible with each other. Thus, we present a framework in which the productivity of students depends both on multi-cultural skills and the quality of university education. Within this setup, we compare and evaluate, for different levels of student mobility, the expenditures in higher education that are chosen by two symmetric, benevolent governments.

Our main result is that the claimed competition effect which is supposed to raise quality is not automatic; it happens only if the externality generated by foreign students is high enough. Indeed, in order for the competition effect to raise quality, it must overcome the free-rider effect that countries prefer their students to obtain their costly education abroad. Only if students are relatively unlikely to return from a foreign education and only if a country is able to appropriate a large share of a foreigner's productivity does the positive competition effect occur.

When the free-rider effect dominates the competition effect, higher student mobility facilitates the acquisition of multi-cultural skills at the expense of lower investments in higher education. The optimal level of student mobility will depend on the outcome of this trade-off. Essentially, a higher mobility of students is called for when multi-cultural skills are more important. If the free-rider effect is stronger, less mobility is preferred.

A more careful analysis of the trade-off reveals a non-monotonic relationship with student mobility; the competition effect is strongest when student mobility is low. The reason for this is that we model student mobility as a process that facilitates information processing. This captures the idea behind the Bologna process that more comparable university systems facilitate the decision process of a student to study abroad. Thus, we interpret higher student mobility as a reduction of the student's information processing ability that is required for making the decision to study abroad. In addition, the student's ability to process information also affects his benefits from

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[1]See, for instance, Jahr et al. (2002, p. 50).

[2]In their discussion of higher education in Europe, Reichert and Tauch (2003, p. 10) note that higher education as "a public good and a public responsibility" will remain the predominant view of European governments. The UK with its relatively high tuition fees is expected to remain an exception in Europe.

university education; more talented students achieve a higher productivity than less able ones. As a consequence, a rise in student mobility lowers the talent pool of mobile students. This composition effect causes a decline in the competition effect; with higher mobility it becomes less attractive for a country to attract the students, because the students' average talent and, therefore, their expected productivity will be lower.

The remainder of the paper is organized as follows. The next section discusses related literature. Section 3 presents the model. Section 4 characterizes the first–best optimum. Sections 5 and 7 discuss the extreme cases with student immobility and full student mobility, respectively. Section 8 analyzes the properties of the second-best optimum for intermediate degrees of student mobility. The final section concludes and relates the results of our model to the Bologna process. All formal proofs are collected in the Appendix.

2 Related literature

The relation between mobility and human capital has for long been on the agenda of economic research. The larger part of the literature that deals with this topic analyzes the consequences that increasing mobility of skilled labor might have on human capital investments. The characteristic time structure of these models includes the assumption that individuals have to decide about their educational effort or costs *before* they eventually become mobile.

Within this framework, the Brain Drain literature identifies two main consequences that increasing mobility of highly productive labor will have on human capital investments. First, as pointed out by Grubel and Scott (1966) and Bhangwati and Hamada (1974) in an asymmetric setting with a pure sender country and a pure receiver country, the sender country will reduce its public investment in education if an increasing fraction of highly educated individuals leaves the country. Similarly, Justman and Thisse (1997) show that in symmetric settings, too, where each country is both a sender and receiver country, exogenous mobility of graduates leads to an underprovision of publicly provided education.

By contrast, Stark et al. (1997), Beine et al. (2001) and Stark and Wang (2002) take also private investments in education into account. They demonstrate that with one poor sender country and one rich receiver country, the reduction in public provision of education in the sender country can be overcompensated by the increase of private investments due to the rising private returns to education if highly skilled labor becomes more mobile.

Poutvaara (2004a) and (2004b) also consider both public and private investment in education. Poutvaara shows that although increasing international applicability of education leads to higher private investments, the governments tend to reduce public funds for internationally applicable education.

Thus, the most stable result that is established by this kind of literature is that although increasing mobility of graduates will lead to higher private investments in education, public provision will decrease. The governments will tend to free ride on the education system of the other country.

Büttner and Schwager (2004) produce a similar result within a different framework. Their paper belongs to the small part of the literature on education economics

that explicitly focuses on the consequences of increasing student mobility. Here, the time structure is different. Students are already mobile when they have to decide about their educational investment; and they are able to choose the country in which they want to study. Büttner and Schwager (2004) show that if students are mobile, welfare states want to free ride on the education system of the other country, so that in equilibrium, public provision of education is too low.

Kemnitz (2005), by contrast, considers not only the free-rider effect, but also the competition effect of governments that provide education for mobile students. If students generate positive expected externalities in the country in which they study, the incentive to free ride on the neighboring country's education system is not the only incentive at work. It may be profitable for the government to raise its funds in order to attract more students. The question which of the two effects prevails depends on the relative importance of the positive externalities and the costs that are generated by students. Kemnitz (2005) compares free-rider and competition effect within a framework where the governments are driven by exploitative incentives.

In relation to the existing literature, our focus is on the effects of student mobility on public provision of education with benevolent governments. Our contribution to the existing literature is twofold. First, we compare the free-rider effect and the competition effect within a symmetric setting where two welfare states provide higher education for their mobile students. Thus, we show that if the governments are not driven by exploitative incentives but are welfare states, a competition effect may be identified that may drive public provision of education upward. Yet, the magnitude of this effect is rather small. Second, we are the first to take into account that student mobility is positively correlated with talent, and that the talent distribution is continuous. This assumption allows us to analyze how the relative weights of free-rider effect and competition effect change with increasing student mobility.

3 The setup

We consider two symmetric countries A and B. Each country consists of an infinite number of students with mass one. Students differ in two dimensions. First, they differ in their learning ability τ which is uniformly distributed over the unit interval [0, 1]. This learning ability represents a student's general ability to process, learn, and use new and complex information. It influences both the returns from the student's intellectual and multi-cultural training. Second, students are heterogeneous with respect to their multi-cultural skills; multi-cultural skills are uniformly distributed over [0, 1] and are independent of learning ability τ. We assume, however, that education has a home-bias; without multi-cultural skills, a local education yields a higher productivity. A home bias is natural, because high schools prepare their students for the domestic university system rather than a foreign one. We model this bias by assuming that multi-cultural skills must be at least one-half in order to outweigh the home-bias. That is, if we represent by a the gain in productivity due to multi-cultural skills net of the home-bias, we find that a is uniformly distributed over the interval $[-1/2, 1/2]$. To summarize, a student k is characterized by a learning ability $\tau_k \in [0, 1]$ and a (net)

multi-cultural skill $a_k \in [-1/2, 1/2]$. Students are fully informed about their characteristics and will take them into account when deciding whether or not to study abroad.

Given the students' population, each government i chooses university quality q_i, with the intention to maximize the welfare of its natives. University quality raises intellectual skills and therefore the productivity of students who graduate from a university.

Next, students choose the country in which they want to study. We model mobility by assuming that only students who are above a given talent level $\hat{\tau}$ are mobile. Indeed, the essence of the Bologna process is that member states increase student mobility by harmonizing educational systems. Hence, Bologna represents a process that lowers the informational rather than the financial barriers to mobility; more divergent university systems represent higher informational barriers than standardized ones. We capture this aspect of the Bologna process with the idea that students must first learn about foreign university systems before they can decide whether to study abroad. With more diverse systems, it is more difficult for a student to acquire and process the relevant information. Since the ability to process information depends on the student's ability τ, only the more able students with $\tau \geq \hat{\tau}$ will find it worthwhile to obtain and process the necessary information for deciding whether to study abroad.[3]

A student's return from a university education depends on the university's quality q_i. In particular, a student k who is born in country i with learning ability τ_k and multi-cultural skills a_k attains a productivity of

$$\pi_{ki} = \tau_k q_i$$

if the student studies at home. If, instead, the student studies abroad, the productivity depends on the foreign university quality q_j. In addition, the productivity is affected by the student's multi-cultural skills (net of the home-bias) a_k. Thus, a foreign study yields a productivity of

$$\pi_{kj} = \tau_k[q_j + ma_k].$$

The parameter $m \geq 0$ thereby measures the relative importance of multi-cultural skills; for $m = 0$ these skills are unimportant.

Whether or not a mobile student migrates depends solely on how much they will gain if they graduate at the foreign university, compared with their gain from studying in their home country. We assume that the graduate appropriates only a fraction $\gamma < 1$ of her productivity π. The remaining fraction $(1 - \gamma)$ is appropriated by the country in which the graduate works. There are no direct migration costs. Consequently, a student k who has been born in country i with multi-cultural skills a_k will migrate

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[3]The linkage between talent level and mobility leads to the "composition" effect that a rise in student mobility lowers the talent pool of mobile students. We emphasize however that this effect also obtains when mobility is modeled differently. For example, one could see mobility as an increase in the number of financial stipends for foreign students (which is, however, not what the Bologna process does). In this case, a linkage between mobility and talent obtains when stipends are rewarded on the basis of grades.
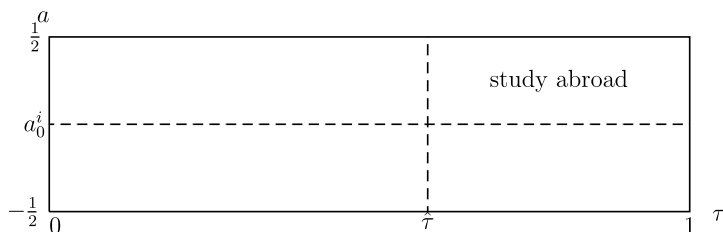
Fig. 1 Students

exactly if

$$\gamma \pi_{kj} \geq \gamma \pi_{ki} \implies q_j + m a_k \geq q_i.$$

Hence, given quality levels q_i and q_j, a student with multi-cultural skills $(q_i - q_j)/m$ is indifferent about studying abroad. Consequently, all students with multi-cultural skills $a > a_0^i$ have an incentive to study abroad, where[4]

$$a_0^i = \max\left\{-1/2, \min\left\{1/2, (q_i - q_j)/m\right\}\right\}.$$

Figure 1 illustrates the share of students who study abroad. Since students are uniformly distributed, the number of students from country $i \in \{A, B\}$ who study abroad is

$$n_{ij} = \left(\frac{1}{2} - a_0^i\right)(1 - \hat{\tau}).$$

The remaining $n_{ii} = 1 - n_{ij}$ students study at home.

After students complete their studies, they start working and receive a share γ from their productivity. The remaining share $1 - \gamma$ is appropriated by the country where the student works. We assume that students who studied at home are immobile, and therefore, work in their home country. Students who studied abroad return to their home country with an exogenous probability $\rho \in [0, 1]$.[5] Hence, a share $1 - \rho$ remains in the foreign country. These students will generate a positive externality of a magnitude $(1 - \gamma)$ on the foreign country.

Countries choose their university quality, q_i, in order to maximize the social welfare of its natives. Social welfare consists of four different components: (1) the contribution to welfare of those students who study at home, W_{ii}^i, (2) the contribution of a country's students who study abroad, W_{ij}^i, (3) the contribution of foreign students who stay working in the country after completing their studies, W_{ji}^i, and (4) the costs that are generated by the total sum of students studying at its university, C_i^i.

A country appropriates the entire surplus of its own students who study at home. As illustrated in Fig. 1, there exist two types of students who study at home: first, those students with $a < a_0^i$ who do not benefit from a foreign education and, second,

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[4]The maxmin expression takes account of possible corner solutions.

[5]The assumption captures the empirical fact (e.g., Jahr et al. 2002) that mobility before and after graduation are positively correlated; mobile students are more likely to emigrate than students who studied at home.

those students who, due to limited access to information, are unable to study abroad. Since a home student of ability τ obtains a productivity of τq_i, their contribution to welfare is

$$W_{ii}^i = \int_{-\frac{1}{2}}^{a_0^i} \int_0^1 \tau q_i \, d\tau \, da + \int_{a_0^i}^{\frac{1}{2}} \int_0^{\hat{\tau}} \tau q_i \, d\tau \, da.$$

The contribution to welfare from students that study abroad will depend on the number of students that return after their studies. Country i benefits from the full productivity $\tau(q_j + ma)$ of these students. But since a student appropriates only a share γ of his productivity, a student (τ, a) who stays abroad contributes only $\gamma \tau(q_j + ma)$ to his country's welfare. Hence, the contribution of students who study abroad is

$$W_{ij}^i = \int_{a_0^i}^{\frac{1}{2}} \int_{\hat{\tau}}^1 \left[\rho + (1 - \rho)\gamma \right] \tau(q_j + ma) \, d\tau \, da.$$

Finally, a country appropriates a share $(1 - \gamma)$ of the productivity of foreign students who, after their studies, remain in the country. The contribution of these foreign students to social welfare is

$$W_{ji}^i = \int_{a_0^j}^{\frac{1}{2}} \int_{\hat{\tau}}^1 (1 - \rho)(1 - \gamma)\tau(q_i + ma) \, d\tau \, da.$$

The provision of quality is costly. The form of the cost function depends on whether university quality is considered a public or a private good. If it is a public good, the costs of providing a given quality level are independent of the number of students who consume this quality. If it is a private good, costs per quality increase with the number of consumers. Both assumptions can be found in the literature. Therefore, we assume that university quality has characteristics of both a public and a private good. In particular, country i's costs from providing quality q_i are

$$C_i = k_1 q_i^2 + k_2 q_i (n_{ii} + n_{ji}).$$

The importance of the public goods and private goods aspect of quality are measured by the parameters k_1 and k_2, respectively. To keep the model tractable, we assume that the public costs are quadratic in quality and the private costs are linear. In order to guarantee interior solutions, we assume $k_1 > 1/m$ and $k_2 < 1/4$.

To summarize, country i's social welfare, W^i, is the sum of the individual components,

$$W^i = W_{ii}^i + W_{ij}^i + W_{ji}^i - C_i^i. \tag{1}$$

Aggregate social welfare is

$$W = W^A + W^B. \tag{2}$$

4 The first-best

In a first-best world, the countries maximize aggregate social welfare, W, under the appropriate feasibility restrictions:

$$\max_{q_A, q_B, \hat{\tau}} \quad W = W^A(q_A, q_B, \hat{\tau}) + W^B(q_A, q_B, \hat{\tau}) \tag{3}$$
$$\text{s.t.} \quad 0 \le \hat{\tau} \le 1, q_A \ge 0, q_B \ge 0.$$

Note that the maximization problem involves two different types of decision variables: student mobility, $\hat{\tau}$, and the quality level of education, $q_.$. Indeed, from a first-best perspective, both types of variables are to maximize aggregate social welfare. This contrasts with Europe's Bologna initiative, where only the mobility parameter, $\hat{\tau}$, is chosen at the aggregate level, while the countries' individual quality levels of education are determined by the individual member states. Hence, our modeling of the Bologna initiative is that after the level of mobility is set cooperatively, the two countries choose their respective quality levels independently. In order to gauge the inefficiencies that arise from this arrangement, this section first derives the first-best solution as a benchmark.

Treating mobility as an exogenous parameter, the following proposition addresses the efficient choice of quality levels.

Proposition 1 *The efficient level of quality is independent of the mobility parameter $\hat{\tau}$ and is $q_A = q_B = q_E$, where*

$$q_E \equiv \frac{1 - 2k_2}{4k_1}.$$

As expected, the efficient level is decreasing in the cost parameters k_1 and k_2. The efficient level, q_E, does not depend on γ and ρ, because these parameters only determine how the graduate's productivity is shared between the two countries. In the aggregate, the division of rents is irrelevant. Finally, the proposition shows that the efficient quality level is independent of student mobility $\hat{\tau}$. We obtain this independence result because intellectual and multi-cultural skills are additively separable components of the graduate's productivity. It implies that from a social welfare perspective, there is no trade-off between quality and mobility.

In a first-best world, benevolent governments would not only implement the efficient quality level of university education, but also choose an efficient degree of student mobility. Since from an aggregate perspective there is no trade-off between quality and mobility and because students take efficient studying decisions, it is optimal to enable all students to develop their multi-cultural skills. The next proposition formalizes this result.

Proposition 2 *If $m = 0$, any degree of student mobility is consistent with the first–best optimum. For $m > 0$, only full mobility $\hat{\tau} = \hat{\tau}^* \equiv 0$ is efficient.*

In a first-best world, quality levels are set at $q_A = q_B = q_E$ and students enjoy full mobility when multi-cultural skills matter ($m > 0$). When these skills do not matter, also mobility does not play a role.

5 Immobile students

Without the possibility of coordination, each country chooses q_i independently with the intention to maximize the social welfare W_i of its natives. This may lead to distortions, because countries will only consider the effect of their decisions on the social welfare of its natives. Yet, a special case obtains when students are fully immobile ($\hat{\tau} = 1$). For this extreme, there is no interaction between the countries. Each country incurs all the costs from educating its citizens and also fully benefits from their productivity. Consequently, countries choose the first-best level of university quality.

Thus, restricting student mobility has the advantage that it yields efficient quality decisions q_E. A disadvantage is however that students are unable to develop their multi-cultural skills. Hence, in the case that such skills matter ($m > 0$), the first-best level of university quality comes at the expense of inefficient cultural skills. The following proposition makes this intuition more precise.

Proposition 3 *If $\hat{\tau} = 1$, the countries choose the efficient quality levels $q_A^* = q_B^* = q_E$. The efficiency loss due to a lack of multi-cultural skills is $m/8$. The first-best optimum is reached only if $m = 0$.*

Hence, full efficiency is reached non-cooperatively when multi-cultural skills do not matter. This result provides an initial justification for leaving the choice of university quality in the hands of the member states of the European Union. But as will be shown, no such justification is possible when multi-cultural skills become part of human capital. As the European Union's economic integration progresses, multi-cultural skills become more important and a total restriction on student mobility forecloses potential gains from productivity.

6 Mobile students

When multi-cultural skills matter ($m > 0$), some graduates may increase their productivity by developing their multi-cultural skills abroad. This yields an efficiency argument in favor of student mobility. This section analyzes this argument in closer detail.

Without coordination, each country chooses its university quality q_i with the goal to maximize its social welfare W^i. Whenever $\hat{\tau} < 1$, its optimal quality choice depends on the choice of the neighboring country. Hence, there exist strategic interactions. The following lemma derives the Nash equilibrium levels that result from the strategic interaction.

Lemma 1 *Suppose multi-cultural skills matter ($m > 0$). Then there exists a unique Nash equilibrium (q_A^*, q_B^*) in pure strategies. The Nash equilibrium is symmetric so that $q_A^* = q_B^* = q^*$ with*

$$q^* \equiv \frac{(1 - 4k_2 + \hat{\tau}^2 + (1 - \hat{\tau}^2)E)m}{8mk_1 + 8k_2(1 - \hat{\tau}) - 4(1 - \hat{\tau}^2)E} \tag{4}$$

and

$$E \equiv (1 - \rho)(1 - \gamma).$$

The lemma shows that, in general, the equilibrium level q^* differs from the efficient level q_E. Countries' non-cooperative quality decisions are distorted away from the first-best, because at the individual level countries do not take into account the effect of their decisions on their neighbors. From the equilibrium levels (4) we may identify two effects that distort choices: a competition and a free-rider effect. Since our main results depend on the interplay of these two effects, we discuss them briefly before continuing our analysis.

First, when foreign students remain in the hosting country after their studies, the hosting country appropriates a part of their productivity. Consequently, foreign students exert a positive externality on the social welfare of a country. The size of the externality is proportional to $E = (1 - \rho)(1 - \gamma)$, because foreign students stay with probability $1 - \rho$ and, in this case, the hosting country appropriates a share $1 - \gamma$ of their productivity. The positive externality gives a country an incentive to attract foreign students. At the same time, countries expect to lose a share E from the productivity of their students who study abroad. The externality E therefore also measures the incentive of a country to induce its natives to study at home. In the aggregate, the parameter E measures the overall incentives of countries to raise the quality of education in order to attract foreign students and keep their own students from studying abroad. Thus, E is a measure of the *competition effect* of student mobility that is claimed in the policy debates surrounding the Bologna process.

The equilibrium levels (4) also reveal that quality choices are distorted even when there is no competition effect ($E = 0$). This is due to a negative *free-rider effect*. If $\hat{\tau} < 1$, countries may be tempted to educate their students abroad in order to save on the cost of education. This option is especially attractive if there does not exist a competition effect ($E = 0$). In this case, there is no loss attached to educating one's students abroad. Because a country saves the costs k_2 on each individual that is educated abroad, the free-rider effect is also stronger when the private goods aspect of education, k_2, is larger.

Hence, whenever students are mobile ($\hat{\tau} < 1$), the countries' quality choices depend on the interplay between the competition effect and the free-rider effect. The remainder of this paper takes a closer look at how student mobility affects this interplay.

7 Full mobility

Section 5 explained that the disadvantage of immobility ($\hat{\tau} = 1$) is that students cannot fully develop their multi-cultural skills. This section focuses on the other extreme of full mobility ($\hat{\tau} = 0$), where students are able to realize their multi-cultural skills to their full potential. Yet, as may be expected, this extreme generally leads to inefficient quality choices. Depending on the relative strengths of the competition and free-rider effect, these quality choices will be either inefficiently low or inefficiently high.

Proposition 4 *At full mobility ($\hat{\tau} = 0$), the equilibrium level of university quality is*

$$q_A^* = q_B^* = q^* = \frac{(1 - 4k_2 + E)m}{8mk_1 + 8k_2 - 4E}.$$

For $E = E_H$, the equilibrium is efficient. For $E < E_H$ equilibrium levels are inefficiently low. For $E > E_H$ equilibrium levels are inefficiently high, where

$$E_H \equiv \frac{mk_1 + 2k_2(1 - 2k_2)}{mk_1 + 1 - 2k_2}.$$

The proposition shows that only for the non-generic case $E = E_H$, full mobility leads to a first-best efficient outcome. In this special case, the positive competition effect and the negative free rider-effect balance each other out exactly. Yet, in general we will have $E \neq E_H$ and, depending on whether the students' externality is smaller or larger than E_H, full mobility leads to either inefficiently low quality levels or inefficiently high quality levels. Hence, when multi-cultural skills matter ($m > 0$) and $E \neq E_H$, the first-best cannot be obtained. The two goals of Bologna of maximizing multi-cultural skills and, at the same time, inducing efficient levels of university quality are not fully compatible. In general, there exists a trade-off between the two. The next section studies this trade-off in more detail.

8 Intermediate student mobility

Section 5 showed that the extreme of fully immobile students ($\hat{\tau} = 1$) induces efficient university quality choices, but leads to an inefficient development of multi-cultural skills. In contrast, Sect. 7 found that the other extreme of full mobility ($\hat{\tau} = 0$) leads to efficient development of skills, but inefficient quality choices. These results indicate that in the second-best world, where only student mobility $\hat{\tau}$ is chosen cooperatively, intermediate levels of student mobility will be optimal. More specifically, the second-best is a solution to

$$\begin{aligned} \max_{\hat{\tau}} \quad & W^A\big(q^*(\hat{\tau}), q^*(\hat{\tau}), \hat{\tau}\big) + W^B\big(q^*(\hat{\tau}), q^*(\hat{\tau}), \hat{\tau}\big) \\ \text{s.t.} \quad & 0 \leq \hat{\tau} \leq 1, \end{aligned} \tag{5}$$

where $q^*(\hat{\tau})$ represents the Nash equilibrium levels as expressed by (4). In this section, we study intermediate levels of student mobility in order to characterize the second-best solution.

In this section, we show how the relative strength of the competition and free-rider effect vary with varying levels of student mobility. Moreover, we study what levels of student mobility may be optimal from a second-best perspective that optimally trades the development of multi-cultural skills off against the effect of student mobility on the choice of university quality.

The previous section already indicated that the direction in which the quality choices are distorted depends on the relative weights of the competition and the free-rider effect. In particular, when the free-rider effect dominates, the two countries
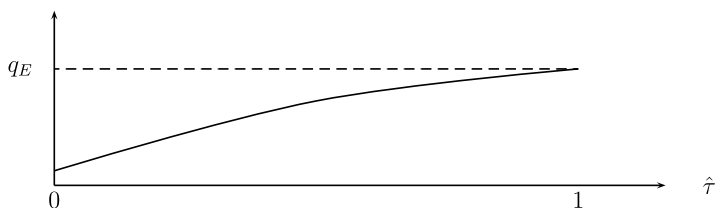
Fig. 2 Curve $q^*(\hat{\tau})$ for $E \leq E_L$

choose inefficiently low quality levels. Clearly, when the dominance of the free-rider effect does not depend on student mobility, we obtain a downward distortion for all levels of student mobility. The following lemma shows that this occurs exactly when the externality E is smaller than a critical threshold

$$E_L \equiv \frac{mk_1 + k_2(1 - 2k_2)}{mk_1 + 1 - 2k_2}.$$

Lemma 2 *Suppose $E \leq E_L$. Then the Nash equilibrium university quality level $q^*(\hat{\tau})$ is increasing in $\hat{\tau}$.*

The lemma demonstrates that, for small externalities ($E \leq E_L$), the free-rider effect dominates the competition effect for all positive levels of student mobility. As illustrated in Fig. 2, this implies the following monotonic relationship between university quality and student mobility. When students are immobile ($\hat{\tau} = 1$), the countries choose an efficient level of quality, q_E. But due to the dominating free-rider effect, an increase of student mobility by lowering $\hat{\tau}$ induces countries to lower their quality of education. The downward distortion is strongest for full mobility ($\hat{\tau} = 0$).

The lemma further implies that with low externalities there exists a trade-off between fostering multi-cultural skills and ensuring an optimal quality of education. The following proposition formalizes that the second-best solution will be a compromise and leads to an underprovision of quality.

Proposition 5 *If $E \leq E_L$, the second-best optimum will be characterized by incomplete student mobility $\hat{\tau} \in (0, 1)$ and underprovision of university quality $q^* < q_E$.*

When externalities are low, there exists a monotonic relationship between quality and student mobility. This raises the question whether such a monotonic relationship also exists for other levels of externalities. The following lemma shows, however, that for externalities that exceed the level E_L, the monotonic relationship is lost. In particular, the relationship between q^* and $\hat{\tau}$ is positive at $\hat{\tau} = 0$ and negative at $\hat{\tau} = 1$. Hence, when we regard quality q^* as a function of student mobility $\hat{\tau}$, then the curve $q^*(\hat{\tau})$ is increasing for small $\hat{\tau}$ and decreasing for larger values of $\hat{\tau}$.

Lemma 3 *University quality $q^*(\hat{\tau})$ is increasing at $\hat{\tau} = 0$ for all E. University quality $q^*(\hat{\tau})$ is strictly decreasing at $\hat{\tau} = 1$ if and only if $E > E_L$.*
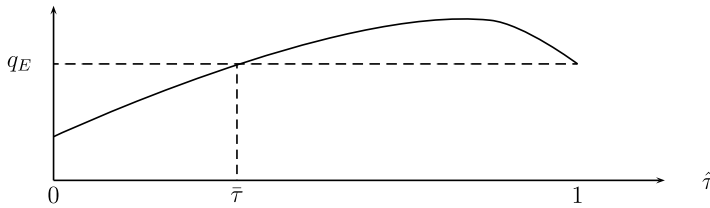
Fig. 3 Curve $q^*(\hat{\tau})$ for $E_L < E < E_H$

Proposition 4 demonstrated that with full mobility ($\hat{\tau} = 0$), quality choices are inefficiently low whenever $E < E_H$. This result together with Lemma 3 implies that for intermediate values $E \in (E_L, E_H)$, the relationship between quality and mobility is as illustrated in Fig. 3. For lower values of $\hat{\tau}$, the free-rider effect dominates and quality is inefficiently low. For larger values of $\hat{\tau}$ the competition effect dominates and university quality levels are inefficiently high. As illustrated in Fig. 3, there exists a threshold value $\bar{\tau}$ at which the free-rider and the competition effect cancel each other out, resulting in an efficient level of quality q_E. The following lemma formalizes this reasoning.

Lemma 4 *If $E_L < E < E_H$, the university quality $q^*(\hat{\tau})$ is increasing at $\hat{\tau} = 0$ and decreasing at $\hat{\tau} = 1$. There exists a unique $\bar{\tau} \in (0, 1)$ with $q^*(\bar{\tau}) = q_E$. The derivative of $q^*(\hat{\tau})$ is continuous.*

Intuitively, the non-monotonic relationship between quality distortion and student mobility is due to the composition effect. With increasing student mobility, the average talent of students who study abroad decreases. Consequently, higher mobility reduces the average gain in productivity from these students. In addition, the average talent of foreign students also declines with higher student mobility. As a result, it becomes less attractive to attract these students, because the average productivity gain from them will be lower. Since the costs of education are independent of a student's innate skills, the reduction in the average talent of mobile students reduces the importance of the competition effect relative to the free-rider effect. This is exactly what happens for intermediate values of E. In this case, the competition effect is only strong enough to outweigh the free-rider effect when the average talent of the mobile students is high.

We now study the optimal second-best student mobility $\hat{\tau}^*$ with intermediate externalities. First, note that for $\hat{\tau} > \bar{\tau}$ there is no meaningful trade-off between quality and student mobility. A level of mobility $\hat{\tau} = \bar{\tau}$ leads to both a more efficient acquisition of multi-cultural skills and a more efficient quality of education than any level $\hat{\tau} > \bar{\tau}$. As a consequence, the optimal level of student mobility lies below $\bar{\tau}$ and leads to an underprovision of educational quality. This is formalized by the following proposition.

Proposition 6 *For $E_L < E < E_H$, the second-best optimum $\hat{\tau}^*$ will be smaller than $\bar{\tau}$ and larger than zero. It induces an underprovision of university quality $q^* < q_E$.*
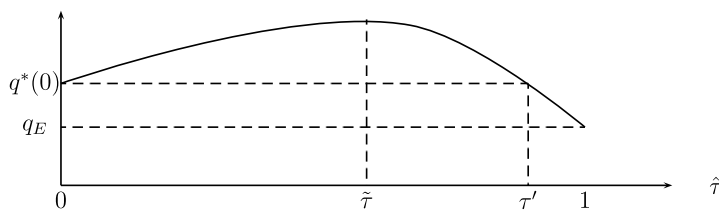
Fig. 4 Curve $q^*(\hat{\tau})$ for $E > E_H$

Proposition 6 is the counterpart of Proposition 5 for intermediate externality levels. Both propositions yield qualitatively equivalent results. For both low and intermediate externality levels, neither full mobility, $\hat{\tau} = 0$, nor full immobility, $\hat{\tau} = 1$, is optimal. In contrast, the optimal second-best level of student mobility is intermediate, $\hat{\tau}^* \in (0, 1)$, and yields an underprovision of university quality.

Finally, we address the possibility that mobile students exercise a considerably high externality on their host country ($E > E_H$). According to Lemma 3, quality is decreasing in the degree of student mobility for low levels of student mobility and increasing for higher levels. This result reflects again the composition effect. For low levels of mobility the average talent of the mobile student is high and the competition effect outweighs the free-rider effect. As student mobility increases, the average talent of the mobile student decreases and the free-rider effect becomes relatively more important. Yet, for $E > E_H$ the competition is so strong that it remains to outdo the free-rider effect even at the extreme of full mobility ($\hat{\tau} = 0$). This result is formalized in the following lemma.

Lemma 5 *If $E > E_H$, university quality $q^*(\hat{\tau})$ is increasing at $\hat{\tau} = 0$ and decreasing at $\hat{\tau} = 1$. Moreover, $q^*(\hat{\tau}) > q_E$ for all $\hat{\tau} \in [0, 1)$. The curve $q^*(\hat{\tau})$ obtains a unique maximum at $\tilde{\tau} \in (0, 1)$ with $q^*(\tilde{\tau}) > q_E$. There exists a unique $\tau' \in (\tilde{\tau}, 1)$ such that $q^*(\tau') = q^*(0)$.*

Figure 4 illustrates the lemma graphically. The curve $q^*(\hat{\tau})$ is decreasing for $\hat{\tau} > \tilde{\tau}$. This reflects the range where the competition effect outweighs the free-rider effect. Yet, for lower $\hat{\tau}$ the composition effect reduces the relative strength of the competition effect. At $\hat{\tau} = \tilde{\tau}$ the free-rider effect is gaining the overhand, and a further reduction in $\hat{\tau}$ reduces the distortion in quality. Yet, for $E > E_H$ the initial competition effect is too strong for the free-rider effect to eliminate the upward distortion in quality and to reverse it. Hence, the curve exceeds the efficient level q_E.

Finally, we address the second-best level of student mobility $\hat{\tau}^*$. For the range $(0, \tau']$ there exists no meaningful trade-off between quality of education and student mobility. In comparison to any level $\hat{\tau} \in (0, \tau']$, full mobility ($\hat{\tau} = 0$) leads to both a more efficient acquisition of multi-cultural skills and a more efficient quality of education. As a consequence, the optimal level of student mobility lies either at $\hat{\tau} = 0$ or $\hat{\tau} \in (\tau', 1)$. Hence, for high externalities, the strong competition effect leads to an overprovision of educational quality.

Proposition 7 *If $E > E_H$, the second-best optimum is characterized by an overprovision of university quality $q^* > q_E$ and either full student mobility $\hat{\tau} = 0$ or positive but incomplete student mobility $\hat{\tau}^* \in (\tau', 1)$.*

A comparison of Proposition 7 to Propositions 5 and 6 reveals that qualitative results for large externalities $E > E_H$ differ from those obtained for smaller externalities $E < E_H$. In particular, we obtain an overprovision of university quality for $E > E_H$ against an underprovision of university quality for $E < E_H$.

9 Conclusion and discussion

The Bologna process is meant to increase student mobility, that, in its turn, is to raise the productivity of European graduates due to two effects. First, mobility is supposed to kindle competition among the union's member states to attract the best students. This competition effect induces governments to raise the quality of their universities. At the same time, higher mobility is expected to provide graduates with higher multi-cultural skills. The current paper examines the economic rationale behind these arguments. It studies the economic effects of student mobility on both the acquisition of multi-cultural skills and the quality of university education.

We obtain a trade-off between multi-cultural skills and university quality. When students are fully immobile, there is no interaction between countries, and governments choose the efficient level of university quality; but, because no multi-cultural skills are gained, efficient university quality comes at the expense of inefficiently low multi-cultural skills. A reversed inefficiency can be observed in the other extreme where students are fully mobile. In this case, students acquire an efficient level of multi-cultural skills, but university quality is generally inefficient because the countries do not internalize the externalities between them. Thus, we do not find a mobility level that induces both efficient quality and an efficient acquisition of multi-cultural skills. As a consequence, optimal mobility levels will have to trade inefficiencies in university quality off against inefficiencies in multi-cultural skills.

What does our model tell us about the European Bologna process? First, our model makes explicit that the Bologna process is supposed to solve a problem that is caused by an artificial dichotomy: the Bologna process represents a framework in which the level of mobility is chosen cooperatively, whereas quality levels are chosen non-cooperatively. Although this historically grown dichotomy is a natural and typical aspect of the dynamic process of European integration, it is often neglected. Indeed, a straightforward solution to the problem is to implement a cooperative decision procedure for mobility *and* expenditures rather than mobility alone. For reasons that lie outside of the scope of this paper, this straightforward solution is not feasible politically.

As a result, we are left facing a trade-off between two main forces: a competition and a free-rider effect. The public debate about the Bologna process neglects the free-rider effect completely, even though the two may be seen as two sides of the same coin. Clearly, the public neglect of the free-rider effect is justified only if its magnitude is small. In the remainder, we argue that available data suggest that this is

not the case. It seems that both the competition and the free-rider effect are substantial and it is, therefore, hard to judge whether educational quality will benefit from the Bologna process.

Regrettably, available data on mobility within Europe is rather sparse. This is first of all due to the fact that the current levels of mobility in Europe are still strikingly low. OECD (2006, Table C3.1) reports 5.8% as the EU19 average for mobility in 2004.[6] As a consequence, the number of mobile students is yet too small to be considered as a determining influence on current expenditure levels. Hence, even though OECD (2006, Table C3.1) reports that from 2000 to 2004, the participation of foreign students increased by over 50%, we cannot yet expect to observe the effect of student mobility on actual expenditures.

As explained, the effect of the Bologna process on educational quality will depend on a trade-off between the free-rider and the competition effect. The strengths of the two effects will foremost depend on the number of foreign graduates who return to the home country after graduation. If the return probability is large, then we may expect that the free-rider effect is substantial, since the home country benefits from the education without paying for it. In this respect, Jahr et al. (2002, p. 36) report that about half (47%) of European students who studied in a foreign country returned to their home country after graduation. This points to a significant free-rider potential. Indeed, recent developments indicate that free-riding between the European countries is already taking place and worsening. For instance, the Netherlands and Germany have rather strict limits on the number of students in the more expensive studies of medicine and dentistry. Dutch students, who miss out on the allocation lottery in their home country, are known to take up their studies in Belgium. Likewise, German students, who are unable to study at home because of lower grades, divert to Austria. In response, both Belgium and Austria try to limit the inflow of foreign students and give priority to their native students. In the case of Austria, the European Court ruled in July 2005 that such practises were against EU law. Based on this decision, the European Commission sent letters of formal notice to Austria and Belgium in January 2007.[7]

On the other hand, we cannot deny the strength of the competition effect. Jahr et al. (2002, p. 36) report that a substantial percentage (41%) of European students who graduated in a foreign country do stay and work there at least 4 or 5 years. Moreover, it is also widely expected that competition for highly skilled migrants will increase in Europe and with it, the competition effect of the Bologna process.[8] The populations in European countries are shrinking and aging and it is generally agreed that, not immigration per se, but immigration of a young and highly qualified work force is needed in order to compensate for the demographic development.[9] Because of

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[6]The OECD makes an OECD-specific distinction between "international" and "foreign" students. Foreign students include students with a foreign nationality who have been living in the host country already before their studies. In our context, the appropriate figures are those concerning "international" students.

[7]Press release European Commission: IP/07/76.

[8]Compare for example the article of Helmut Merschmann in *Migration* 57, 15. 01. 2007, p. 10.

[9]Compare the study of the Deutsche Bank Research, *Aktuelle Themen. Demografie Spezial.* 14. 07. 2003, nr. 277.

their relatively high educational standards and their geographic location, competition for young high-skilled labor between the European countries will intensify. Hence, students with their natural propensity to stay and work in the country in which they graduate constitute a highly attractive group of potential immigrants. We, therefore, see an intimate tie between student mobility and quality competition within Europe.[10]

Finally, in our model, the outcome of the trade-off also depends on a composition effect. The low number in mobility suggests that the composition effect is probably still positive in the sense that the marginal mobile student is more productive than the average student. Indeed, Jahr et al. (2002, Chap. 4) provide some indication of this. They show that the mobility of students is positively related with their grades and the education of their parents. In addition, they show that graduates who have been mobile as students work two hours per week longer than those who have not been mobile. Hence, at the present low level of mobility, the more mobile students are the more productive ones. This is consistent with our composition effect: at low levels of mobility, the marginal mobile student is more productive than the average student. This plays in the hand of the competition effect. It makes it more attractive to countries to attract foreign students and retain their more able native students by providing high quality education. Yet, as the Bologna process progresses and mobility increases, the composition effect dampens the competition effect.

This leads us to conclude that both the competition and the free-rider effect are large and it is too early to say which effect will finally dominate. We, therefore, may only warn that the current neglect of the free-rider effect in the public debate is misplaced. In contrast, we view the development of multi-cultural skills as an unambiguous benefit of the Bologna process.

Appendix

Proof of Proposition 1 We solve the maximization problem $\max_{q_A, q_B} W(q_A, q_B)$. The function $W(q_A, q_B)$ is continuous, but, due to corner conditions, consists of three parts. Whenever $|q_A - q_B| \leq m/2$ we have

$$
W(q_A, q_B) = \big[4m\big(q_A - 2q_A(k_2 + k_1 q_A) + q_B - 2q_B(k_2 + k_1 q_B)\big) \\
+ m^2(1 - \hat{\tau}) + 4(q_A - q_B)^2\big(1 - \hat{\tau}^2 - 4k_2(1 - \hat{\tau})\big)\big]/(8m).
$$

Since W is concave in q_A, q_B, first order conditions are sufficient and yield $q_A = q_B = (1 - 2k_2)/(4k_1)$.

Whenever $q_A - q_B > m/2$ we have $a_A^0 = -1/2$ and $a_B^0 = 1/2$ so that

$$
W(q_A, q_B) = \big[2m\big(q_B - k_1\big(q_A^2 + q_B^2\big) + (q_A - q_B)\hat{\tau}^2\big) \\
- 2k_2 m(q_A + q_B) + 2(q_A - q_B)^2(1 - \hat{\tau})\big]/(2m).
$$

This expression is concave in (q_A, q_B) so that first order conditions are sufficient. First order conditions yield $q_A - q_B = -m(1 - \hat{\tau}^2)/(2k_1 m + 8k_2(1 - \hat{\tau})) < 0$, which violates $q_A - q_B > m/2$. Hence, there is no internal maximum for W on the domain $q_A - q_B > m/2$.

Whenever $q_A - q_B < -m/2$ we have $a_A^0 = 1/2$ and $a_B^0 = -1/2$ so that

$$W(q_A, q_B) = \left[2m\left(q_A(1 - k_2 - k_1 q_A) - k_2 q_B - k_1 q_B^2\right) \right.$$
$$\left. - 4k_2(q_A - q_B)^2(1 - \hat{\tau}) - m(q_A - q_B)\hat{\tau}^2 \right]/(2m).$$

This expression is concave in (q_A, q_B) so that first order conditions are sufficient. First order conditions yield $q_A - q_B = m(1 - \hat{\tau}^2)/(2k_1 m + 8k_2(1 - \hat{\tau})) > 0$, which violates $q_A - q_B < -m/2$. Hence, there is no internal maximum for W on the domain $q_A - q_B < -m/2$.

Since $W(q_A, q_B)$ is continuous over its entire domain, the maximum is unique and obtained for

$$q_A = q_B = \frac{1 - 2k_2}{4k_1}. \qquad \square$$

Proof of Proposition 2 Substitution of $q_A = q_B = q_E$ into $W(q_A, q_B)$ and a re-arrangement of terms yields

$$W(q_E, q_E) = \frac{mk_1(1 - \hat{\tau}^2) + (1 - 2k_2)^2}{8k_1}.$$

For $m = 0$ this expression is independent of $\hat{\tau}$. For $m > 0$ the expression is strictly decreasing for $\hat{\tau} > 0$. Hence, $\hat{\tau} = 0$ is optimal. $\qquad \square$

Proof of Proposition 3 The first statement follows directly from Proposition 1 and 2. The efficiency loss computes as the difference $W(q_E, q_E)|_{\hat{\tau}=0} - W(q_E, q_E)|_{\hat{\tau}=1} = m/8$. $\qquad \square$

Proof of Lemma 1 The pair (q_A^*, q_B^*) is a Nash equilibrium whenever

$$q_A^* = \arg\max_{q_A} W_A(q_A, q_B^*) \quad \text{and} \quad q_B^* = \arg\max_{q_B} W_B(q_A^*, q_B).$$

Whenever $k_1 > 1/m$ and $k_2 < 1/4$ the solution, for $|q_A - q_B| \leq m/2$, is

$$q_A = q_B = q^* = \frac{(1 - 4k_2 + \hat{\tau}^2 + (1 - \hat{\tau}^2)E)m}{8mk_1 + 8k_2(1 - \hat{\tau}) - 4(1 - \hat{\tau}^2)E},$$

which is consistent with the assumption $|q_A - q_B| \leq m/2$.

We now show that $q_A < q_B - m/2$ is not a best-response to $q_B = q^*$. For $q_A < q_B - m/2$ the social welfare of country A is

$$W^A = W_1^A \equiv \hat{\tau}^2 q_A/2 + (1 - E)(1 - \hat{\tau}^2)q_B/2 - k_1 q_A^2 - k_2 \hat{\tau} q_A.$$

Note that for the range $q_A \in [0, q_B - m/2]$ the expression

$$\partial W_1^A/\partial q_A = \hat{\tau}^2/2 - 2k_1 q_A - k_2 \hat{\tau}$$

is maximized for $q_A = q_B - m/2$. For $q_B = q^*$ it then follows

$$\frac{\partial W_1^A}{\partial q_A} = \hat{\tau}^2/2 - k_2\hat{\tau} - 2k_1\left(\frac{m(1 + E - 4k_2 + \hat{\tau}^2(1 - E))}{8(k_2(1 - \hat{\tau}) + k_1 m) - 4E(1 - \hat{\tau}^2)} - \frac{m}{2}\right).$$

This expression is decreasing in E so that the expression is smallest for $E = 1$:

$$\frac{\partial W_1^A}{\partial q_A} = \hat{\tau}^2/2 - k_2\hat{\tau} - 2k_1\left(\frac{m(2 - 4k_2)}{8(k_2(1 - \hat{\tau}) + k_1 m) - 4(1 - \hat{\tau}^2)} - \frac{m}{2}\right).$$

For $k_1 > 1/m$ and $k_2 < 1/4$ the expression is positive. This shows that $W^A(q_A, q^*)$ is increasing on $q_A \in [0, q^* - m/2)$ so that $q_A \in [0, q^* - m/2)$ is not a best-response to $q_B = q^*$.

Next we show that also $q_A > q_B + m/2$ is not a best-response to $q_B = q^*$. For $q_A > q_B + m/2$ it follows

$$W^A = W_2^A \equiv q_A\left(1 - 4k_2 + E\left(1 - \hat{\tau}^2\right) - 2k_1 q_A + 2k_2\hat{\tau}\right)/2.$$

Hence,

$$\frac{\partial W_2^A}{\partial q_A} = \left(1 - 4k_2 + E\left(1 - \hat{\tau}^2\right) - 4k_1 q_A + 2k_2\hat{\tau}\right)/2 \tag{6}$$

for $q_A > q_B + m/2$. For $k_1 > 1/m$, $k_2 < 1/4$, and $q_B = q^*$ it may be shown that expression (6) evaluated at $q_A = q^* + m/2$ is negative. From this and the fact that (6) is decreasing in q_A it follows that $W^A(q_A, q^*)$ is decreasing for $q_A > q^* + m/2$ so that $q_A > q^* + m/2$ is not a best-response to $q_B = q^*$.

It follows that $q_A = q^*$ is a best-response to $q_B = q^*$. Due to symmetry $q_B = q^*$ is also a best-response to $q_A = q^*$. Therefore $q_A = q_B = q^*$ is the unique symmetric equilibrium. $\qquad\square$

Proof of Proposition 4 Substitution of $\hat{\tau} = 0$ in (4) and its comparison to q_E yields the result. $\qquad\square$

Proof of Lemma 2 Taking the derivative of (4) with respect to $\hat{\tau}$ yields

$$\frac{dq^*}{d\hat{\tau}} = \frac{k_2(1 - 4k_2 + E) + 2((mk_1 + k_2)(1 - E) - E)\hat{\tau} - k_2(1 - E)\hat{\tau}^2}{2(2(mk_1 + (1 - \hat{\tau})k_2) - E(1 - \hat{\tau}^2))^2/m}. \tag{7}$$

Since the denominator of (7) is strictly positive, this derivative is continuous for all $\hat{\tau} \in [0, 1]$. Moreover, the numerator determines its sign. Because the numerator is quadratic in $\hat{\tau}$ with a negative coefficient $-k_2(1 - E) < 0$, the sign of $dq^*/d\hat{\tau}$ changes at most once on $\hat{\tau} \in [0, 1]$. Due to $k_2 < 1/4$, the numerator is positive at $\hat{\tau} = 0$. Hence, the sign changes if and only if the numerator in (7) evaluated at $\hat{\tau} = 1$ is negative.

That is whenever

$$E > \frac{mk_1 + k_2(1 - 2k_2)}{mk_1 + 1 - 2k_2}. \qquad \square$$

Proof of Proposition 5 After a substitution of the Nash values (4) into the aggregate social welfare function (2), we may rewrite the change in welfare as

$$\frac{\mathrm{d}W}{\mathrm{d}\hat{\tau}} = \frac{\mathrm{d}q(\hat{\tau})}{\mathrm{d}\hat{\tau}} \left[q_E - q(\hat{\tau}) \right] - \frac{\hat{\tau}m}{4}. \qquad (8)$$

Since $q(1) = q_E$ the evaluation of the derivative at $\hat{\tau} = 1$ yields $-m/4$. Hence, aggregate social welfare is decreasing at $\hat{\tau} = 1$. The derivative evaluated at $\hat{\tau} = 0$ yields

$$\frac{(1 - 4k_2 + E)k_2 m[(1 - E)k_1 m + (2k_2 - E)(1 - 2k_2)]}{2(2(k_2 + k_1 m) - E)^3}.$$

This expression is positive if and only if $E < E_H$. Hence, for $E < E_L < E_H$, aggregate social welfare is increasing at $\hat{\tau} = 0$ and decreasing at $\hat{\tau} = 1$ It follows for the optimal degree of mobility that $\hat{\tau}^* \in (0, 1)$. From Proposition 3 and Lemma 3 it follows that there is an underprovision of quality. $\qquad \square$

Proof of Lemma 3 The statement is a corollary of the proof of Lemma 2. $\qquad \square$

Proof of Lemma 4 In the proof of Lemma 2 we established that $\partial q^*/\partial \hat{\tau}$ is continuous on $\hat{\tau} \in [0, 1]$, changes sign at most once, and has at most one maximum. Moreover, the proof of Lemma 2 established that $\partial q^*/\partial \hat{\tau}$ at $\hat{\tau} = 0$ is positive, so that q^* is increasing at $\hat{\tau} = 0$.

Evaluation of $\partial q^*/\partial \hat{\tau}$ at $\hat{\tau} = 1$ yields

$$\frac{\partial q^*}{\partial \hat{\tau}} \Big|_{\hat{\tau}=1} = \frac{(1 - E)k_1 m + (1 - 2k_2)(k_2 - E)}{4k_1^2 m},$$

which is negative for $E > E_L$. Hence, q^* is decreasing at $\hat{\tau} = 1$.

Since q^* at $\hat{\tau} = 0$ exceeds q_E and, due to Proposition 4, q^* is smaller than q_E at $\hat{\tau} = 1$, continuity of $\partial q^*/\partial \hat{\tau}$ and the fact that it changes sign only once imply that there exists a unique $\bar{\tau} \in (0, 1)$ such that $q^*(\bar{\tau}) = q_E$. $\qquad \square$

Proof of Proposition 6 By Lemma 4 there exists a unique $\bar{\tau} \in (0, 1)$ such that $q(\hat{\tau}) < q_E$ for all $\hat{\tau} \in (0, \bar{\tau})$ and $q(\hat{\tau}) > q_E$ for all $\hat{\tau} \in (\bar{\tau}, 1)$. Since $q^*(1) = q_E$ the continuity of $q(\hat{\tau})$ implies that there exists a maximum $q(\tilde{\tau}) > q_E$ at some $\tilde{\tau} \in (\bar{\tau}, 1)$. We first establish that $\hat{\tau} > \tilde{\tau}$ cannot be optimal. To see this, observe that there exists a $\tau' \in [\bar{\tau}, \tilde{\tau})$ such that $q(\tau') = q(\hat{\tau})$. Consequently, the difference in aggregate welfare can be expressed as

$$W(\hat{\tau}) - W(\tau') = \int_{\tau'}^{\hat{\tau}} \frac{\mathrm{d}W}{\mathrm{d}\hat{\tau}} \, \mathrm{d}\tau = \int_{\tau'}^{\hat{\tau}} \frac{\partial W}{\partial \hat{\tau}} \, \mathrm{d}\tau = \int_{\tau'}^{\hat{\tau}} -\frac{m\tau}{4} \, \mathrm{d}\tau < 0,$$

where the second equality follows because $q(\tau') = q(\hat{\tau})$. Hence, $\hat{\tau} > \tilde{\tau}$ is not optimal.

Second we establish that $\hat{\tau} \in [\bar{\tau}, \tilde{\tau})$ cannot be optimal. This follows from the observation (8) that

$$\frac{\mathrm{d}W}{\mathrm{d}\hat{\tau}} = \frac{\mathrm{d}q}{\mathrm{d}\hat{\tau}}\big[q_E - q(\hat{\tau})\big] - \hat{\tau}/4.$$

Since for $\hat{\tau} \in [\bar{\tau}, \tilde{\tau})$ we have $\mathrm{d}q/\mathrm{d}\hat{\tau} < 0$ and $q(\hat{\tau}) > q_E$ the expression $\mathrm{d}W/\mathrm{d}\hat{\tau}$ is negative for any $\hat{\tau} \in [\bar{\tau}, \tilde{\tau})$.

Consequently, the second-best optimum is characterized by some $\hat{\tau} \in (0, \bar{\tau})$. As for $\hat{\tau} < \bar{\tau}$, it follows $q(\hat{\tau}) < q_E$, there is underprovision of quality. □

Proof of Lemma 5 All but the last statement follow directly from the proof of Lemma 4. The last statement follows from the fact that $q^*(\tilde{\tau}) > q^*(0) > q_E = q^*(1)$. Hence, continuity of $q^*(\cdot)$ implies existence of $\tau' \in (\tilde{\tau}, 1)$ such that $q^*(\tau') = q^*(0)$. □

Proof of Proposition 7 For any $\hat{\tau} \in (\tilde{\tau}, \tau')$ there exists a $\tau \in (0, \tilde{\tau})$ with $q(\tau) = q(\hat{\tau})$. Consequently, the difference in aggregate welfare can be expressed as

$$W(\hat{\tau}) - W(\tau) = \int_{\tau}^{\hat{\tau}} \frac{\mathrm{d}W}{\mathrm{d}\hat{\tau}}(t)\,\mathrm{d}t = \int_{\tau}^{\hat{\tau}} \frac{\partial W}{\partial \hat{\tau}}(t)\,\mathrm{d}\tau = \int_{\tau}^{\hat{\tau}} -\frac{m\tau}{4}\,\mathrm{d}\tau < 0,$$

where the second equality follows because $q(\tau) = q(\hat{\tau})$. Hence, $\hat{\tau} \in (\tilde{\tau}, \tau')$ is not optimal.

Equation (8) implies that whenever $q^*(\tau) > q_E$ and $q^*(\tau)$ is decreasing, then aggregate welfare $W(\hat{\tau})$ is decreasing in $\hat{\tau}$. Consequently, $\hat{\tau} \in (0, \tilde{\tau})$ cannot be optimal.

Hence, the second-best $\hat{\tau}$ lies either in the interval $(\tau', 1)$ or at 0. □

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