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Reference-Dependent Preferences in Contests and Non-Cognitive Ability in the Labour Market

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Abstract

The dissertation includes four individual essays that are laid out over four separate chapters. Following a short overall introduction in Chapter 1, Chapter 2 models the strategic interaction between two agents who engage in a game-theoretical contest and hold expectation-based reference-dependent preferences. We show, that agents who find themselves disadvantaged ex ante, in this setting end up as favourites in two out of three possible equilibria. In Chapter 3 we investigate, using field data, whether it is possible to invest in non-cognitive ability through an educational policy. We measure the impact of a study abroad experience on non-cognitive skills and compute its monetary implications using wage data from the German Socio-Economic Panel. The project presented in Chapter 4 is an outcome of initiating the study series Fachkraft 2020 which is, at the moment of writing, the biggest student survey in Germany with more than 40,000 annual participants. Based on about 23,000 student responses we examine whether there is selection and change of non-cognitive abilities in different study tracks of German higher education. We find sizeable selection, but little change. Lastly, Chapter 5 models the impact of the internationalisation of higher education on economic growth in a two country setting. We provide conditions necessary for internationalisation to be beneficent and simulate different growth paths for both countries.

Parts of this thesis have been published in the following articles:

- Bergerhoff, Borghans, Seegers, and van Veen (2013)
- Bergerhoff and Vosen (2015) (working paper)

für meine Mutter

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Locus of Control, one of the personality measures we use, describes how much you think that what you experience is the result of your own making and to what extend it depends on the decision of other people. While I believe to have some control, I am in no way blind to the enormous support I have received from many great people over the years.

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Contents

Chapter 1

Introduction

When I left home and moved to England to attend school there, this was a big change. Meeting these new people, teachers and kids alike, had a profound impact on me. Before moving to England I wanted to study law. When I came back I enrolled in economics.

One could argue that understanding a decision like this is not a function of economics and that economists, who have set themselves a task difficult enough, should leave it to other disciplines. Yet decisions of individuals or groups are at the heart of economic models. Real outcomes, be it in small markets or in the economy as a whole, are the product of both chance and individual decisions, some of which are based on rational calculations, but others are based on heuristics, personality traits, or reference points (a clearly non-exhaustive list). In economic theory, agents confronted with a decision pick the option that maximises their utility. On a meta level, this is a satisfactory concept since utility can be derived from almost anything. But when trying to tune in on actual human utility, economists struggle to sort and combine the various potential sources of human motivation. As a result, such "non-orthodox" preferences are, if they are, typically introduced to economic theory in isolation and one at a time.

An interesting class of non-standard motives are reference-dependent preferences. The concept that received much attention following the article of Köszegi and Rabin (2006) reflects the empirical finding that one is particularly happy when an event exceeds expectations and particularly sad when something falls short.[1] Next to its intuitive appeal, modelling reference point formation explicitly could help provide a more unified framework for difference sources of motivation.[2] However, adding reference-dependent preferences to the classical utility makes the agent more complex to model.

[1]This is an example for expectation based reference points. However, reference points can also be influenced by other factors like a social norm or a status quo.

[2]Schwerter (2013) for example finds that people have social reference points that can explain their inequity aversion.

But introducing such agents to existing economic models potentially changes their predictions and produces new results. The model studied in Chapter 2 of this thesis exemplifies this.[3] Two agents engage in a tournament and face a difficult decision: Spending more effort than the opponent increases the probability of winning a prize, but effort is unpleasant and hence to be avoided. Finding a set of effort levels such that both agents cannot individually improve their position (an equilibrium) can be hard. To get solutions agents are taken to be simple, i.e., they receive the same utility from the prize and suffer the same disutility from spending effort. We extend this classical set of motivations (Lazear & Rosen, 1981) and allow them to be affected by their own expectations about the likelihood of winning.

Even when both agents are exactly identical reference-dependence allows for multiple equilibria. However, when the game is unsymmetric, i.e. one player has head-start, then in two out of three equilibria the person behind spends more effort and is actually more likely to win. The model presents one possible rationalisation for the finding of Berger and Pope (2011) who, using basketball data and laboratory evidence, show that contestants in a tournament who find themselves behind at half time are more likely to win overall. Tournament models commonly predict the opposite.

Chapter 2 shows that when agents have reference-dependent preferences, the reactions and decisions we expect of them change. However, even the way that reference points are formed may differ between people. More generally, there is a sizeable and persistent heterogeneity of preferences: Psychological character traits like the Big 5 (Openness, Conscientiousness, Extraversion, Agreeableness and Neuroticism) and locus of control or economic preferences like risk aversion, impatience, altruism or trust and reciprocity capture the multitude of differences. Because these traits matter for individual decision-making, a large literature in economics has come about investigating their influence on outcomes like wages, health and subjective well-being. The implicit consensus in this research is that some personality profiles achieve better outcomes than others.

In Chapter 3 we start from this consensus and ask whether it is possible for an educational policy to change these preferences in way that would be associated with better outcomes.[4] We set out to test whether a semester abroad at university has a lasting impact on the personality of students and collected new data with the help of the study abroad programme at Maastricht University's School of Business and Economics. Students at the school need to go abroad in their third academic year, with roughly half of them going in the first and another half going in the second semester. We find that students return from their study abroad with greater Emotional Stability (i.e., lower Neuroticism) and a more inward locus of control compared to the

[3]Chapter 2 is joint work with Agnes Vosen.
[4]Chapter 3 is joint work with Philipp Seegers.

group that stays in Maastricht.

Both personality changes carry returns in the labour market in addition to being associated with better health and higher subjective well-being in the literature (DeNeve & Cooper, 1998). Using German Socio-Economic Panel data (Schupp & Wagner, 2002) on wages and personality we convert the personality changes to a monetary equivalent of more than 25,000 Euros. While we do not believe that this number is a precise representation of the actual benefits, we argue that it underlines the potential economic benefits of making non-cognitive skills a policy objective.

The concept that stable personality traits can change as a result of making certain experiences is relatively new in the economics literature. In two articles Cobb-Clark and Schurer (2012) and Cobb-Clark and Schurer (2013) were the first to investigate this question for the Big 5 and for locus of control, respectively. Using panel data they found that personality traits do not change much in response to big life events like unemployment or severe illness. In the psychological literature, however, personality change for adults, though also being not universally accepted, has been documented both in panel data (Roberts, Walton, & Viechtbauer, 2006) and in interventionist studies (Jackson, Hill, Payne, Roberts, & Stine-Morrow, 2012). The existence of selection based on personality, on the contrary, is widely accepted. Several large meta-studies have concluded that personality traits are related to job performance, but that returns to traits are often job-specific (Barrick and Mount (1991); Salgado (1997); Barrick, Mount, and Judge (2001)).

Since most jobs require certain qualifications it is not clear at which stage selection into them actually occurs. Studying a certain subject at university, for example, has a considerable impact on the set of possible employments graduates face. If the cost of switching professions is high enough, graduates may decide to stay in their area of study for a long time. Consequently, character traits that influence the choice of a university subject might be an important determinant for the personality selection found in the industry later on. In Chapter 4 we examine the selection into study tracks along such personality traits.[5] If the personality of graduates in a certain field differs from the average, this can be due to a selection effect, to a change effect, or due to a combination of the two. Students that enrol in a track may be different *ex ante* (selection), but their personality could change in response to engaging with that subject. We study both effects simultaneously.

Working on this project was particularly exiting as it involved the creation of what is now, as of writing this thesis, the biggest student survey in Germany: *Fachkraft 2020.* To collect the data we entered a cooperation with the Cologne-based company STUDITEMPS which runs a large student job platform in Germany and allowed us to send out questionnaires into their

[5] Chapter 4 is joint work Philipp Seegers.

user base of currently more than 400,000 students. The project developed into a study series for which we collect data once every semester. Over the last three years we received more than 100,000 responses through this channel, with an average time spend on each survey of up to 55 minutes. To find out more about personality and university subject choice we asked Fachkraft 2020 participants about their university or technical school and about the subject they were enrolled in. We also included a comprehensive personality test. For the 23,000 students in our sample we find a clear selection into subjects based on personality. Out of the 110 subject-trait relationships we investigate, 53 show significant differences to the overall student average. Studying a subject itself, however, does not have an effect on student personality. If this finding is accurate, then it seems likely that much of the personality-based job sorting is being decided at the moment of subject choice.

The project presented in the last chapter chronologically came first.[6] Whereas Chapter 3 investigates effects of studying abroad on students, Chapter 5 deals with the effect of the internationalisation of higher education from the perspective of a country at large. Two countries, large and small, are depicted using a simplified education based growth model.[7] The model is extended to capture several potential effects of international education. If education in the host country is subsidised, educating foreign nationals is a monetary investment. Especially if student flows do not balance (like it can easily happen between large and small countries) the question emerges whether this money is well spent. One upside for the hosting countries is that there is a chance that a foreign student decides to stay and join the host country's labour force bringing in more than 15 years worth of education. The model also allows for different productivities of purely national and international education: The personal development found in Chapter 3, for example, could hint that international education is more productive than purely domestic education.

Calibrating the parameters of the model to match the case for Germany and the Netherlands we simulate economic output after a shock introduction of international education moved both economies out of their long run steady state. The simulations yield parameter restrictions necessary to make a country a net beneficiary of the internalisation of education. To make all countries benefit in the long run, a greater return of international education is an important factor. In Bergerhoff et al. (2013) we rationalised this by referring to Oosterbeek and Webbink (2006) and saying:

> "International education, indeed, catches a wage premium in

[6] Chapter 5 is joint work with Philipp Seegers, Lex Borghans and Tom van Veen.

[7] The idea for it was born as part of a Maastricht Research Based Learning project. For the article Bergerhoff et al. (2013) that is the basis of Chapter 5 we could use some insights of our earlier work with Tom van Veen.

> the labour market, but currently it is uncertain how much of it is attributable to selection."

Knowing the results of Chapter 3, we would now be more confident.

Chapter 2

Can being behind get you ahead?

Reference-dependent preferences and Asymmetric Equilibria in an Unfair Tournament.

2.1 Abstract

Everyone remembers a plot where a disadvantaged individual facing the prospect of failure, spends more effort, turns around the game and wins unexpectedly. Most tournament theories, however, predict the opposite pattern and see the disadvantaged agent investing less effort. We show that 'turn arounds', i.e. situations where the trailing player spends more effort and becomes the likely winner of the tournament, can be the outcome of a Nash equilibrium when the initial unevenness is known and players have reference-dependent preferences. Under certain conditions, they are the only pure strategy equilibrium. If the initial unevenness is large enough the advantaged player will always invest the most effort. We also show that equilibria in which the player behind catches up without becoming the likely winner do not exist.

2.2 Introduction

Rank order tournaments are a common mechanism for providing social and economic order. They are somewhat special, because they tie the privilege of receiving a certain good or benefit to the effort of performing best at some productive task. Politicians need to convince their constituents to be elected and business men need to create value for their company to be considered for promotion. Especially when high stakes are involved any indication of the likely outcome of a tournament is an asset. Consider for example the large betting industry that offers bets at dynamic quotes during the progress of many publicly fought contests.

Many times tournaments are not entirely fair with one player, for example, having more information or better relations with the tournament decider. However, even more often such unevenness occurs in dynamic contests. Most real world tournaments are dynamic in the sense that they require repeated decisions by the competitors between which contestants can process new information and recalibrate their tactics and effort investment. The most general piece of new information is the intermediate score which exists in most tournament settings. Politicians obtain interims feedback through opinion polls and direct contact, students write mid-term or mock exams and sports men can usually collect a time or score signalling their relative position in the tournament. That such feedback is entirely even seems to be the exception rather than the rule.[1]

Previous research like the work on dynamic tournaments by Chan, Courty, and Hao (2009) or Aoyagi (2010) found that equilibria are “effort-symmetric” with respect to feedback. This means that independent of the interims feedback, both competitors invest the same level of effort and only the sum of efforts decreases the more uneven the feedback is. Without any difference in effort provisions and the corresponding changes in the relative winning probabilities these tournaments are essentially decided by the initial unevenness and chance. Providing information about the intermediate state of the game does not matter for the tournament outcome. The implicit assumption here is that the interims feedback does not affect the agent’s utility directly. In such a world, a victory against all odds that follows a drastic comeback after having been far behind initially is the same as any other victory in terms of utility.

Gill and Stone (2010) were the first to account for the direct effect of feedback on utility by introducing “fairness and desert” concerns in the form of reference-dependent preferences. They investigate the influence of experiencing something as deserved on equilibrium formation. Focussing on effort-symmetric equilibria they could show that for uneven games, symmetric effort equilibria, in which the interims score is immaterial to the outcome

[1] How humans react to feedback is not yet fully understood. One potentially related idea is the concept of cognitive dissonance (Festinger, 1962), which proposes that anyone who holds contradictory beliefs will try to actively reduce this dissonance. Adjusting one’s reference categories could be seen as one way to overcome the dissonance between the desire for a certain prize and the naturally limited resources to obtain it.

of the tournament, do not exist. However, currently it is not clear whether asymmetric equilibria exist and if so whether they favour the victory of the player ahead or behind.[2]

Gill and Stone (2010) derive predictions for asymmetric equilibria, but only for the case where chance in the game is uniformly distributed. Uniformly distributed errors are commonly used in economic models and laboratory experiments. Indeed, without further knowledge of the situation at hand it may be as well-suited as any other distribution. However, when thinking about many examples of rank order tournaments the assumption that all random events, no matter how extreme, are equally likely and that at the same time more extreme events carry probability of zero appears odd. In many tournament applications like job or sport contests the notion that extreme events can happen, but do so with a low probability, has an intuitive appeal.[3]

With uniformly distributed errors Gill and Stone (2010) find that just one class of equilibria exists, in which the player ahead always spends more effort than the trailing player. Our paper makes new and very different predictions for the same setting when uncertainty is normally distributed. We find that, depending on the strength of the reference-dependence, the tournament prize and the initial unevenness three different classes of equilibria exist. Remarkably, in two of these classes the player being behind overtakes the opponent and ends up with a higher probability of winning the tournament. In tournaments where the initial unevenness is strongly favourable for one party we find a unique equilibrium, in which the leading player extends the lead by investing more effort than the player behind. However, when the game is tight and the tournament prize is large enough to motivate the trailing player to overcome the initial disadvantage, equilibria where the player behind spends much more effort than the player ahead and obtains a higher probability of winning the tournament, always exist.

In the first class of what we call Turn Around Equilibria (TAE) the agent behind turns a marginal disadvantage ex ante, a 48 percent probability of winning, into a marginal advantage with slightly more than a 53 percent chance of winning. In the second class, the turn around can be much more pronounced. Here a trailing player starting with a winning probability of say around 30 percent may turn the game into one which yields almost certain victory with the winning probability exceeding 90 percent. We show that whenever the player behind catches up on the opponent the extra effort will be sufficient to overcome, and even exceed the entire initial disadvantage. Situations where the trailing player makes up some of the disadvantage without

[2] In a new article Dato, Grunewald, and Mueller (2015) further explore the circumstances under which symmetric equilibria arise.

[3] Stern (1991) investigates score differences in football and cannot reject that they are normally distributed.

becoming the favourite winner do not exist in equilibrium. We show that depending on parameter values, the only possible pure strategy equilibrium is one in which the disadvantaged player turns the game. Lastly, we predict that equilibria where one agent catches up without taking the lead do not exist.

The model is set up as a version of the tournament formulated by Lazear and Rosen (1981) with the defining characteristic that the element of chance enters additively into the contest success function. Since we introduce reference-dependent preferences we use the notion of choice acclimating personal equilibrium, that was introduced by Kőszegi and Rabin (2007), in which the reference point is endogenous to maximisation process as a solution concept. This means that agents take into account that their effort choice affects their reference utility, i.e. that a high effort level makes winning more likely and, hence, increases the reference point.

We contribute to a growing literature taking an interest in dynamic and uneven tournaments. Contributions like Gill and Stone (2010) discuss that in a dynamic setting agents have time to emotionally react to events and deviate from standard rationality. How emotions within a sports game can impact the motivation and ability of players psychologically is described by Lazarus (2000). Klaassen and Magnus (2001) support this notion empirically by showing, with a large data set of tennis matches, that points in tennis are not individually and identically distributed. Gill and Prowse (2012) confirm experimentally the key economic concept of strategy functions where the effort of one agent crowds out the effort of the competitor. They introduce a dynamic frame by letting subjects choose their effort sequentially providing complete information about the choice of the first subject. Ederer (2010) studies asymmetric equilibria as a result of asymmetrically distributed ability between two agents. In his model interim feedback gives competitors the chance to update their beliefs about their opponent's ability. This leaves the agent who is ahead in the game more confident of the value of his own effort investment and results in relatively greater effort provision from the leading player.

Our model provides a theoretical explanation for the existence of turn arounds. Our results can explain the puzzling empirical evidence presented by Berger and Pope (2011), who investigate data from $18,060$ American basketball games and find that teams which are slightly behind at half time have a significantly higher probability to win the game. As basketball is a complex sport it could be argued, for example, that their results are not directly linked to effort investment. However, they consolidate their finding by running an experiment in a controlled laboratory environment where participants had to compete in a real effort task that involved fast clicking and were told an intermediate score at half time. Those who were slightly behind at half time showed a marked increase in clicks in the second half compared to those who were ahead or to the no feedback control group. Previous literature was not able to explain this pattern.[4]

2.3 The Model

The model studies a contest with two players $j \in \{A, B\}$ who exert effort e^j. The initial unevenness is given by δ_1 which represents an advantage for Player A when positive and vice versa. The parameter δ_1 is exogenous and observable. The unobservable random noise parameter ϵ is not affected by effort and follows a normal distribution with mean 0 and variance σ^2.[5] The initial unevenness δ_1, the shock term ϵ and the two choice variables e^A and e^B constitute the final outcome which is determined by $\delta_2 = \delta_1 + e^A - e^B + \epsilon$.

The prize received by Player j is given by z_j. If the player wins the tournament the player receives the winner prize w, while the loser prize is normalised to zero. Therefore: Player A wins if $\delta_2 > 0$ and receives $z_A = w$, while Player B obtains $z_B = 0$ and vice versa. In this setting, the probability that Player A wins the contest equals $Prob(\delta_2 > 0)$ which implies $Prob(\epsilon > -\delta_1 + e^B - e^A)$. Using the fact that ϵ is normally distributed we can rewrite this as $1 - F(-\delta_1 + e^B - e^A)$ where $F(\cdot)$ is the cumulative distribution function of the normal distribution. From the symmetry of the normal distribution it follows that:

$$Prob_{\{\text{A wins}\}} = Prob(\delta_2 > 0) = 1 - F(-\delta_1 + e^B - e^A) = F(\delta_1 + \Delta e)$$
where $\Delta e = e^A - e^B$

2.3.1 Utility with reference-dependent preferences

In the first part of our analysis we make no assumptions about how the reference points $\{r^A, r^B\}$ are formed. Instead, we study the additional incentives reference-dependence imposes on the players. Afterwards, we investigate how a reference point contributes to determine the tournament winner assuming that it is formed endogenously as described by Köszegi and Rabin (2006).

A player's utility under a reference point r^j is given by:

$$U^j = v(z_j) + m(z_j|r^j) - c(e^j) \text{ where } m(z_j|r^j) = \begin{cases} \eta(w - r^j) & \text{if j wins} \\ \eta(1+\theta)(0 - r^j) & \text{if j loses} \end{cases}$$

and $v(z_j) = z_j$, $c(e^j) = \frac{1}{2}(e^j)^2$, $\eta \geq 0$, $\theta \geq 0$

[4]In Ederer (2010) and Gill and Stone (2010), for example, the only type of asymmetric equilibrium is one, where the leading player exerts more effort than the disadvantaged opponent.

[5]To ensure pure-strategy equilibria the variance has to be sufficiently large as described in (Lazear & Rosen, 1981).

We assume $r^j \in [0, w]$ as the reference point for the tournament prize should give us a value between the lowest possible outcome and the highest possible outcome of the tournament. The utility is composed of a convenient consumption part v, for which a linear specification is used, the cost of effort provision $c(e^j)$ and a reference-dependent term. The weight of the reference utility is calibrated by η, such that setting $\eta = 0$ returns the model without reference-dependence. The parameter θ introduces loss aversion. It represents the difference between the disutility of falling short of the reference point and the utility of exceeding it by one unit. We assume that losses loom larger than gains and consequently take θ to be positive. We use quadratic costs of effort for simplicity.

Both players choose an effort level to maximise their expected utility given the unevenness δ_1. Player A maximises expected utility with respect to e^A. Consequently, the optimisation problem for Player A can be written as:

$$\max_{e^A} F(\delta_1 + \Delta e)(w + \eta(w - r^A)) + (1 - F(\delta_1 + \Delta e))(-\eta(1 + \theta)r^A) - c(e^A).$$

The first term $F(\delta_1 + \Delta e)(w + \eta(w - r^A))$ represents the utility in case the agent wins the tournament. It is added to the utility of losing $(1 - F(\delta_1 + \Delta e))(-\eta(1 + \theta)r^A)$ and the costs of effort which have to be paid independent of the outcome. We define P^j as winning-probability of player j, i.e. $P^A = F(\delta_1 + \Delta e)$ and $P^B = 1 - F(\delta_1 + \Delta e)$. The contribution of reference-dependent utility lies in adding the term below to the standard objective function $wF(\delta_1 + \Delta e) - c(e^A)$:

$$R^j := \eta\Big(P^j w - r^j\big[1 + \theta\big(1 - P^j\big)\big]\Big)$$

Except for the potentially different reference points and the individual winning probability the term R^j is the same for both players. While the sign of R^j depends on the actual parameter values, it becomes apparent that a greater reference point reduces the agents' utility. This is intuitive as a higher reference point renders a victory less sweat, but a defeat all the more bitter. Moreover, reference-dependence contributes an incentive effect which is given by

$$\frac{\partial R^A}{\partial e^A} = \eta\Big(f(\delta_1 + \Delta e)(w + r^A\theta) - \frac{\partial r^A}{\partial e^A}\big[1 + \theta(1 - P^A)\big]\Big).$$

The expression reveals the delicate nature of the effect which may take different sizes locally over the decision space. The first term $\eta f(\delta_1 + \Delta e)(w + r^A\theta)$ adds a positive incentive, that is caused by an increase of the effective prize spread. Since Lazear and Rosen (1981) it has been known that when there are no participation constraints an agent's effort decision is not affected by the absolute level of prizes, but by the spread between the winner and loser prize. reference-dependence increases the effective prize spread, making the valuation of both tournament outcomes more extreme. The strength of its impact, however, depends on the reference point r^A which may take different values for different $\{e^A, e^B, \delta_1\}$. The second term reduces to 0 in case of an exogenous reference point as the derivative $\frac{\partial r^A}{\partial e^A}$ remains 0.

2.3.2 Endogenous Reference Points

In the following we endogenise the reference points and employ the choice-acclimating personal equilibrium concept of Köszegi and Rabin (2006) to derive the player's first and second order conditions. After establishing a necessary and sufficient condition for the interiority of all solutions in Lemma 1, we show in Lemma 2 and Lemma 3 that both first and second order conditions can be reduced to one equivalent expression. We proceed to define the three classes of equilibria and derive conditions for their existence in Proposition 1 to Proposition 3. In Proposition 4 we give conditions for the uniqueness of a Turn Around Equilibrium. Finally, in Proposition 5 we discuss a fourth class of equilibria and interpret our results.

Modelling the reference point formation explicitly makes the precise effect of reference-dependence tractable. We assume expectation based reference points, but remain agnostic about whether expectations are formed as in the reference-dependence theory of Köszegi and Rabin (2006) or as in disappointment aversion theory developed by Bell (1985) and Loomes and Sugden (1986). Additionally, we will allow the reference point to adjust in the process. As solution concept we use choice-acclimating personal equilibria (CPE) that are defined "as a decision that maximises expected utility given that it determines both the reference lottery and the outcome lottery" (p.1049, Kőszegi and Rabin (2007)). In consequence, the reference points are taken to be the endogenous winning probability of each player multiplied by the winner prize, which constitutes the expected gain of each player. Explicitly, the reference points are modelled as $r^A = F(\Delta e + \delta_1)w$ for Player A and $r^B = (1 - F(\Delta e + \delta_1))w$ for Player B.[6] The explicit reference point enables us to rewrite the contribution term R^A for both players to $-w\eta\theta F(\Delta e + \delta_1)(1 - F(\Delta e + \delta_1))$. The negative sign shows that each player has an incentive to minimise this term. For player A this results in the following incentive effect[7]:

[6] Like Gill and Stone (2010) we do not model a reference point in the effort domain. We believe that further conceptual work on what a reference point in the effort domain could be is interesting and could yield a valuable addition to this and other models. Yet with all its psychological and technical implications it exceeds the scope of this paper.

[7] The corresponding term for Player B is $\frac{\partial R}{\partial e^B} = w\eta\theta f(\delta_1 + \Delta e)(1 - 2F(\delta_1 + \Delta e))$.

$$\frac{\partial R^A}{\partial e^A} = w\eta\theta f(\delta_1 + \Delta e)(2F(\delta_1 + \Delta e) - 1)$$

The derivative above is positive if $\delta_1 + \Delta e > 0$ and negative if $\delta_1 + \Delta e < 0$. The absolute value of R^A is highest for close games when $\delta_1 + \Delta e$ is zero and falls steadily when the game gets less tight. In other words, players have an incentive to flee the middle and avoid the uncertainty associated with close games, which has also been described by Gill and Stone (2010). Note that the incentive does not point the player into a particular direction. Whether the player "gets ahead" or "falls behind" is not important. Evenness at the end of the period is unattractive for agents with reference points since it jointly maximises the size of the disutility from falling short of the reference point weighted by the probability of its occurrence. With normally distributed chance in the game, this opens up the possibility for multiple equilibria.

To understand this last point better consider Figure 2.1 which sketches both player's marginal costs and benefits.[8] In the upper graph, which depicts the standard Lazear and Rosen (1981) tournament without reference-dependence, both player's marginal benefit curves coincide with the equilibrium being reached at their peak. The effect of reference-dependence in the lower graph of Figure 2.1 is to steepen and drive apart both player's marginal benefits. The peak of the marginal benefits of both players is now located in the area where they themselves are more likely to win. Intuitively, both players benefit most from their effort when they can use it not only to increase their own winning probability, but also to decrease the uncertainty of the game. Here, without further asymmetries (i.e. $\delta_1 \neq 0$) the same symmetric equilibrium continues to exist.

This can also be seen in two top panels of Figure 2.2 which plots both players' best response functions along with a 45 degree line for the given parameter values $\eta = 1, \theta = 1, \delta_1 = 0.2, \sigma = 2$ and $w = 3\pi$. Moving from the top panel to the middle one with reference-dependence the symmetric equilibrium is preserved. However, we can now see that also two other potential asymmetric equilibria on either side do exist. Again both players peak best response effort lies on the side of the 45 degree line where they are more likely to win. When we introduce asymmetry in favour of Player A (i.e. $\delta_1 > 0$) we can see that A's peak best response effort moves towards the 45 degree line while Player B's moves away from it. From the intersections of the two functions we can thus identify three potential equilibrium candidates, two of whom lie above the 45 degree line which implies that the disadvantaged player behind spends more effort than the advantaged player.The best response functions have the simple structure:

[8] The marginal benefits are given by $MB^A = MB^B = w * f(\delta_1 + \Delta e)$

$$
\begin{aligned}
e^A &= wf(\delta_1 + \Delta e)\big[1 + \eta\theta\big(2F(\delta_1 + \Delta e) - 1\big] = wf(x)\big[1 + \gamma G(x)\big] \\
e^B &= wf(\delta_1 + \Delta e)\big[1 - \eta\theta\big(2F(\delta_1 + \Delta e) - 1)\big] = wf(x)\big[1 - \gamma G(x)\big]
\end{aligned}
$$

We define $x = \delta_1 + \Delta e$, $\gamma = \eta\theta$ and $G(x) = 2F(x) - 1$. The variable x, thus, represents the state of the game just before the random shock ϵ is realised. Since the two conditions for e^A and e^B must be fulfilled in equilibrium they provide information about when equilibria are interior, i.e. when both agents provide strictly positive effort. From $wf(x) > 0$ we know that there is an interior solution whenever $(1 + \gamma G(x))$ and $(1 - \gamma G(x))$ are both strictly greater than zero. Small rearrangement implies that both conditions are fulfilled whenever $\gamma < |\frac{1}{G(x)}|$. Since the set of possible values of $|G(x)|$ which is bounded above by one,[9] a simple corollary is that for $\gamma \leq 1$ the condition is fulfilled and the corresponding equilibrium must be interior. This leads to the first lemma.

[9] $|G(x)| = |2F(x) - 1|$ converges to 1, since the cdf of the normal distribution converges to 0 for $x \to -\infty$ and to 1 for $x \to \infty$.

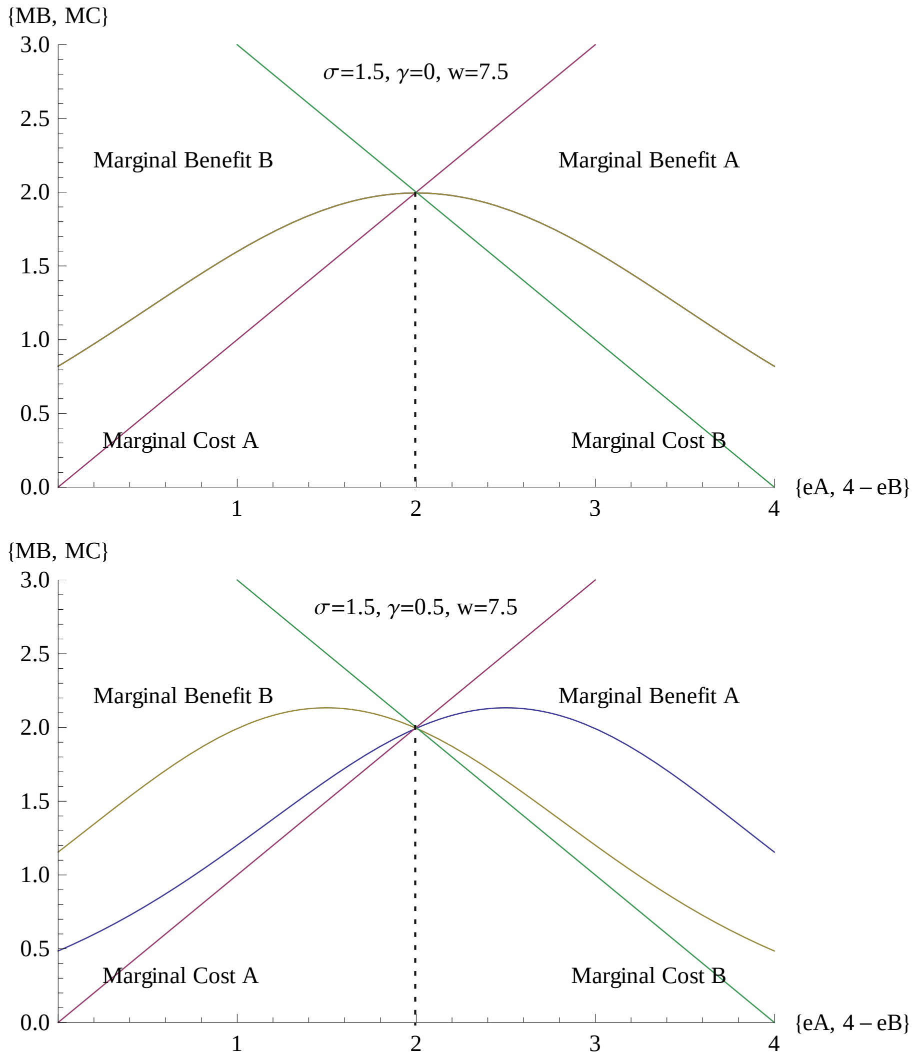

Figure 2.1: The Figure shows the **Marginal Costs and Benefits** of both players. Player B's effort increases from left to right. In the top panel without reference-dependence ($\gamma = 0$) marginal benefits of both players are identical. Introducing reference-dependence changes that. The Marginal Benefit curves are now only equal at the equilibrium effort levels, which without initial asymmetry are still symmetic (they are equal to two in this case).

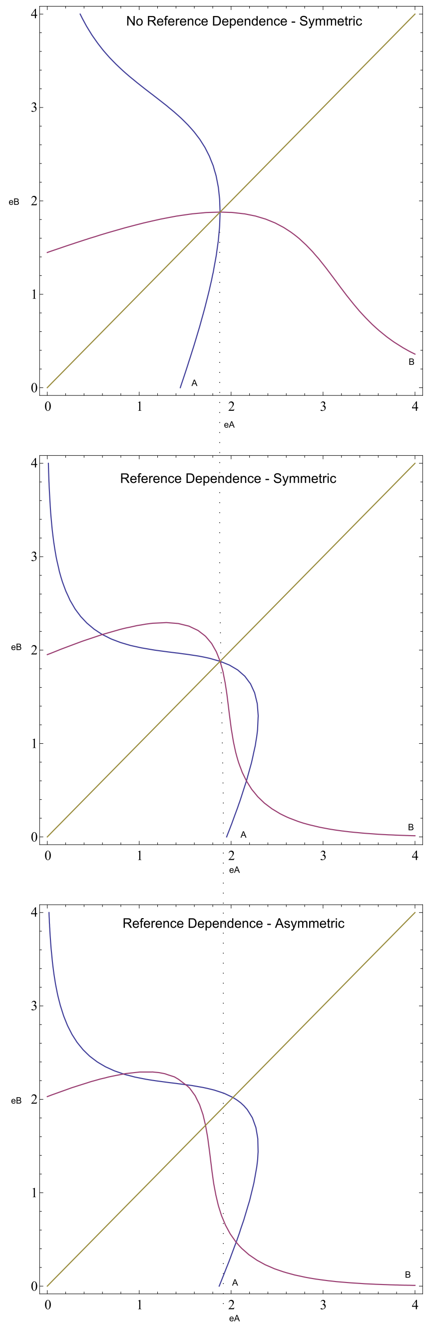

Figure 2.2: Effort combinations which fulfil each players First Order Condition. All intersections are potential equilibrium candidates. Below the 45 line Player A exerts greater effort, above it Player B exerts more. The top panel assumes $w = 3\pi$ and $\sigma = 2$. In the middle panel the reference-dependence parameter $\gamma = 1$. In the lower panel Player A is additionally given an advantage of $\delta_1 = 0.2$.

Lemma 1. *An equilibrium is interior if* $\gamma < |\frac{1}{G(x)}|$. *Therefore all equilibria are interior whenever* $\gamma \leq 1$.

All lemmas and propositions are proven formally in Appendix 1. The term $\frac{1}{G(x)}$ is always defined as $G(x) \neq 0$ for all x that describe equilibria. To ensure that all equilibria are interior, we will assume $\gamma < |\frac{1}{G(x)}|$. This is not a restrictive assumption as for any x, $|G(x)|$ is always between zero at the origin and one as x becomes arbitrarily small or large. Hence, all moderate forms of loss aversion where $\gamma \leq 1$ are covered as well as many stronger versions depending on the degree of the state of the game x.

For simplification we proceed by combining both first order conditions as well as both second order conditions to obtain two new functions we term candidate and maximum condition function.

Lemma 2. *The system of first order conditions can be expressed as the candidate function* $\delta_1 = x - 2w\gamma f(x)G(x)$. *All combinations of* $\{e^A, e^B, \delta_1\}$ *which fulfil this equation are referred to as candidate points.*

Lemma 3. *If* x *fulfils the maximum condition* $0 < \frac{1}{wf(x)} - \gamma(2f(x) - \frac{x}{\sigma^2}G(x)) - \frac{|x|}{\sigma^2}$ *then at the corresponding vector* $\{e^A, e^B, \delta_1\}$ *both second order conditions are fulfilled.*

We call the function that describes the border of the inequality given in Lemma 3, $\frac{|x|}{\sigma^2} = \frac{1}{wf(x)} - \gamma(2f(x) - \frac{x}{\sigma^2}G(x))$, the maximum condition function. We can plot the candidate function and the maximum condition functions into one system as illustrated in Figure 2.3. Both graphs depend on x which is given on the horizontal axis. The candidate function is depicted by the blue curve and every point on it represents an equilibrium in case the second order conditions are fulfilled for the same x-value. The second order conditions are jointly represented by the maximum condition function in red. In case this function has a positive value for a certain x both second order conditions are fulfilled. Remember that x was initially defined as $e^A - e^B + \delta_1$. For this reason we know that Player A has a higher winning probability for positive and Player B for negative x, but we also know that Player B must have chosen a significantly higher effort than A in case of a negative x-value and $\delta_1 > 0$. We can now read Figure 2.3 in a convenient way. The vertical axis is also a scale for δ_1; hence we can choose a particular initial unevenness δ_1, take the corresponding x-value from the candidate function and evaluate it using the maximum condition function. When it is positive at that point, the combination of x, δ_1 must be an equilibrium. Lemma 2 shows that with the help of the first order conditions the unique pair of $\{e^A, e^B\}$ can be retrieved.

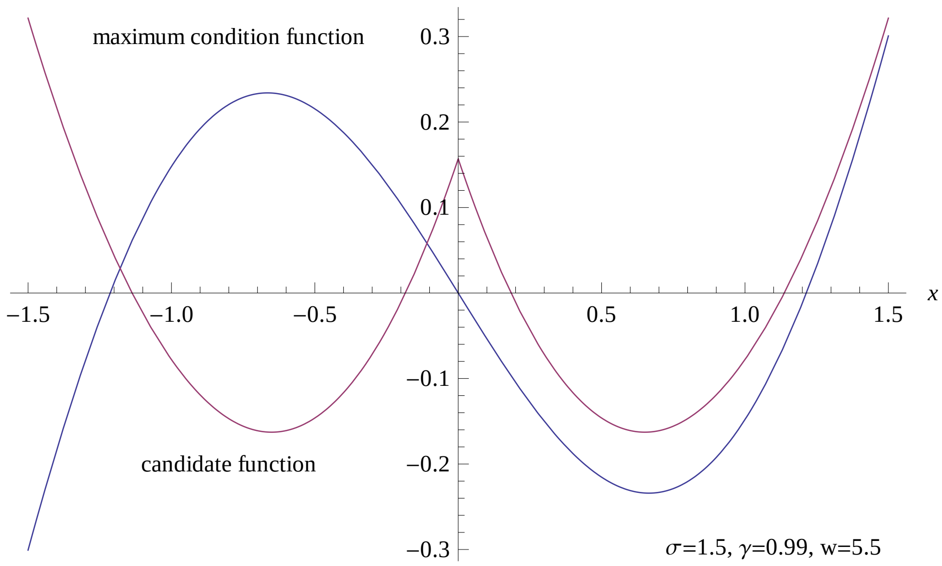

Figure 2.3: maximum condition and candidate function with positive intersections

2.4 Multiple Equilibria

In the following, we leave most technical details to the appendix but provide some intuition verbally and graphically for why asymmetric equilibria exist. We will assume throughout that $\delta_1 > 0$, i.e. Player A is ahead and benefits from the initial unevenness.[10]

2.4.1 Confirming Asymmetric Equilibria

As explained earlier, introducing reference-dependence renders the middle ground, i.e. when $\delta_1 + \Delta e$ is close to zero, unattractive to both players. Without reference-dependence Player B and Player A would always choose the same level of effort since both players have the same marginal costs and benefits are also the same due to the symmetry of the normal distribution's density. Therefore, the player ahead always maintains the same advantage in the relative winning probability. An extra incentive rewarding more unequal winning probabilities like reference-dependent preferences, in this setting, would just widen the already existing probability spread. To achieve this the player ahead needs to put in relatively more effort than the player behind. Thus, when reference-dependence increases the effective prize spread, both players will invest more effort, but the player ahead claims a larger share of the extra contribution. In the following this is referred to as Confirming

[10] Due to the symmetry of the problem all results also apply in case Player B is ahead.

Asymmetric Equilibrium.

Definition 1. *Confirming Asymmetric Equilibrium (CAE)*
A Confirming Asymmetric Equilibrium is an equilibrium where the advantaged player spends more effort than the other player.

Figure 2.4 shows CAEs explicitly when Player A being initially advantaged. When δ_1 is positive, Player A ends up with a higher winning probability and the CAEs are located in the upper right quadrant of the coordinate system. We see that each $\{x, \delta_1\}$ combination, for which the candidate function lies in this quadrant, is a CAE in case the maximum condition function is positive for this x-value as well. In the depicted case there exists a CAE for all values of δ_1. However, this does not need to be the case.[11] While there will always be candidate CAEs for all values of δ_1, the maximum condition is not necessarily fulfilled. We prove the following proposition:

Proposition 1. *For δ_1 large enough there always exists one Confirming Asymmetric Equilibrium (CAE) that is a unique equilibrium.*

For tournaments without reference-dependence, Lazear and Rosen (1981) show that symmetric equilibria do not necessarily exist and depend on the wage-schedule as well as the degree of uncertainty inherent to the tournament.[12] Proposition 1 shows that strong unevenness at the start of the tournament curbs the first point. For sufficient uncertainty, it eventually guarantees the existence of a pure strategy equilibrium. While equilibria in which a leading player extends the lead are not uncommon in the literature, we now introduce two further types of equilibria.

2.4.2 Type One Turn Around Equilibria

reference-dependence as described above introduces an incentive to “flee the middle”, but this can be done in yet another way. As an alternative to the CAE the player behind may decide to outspend the leading player. Such an equilibrium is called Turn Around Equilibrium.

[11] It can happen, that the candidate function produces combinations of x and δ_1 at which the maximum condition function is still negative. In consequence CAEs are guaranteed for great x and δ_1, but given parameter values they may not exist for the whole range of δ_1.

[12] Imagine there was no uncertainty in the tournament. Then, each player would try to marginally overbid the opponent and no equilibrium in pure strategies would exist. Besides there would of course exist a symmetric mixed strategy equilibrium.

Definition 2. *Turn Around Equilibrium (TAE)*
A Turn Around Equilibrium is an equilibrium where the initially disadvantaged player spends so much more effort that this player has higher probability to win the game than the opposing player.

Definition 3. *Type one Turn Around Equilibria (TAE1)*
Type one Turn Around Equilibria (TAE1) are TAEs that exist over an interval for $\{e^A - e^B + \delta_1\}$ *that is open and bounded above by* 0.

Suppose that Player B is initially disadvantaged and considers investing more effort than Player A. For Player A this could be an equilibrium since the player is willing to settle at a point where the marginal benefits together with the marginal reduction of the reference-dependence cost meets the marginal costs. The key to understanding this intuition is to see that the incentive effect of reference-dependence changes sign at $x = \delta_1 + \Delta e = 0$. When Player A backs off, the incentive effect $\frac{\partial R^A}{\partial x} = w\gamma f(x)(2F(x) - 1)$ flips and the player will accept an equilibrium where the lower marginal benefit minus the reference cost of increasing effort equals the marginal cost. This intuition is intact as long as the unevenness is rather small and the wage level is high enough to motivate Player B to overcome the initial disadvantage, but not so high as to make it intolerable for Player A to back off.

This leads to the following proposition:

Proposition 2.

i) If $w > \frac{1}{4\gamma f(0)^2}$ *and* $w < \frac{1}{2\gamma f(0)^2}$, *a type one Turn Around Equilibrium (TAE1) always exists.*

ii) TAE1s are always interior.

The condition provided formulates a parameter range for the exogenous tournament prize w and the reference-dependence variables $\gamma = \eta\theta$. Under the conditions of Proposition 2 no symmetric equilibria exist.[13]

In case of an initial disadvantage for Player B, TAEs are defined as equilibrium points where Player B spends sufficiently more effort than Player A to become the favourite for winning the tournament. In consequence, TAEs for positive δ_1 can be found in the upper left quadrant of Figure 2.4. When $\delta_1 > 0$, as we assume throughout without loss of generality, TAE1s are equilibria located in the negative x-domain bordering zero. Depending on the parameter values of w and γ these equilibria exist since the curvature of the candidate function is strong enough to reach into the positive range of δ_1

[13]This is also shown in Gill and Stone (2010).

while the maximum condition function is still fulfilled for those x-values as can be seen in Figure 2.4.[14]

The TAE1s that follow from Proposition 2 occur only for tight games and the magnitude of the turn around is generally small. For illustration consider the example where the tournament prize $w = 5.5$, chance has standard deviation of $\sigma = 1.5$, the experience of losses is twice as strong as that of gains ($\theta = 1$), and reference utility is weighted equally strongly as consumption utility $\eta = 1$ such that $\gamma = 1$. Then, in a game where Player A is ahead by 0.033 standard deviations initially, Player B can overtake in equilibrium turning around a disadvantage of 0.06 standard deviations into a lead of roughly 0.06 standard deviations. In terms of winning probabilities Player B starts the tournament with a chance of winning of about 48.6 percent and ends it with about 52.4 percent. So the leading player has a 3.8 percentage points lower probability to win the game in the end. This is similar to the empirical evidence of Berger and Pope (2011) who conduct an experiment where participants compete against each other over two periods in a real effort task. They find that their subjects inserted most effort in the second period when being told that they were slightly behind their opponent and were more likely to win as a result. Berger and Pope (2011) also find a significant increase of winning probability for basketball teams that are slightly behind before the break compared to the leading team. Instead of having a lower probability to win, the team being behind by one point is more likely to win the game. In case of the NBA data the trailing team has 1.1 percentage points higher probability to win the game than the leading team. For the NCAA the result is even stronger: 5.6 percentage points. The difference in winning probability at the breakpoint is significant. Naturally, this field data result can have various explanations, one of which would be to describe it as a TAE1 under the premises of this model.

2.4.3 Type Two Turn Around Equilibria

While the TAE1s described above are tight in the sense that the initially disadvantaged player increases his winning probability only marginally above fifty percent, there can also be TAEs where the lagging player outspends the opponent sufficiently to increase the winning probability to much more than fifty percent.

[14] To verify that TAE1s are not only pathological cases, but appear over a range of x, we estimate an interval of x values over wich TAE1s exist. For this we use a linear approximation of the maximum condition function. Because of the convexity of the maximum condition function we can evaluate a conservative estimation guarantees us TAE1 for $x \in \left[\frac{(w\sigma\gamma - 2\sigma^3\pi)}{\sqrt{2\pi}w}, 0\right)$. The maximum condition function is convex for the whole range of w used in this proposition. The proof is given in Lemma 5. The boundaries for the set are derived in the proof of Proposition 2.

Definition 4. *Type two Turn Around Equilibria (TAE2)*
Type two Turn Around Equilibria (TAE2) are TAEs that exist over intervals for $\{e^A - e^B + \delta_1\}$ *that are bounded above by some* $x_\delta \leq 0$.

In this second class of TAEs the leading player backs off much to benefit from the following reference point reduction. This equilibrium may also exist for greater values of w, which becomes apparent once we remember that the weight of the reference-dependence effect, $\frac{\partial R^A}{\partial e^A} = \eta f(\delta_1 + \Delta e) w(\theta(2F(\delta_1 + \Delta e) - 1))$, increases in w. The stronger impact of reference-dependence makes it more important in the turn around case for the leading player to reduce the effort and flee the middle. As a result, even for high w, TAE2s exist.

To construct the formal criterion we will use the point where the candidate function and the maximum condition function intersect. This point is given by $x^s = \frac{(2f(x^s)^2 w\gamma - 1 - 2f(x^s)^2 G(x^s) w^2 \gamma)\sigma^2}{f(x^s) w(1 + G(x^s)\gamma - \sigma^2)}$. As x^s is exogenously determined by the parameters of the model the conditions for w and γ provided in the proposition are exogenous as well.

Proposition 3.

i) When $w \in \left(\frac{1}{4\gamma f(0)^2}, \frac{1}{2\gamma f(x^s)^2 + B}\right)$ *where* $\gamma \in \left[0.54, -\frac{1}{G(x^s)}\right)$, σ *sufficiently large and* $B = \sqrt{-\gamma f(x^s)^2 \frac{2G(x^s)(1+\gamma G(x^s))}{\sigma^2}} \geq 0$, *a type two Turn Around Equilibrium (TAE2) in which the agent behind spends much more effort than the agent ahead exists. The parameter* x^s *determines the intersection between candidate function and maximum condition function exogenously.*

ii) If there exist TAE2s there also exist Confirming Asymmetric Equilibria (CAEs) for small δ_1.

iii) If the maximum condition function and the candidate function intersect but there are no TAE2s also CAEs for small δ_1 *do not exist.*

The conditions in Proposition 3 appear more complex than they are. Unlike Proposition 2, Proposition 3 requires a minimum strength of reference-dependence γ. If this condition is not met, it is never optimal for the leading player to back off as much as required in the TAE2. To illustrate this consider the following example: Suppose the tournament prize is $w = 10$, chance again enters with a standard deviation of $\sigma = 1.5$, experience of losses is twice as strong as that of gains ($\theta = 1$) and reference utility enters fully with $\eta = 1$ such that $\gamma = 1$. Then, TAE2 exist for any unevenness that is smaller or equal to 0.07 standard deviations. From an initial probability of winning of around 47.3 percent the lagging player in this equilibrium improves his chances to 87.8 percent. This will only be optimal for the player ahead if it is possible to benefit sufficiently from lowering the reference point and hence γ must exceed a certain value. The new condition for w has a similar spirit. While the lower bound coincides with the one in Proposition 2, the upper bound is tightened by $B \geq 0$ which added to the denominator. Again, the reason is that for large tournament prizes it is never optimal for the leading player to allow the other player to overtake. Imagine for example a student who is competing with a class mate over relative grades in a course that is not too important to both. After beating his mate in the midterms that student could still decide not to prepare much for the final exam. He knows that he will probably not come in first. Yet, that would not be too bad, because he also knows that it happened because he was not really trying and could not expect to do any better given his effort.

The definition of TAE2s includes all TAE1s, but TAE2s are potentially located further away from zero than TAE1s as illustrated in Figure 2.4. Due to the symmetry properties of the candidate and maximum condition function they can be seen as mirror images of certain CAEs. The maximum condition function is axis-symmetric whereas the candidate function is point-symmetric. Consequently, any intersection of the candidate function with the x-axes on the negative domain also exists in the positive domain and vice versa. For x-values larger than the positive root of the candidate function there are CAEs while for x-values above the negative root there exist TAE2s given that the maximum condition function to be positive. Due to axis-symmetry of the maximum condition function it returns the same value at both outer roots of the candidate function. Therefore, if the one equilibrium exist for small δ_1 the other does as well.[15]

2.4.4 Unique Turn Around Equilibria

The equilibria described spark questions about why the leading player may allow the other player to overtake. One conceivable explanation would be that Turn Arounds are somewhat "lazy equilibria" where the agent ahead has discovered that he greatly benefits from lowering its reference point. However, such an intuition does not truly capture the dynamics of the model. When there are three equilibria, TAE1s are the equilibria with the highest total effort investment. Only for the CAE and TAE2s large asymmetries are possible because one player benefits from lowering his reference point. Moreover, we show that for certain parameter values where the CAEs do not exist a TAE1 is the unique equilibrium.

Proposition 4. *When* $\frac{1}{4f(0)^2\gamma} < w < \frac{1}{2f(0)^2\gamma}$ *and* $\gamma \leq -\frac{f(x^s)^2 G(x^s)\pi^2}{\frac{2}{\sigma^2}+f(x^s)^2\pi(-2+G(x^s)^2\pi)}$

[15] Because of continuity this is at least the case for an ϵ-ball around the root of the candidate function.

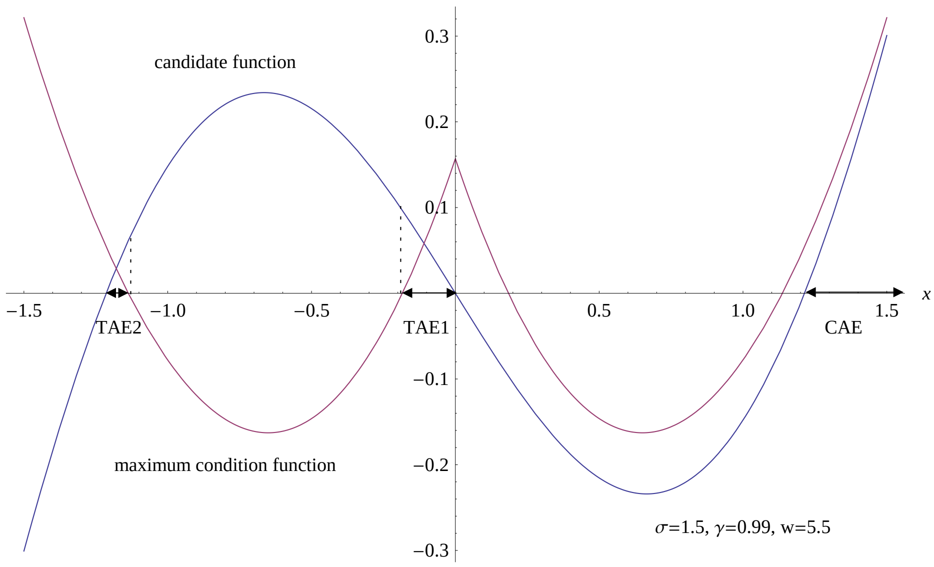

Figure 2.4: maximum condition and candidate function with all equilibria

then for small unevenness the unique equilibrium in pure strategies is a type one Turn Around Equilibrium (TAE1), where x^s *exogenously determines the intersection between candidate function and maximum condition function.*

The condition for w ensures that TAE1s exist, while the condition for γ rules out the existence of TAE2s and even of CAEs for the particular interval of unevenness over which TAE1s exist. This surprising result is made possible by the missing guarantee for the existence of equilibria in Lazear and Rosen (1981) type tournaments. In a region where the second order conditions do not allow CAEs to exist, the TAE1 candidate point close to, but smaller than zero, satisfies them as illustrated in Figure 2.5.

Proposition 4 demonstrates that a TAE1 can be the only equilibrium in pure strategies. While we do not engage in equilibrium selection, this shows that at least among pure strategies there are situations where TAE1s must be played, as no other equilibria exist. Thus, we show that it does not need differences in ability or imperfect information to obtain the unambiguous prediction that a trailing player wins a tournament. Having expectation based reference-dependent preferences can be sufficient for given parameter constellations.

2.4.5 Catching Up Equilibria

At first glance the notion of Turn Around Equilibria maybe appears (too) strict. It would have been possible to define TAEs as all asymmetric equilib-

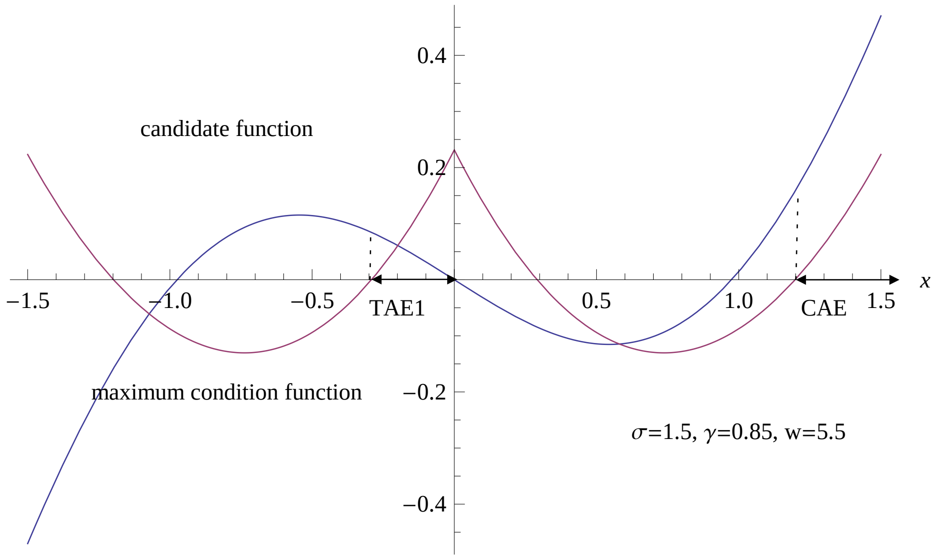

Figure 2.5: maximum condition and candidate function with only TAE1

ria in which the initially disadvantaged player spends more effort than the advantaged player irrespective of whether the difference is significant enough to turn the game. We call this broader class of equilibria Catching Up Equilibria (CUE).

Definition 5. *Catching Up Equilibrium (CUE)*
A Catching Up Equilibrium is an equilibrium where the initially disadvantaged player spends more effort than the opposing player.

From the definition it is apparent that every TAE must also be a CUE. However, we show that the converse holds as well. Every equilibrium in which the player being behind invests more effort than the opponent is also a TAE. In other words, situations where trailing player catches up a little without turning the game do not exist.

Proposition 5. *Every Catching Up Equilibrium is also a Turn Around Equilibrium.*

For an intuition consider again the equilibrium in the model without reference-dependence. Although one player is advantaged at the start of the tournament both players pick the same effort. Compared to the trailing player in this set-up, a player who tries to catch up, but not overtake, in the model with reference-dependent preferences faces greater marginal effort costs, larger marginal benefits[16] and a more negative marginal utility from reference comparison as the game becomes more even. If the agent had favoured the greater marginal benefits over the marginal effort cost, it would have chosen to insert more effort ex ante. Introducing an additional marginal cost in the form of reference-dependence cannot motivate the agent to try catching up. Only when the sign of the marginal effect of reference-dependence changes, as it is the case once one agent overtakes the other, this can be an equilibrium.

2.5 Conclusion

Which factors motivate players to invest in contest success is still a vibrant topic of debate. While classical tournament theory as introduced by Lazear and Rosen (1981) focuses on the higher probability of winning as benefit and the unpleasantness of effort as a cost, a large recent literature indicates that players evaluate outcomes also along certain reference points. Such reference-dependent preferences are an economically powerful concept, as they can imply that an otherwise positive event causes negative utility if the reference category was even more positive and vice versa. As a result, theoretical predictions can change drastically once a model is augmented by reference-dependence. In the context of tournaments, predicting a different winner could be considered such a change.

We add to the work of Gill and Stone (2010), who focus on symmetric equilibria when the half time score is even. For the large class of non even scores Gill and Stone (2010) show that symmetric equilibria do not exist. We find that depending on the strength of the reference-dependence, the tournament prize and the initial unevenness three different classes of equilibria exist. In games where the initial unevenness is strongly favourable for one party we find a unique equilibrium, in which the leading player invests more effort than the player behind. However, when the game is tight and the tournament prize is large enough to motivate the lagging player to overcome the initial disadvantage, Turn Around Equilibria, where the player initially behind spends much more effort than the player ahead and has a higher probability of winning the tournament, always exist.

Our results can help to explain tournament outcomes that so far have been economically puzzling as presented by Berger and Pope (2011). Our results generate further testable predictions. We find that for all equilibria where the player behind spends more effort than the opponent, this player also has a greater chance of winning the tournament. Thus, we show that equilibria, in which the player behind merely catches up with the leading player do not exist. Furthermore, we can show that under certain conditions the TAE is

[16]Since the probability density function of the normal distribution is single peaked at $x = 0$.

the unique pure strategy equilibrium. While dynamic implications of this framework were only touched upon, future research adding a further optimisation period may provide interesting insights into how the anticipation of possible TAEs affects agents' incentives in an initial period.

2.6 Appendix 1

In this appendix we prove all propositions and the lemmas stated in the main section. The proofs will make use of additional lemmas which are proven within the proposition where they are used first. Throughout we will assume without loss of generality that $\delta_1 > 0$, which implies that Player A is at an advantage. However, due to the symmetry of both players all results are also valid when $\delta_1 < 0$. All equilibria described assume that a solution to the tournament exists. As described by Lazear and Rosen (1981) this is always the case when precision of the random term given by $\frac{1}{\sigma}$ is sufficiently small.[17] The following proofs hold for $\sigma^2 \geq 1$.

Lemma 1. *An equilibrium is interior if* $\gamma < |\frac{1}{G(x)}|$. *Therefore all equilibria are interior whenever* $\gamma \leq 1$.

Proof. This follows directly from the first order conditions. Using $x = \Delta e + \delta$ and $\gamma = \eta\theta$ the first order conditions yield:

$$e^A = wf(x)(1 + \gamma G(x))$$
$$e^B = wf(x)(1 - \gamma G(x))$$

Since $wf(x)$ must be positive we will obtain interior solutions whenever $(1 + \gamma G(x))$ and $(1 - \gamma G(x))$ are also greater than zero. This implies that both conditions are fulfilled whenever $\gamma < |\frac{1}{G(x)}|$.

The term $G(x)$ will never be 0 for any equilibrium with $\delta_1 > 0$:
Suppose: $G(x) = 0 \Rightarrow 2F(x) - 1 = 0 \Leftrightarrow F(x) = \frac{1}{2} \Leftrightarrow 0 = x = \delta_1 + \Delta e$. From the first order conditions we know that in case of $x = 0$ $e^A = e^B = wf(0) \Rightarrow \Delta e = 0$. This leads to a contradiction with $\delta_1 > 0$.[18]

Since the function $|G(x)|$ is bounded above by one and open there, a simple corollary is that for $\gamma \leq 1$ the condition is fulfilled and the corresponding equilibrium must be interior. □

Lemma 2. *The system of first order conditions can be expressed as the candidate function* $\delta_1 = x - 2w\gamma f(x)G(x)$. *All combinations of* $\{e^A, e^B, \delta_1\}$ *which fulfil this equation are referred to as candidate points.*

Proof. Using $x = \Delta e + \delta$ and $\gamma = \eta\theta$ the first order conditions yield:

$$e^A = wf(x)(1 + \gamma(2F(x) - 1))$$

$$e^B = wf(x)(1 - \gamma(2F(x) - 1))$$

[17] See Lazear and Rosen (1981) p.845 for more information.
[18] This also reveals that there cannot exist symmetric equilibria with initial unevenness.

Subtracting both equations and substituting $G(x) = 2F(x) - 1$ leads to:

$$e^A - e^B = 2wf(x)\gamma G(x) \tag{2.1}$$

Since $x - \delta_1 = e^A - e^B$ we can reformulate the above expression as:

$$\delta_1 = x - 2wf(x)\gamma G(x)$$

The variable x describes an equilibrium uniquely whereas the exact corresponding effort combination can be revealed by inserting x back into the first order conditions. □

Lemma 3. *If x fulfils the maximum condition $0 < \frac{1}{wf(x)} - \gamma(2f(x) - \frac{x}{\sigma^2}G(x)) - \frac{|x|}{\sigma^2}$ then at the corresponding vector $\{e^A, e^B, \delta_1\}$ both second order conditions are fulfilled.*

Proof. The second order conditions for a local maximum are given by:

$$wf'(x) - wf'(x)\gamma + 2\gamma w\left[f'(x)F(x) + f(x)^2\right] - 1 < 0 \tag{2.2}$$

$$wf'(x)(-1) - wf'(x)\gamma + 2\gamma w\left[f'(x)F(x) + f(x)^2\right] - 1 < 0 \tag{2.3}$$

We use the following property of the normal distribution:

$$f'(x) = \frac{-x}{\sigma^2}f(x) \tag{2.4}$$

By substituting (2.4) into (2.2) and (2.3) we can derive new inequalities which include only the density and the distribution function of the normal distribution. Using that $G(x) = 2F(x) - 1$ we can solve for:

$$wf(x)\left\{2\gamma f(x) - \frac{x}{\sigma^2}\left[1 + \gamma G(x)\right]\right\} - 1 < 0$$

$$wf(x)\left\{2\gamma f(x) + \frac{x}{\sigma^2}\left[1 - \gamma G(x)\right]\right\} - 1 < 0$$

We will use the symmetry of the above two statements to condense their informational content into a single condition. Using $a = 2\gamma wf(x)^2$, $b = w\frac{x}{\sigma^2}f(x)$ and $c = \gamma G(x)$ we can reformulate the statements to:

$$a - b(1 + c) - 1 < 0$$

$$a + b(1 - c) - 1 < 0$$

which can be rewritten as:

$$-b < 1 - a + bc$$
$$b < 1 - a + bc$$

It is now clear that both conditions must be fulfilled whenever $|b| < 1-a+bc$ holds. Substituting back we obtain $0 < \frac{1}{wf(x)} - \gamma(2f(x) - \frac{x}{\sigma^2}G(x)) - \frac{|x|}{\sigma^2}$.

□

2.6.1 Proof of Proposition 1:

Proposition 1.

For δ_1 large enough there always exists one Confirming Asymmetric Equilibrium (CAE) that is a unique equilibrium.

Proof. We first showed in Lemma 2 that we can rewrite the system of first order conditions to a simpler, but equivalent representation. Afterwards, using symmetry we derived a single bound from the second order conditions which will be necessary and sufficient to identify equilibria in Lemma 3.
We make use of the candidate function from Lemma 2 and the maximum condition derived in Lemma 3.

$$0 < \frac{1}{wf(x)} - \gamma(2f(x) - \frac{x}{\sigma^2}G(x)) - \frac{|x|}{\sigma^2}$$

$$\delta_1 = x - 2w\gamma f(x)G(x)$$

We know that $f(x)G(x) \to 0$ for $x \to \infty$ since $f(x) \to 0$ and $G(x) \to 1$. For this reason letting δ_1 go towards ∞ implies that $x \to \infty$.

As $x > 0$ we can simplify the maximum condition to:

$$1 < \frac{\sigma^2}{f(x)wx} - \frac{\sigma^2\gamma(2f(x) - \frac{x}{\sigma^2}G(x))}{x}$$

The second term on the RHS will converge to the constant γ as $x \to \infty$. The first term can be reformulated as

$$\frac{\sigma^2}{f(x)wx} = \frac{\sigma^3\sqrt{2\pi}e^{\frac{x^2}{2\sigma^2}}}{wx}$$

Following L'Hôpital's rule

$$\frac{\sigma\sqrt{2\pi}xe^{\frac{x^2}{2\sigma^2}}}{w*1} \to \infty \qquad \Rightarrow \qquad \frac{\sigma^2}{f(x)wx} \to \infty$$

So the maximum condition will be fulfilled for sufficiently large δ_1. It is not only unique in the class of asymmetric equilibria but for all equilibria as symmetric equilibria cannot exist for $\delta_1 \neq 0$ (see Proposition 4 in Gill and Stone (2010)).

□

2.6.2 Proof of Proposition 2:

To prove Proposition 2 we first show that under certain conditions candidate points in the sense of Lemma 2 exist that are potentially type one Turn Around Equilibria. We proceed by showing that the maximum condition function introduced in Lemma 3 is strictly convex over some interval.

Lemma 4. *For $w > \frac{1}{4f(0)^2\gamma}$, there always exist a positive δ_1 such that its corresponding extreme points include candidate Turn Around Equilibria (i.e. $x < 0$).*

Proof. We show that under the condition TAE candidates (i.e. points where both player's First Order Conditions are fulfilled s.t. $x < 0$) exist for small positive values of δ_1. The inverse of the candidate function Lemma 2 would yield the equilibrium candidates for each value of δ_1. Since it is not possible to express the inverse explicitly we show that the function produces a small positive $\delta_1(x)$ when given a small negative value for x as an argument. Note that for $x < 0$ the function $G(x) < 0$ as well.

$$\delta_1(x) = x - 2w\gamma f(x)G(x) \tag{2.5}$$

The derivative of this function with respect to x yields:

$$\frac{\partial \delta_1(x)}{\partial x} = 1 - 4w\gamma f(x)^2 + \frac{x}{\sigma^2} 2w\gamma f(x)G(x)$$

When $x = 0$ and $w = \frac{1}{4f(0)^2\gamma}$ the above expression equals zero and is negative for any w larger than $\frac{1}{4f(0)^2\gamma}$. Given this negative slope at $x = 0$ the function must be positive for some small negative x.

□

Lemma 5. *The maximum condition function $\frac{1}{wf(x)} - \gamma(2f(x) - xG(x)) - \frac{|x|}{\sigma^2}$ is strictly convex for all $w \in \left[\frac{1}{4f(0)^2\gamma}, \frac{1}{f(0)^2\gamma}\right]$.*

Proof. The maximum condition $0 < \frac{1}{wf(x)} - \gamma(2f(x) - \frac{x}{\sigma^2}G(x)) + \frac{x}{\sigma^2}$ for $x < 0$ is convex if the second derivative is positive:

$$\frac{\sigma^2 + x^2}{2f(x)^2 w\sigma^2} + \left(3 - \frac{2x^2}{\sigma^2}\right)\gamma > 0 \tag{2.6}$$

To find the prize w for which this condition is always fulfilled we substitute $w = \frac{1}{f(0)^2\gamma * a}$ and obtain $\frac{af(0)^2}{2f(x)^2\sigma^2}(\sigma^2 + x^2) + (3 - 2\frac{x^2}{\sigma^2}) > 0$. Solving as an equality for a yields

$$a = \frac{4x^2 - 6\sigma^2}{\frac{f(0)^2}{f(x)^2}(\sigma^2 + x^2)} \tag{2.7}$$

We then find the maximum value for 2.7 using the following first order condition,

$$8\sigma^2 + x^2 - 2\frac{x^4}{\sigma^2} = 0$$

which is fulfilled whenever $x_{max} = -\frac{1}{2}\sigma\sqrt{1 + \sqrt{65}}$.[19] Then, at the maximum σ drops out and we obtain $a(x_{max}) = (9 - \sqrt{65})e^{-0.25(1+\sqrt{65})} \approx 0.97$. Consequently the second order condition must be fulfilled when $w < \frac{1}{f(0)^2\gamma}$.

□

Proposition 2.

i) If $w > \frac{1}{4\gamma f(0)^2}$ and $w < \frac{1}{2\gamma f(0)^2}$, a type one Turn Around Equilibrium (TAE1) always exists.

ii) TAE1s are always interior.

Proof. We showed in Lemma 4 that for certain values of w extreme point couples (for values of $\{e^A, e^B, \delta_1\}$) exist that could be type one Turn Around Equilibria (TAE1). Lemma 5 gives us the convexity of the maximum condition for certain values of w.

We will execute the proof of part i) by using Lemma 4 and by showing that given $w < \frac{1}{2\gamma f(0)^2}$ the maximum condition derived in Lemma 3 is fulfilled. From Lemma 3 we know that both second order conditions will be fulfilled whenever

$$0 < \frac{1}{wf(x)} - \gamma(2f(x) - \frac{x}{\sigma^2}G(x)) - \frac{|x|}{\sigma^2} \tag{2.8}$$

Since $w < \frac{1}{2\gamma f(0)^2}$ we know that

$$\frac{2\gamma f(0)^2}{f(x)} - \gamma(2f(x) - \frac{x}{\sigma^2}G(x)) - \frac{|x|}{\sigma^2} < \frac{1}{wf(x)} - \gamma(2f(x) - \frac{x}{\sigma^2}G(x)) - \frac{|x|}{\sigma^2}$$

[19]The Second Order Condition at x_{max} is negative and yields $\frac{(7\sqrt{65}-65)8e^{-0.25(1+\sqrt{65})}}{5\sigma^2} \approx \frac{-1.42}{\sigma^2}$.

Now suppose $x = 0$. We obtain:

$$2\gamma f(0) - 2\gamma f(0) + 0 - 0 = 0 < \frac{1}{wf(0)} - 2\gamma f(0)$$

Therefore we know that for all $w < \frac{1}{2\gamma f(0)^2}$ the maximum condition function $\frac{1}{wf(x)} - \gamma(2f(x) - \frac{x}{\sigma^2}G(x)) - \frac{|x|}{\sigma^2}$ will take up a value greater than zero when $x = 0$. Then, it follows by the continuity of the maximum condition function that for any such w there exist some ϵ close to zero such that $0 < \frac{1}{wf(\epsilon)} - \gamma(2f(\epsilon) - \frac{\epsilon}{\sigma^2}G(\epsilon)) - \frac{|\epsilon|}{\sigma^2}$.

To obtain a conservative estimate of an interval in which the TAE1s lie, we use the strict convexity of the maximum condition function shown in Lemma 5. Now we can derive the first order Taylor approximation around $x = 0$ for $x \leq 0$ which yields:

$$T_1(0) = \left(\frac{\sigma\sqrt{2\pi}}{w} - \frac{1}{\sigma\sqrt{2\pi}}\gamma \right) + \frac{x}{\sigma^2}$$

Given the positive slope and the convexity of the maximum condition function we know, that the intersection of the approximation with the abscissa will provide a conservative lower bound for the interval. The resulting interval of x-values in which TAE1s exist can be expressed as:

$$\left[\frac{(w\sigma\gamma - 2\sigma^3\pi)}{\sqrt{2\pi}w}, 0 \right)$$

As $G(x) \to 0$ for $x \to 0$ all TAE1s close to zero are interior as stated in part *ii)*.

□

2.6.3 Proof of Proposition 3:

To prove Proposition 3 we first show in Lemma 6 that there is only one convex interval for x over which candidate TAEs exist. We continue by showing in Lemma 7 that the candidate function and the maximum condition function have an intersection where $\delta_1 > 0$ or the maximum condition is always fulfilled. Then, we show in Lemma 8 that the maximum condition function cannot intersect the horizontal axis more than twice. Lastly, we establish in Lemma 9 that the maximum condition function may not have these two roots over an interval over which it is strictly greater than the candidate function.

Definition 6. *Intersection in positive/negative range*
We say that two function intersect in positive/negative range, when they return a positive/negative value at that intersection.

Lemma 6. *For $w > \frac{1}{4f(0)^2\gamma}$, the candidate function $\delta_1(x) = x - 2w\gamma f(x)G(x)$ has exactly one maximum on the domain $x \in (-\infty, 0)$. At this maximum the candidate function is positive. There exists some $x^* < 0$ such that $\delta_1(x^*) = 0$.*

Proof. We know from Lemma 4 that when $w > \frac{1}{4f(0)^2\gamma}$ Turn Around candidates with $x < 0$ and $\delta_1(x) > 0$ exist for some x close to zero. Moreover, it is easy to see that $\delta_1(x) \to -\infty$ when $x \to -\infty$ and that $\delta_1(0) = 0$. Since the candidate function is continuous there must be at least one maximum point for negative x. In the following we will show that there is only one. Consider the first and second derivative of the candidate function:

$$\frac{\partial \delta_1(x)}{\partial x} = 1 + \frac{2w\gamma x f(x)G(x)}{\sigma^2} - 4w\gamma f(x)^2 \tag{2.9}$$

$$\frac{\partial \delta_1(x)^2}{\partial^2 x} = \frac{8x\gamma w f(x)^2}{\sigma^2} + \frac{2w\gamma f(x)}{\sigma^2}(G(x) + x(2f(x) - \frac{xG(x)}{\sigma^2})) \tag{2.10}$$

Note that $|G(x)| < 0$ for $x < 0$ so that (2.10) is strictly negative and hence the first derivative is monotonously decreasing as long as $\frac{G(x)x}{\sigma^2} \leq 2f(x)$. This is fulfilled as long as $\frac{2f(x)\sigma^2}{G(x)} \leq x$ and $x < 0$. Inserting the boundary case $x = \frac{2f(x)\sigma^2}{G(x)}$ in (2.9) simplifies it to:

$$1 - 2w\gamma(-2f(x)^2 + 2f(x)^2) = 1 > 0$$

However when $x = 0$ equation (2.9) is smaller than zero if $w > \frac{1}{4f(0)^2\gamma}$. Thus the first derivative of the candidate function is below zero for $x = 0$ and greater than zero when $x = \frac{2f(x)\sigma^2}{G(x)}$ and it is monotonously decreasing over the interval $[\frac{2f(x)\sigma^2}{G(x)}, 0)$. Thus, the first derivative intersects the abscissa exactly once over that interval. Furthermore, when $x < \frac{2f(x)\sigma^2}{G(x)}$ condition (2.9) is always positive and therefore does not have another root for negative x. □

Lemma 7. *When $w \in \left(\frac{1}{4\gamma f(0)^2}, \frac{1}{\gamma f(x^s)^2 + \sqrt{\gamma f(x^s)^2(\gamma f(x^s)^2 - \frac{2G(x^s)(1+\gamma G(x^s))}{\sigma^2})}}\right)$,*
$\gamma \in \left[0.54, -\frac{1}{G(x^s)}\right)$ and σ large enough

- *either the maximum condition function and the candidate function intersect and do so for $x < 0$ when $\delta_1 > 0$ only*

- *or in case of no intersection the maximum condition is fulfilled for all x where the candidate function has positive values.*

Proof. To derive the conditions for when the intersection is within positive range (as illustrated in Figure 2.3) we begin by setting both functions equal. The intersection point is endogenously described by a value for x that is $x^s = \frac{(2f(x^s)^2 w\gamma - 1 - 2f(x^s)^2 G(x^s) w^2 \gamma)\sigma^2}{f(x^s) w (1+G(x^s)\gamma - \sigma^2)}$ and is used as an argument for the maximum condition which, then, yields $0 < -\frac{2f(x^s)^2 w\gamma (G(x^s) w + G(x^s)^2 w\gamma - \sigma^2) + \sigma^2}{f(x^s) w (1+G(x^s)\gamma - \sigma^2)}$. Using $\sigma^2 \geq 1$ we can derive the following condition. The latter expression is larger than zero whenever either of the following hold:

$$w < \frac{1}{\gamma f(x^s)^2 - \sqrt{\gamma f(x^s)^2 (\gamma f(x^s)^2 - \frac{2G(x^s)(1+\gamma G(x^s))}{\sigma^2})}} \tag{2.11}$$

$$w < \frac{1}{\gamma f(x^s)^2 + \sqrt{\gamma f(x^s)^2 (\gamma f(x^s)^2 - \frac{2G(x^s)(1+\gamma G(x^s))}{\sigma^2})}} \tag{2.12}$$

To ensure that the equilibrium is interior we assume $\gamma < -\frac{1}{G(x)}$. When $\gamma < -\frac{1}{G(x)}$, (2.11) is always negative and is therefore neglected. Instead we employ (2.12) as an upper bound. To ensure that the lower bound $w > \frac{1}{4\gamma f(0)^2}$ is below (2.12) another restriction for γ is required which is obtained by solving the following for γ:

$$\frac{1}{4\gamma f(0)^2} < \frac{1}{\gamma f(x^s)^2 + \sqrt{\gamma f(x^s)^2 (\gamma f(x^s)^2 - \frac{2G(x^s)(1+\gamma G(x^s))}{\sigma^2}}}$$

This can be rearranged as condition for γ:

$$\gamma > -\frac{f(x^s)^2 G(x^s)\pi^2}{\frac{2}{\sigma^2} + f(x^s)^2 \pi(-2 + G(x^s)^2 \pi)} \tag{2.13}$$

This expression appears to be complicated and restrictive. However, it can be simplified at little cost in terms of accuracy. Using that $G(x) < 0$ for negative x and that $f(x)^2 < \frac{1}{2\pi\sigma^2}$, one can quickly see that the denominator will always be larger than one. The numerator contains $G(x)$ which equals $2F(x) - 1 = Erf(\frac{x}{\sqrt{2}\sigma}) = \frac{2}{\sqrt{\pi}} \int_0^{\frac{x}{\sqrt{2}\sigma}} e^{-t^2} \mathrm{d}t$. It must hold that the actual area underneath the integrated function is smaller than the area of the rectangle formed by the global maximum of the function over the x-interval. The largest value e^{-t^2} may assume is one. Thus, it holds for negative x that $-G(x) = -Erf(\frac{x}{\sqrt{2}\sigma}) \leq -\frac{2}{\sqrt{2\pi}\sigma} x * 1$. For the entire numerator this implies that $-f(x)^2 G(x)\pi^2 \leq -\frac{\sqrt{\pi}}{\sqrt{2}\sigma} x e^{-\frac{x^2}{\sigma^2}}$, the maximum of which is at $x = -\frac{\sigma}{\sqrt{2}}$.

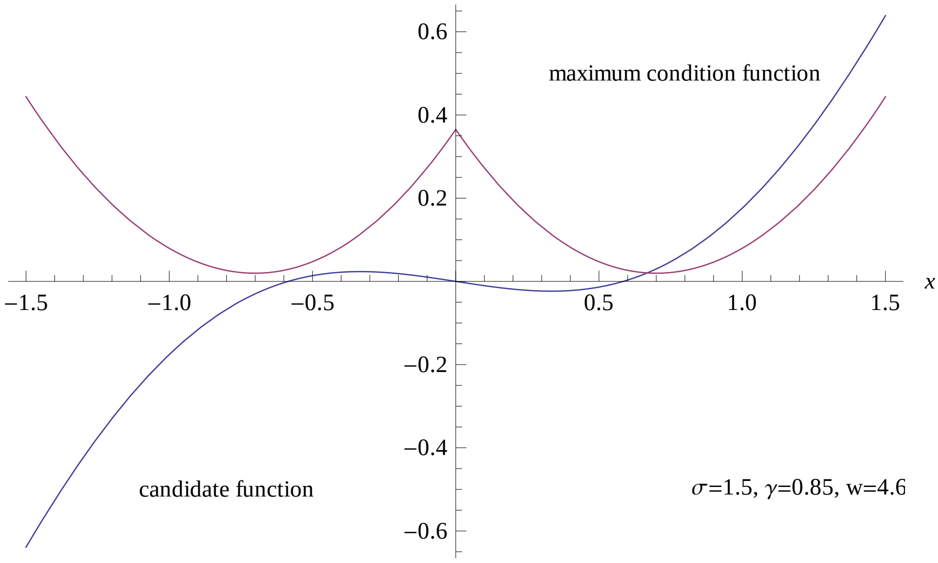

Figure 2.6: maximum condition and candidate function having no intersection points in the negative domain

Hence, the numerator will not exceed $\frac{\sqrt{\pi}}{\sqrt{4}}e^{-\frac{1}{2}} \approx 0.53$ and whenever $\gamma \geq 0.54$, condition (2.13) will also be satisfied. When both conditions are fulfilled any intersection between the maximum condition and the candidate function occurs in positive range.

Suppose no intersection between the candidate function and the maximum condition function and hence no x^s exists (as illustrated in Figure 2.6). For sufficiently small x we know that the maximum condition function is always positive while the candidate function is strictly negative. Without an intersection the continuity of both functions implies that the maximum condition function lies above the candidate function for all $x < 0$. However, when $w > \frac{1}{4f(0)^2\gamma}$ it is known from Lemma 4 that there are always values for $x < 0$ where the candidate function is positive. Since the maximum condition function must return greater values than the candidate function it also must be positive.

□

Lemma 8. *The maximum condition function has no more than two roots when $x < 0$ and $w < \frac{1}{2f(x)^2\gamma}$.*

Proof. Setting the maximum condition function equal to zero and solving for x yields $x^R = \frac{\sigma^2(2w\gamma f(x)^2-1)}{wf(x)(1+\gamma G(x))} = x^R(x)$. This equation must be fullfilled for every root of the maximum condition function. We show that the maximum condition function has at most two roots by showing that this equation has at most two solutions for $x < 0$. For this we demonstrate in the remainder of the proof that the function $x^R(x) = \frac{\sigma^2(2w\gamma f(x)^2-1)}{wf(x)(1+\gamma G(x))}$ is strictly concave and can, thus, have at most one maximum. To understand why this implies the statement in the lemma, consider the following: We want to know for how many x the equation $x^R = x^R(x)$ can be fulfilled. We also know that x^R (the left-hand-side of the equation) is a straight line with slope one. If we now knew that $x^R(x)$ was strictly concave, we would know that it cannot intersect the straight line x^R more than twice (and hence that the maximum condition function may not have more than two roots). Thus, in the remainder of the proof we show that the second derivative of $x^R(x)$ ist strictly smaller than zero for $x < 0$. The second derivative of $x^R(x)$ is given by:[20]

$$\frac{\partial x^R(x)^2}{\partial^2 x} = \frac{8\gamma^2\sigma^2 f(x)(2w\gamma f(x)^2-1) + 2x\gamma(1+\gamma G(x))(6w\gamma f(x)^2+1)}{w(1+\gamma G(x))^3}$$
$$- \frac{(\frac{1}{f(x)}(1+2w\gamma f(x)^2) + \frac{x^2}{\sigma^2 f(x)}(1-2w\gamma f(x)^2))}{w(1+\gamma G(x))} < 0$$

We now show that the term above is strictly negative. For this it suffices to look at the numerator of both fractions as the denominators are strictly positive under the assumption of Lemma 1 that $\gamma < |\frac{1}{G(x)}|$. The numerator of the first fraction is a sum of two elements. The first element must be negative, since $(2w\gamma f(x)^2 - 1) < 0$ when $w < \frac{1}{2f(x)^2\gamma}$. The second element is all positive except for the x which is taken to be smaller than zero. Thus, we know that the first fraction is negative. The second fraction, which gets substracted, is positive. It is also composed of two elements, the first of which is unambiguously positive while the second is positive as long as $w < \frac{1}{2f(x)^2\gamma}$. In consequence, the second derivative of $x^R(x)$ is strictly smaller than zero.

Therefore, the equation $x^R(x) = \frac{\sigma^2(2w\gamma f(x^R)^2-1)}{wf(x^R)(1+\gamma G(x^R))}$ has at most two solutions and the maximum condition function has at most two roots. □

Lemma 9. *The maximum condition function cannot have two roots within an interval over which it is strictly larger than the candidate function for* $w < \frac{1}{2f(x)^2\gamma}$.

Proof. Consider again the root of the maximum condition function as given by $x^R(x) = \frac{\sigma^2(2w\gamma f(x^R)^2-1)}{wf(x^R)(1+\gamma G(x^R))}$. We will show that its first derivative is strictly positive if the maximum condition function lies above the candidate function. The latter is true whenever:

$$\frac{1}{wf(x)} - \gamma\left(2f(x) - \frac{x}{\sigma^2}G(x)\right) + \frac{x}{\sigma^2} > x - 2w\gamma f(x)G(x)$$

[20] The first derivative is given by $\frac{\partial x^R(x)}{\partial x} = \frac{-x(1+\gamma G(x))(2wf(x)\gamma + \frac{1}{f(x)}) - 4w\sigma^2\gamma^2 f(x)^2 + 2\gamma\sigma^2}{w(1+\gamma G(x))^2}$

which can be rewritten as an upper bound for w:

$$w < \frac{\sigma^2}{f(x)^2\gamma\sigma^2 - \frac{f(x)x((1+G(x)\gamma)-\sigma^2)}{2} + \frac{\sqrt{f(x)^2(-8G(x)\gamma\sigma^4+(x+G(x)x\gamma-(x+2f(x)\gamma)\sigma^2)^2)}}{2}} = \tilde{w} \tag{2.14}$$

Now consider the first derivative of the root function $x^R(x)$:

$$\frac{\partial x^R(x)}{\partial x} = \frac{-x(1+\gamma G(x))(2wf(x)\gamma + \frac{1}{f(x)}) - 4w\sigma^2\gamma^2 f(x)^2 + 2\gamma\sigma^2}{w(1+\gamma G(x))^2} \tag{2.15}$$

As the denominator is positive it remains to show that the numerator is strictly positive. We start by rewriting the term to the following inequality:

$$\sigma^2(1-2w\gamma f(x)^2) - \frac{x}{2f(x)\gamma}(1+\gamma G(x)) - wxf(x)(1+\gamma G(x)) > 0 \tag{2.16}$$

The last two subtrahends of the numerator are negative for all $x < 0$ whereas the first summand is positive in case $w < \frac{1}{2\gamma f(x)^2}$. Thus, if condition (2.14) implies $w < \frac{1}{2\gamma f(x)^2}$, the lemma must be true. Consequently, we verify in the following that $w < \frac{1}{2\gamma f(x)^2}$ holds if the maximum condition function is bigger than the candidate function.

We begin by considering the large term under the root in the denominator of $\tilde{w}$ in condition (2.14):

$$\sqrt{f(x)^2(-8G(x)\gamma\sigma^4 + (x+G(x)x\gamma - (x+2f(x)\gamma)\sigma^2)^2)} =$$

$$\sqrt{f(x)^2(4f(x)^2\gamma^2\sigma^4 + x^2((1+\gamma G(x)) - \sigma^2)^2 + C)}$$

Firstly, we show that the term $C = -8G(x)\gamma\sigma^4 - 4f(x)\gamma\sigma^2 x((1+G(x)\gamma)-\sigma^2)$ is positive.

$$0 < -4(2G(x)\gamma\sigma^4 + f(x)\gamma\sigma^2 x((1+G(x)\gamma)-\sigma^2))$$

$$\Leftrightarrow \quad 0 < -4\gamma\sigma^2(\sigma^2(2G(x) - f(x)x) + f(x)x(1+\gamma G(x)))$$

$$\Leftrightarrow \quad 0 > \sigma^2(2G(x) - f(x)x) + f(x)x(1+\gamma G(x))$$

It is easy to verify that $(2G(x) - f(x)x)$ is strictly negative[21] for all $x < 0$. Since the term $(1+\gamma G(x))$ is positive by the assumptions on γ, the statement

[21] Its derivative $f(x)(3+\frac{x^2}{\sigma^2})$ is strictly positive. Moreover it is zero when $x = 0$ and approaches -2 when $x \to -\infty$.

above must be true and C is indeed positive. Having established that C is positive we can now overestimate $\tilde{w}$ by dropping C. Thus,

$$\tilde{w} < \frac{1}{f(x)^2\gamma\sigma^2 - \frac{f(x)x((1+G(x)\gamma)-\sigma^2)}{2} + \frac{\sqrt{f(x)^2[x((1+G(x)\gamma)-\sigma^2)+2f(x)\gamma\sigma^2]^2}}{2}}$$

which can be simplified to:

$$\tilde{w} < \frac{1}{f(x)^2\gamma\sigma^2 - \frac{f(x)x((1+G(x)\gamma)-\sigma^2)}{2} + \frac{2f(x)^2\gamma\sigma^2+f(x)x((1+G(x)\gamma)-\sigma^2)}{2}} = \frac{1}{2f(x)^2\gamma\sigma^2}$$

Hence, $\tilde{w} < \frac{1}{2\gamma f(x)^2}$ is true as well. Consequently, (2.16) holds for all $x < 0$ where the maximum condition function lies above the candidate function. □

Proposition 3.

i) When $w \in \left(\frac{1}{4\gamma f(0)^2}, \frac{1}{2\gamma f(x^s)^2+B}\right)$ *where* $\gamma \in \left[0.54, -\frac{1}{G(x^s)}\right)$, σ *sufficiently large and* $B = \sqrt{-\gamma f(x^s)^2 \frac{2G(x^s)(1+\gamma G(x^s))}{\sigma^2}} \geq 0$ *, a type two Turn Around Equilibrium (TAE2) in which the agent behind spends much more effort than the agent ahead exists. The parameter* x^s *determines the intersection between candidate function and maximum condition function exogenously.*

ii) If there exist TAE2s there also exist Confirming Asymmetric Equilibria (CAEs) for small δ_1*.*

iii) If the maximum condition function and the candidate function intersect, but there are no TAE2s, also no CAEs for small δ_1 *exist.*

Proof. i) To establish the existence of TAE2s, i.e. TAEs over an x-interval which is not necessarily adjacent to zero, one needs to show that over such an interval and under some conditions both the candidate function and maximum condition function return positive values. In Lemma 6 it was established that the candidate function has exactly one maximum and no other extreme points over the domain of strictly negative x. We also know from Lemma 4 that when $w > \frac{1}{4\gamma f(0)^2}$ the candidate function always returns positive values over the interval given by the roots of candidate function $(x^*, 0)$ where $x^* = 2w\gamma f(x^*)G(x^*)$. Lemma 7 implies that when candidate and maximum condition function do not intersect for $x < 0$ the maximum condition derived in Lemma 3 is fulfilled for all x where the candidate function is positive. Especially at the left root of the candidate function this leads to TAE2s that are rather 'far away' from $x = 0$. Additionally, given its conditions Lemma 7 implies that if intersections between the candidate and the maximum condition function exist for some $x < 0$, then both the maximum condition and the candidate function are positive at the intersection as illustrated in figure 2.4. It follows that around this intersection TAE2s exist.

Before we continue with part *ii*) we show that Lemma 8 and Lemma 9 also hold for the upper bound of w given in Proposition 3. We will proceed with the proof for the general case using x so it will also hold for a specific x^s. We want to show that $\frac{1}{2f(x)^2\gamma} > \frac{1}{2f(x)^2\gamma+B}$ which holds if B is strictly positive. If this holds the upper bound used in Proposition 3 is always smaller than the one used in Lemma 8 and Lemma 9 meaning they also hold for this proposition. First we show that the upper bound for w given in Proposition 3 is tighter than the upper bound of Lemma 7. The latter's denominator can be reformulated as follows:

$$\gamma f(x)^2 + \sqrt{\gamma f(x)^2(\gamma f(x)^2 - \frac{2G(x)(1+\gamma G(x))}{\sigma^2})}$$

$$= \gamma f(x)^2 + \sqrt{\gamma^2 f(x)^4 - \frac{2\gamma f(x)^2 G(x)(1+G(x)\gamma)}{\sigma^2}} = \gamma f(x)^2 + \sqrt{\gamma^2 f(x)^4 - A}$$

$$\leq 2\gamma f(x)^2 + \sqrt{-A} = 2\gamma f(x)^2 + B$$

This last step was established by using Jensen's inequality. Since the numerators of both upper bounds are equal this step shows that the upper bound given in Proposition 3 is tighter than that of Lemma 7. Solving for B leads to:

$$B \geq -\gamma f(x)^2 + \sqrt{\gamma^2 f(x)^4 - A} > 0$$

This holds as A is negative for $\gamma \leq |\frac{1}{G(x)}|$.

Since $B > 0$ it must be that $\frac{1}{2f(x)^2\gamma} > \frac{1}{2f(x)^2\gamma+B}$. This also holds for the case $x = x^s$.

ii) To study the relationship between strong TAEs and CAEs for small δ_1 we make use of the symmetry property of the candidate function $\delta_1(x)$ as well as the maximum condition function $maxcond(x)$:

$$\delta_1(x) = -\delta_1(-x)$$

$$maxcond(x) = maxcond(-x)$$

Having CAEs means that $\delta_1(x) > 0$ for $x > 0$ and the $maxcond(x) > 0$. Using the symmetry this is equivalent to $\delta_1(-x) < 0$ while $maxcond(-x) < 0$.

From Lemma 6 we know that the candidate function has only one maximum on the negative domain and in Proposition 1 we derived that the candidate function approaches infinity if $x \to \infty$. By symmetry this implies that the candidate function goes towards minus infinity if $x \to -\infty$. Since $\delta_1(0) = 0$ it follows from continuity that candidate CAEs (not necessarily CAEs) exist for all values of δ_1.

To find CAEs we have to insure that the maximum condition is fulfilled. We use the previously derived lemmas to make a statement about the maximum condition for all $x < x_\delta$, where x_δ is the negative root of the candidate function, and, then, use the symmetry properties from above to apply it to the candidate CAEs. We know that the maximum condition as derived in Lemma 3 goes to infinity when $x \to -\infty$ and since we have shown the existence of TAE2s in part i) there also exist some $x < 0$ where maximum condition and candidate function are both positive.

In consequence for the maximum condition to become negative over $x < 0$ it has to have at least two roots on the same domain. Moreover, we know from Lemma 8 that the maximum condition function cannot not have more than 2 roots for $x < 0$.

One possibility would be that the maximum condition function could have one root below x_δ and one above. In this case there would be a negative intersection of the maximum condition function with the candidate function as the candidate function must be negative for $x < 2w\gamma f(x)G(x)$ by Lemma 4. Since our conditions for TAE2s ensure that all intersection points are positive for $x < 0$ this case can be excluded. Secondly, the roots of the maximum condition function could both be below x_δ. This, however, directly contradicts Lemma 9 as the maximum condition has to be bigger than the candidate function at x_δ. Otherwise this would be equivalent to the previous example. Using symmetry this implies the existence of CAEs for small δ_1.

Lastly we address part iii). Following the same argument we know that in cases where no TAE2s exist, but the candidate and maximum condition functions still intersect, the intersection point must lie in negative range. Since the candidate function is negative for sufficiently small x, we know from Lemma 6 that the candidate function will not have an intersection with the abscissa for $x < 0$. This implies, that, because of the symmetry property of the candidate function, CAEs for small δ_1 do also not exist.

□

2.6.4 Proof of Proposition 4:

Proposition 4. *When* $\frac{1}{4f(0)^2\gamma} < w < \frac{1}{2f(0)^2\gamma}$ *and* $\gamma \leq -\frac{f(x^s)^2G(x^s)\pi^2}{\frac{2}{\sigma^2}+f(x^s)^2\pi(-2+G(x^s)^2\pi)}$ *then for small unevenness the unique equilibrium in pure strategies is a type one Turn Around Equilibrium (TAE1), where* x^s *exogenously determines the intersection between candidate function and maximum condition function.*

Proof. We know from Proposition 3 and Lemma 7 that TAE2s only exist when:

$$\gamma > -\frac{f(x^s)^2G(x^s)\pi^2}{\frac{2}{\sigma^2} + f(x^s)^2\pi(-2 + G(x^s)^2\pi)} \tag{2.17}$$

Moreover, we know from Proposition 3 that for δ_1 small enough CAEs only exist if TAE2s exist as well. TAE1s as described in Proposition 2 on the other hand, always exist when

$$\frac{1}{4f(0)^2\gamma} < w < \frac{1}{2f(0)^2\gamma}$$

Since the lower bound for γ (2.17) is strictly positive and lower and upper bound for w cannot intersect, we know that when the condition for γ is not satisfied there is yet a prize level w for which a TAE1 exists and is the only equilibrium for small enough δ_1.

□

2.6.5 Proof of Proposition 5:

Proposition 5. *Every Catching Up Equilibrium (CUE) is also a Turn Around Equilibrium (TAE).*

Proof. Remember that x was defined as $x = \Delta e + \delta_1$. Suppose again without loss of generality that player 1 is initially ahead, i.e. $\delta_1 > 0$, and that at the CUE player 2 spends more effort than player 1 with $\Delta e < 0$, but not enough to turn the game, i.e. $\Delta e + \delta_1 > 0$. From Lemma 2 we know that the candidate function provides all possible equilibrium candidate points:

$$\delta_1(x) = x - 2f(x)w\gamma G(x)$$

To find a CUE that is no TAE we need to show that there exist candidate points where for $x > 0$ and $\Delta e = x - \delta_1 < 0$. We show that this can never be the case:

$$x - \delta_1 = 2f(x)w\gamma G(x)$$

For $x > 0$ the RHS cannot be negative since $G(x)$ is positive for all $x > 0$ and the other terms are always positive. So $x - \delta_1$ will be positive for all $x > 0$.

□

Appendix 2

2.7 Technicalities

We provide these pages as an additional aid for the verification of some expressions.

2.7.1 Derivation of (2.11) and (2.12) in Lemma 7

We want to find a condition for w that ensures that the intesection between the candidate and the maximum condition function occurs in positive range. We show in Lemma 7 that this must be the case when:

$$0 < \frac{-2f(x^s)^2 w\gamma(G(x^s)w + G(x^s)^2 w\gamma w - \sigma^2) + \sigma^2}{f(x^s)w(1 + G(x^s)\gamma - \sigma^2)}$$

Note that as $G(x^s)\gamma < 0$ and $\sigma^2 \geq 1$ the denominator is smaller zero. Collecting the w terms and multiplying with the negative denominator yields:

$$0 > w^2(-2f(x^s)^2\gamma G(x^s)(1 + G(x^s)\gamma)) + 2f(x^s)^2 w\gamma\sigma^2 - \sigma^2$$

Next, we solve the above inequality as a quadratic equation for w. This gives:

$$w = \frac{\sigma^2(2\gamma f(x^s)^2 \pm \sqrt{f(x^s)^2\gamma(f(x^s)^2\gamma - \frac{2G(x^s)(1+\gamma G(x^s))}{\sigma^2})}}{2f(x^s)^2\gamma G(x^s)(1 + \gamma G(x^s))} = \frac{\sigma^2(A \pm \sqrt{B})}{C}$$

We now get to (2.11) and (2.12) by recognising that $C = \sigma^2(A + \sqrt{B})(A - \sqrt{B})$. Thus

$$w = \frac{\sigma^2(A \pm \sqrt{B})}{\sigma^2(A + \sqrt{B})(A - \sqrt{B})} = \frac{1}{(A - \sqrt{B})} \text{ or } \frac{1}{(A + \sqrt{B})}$$

The first possible solution is equivalent to (2.11), the second to (2.12) in Lemma 7.

2.7.2 Derivation of (2.13) in Lemma 7

We want to derive the lower bound for γ given in (2.13). Starting with the inequality

$$\frac{1}{4\gamma f(0)^2} = \frac{\pi\sigma^2}{2\gamma} < \frac{1}{\gamma f(x^s)^2 + \sqrt{\gamma f(x^s)^2(\gamma f(x^s)^2 - \frac{2G(x^s)(1+\gamma G(x^s))}{\sigma^2})}}$$

first rearranging leads to

$$\gamma f(x^s)^2 + \sqrt{\gamma f(x^s)^2(\gamma f(x^s)^2 - \frac{2G(x^s)(1+\gamma G(x^s))}{\sigma^2})} < \frac{2\gamma}{\pi\sigma^2}$$

Suqaring the next rearrangement

$$\sqrt{\gamma f(x^s)^2(\gamma f(x^s)^2 - \frac{2G(x^s)(1+\gamma G(x^s))}{\sigma^2})} < \frac{2\gamma}{\pi\sigma^2} - \gamma f(x^s)^2$$

gives us

$$\gamma f(x^s)^2(\gamma f(x^s)^2 - \frac{2G(x^s)(1+\gamma G(x^s))}{\sigma^2}) < \gamma^2(\frac{2}{\pi\sigma^2} - f(x^s)^2)^2$$

$$\Leftrightarrow \qquad f(x^s)^4 - \frac{2G(x^s)f(x^s)^2}{\sigma^2\gamma} - \frac{2f(x^s)^2G(x^s)^2}{\sigma^2} < (\frac{2}{\pi\sigma^2} - f(x^s)^2)^2$$

$$\Leftrightarrow \qquad -\frac{2G(x^s)f(x^s)^2}{\sigma^2\gamma} < (\frac{2}{\pi\sigma^2} - f(x^s)^2)^2 - f(x^s)^4 + \frac{2G(x^s)f(x^s)^2}{\sigma^2\gamma}$$

In the next step, we need to solve for γ.

$$\frac{2G(x^s)f(x^s)^2}{\sigma^2((\frac{2}{\pi\sigma^2} - f(x^s)^2)^2 - f(x^s)^4 + \frac{2f(x^s)^2G(x^s)^2}{\sigma^2})} < \gamma$$

Simplifying the the LHS reveals (2.13).

$$-\frac{2G(x^s)f(x^s)^2}{\sigma^2(\frac{4}{\pi^2\sigma^4} - \frac{4f(x^s)^4}{\pi\sigma^2} + f(x^s)^4 - f(x^s)^4 + \frac{2f(x^s)^2G(x^s)^2}{\sigma^2})} =$$
$$-\frac{f(x^s)^2G(x^s)\pi^2}{\frac{2}{\sigma^2} + f(x^s)^2\pi(-2 + G(x^s)^2\pi)} < \gamma$$

2.7.3 Derivation of (2.14) in Lemma 9

$$\frac{1}{wf(x)} - \gamma\left(2f(x) - \frac{x}{\sigma^2}G(x)\right) + \frac{x}{\sigma^2} > x - 2w\gamma f(x)G(x)$$

can be rewritten as:

$$w < \frac{\sigma^2}{f(x)^2\gamma\sigma^2 - \frac{f(x)x((1+G(x)\gamma)-\sigma^2)}{2} + \frac{\sqrt{f(x)^2(-8G(x)\gamma\sigma^4 + (x+G(x)x\gamma - (x+2f(x)\gamma)\sigma^2)^2)}}{2}} = \tilde{w}.$$

We begin by bringing all terms to the left side and multiplying by $wf(x)$:

$$w^2 2\gamma f(x)^2 G(x) + wf(x)(x(\frac{1}{\sigma^2} - 1) - \gamma(2f(x) - \frac{x}{\sigma^2}G(x))) + 1 > 0$$

Collecting all x together and multiplying by σ^2 we obtain:

$$w^2 2\gamma f(x)^2 G(x)\sigma^2 + wf(x)(x((1+\gamma G(x)) - \sigma^2) - 2\gamma f(x)\sigma^2) + \sigma^2 > 0$$

To solve for w we now use the quadratic formula for the equality $w = \frac{-b\pm\sqrt{b^2-4ac}}{2a}$ where $a = 2\gamma f(x)^2 G(x)\sigma^2$, $b = f(x)(x((1+\gamma G(x)) - \sigma^2) - 2\gamma f(x)\sigma^2)$ and $c = \sigma^2$. Plugging in a, b and c yields:

$$\begin{aligned} w =& \frac{f(x)(x(\sigma^2 - (1+\gamma G(x))) + 2\gamma f(x)\sigma^2)}{4\gamma\sigma^2 f(x)^2 G(x)} \\ & \frac{\pm\sqrt{(f(x)(x((1+\gamma G(x)) - \sigma^2) - 2\gamma f(x)\sigma^2))^2 - 8\gamma\sigma^4 f(x)^2 G(x)}}{4\gamma\sigma^2 f(x)^2 G(x)} \end{aligned}$$

To deal with this big term we now temporarily express it as $\frac{s-\sqrt{t}}{4\gamma\sigma^2 f(x)^2 G(x)}$. We neglect the postive root, as we are looking for a conservative upper bound. The crucial step to obain (2.14) is to realise that the denominator $4\gamma\sigma^2 f(x)^2 G(x)$ can be rewritten as $\frac{s^2-t}{2\sigma^2}$, which we now show:

$$\begin{aligned} s^2 - t =& (f(x)(x((1+\gamma G(x)) - \sigma^2) - 2\gamma f(x)\sigma^2))^2 \\ & - (f(x)(x((1+\gamma G(x)) - \sigma^2) - 2\gamma f(x)\sigma^2))^2 + 8\gamma\sigma^4 f(x)^2 G(x) \\ =& 8\gamma\sigma^4 f(x)^2 G(x) \end{aligned}$$

Thus $\frac{s^2-t}{2\sigma^2} = 4\gamma\sigma^2 f(x)^2 G(x)$. We can now say $\frac{2\sigma^2(s-\sqrt{t})}{s^2-t} = \frac{2\sigma^2(s-\sqrt{t})}{(s-\sqrt{t})(s+\sqrt{t})} = \frac{2\sigma^2}{s+\sqrt{t}}$ which is equal to:

$$\frac{\sigma^2}{f(x)^2\gamma\sigma^2 - \frac{f(x)x((1+G(x)\gamma)-\sigma^2)}{2} + \frac{\sqrt{f(x)^2(-8G(x)\gamma\sigma^4 + (x+G(x)x\gamma - (x+2f(x)\gamma)\sigma^2)^2)}}{2}}$$

Chapter 3

Investing in Personality?

The Impact of International Education on Non-Cognitive Ability.

3.1 Abstract

Adapting to new challenges and environments can change the knowledge and skill set of an individual, but it may also have an impact on personal preferences and interests. While such traits seem to be important determinants of labour market outcomes, health and subjective well-being, they are regarded as relatively stable. In this study we test whether Big 5 and Locus of Control personality traits can be changed through an international experience at university. We find that university students who go abroad return with lower Neuroticism and a more inward Locus of Control. Other studies and our own estimates from the German Socio Economic Panel suggest that these changes carry a premium in the labour market.

> "Personality change has been conceptualized as a bottom-up process in which individuals gradually come to see themselves in a different light in part as a consequence of taking on new roles that require novel behaviours."
> *p.2, Jackson, Hill, et al. (2012) on Roberts, Wood, and Caspi (2008)*

> "It's a dangerous business, Frodo, going out of your door," he used to say. "You step into the Road, and if you don't keep your feet, there is no telling where you might be swept off to."
> *-Frodo about Bilbo Baggins.*

3.2 Introduction

Personality, like cognitive ability, has been suggested to determine a wide range of life outcomes. Several studies have linked it to educational attainment, occupational choice, job performance and health. An implicit consensus from this research is that certain personality profiles generate better outcomes than others. If personality was somehow transformable, for example through experience, the question would emerge whether it is possible to invest in it directly.

The aim of this paper is to test whether personality can be affected by an educational policy. To this end we evaluate an international education programme that offers students an international experience during their time at university, an area that can be easily targeted by policies. We ask participants of the student exchange programme at Maastricht University to fill in personality questionnaires at three points in time, where a small timing asymmetry is used to create a treatment and a control group. We find that students who go abroad experience changes in two personality domains, which, among others, are associated with greater productivity in the labour market. Our evidence suggests that the changes could be persistent.

To study the average treatment effect of international education on any given person, one would require randomly selected subjects, that are randomly divided into a going-abroad treatment and staying-home control group. In the context of international education such data is not easy to come by, especially since some portion of the population does not want to go abroad. If we wanted to evaluate policies that would force people into international education, this would be problematic. Moreover, all programmes known to us are rather opt-in by nature including study programmes with mandatory study abroad that have a form of voluntary 'early' selection by students. We, hence, focus on the treatment effect on the treated, knowing that the effect on somebody who did not select into such a programme might be different.

For our study we make use of a the timing asymmetry resulting from the fact that it is more economical for a university if not too many students go abroad at the same time. At Maastricht University's School of Business and Economics (SBE), where all Bachelor students take a mandatory semester abroad in their third year, this means that some students go in the first semester of their third year, while others go in the second semester, but all of them go eventually. Students were asked to fill in questionnaires at the beginning, the middle, and the end of the academic year. The design is summarised in Figure 3.1 and provides us with variation across and within subjects. We follow a differences-in-differences identification strategy comparing the changes from those who went abroad to those who stayed in Maastricht. This distinguishes us from earlier psychological work by Zimmermann and Neyer (2013), who carefully analyse possible channels of personality change in response to

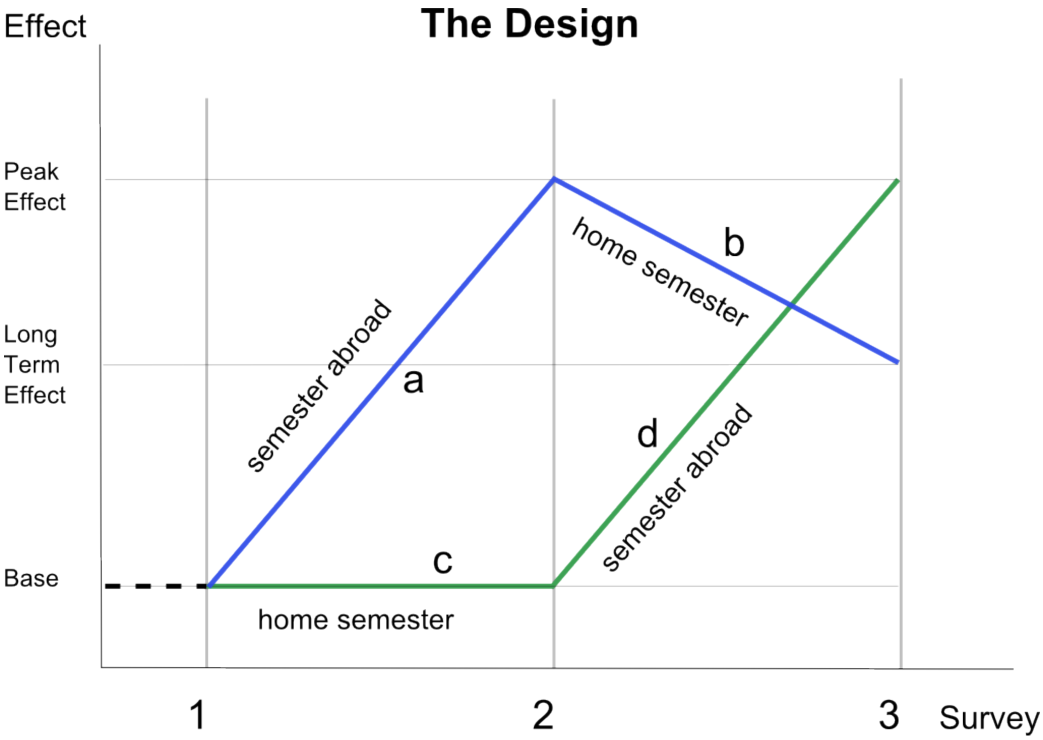

Figure 3.1: A three survey design: a= Change after being abroad in autumn (group A), b= Change after staying the spring in Maastricht (group A), c= Change after staying the autumn In Maastricht (group B), d=Change after being abroad in spring (group B).

a study abroad, but only control by using students who decided not to go abroad. The data allows to study both the initial effect of studying abroad and its persistence after an equally long period in Maastricht.

We find that going abroad has a significant and lasting impact on Locus of Control, which measures to what extend a person feels in control of life events, and on Neuroticism. On the 23 point Locus of Control scale students become more than 2 points (or 0.38 standard deviations) more inward after having gone abroad compared to the control group of students staying in Maastricht. An internal Locus of Control is associated with the believe that own decisions and effort have a decisive impact on individual life events, and according to Heckman, Stixrud, and Urzua (2006) is linked to improved labour-market outcomes. The result is robust irrespective of whether the groups going in the two semesters are pooled and significant across specifications. For the smaller sample, where it was possible to observe long term effects the hypothesis that mean reversion does not exist could not be rejected at a significance level of more than eighty percent. For the Big 5 personality traits, the results are mixed. We find significant decreases of Neuroticism, the trait capturing low self esteem and tendencies for experiencing anxiety and depression. For the remaining traits, no stable patterns are detected.

Overall, our results suggest that studying abroad has an impact on a student's personality. A back-of-the-envelope calculation that uses correlations between wages and personality traits from the German Socio Economic Panel (GSOEP, Schupp and Wagner (2002)) suggests that the productivity increase from the mean-level personality changes we measured could be around 2.4%. Under some assumptions this would equivalent to a net present value in monetary terms of 21,525 EUR (24,022$ at current exchange rate of 1.116$/EUR).[1] Naturally, such a result should applied with caution since, for example, it is not proven that the effect will persist over a longer time horizon.

A more inward Locus of Control and lower Neuroticism are also said to be related positively to health and subjective well-being. In their meta-study DeNeve and Cooper (1998) find that Locus of Control and emotional stability (the inverse of Neuroticism) correlate most strongly with subjective well-being. The correlation between Locus of Control and health was so apparent that specific health Locus of Control scales have been developed (see for example Wallston, Wallston, and DeVellis (1978)). Besides these studies and our own estimations a large literature on personality helps to interpret our results.

We devote one section of the paper to review the meanings and roles played by the different personality constructs. Almlund, Duckworth, Heckman, and Kautz (2011) interpret personality as a "strategy function for responding to life situations" (p. 8). To deal with the large pool of life situations humans pick from an even larger pool of strategies; the fact that their choices are correlated makes it possible to aggregate them into personality traits: Those who enjoy art, for example, are also more likely to try out foreign food, those who value punctuality tend to also prefer hierarchical structures and strive for achievement.

Several papers have highlighted the importance of such preference clusters. Especially Conscientiousness (Salgado (1997), Barrick and Mount (1991)), Neuroticism (Nyhus and Pons (2005), Salgado (1997)) and Locus of Control (Heckman et al., 2006) correlate with labour market outcomes. Depending on the outcome variable, correlations with other domains are reported. Rothmann and Coetzer (2003), for example, find a strong positive correlation between Openness and management performance in a pharmaceutical company. Heckman et al. (2006) estimate that through direct and indirect channels (like educational attainment) non-cognitive abilities account for as much variation in adult earnings as cognitive ability. Becker, Deckers, Dohmen, Falk, and Kosse (2012) argue that personality traits complement the classical economic measures like trust or risk aversion in explaining economic behaviour.

[1]The assumptions are: average starting wage of 42,000 EUR (46,872$ at current exchange rate), zero wage growth, a 3.5% discount rate and a forty year working life.

Our results also contribute to the literature on the stability of personality traits and personality change. Roberts et al. (2006) argue that while personality traits are fundamentally consistent across time and age[2] mean-level changes occur and are triggered by certain experiences such as leaving the parental home or starting a career. Our results support this viewpoint.

In the economics literature, however, personality has been regarded as relatively stable. As an assumption this allows studying the impact of personality on economic outcomes, but if it is not fulfilled it can lead to biased conclusions (Cobb-Clark & Schurer, 2012). Using the Australian Household, Income and Labour survey (HILDA), Cobb-Clark and Schurer (2013) do not find large mean-level changes for the Big 5, and also Locus of Control (Cobb-Clark & Schurer, 2012), in response to adverse life events over a period of four years. Sahm (2012) uses the American Health and Retirement Study (HRS) to investigate risk tolerance over a period of ten years (1992-2002) and finds that individual life events only play a minor role. The literature on the effectiveness of early childhood intervention, however, recognizes personality changes as an important channel (Heckman, Pinto, & Savelyev, 2012) of such programs. So far, to the best of our knowledge, there is no evidence on the stability of personality following a more experimental approach in the economics literature.

Our results can partially explain why international education has become increasingly popular both with students and policy makers, why universities have invested in student exchange-programmes, and institutions like the European Union have implemented policies that offer students organisational and financial support to study abroad.[3] Our findings contribute to the literature on education new evidence on a specific merit of international education which may be relevant for policy evaluations and can be used to calibrate structural parameters in models like Bergerhoff et al. (2013) that model human capital formation through education.

The structure of the paper is as follows. The next section discusses the measures of personality which are used in this study. Thereafter, we present our data and the results. Then, we discuss the magnitude of the effects found and conclude.

[2]Roberts and DelVecchio (2000) show that rank-order-consistency, measuring changes of the individual rankings in the population wide distribution of a trait, increases from 0.31 in children to 0.54 during the college years to 0.74 between the ages of 50 and 70.

[3]Indeed, Vossensteyn, Lanzendorf, and Souto-Otero (2008) in a report for the European Commission evaluating the ERASMUS Programme summarise: "At the individual level previous studies indicated that the ERASMUS experience has had an effect on the nature of graduate careers... The effect on academic development is detected, but particularly personal development... is recognised by participants." (p. 10)

3.3 Personality Measures

Personality measures can be seen as clusters that comprise many individual traits elicited by individual questions like: *Do you enjoy trying foreign food?* For each domain of the Big 5 inventory participants needed to indicate how much they agree with 12 statements about themselves on a five-point Likert Scale. Psychologists have assorted these preferences into separate clusters of traits that correlate strongly with one another (convergent validity) and little with components from other clusters (discriminatory validity). While there are various competing frameworks, many psychologists nowadays use the Big 5, a set of traits including Openness to Experience, Conscientiousness, Extraversion, Agreeableness and Neuroticism, developed by Costa Jr and McCrae (1989).

In the following we present a brief syntheses of the literature on the personality traits we use in our analysis. Individuals with high **Openness** to experience (or *Intellect*) are imaginative, aesthetically sensitive and have a rich emotional life. They are intellectually curious, have a need for variety and tend to be undogmatic and behaviourally flexible (McCrae and Costa (1989), McCrae and Costa Jr (1985)). Empirical results linking Openness to labour market outcomes are mixed. Dunn, Mount, Barrick, and Ones (1995) report that from the perspective of recruiters Openness was considered important only for jobs which needed some degree of creativity.[4] Rothmann and Coetzer (2003) find a positive correlation between Openness and management performance, but not with creativity or task performance. Barrick and Mount (1991) find that Openness is positively associated with job training performance ratings, but do not find a strong association with job performance.

Conscientiousness (or *Will to Achieve*) refers to the personal need for organisation (i.e. punctuality, hierarchy etc.), persistence and achievement. The American Psychology Association dictionary describes it as the "tendency to be organised, responsible and hard-working."' Perhaps unsurprisingly, Conscientiousness has been found to be a strong, positive predictor of job performance and labour-market outcomes (Barrick and Mount (1991), Salgado (1997), Nyhus and Pons (2005)). The ability to delay gratification, a component of Conscientiousness, for example predicts a large range of life time outcomes including health, happiness and educational attainment (Almlund et al., 2011); a channel through which part of the effect may be transmitted. Heckman, Humphries, Urzua, and Veramendi (2011) suggest in a working paper that much of the correlation with job performances should be moderated by educational attainment.

Extraversion (or *Surgency*) measures individual traits such as sociability, activity, dominance, and the tendency to be enthusiastic and experience pos-

[4]In their paper these occupations were journalist and medical technologist.

itive emotions (McCrae & Costa, 1989). Extraversion was found to predict job performance in occupations where success largely depends on social interaction like in management and sales (Barrick & Mount, 1991). In their meta analysis with a focus on sales Vinchur, Schippmann, Switzer III, and Roth (1998) find that both Extraversion and Conscientiousness predict success in actual sales better than cognitive ability.

Agreeableness (or *Likeability*) captures characteristics like sympathy, trust, cooperation, modesty and altruism. Agreeable subjects tend to be sensitive and try to maintain harmony in relationships. Becker et al. (2012) find that unlike other traits Agreeableness is correlated with several economic preferences such as patience, i.e., discount rates, trust, altruism and with positive as well as negative reciprocity. Nyhus and Pons (2005) report a negative correlation between earnings and Agreeableness for women. In contrast, Rothmann and Coetzer (2003) find a positive correlation between Agreeableness and management performance. Barrick and Mount (1991) find that Agreeableness does not show strong associations to any type of occupation[5] investigated.

Neuroticism (or *Emotional Instability*) describes the tendency to experience negative emotions such as anxiety, anger, depression and other manifestations of emotional instability (McCrae & Costa, 1989). High scores of Neuroticism may indicate some form of psychiatric problem. Neuroticism has been found to be negatively associated with job performance (Nyhus and Pons (2005), Salgado (1997)). Dunn et al. (1995) find that Neuroticism is the second most important personality component (after Conscientiousness) of employability in the eyes of recruiters. A possible explanation for this could be that subjects scoring high on Neuroticism find it harder to cope with stressful situation in the workplace.

The type of questions used by psychologists to elicit the Big 5 and Locus of Control differ substantially. To elicit Locus of Control students needed pick the, sometimes controversial statement they agreed relatively more with from a battery of 29 statement couples.

Locus of Control assesses to what extent subjects feel in control of events in life and how much they attribute to chance, fate, or circumstances. It originally received attention by economists because of its appearance in the National Longitudinal Survey (NLSY), where it was used by Heckman et al. (2006) as a measure for non-cognitive skills. While it was developed separately from the Big 5, it has been found to correlate with Neuroticism,especially with its sub-construct anxiety (Judge, Erez, Bono, & Thoresen, 2002). Using data from the German Socio Economic panel, Becker et al. (2012) find that Locus of Control correlates more strongly with wages than any of the Big 5 domains.

[5] Their sample includes professionals (accountants, engineers, teachers etc.), managers, police, sales and skilled/semi-skilled (i.e. nurses, farmers, clerics etc.) occupations.

3.4 Data

The Bachelor students at Maastricht University's School of Business and Economics (SBE) take a mandatory semester abroad. They choose their preferred destinations from a long list of possible exchange partners from all over the world, and depending on their first year average grade their preferences are fulfilled. Students select to go abroad during the first or the second semester of their last year. A market like allocation system for exchange destinations based on first year average grades ensures that semesters are roughly equally popular.[6]

The students can choose from the same list of over a hundred SBE partner universities in 38 different countries. To allocate the places all students are ranked according to their first-year grade point average and are asked to submit their top three preferences. If the top preference cannot be fulfilled because all places at the destination were occupied by students with a higher ranking, the second preference becomes the new top preference. If this cannot be satisfied either, the focus shifts to the third preference. Only when none of the preferred destinations could be offered, the student is pooled with others without allocation and asked to choose out of the remaining places using the same procedure as before.

The data was collected over the academic year 2012/2013 via an online survey to which all economics and business students who were identified as going abroad by the university's International Relations Office (IRO) in that year were invited to. Emails were sent via an official IRO email account to attract attention, but no information about the purpose of the study was released. Students were asked to fill in three separate questionnaires at the start, the middle, and at the end of the year, where every participant who completed all three surveys was awarded a ten Euro shopping voucher and had opportunity to request a personality profile in the final questionnaire.

Assuming that the treatment assignment is random or linked to fixed effects only, this data allows us to study the mean-level personality changes sparked by the experience of the going-abroad programme. The responses from students staying a semester longer in Maastricht before their abroad experience form the control group. This is different from Zimmermann and Neyer (2013), whose control group consists of students who indicated that they do not go abroad in the next twelve months. Zimmermann and Neyer (2013) find that these students differ from the going-abroad group systematically in the domains Openness, Conscientiousness and Extraversion. By

[6] Since our design allows us to take first differences and compare them within and across both groups, we are not that concerned about minor differences between both groups. While Maastricht University has not disclosed the full grade distribution to us, we were informed that the difference of both groups in terms of grades is insignificant, that is to say, smaller than 0.5 on a grading scale from 1 to 10.

avoiding such systematic differences our control group resembles the hypothetical counter-factual[7] more closely. Zimmermann and Neyer (2013) do not elicit Locus of Control.

3.5 Results

Figure 3.2 reports the mean values for each personality trait as measured by the different surveys for each group. We can see some pattern for Neuroticism and Locus of Control in the bottom of the panel. The average value of Neuroticism decreases for both groups during their study-abroad experience and increases to a lesser degree during the semester in Maastricht. Furthermore, students on average report a more inward Locus of Control after their semester abroad. The relation between a more inward Locus of Control and lower Neuroticism has also been found in other studies (Almlund et al., 2011).[8]

Short	Long	Description
a	$Trait_{A2} - Trait_{A1}$	Abroad in autumn change
b	$Trait_{A3} - Trait_{A2}$	Back in Maastricht change
c	$Trait_{B2} - Trait_{B1}$	Staying first in Maastricht change
d	$Trait_{B3} - Trait_{B2}$	Abroad in spring change

Table 3.1: The long form notation is Trait_{it} where $i \in \{A, B\}$ and $t \in \{1, 2, 3\}$. Students with sub-index A study abroad in autumn and stay in Maastricht during spring. Students with index B do this in reverse order. The index t refers to the questionnaire where the first, second and third were administered at the start, middle and end of the academic year respectively.

Before comparing treatment and control outcomes, we check which of the changes we measured are significantly different from zero. Overall, the patterns of Figure 3.2 are confirmed by the one-sample t-tests shown in Table 3.2.[9]

Students who go abroad report a more inward Locus of Control and lower Neuroticism afterwards. The change is different from zero at the 5% level of significance for Neuroticism and below 1% for Locus of Control as shown in

[7]What would have happened to the personality of students had they not gone abroad at that time.

[8]The correlation between Neuroticism and Locus of Control is not obvious as the metrics used to construct both measures are quite different.

[9]Throughout the paper all p-values given are two-sided. To avoid confusion with the short-hand notations a, b, c and d, it is easiest to refer to Figure 3.1 or to Table 3.1 for the formal definitions.

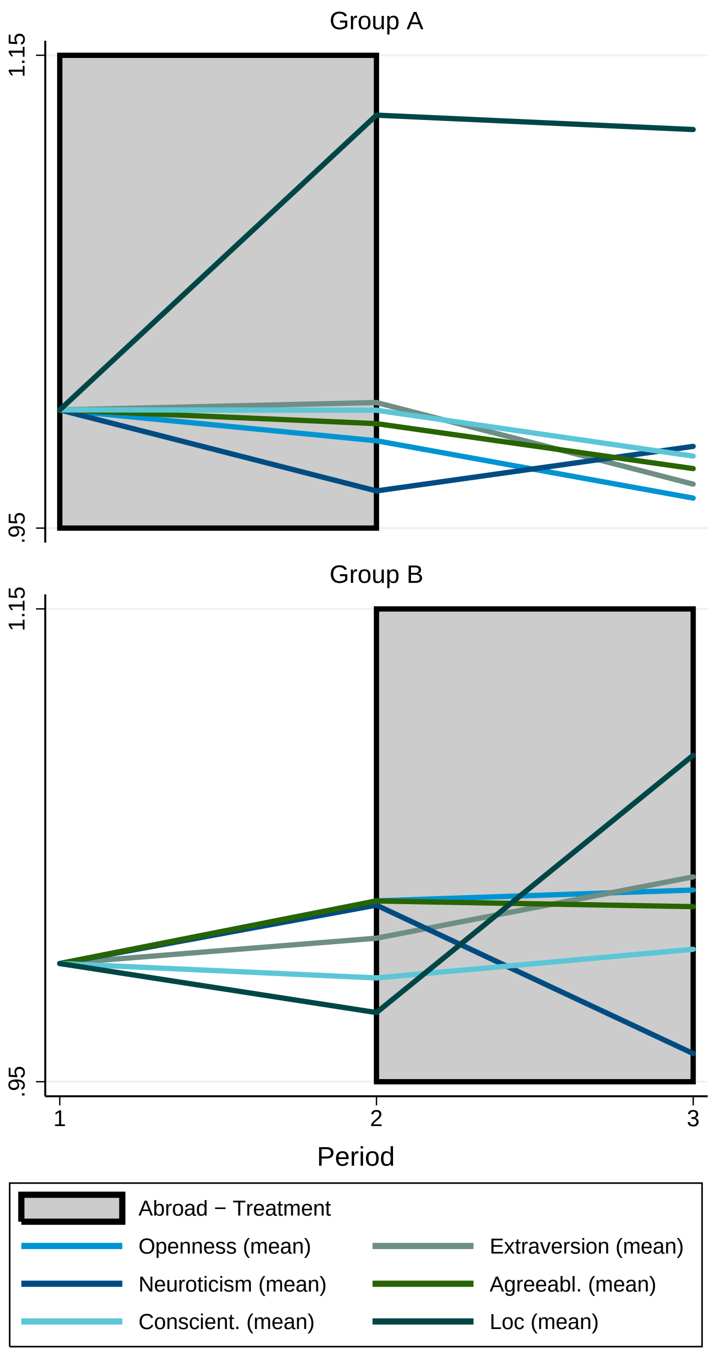

Figure 3.2: Average personality traits at each survey. All values are scaled by their first period mean, such that all lines start at the value one.

Trait	n_1	p	Δ	Trait	n_1	p	Δ	Trait	n_1	p	Δ
	a&d=0				b=0				c=0		
open	78	0.753	-0.13	open	42	0.070	-0.98	open	34	0.14	0.97
consc	80	0.661	0.21	consc	41	0.099	-0.90	consc	34	0.90	-0.09
extra	80	0.220	0.60	extra	42	*0.044*	-1.02	extra	35	0.52	0.43
agree	78	0.883	-0.06	agree	42	0.924	-0.05	agree	34	0.21	0.82
neuro	79	*0.045*	-1.14	neuro	40	0.919	0.08	neuro	35	0.30	0.80
loc	80	*0.001*	1.33	loc	42	0.245	-0.48	loc	35	0.66	-0.23

Table 3.2: Tests whether effects between the two surveys are significantly different from zero. All p-values given are two-sided. a= Change after being abroad in autumn (group A), b= Change after staying the spring in Maastricht (group A), c= Change after staying the autumn In Maastricht (group B), d=Change after being abroad in spring (group B).

the left panel of Table 3.2. The students staying in Maastricht after their abroad experience are used to analyse the long-term impact of going abroad. The test for $b = 0$ in the middle of Table 3.2 cannot reject that these changes are persistent. During their semester back in Maastricht following the study abroad semester, Neuroticism for group A increases a little and Locus of Control becomes slightly less inward. The effect sizes, however, are not that large and none of them is statistically indistinguishable from zero. If there is mean reversion it appears to be modest. The third panel of Table 3.2 investigates whether staying in Maastricht for a semester has any effect in itself. As the outcome of non-assignment it is the empirical benchmark against which the study-abroad treatment will be evaluated. It does not hint at any systematic effects.

For the treatment-control comparison we formulate the following hypothesis:

Hypothesis	The test assesses the ...
H1: a=c	abroad effect across students at the same time.
H2: c=d	abroad effect within students over time.
H3: a&d=c	pooled, across and within going abroad effect.
H4: b=c	persistance of going abroad effect within students.
H5: a&d=b&c	pooled, across and within going abroad effect.

Table 3.3: Summary of the main hypothesis.

What distinguishes this paper from previous work is the possibility to construct a treatment with a control group. We test five hypothesis which are summarised in Table 3.3 while the results are presented in Table 3.4. Hypothesis $H1 : a = c$ focusses on the first semester and compares the average changes in the study abroad group with the changes in the staying in Maastricht group. In the top panel of Table 3.4 using an unpaired, two-sample t-test, we see a similar pattern and effect size for Neuroticism and Locus of Control, but little other systematic variation.

The same is found when testing the hypothesis $H2 : c = d$ which only uses the within subject variation. While effect sizes are similar, they lose some statistical significance which may be the result of the relatively small sample size (below 40) in Group B. We again use an unpaired, two-sample test, as we are working with first differences. Fixed effects between identical individuals, therefore do not interfere with the independence of both samples. To rule out interference of higher order effects we later perform paired and partially tests. The results do not change.

In hypothesis $H3 : a\&d = c$ we pool both going abroad semesters and compare them against the effect of staying in Maastricht in the first semester. Since the effects d and c are derived from the same set of individuals some, but not all students studied in $a\&d$ and c are identical. The t-test signals a significant reduction of Neuroticism and an inward moving Locus of Control in the going abroad treatment group.

Given this pattern, hypothesis $H4 : b = c$ tests whether these effects are persistent. More precisely, it investigates whether the changes felt by group A in the semester after the study abroad experience are different from the changes felt by group B in the semester before their study abroad experience. Like the test for $b = 0$ in Table 3.2, no strong patterns for Neuroticism or Locus of Control are detected. In fact, in both groups the effects have the same sign. Finally, we pool both going-abroad periods and both staying-in-Maastricht periods and test for equality in hypothesis $H5 : a\&d = b\&c$. Again, we find the same pattern with a significant reduction in Neuroticism and a significantly more inward Locus of Control in the going-abroad group.

Asking the same individuals at different times points towards using a paired test. Instead, we present unpaired tests in Table 3.4 because we are already comparing changes rather than levels. Thus, the correlation from fixed effects, a major reason for using the paired test,is no longer present. Table 3.5, however, shows paired tests for H2 and H5 and a partially paired test for H3, where use a correction adjusting for the fact that only the c and d parts of the sample can be paired. The results point in the same direction with the reduction in Neuroticism losing some significance. We also asked students about their study abroad destinations. Around 61% were heading for a university outside of Europe, where South-America was the most popular Non-European destination with a share (among all options) of roughly 25%. A test whether the study abroad effect was different for students staying in Europe compared to those studying further away yielded no difference. For

Hypothesis	n_1	n_2	p	μ_1	μ_2
H1: a = c, abroad effect (A) vs. control (B)					
open	49	34	0.142	-0.224	0.971
consc	50	34	0.908	0.020	-0.088
extra	50	35	0.825	0.240	0.429
agree	49	34	0.282	-0.122	0.824
neuro	49	35	0.060*	-1.122	0.800
loc	50	35	0.022**	1.420	-0.229
H2: c = d, abroad effect (B) vs. control (B)					
open	34	29	0.339	0.971	0.034
consc	34	30	0.554	-0.088	0.533
extra	35	30	0.509	0.429	1.200
agree	34	29	0.381	0.824	0.034
neuro	35	30	0.128	0.800	-1.167
loc	35	30	0.094*	-0.229	1.167
H3: a&d = c, abroad effect (A,B) vs. control (B)					
open	78	34	0.153	-0.128	0.971
consc	80	34	0.724	0.213	-0.088
extra	80	35	0.836	0.600	0.429
agree	78	34	0.258	-0.064	0.824
neuro	79	35	0.044**	-1.139	0.800
loc	80	35	0.018**	1.325	-0.229
H4: b = c, persistance (A) vs. control (B)					
open	42	34	0.022**	-0.976	0.971
consc	41	34	0.357	-0.902	-0.088
extra	42	35	0.085*	-1.024	0.429
agree	42	34	0.289	-0.048	0.824
neuro	40	35	0.495	0.075	0.800
loc	42	35	0.708	-0.476	-0.229
H5.: a&d = b&c, abroad (A,B) vs. control (A,B)					
open	78	76	0.969	-0.128	-0.105
consc	80	75	0.251	0.213	-0.533
extra	80	77	0.132	0.600	-0.364
agree	78	76	0.491	-0.064	0.342
neuro	79	75	0.045**	-1.139	0.413
loc	80	77	0.001***	1.325	-0.364

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.4: Testing the hypothesis of Table 3.3. (A) and (B) refer to groups A and B. Sample sizes n and means μ are presented from left to right. For H1: a=c this means that n_1 is the number of observations for a and n_2 is the number of observations for c. All tests are unpaired and have been performed assuming an unequal variance using Satterthwaite's estimate for the degree of freedoms. Paired and partially paired tests are presented in Table 3.5.

all traits the hypothesis that the changes were equal could not be rejected with high p-values.

Hypothesis	n_1	n_2	p	μ_1	μ_2
H2: c = d, abroad (B) vs. control (B): paired					
open	29	29	0.459	0.931	0.034
consc	29	29	0.624	0.034	0.690
extra	30	30	0.572	0.333	1.200
agree	29	29	0.776	0.310	0.034
neuro	30	30	0.280	0.567	-1.167
loc	30	30	0.201	-0.167	1.167
H3: a&d=c, abr. (A,B) vs. cont. (B): part. paired					
open	78	34	0.144	-0.128	0.971
consc	80	34	0.749	0.213	-0.088
extra	80	35	0.862	0.600	0.429
agree	78	34	0.182	-0.064	0.824
neuro	79	35	0.100	-1.139	0.800
loc	80	35	0.005***	1.325	-0.229
H5: a&d=b&c, abr. (A,B) vs. cont. (A,B): paired					
open	70	70	0.890	-0.171	-0.271
consc	70	70	0.393	0.214	-0.514
extra	72	72	0.139	0.792	-0.458
agree	70	70	0.674	-0.143	0.143
neuro	69	69	0.155	-1.101	0.290
loc	72	72	0.005***	1.417	-0.347

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.5: This Table presents paired and partially paired t-tests. A paired t-test can be applied to account for the dependence between observations from the same individuals at different points in time. However, we do not compare individual characteristics, but changes in these. Thus, the dependence one would expect from fixed effects has already been extracted. We present the paired t-tests as a robustness check against non-linear dependencies.

3.6 The size of the effect

To assess the magnitude of these level changes, Table 3.6 provides the means and standard deviations of all traits at each point of testing. Locus of Control always has the lowest standard deviation of all traits. Taking the effect

	open	sd	consc	sd	extra	sd	agree	sd	neuro	sd	loc	sd
1												
Male	40.89	*6.06*	43.42	*6.73*	41.28	*5.79*	39.44	*6.16*	30.11	*7.79*	11.22	*3.48*
Fem.	41.00	*5.95*	45.64	*5.69*	41.41	*6.50*	42.69	*6.52*	34.18	*8.58*	10.26	*3.51*
2												
Male	40.74	*5.85*	43.24	*7.47*	40.93	*6.16*	39.62	*5.00*	30.50	*7.51*	12.20	*3.90*
Fem.	41.58	*5.22*	45.64	*5.84*	42.51	*6.58*	43.18	*5.10*	33.00	*8.82*	10.72	*3.98*
3												
Male	40.38	*5.74*	42.62	*6.31*	40.88	*5.69*	38.86	*5.44*	30.73	*7.98*	12.38	*4.78*
Fem.	40.83	*5.88*	46.03	*5.84*	41.57	*7.31*	43.40	*6.12*	31.86	*8.17*	11.27	*4.50*

Table 3.6: Reports the average values for the different personality domains and standard deviations for all three surveys.

size from the first panel of Table 3.2 would imply that students on average obtained a $\Delta_{\text{loc}} = 1.33$ points more inward Locus of Control which is about 38% of a pre-treatment standard deviation. For Neuroticism the effect size is slightly below 15% of one pre-treatment standard deviation.

To obtain an impression about the relevance of our results we investigate how Neuroticism and Locus of Control are jointly related to productivity in the work place. We use data from the German Socio Economic Panel (GSOEP)[10] which includes information on the Big 5 and Locus of Control as well as on wages which we use as a proxy for productivity and several other socio demographic characteristics. It also captures economic preferences like risk aversion, patience, trust, altruism and reciprocity.[11] We estimate the following regression model:

$$\text{hourlywage}_i = \beta_0 + \beta_1 \text{ loc}_i + \beta_2 \text{ big5}_i + \beta_3 \text{ controls}_i + \epsilon_i. \qquad (3.1)$$

The estimation results are summarised in Table 3.7. In the first three models we estimate Equation 3.1 with varying controls. Model 1, the model with the largest effect sizes, simply regresses hourly wages on the six traits without further controls.[12] A more inward Locus of Control and low Neuroticism

[10]The GSOEP is a large panel data set that is representative of the German adult population (Schupp & Wagner, 2002).

[11]The relationship between the Big 5 and these economic preferences in the SOEP was investigated by Becker et al. (2012). We use the same data (waves 2003 to 2009) as Becker et al. (2012) restricting the sample to individuals where information about each trait is available. The sample size is further reduced by missing data on wages and work hours. All traits are standardised.

[12]With the exception of Extraversion the direction of all effects is preserved when more

	(1) hourly wage	(2) hourly wage	(3) hourly wage	(4) hourly wage if uni
loc	2.119***	1.428***	1.080***	1.524*
	(16.07)	(4.88)	(3.75)	(1.82)
open	1.163***	1.276***	0.719**	0.192
	(7.96)	(3.87)	(2.20)	(0.21)
consc	0.247*	0.0454	0.293	0.124
	(1.70)	(0.14)	(0.93)	(0.15)
extra	-1.158***	-0.272	0.103	0.431
	(-8.32)	(-0.84)	(0.32)	(0.47)
agree	-1.258***	-0.671**	-0.681**	-1.560
	(-9.26)	(-2.05)	(-2.12)	(-1.62)
neuro	-1.353***	-0.987***	-0.751**	-0.197
	(-9.55)	(-3.19)	(-2.48)	(-0.22)
iq		1.353***	0.822**	0.914
		(3.25)	(2.00)	(0.82)
_cons	15.28***	-4.463	-15.52***	-1.217
	(126.77)	(-1.32)	(-4.26)	(-0.10)
economic traits	No	Yes	Yes	Yes
other controls	No	Yes	Yes	Yes
schooling	No	No	Yes	No
N	6023	1155	1121	289

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.7: Regression table: Based on SOEP data the table provides regression estimates where hourly wages are the dependent and the six personality traits discussed are the independent variables (model 1). Model 2 includes control measures for the economic personality traits patience, risk aversion, trust, altruism and positive/negative reciprocity. It also includes further controls for gender, age, age^2 and for whether the individual lives in eastern Germany. Furthermore it takes into the account the results of a short cognitive ability test. Model 3 additionally controls for the secondary school degree. Model 4 then resticts the sample to those who have attended university.

are associated with higher hourly wages. Controlling for cognitive ability,[13] economic preferences and demographics reduces most individual coefficients in model 2, but the overall pattern remains unchanged. This is also true when we include educational attainment in model 3, which is seen as an important mediator between personality and labour market outcomes by Almlund et al. (2011). To increase comparability to the Maastricht student population in model 4 we restrict the sample to respondents holding a university or technical college degree.[14] Due to the lower sample size, standard errors are pushed up and the statistical significance decreases. Only Locus of Control remains weakly significant.

Using the coefficients from model 4 we perform a simple calculation to translate the changes in Locus of Control and Neuroticism which we attribute to the study abroad experience into working productivity using hourly wages as proxy. Since all trait measures in the regression were standardised, we assess the productivity change as follows:

$$\Delta_{\text{productivity}} = \frac{\Delta_{\text{loc}}}{sd_{\text{loc}}} * \beta_{\text{loc}} + \frac{\Delta_{\text{neuro}}}{sd_{\text{neuro}}} * \beta_{\text{neuro}}. \tag{3.2}$$

The calculation suggests that the personality change following from a half year study-abroad experience may improve the productivity (as proxied by hourly wages) of the participating individuals by a magnitude of 2.4%. With an average starting wage of 42,000 EUR (46,872\$ at current exchange rate of 1.116 \$/EUR)), zero growth and a discount rate of 3.5% this would amount to a present monetary value of 21,525 EUR (24,022\$) over the course of a forty year working life. If the effect vanished after five years this number would decrease to 4,551 EUR (5,079\$).

3.7 Conclusion

In this paper we presented evidence that suggests that investment in personality is possible. We find that a going-abroad experience changes the personality of university students by comparing two student groups from the same programme who go abroad in different semesters. We find that going abroad leads to a 38% standard deviations more inward Locus of Control and to 15 % of a standard deviation lower Neuroticism. Both, a more inward Locus of Control and lower Neuroticism, in the literature are associated with

control variables are included.

[13]Cognitive ability is measured by a word fluency test (respondents had to name as many animals as possible in 90 seconds) and by a symbol correspondence test (participants had to match numbers to as many sings as possible in 90 seconds according to a codebook).

[14]We do this since the large majority of students that is granted permission to go abroad at SBE also completes their degree.

higher subjective well being and better health with some studies suggesting that, of all traits, Locus of Control and Neuroticism have the highest correlation with these outcomes. Using GSOEP data we confirm previous findings that a more inward Locus of Control and lower Neuroticism are positively related to earnings. For a sample of university graduates in the GSOEP we find that the personality changes measured on average in our treatment groups would imply an increase in gross wages of about 2.4%. Under some assumptions this suggests a present monetary value of 21,525 EUR (24,022$ at current exchange rate of 1.116 $/EUR). The number would be lower if the study abroad would eventually fade out. While this number is not in any way exact, it provides some guidance for the potential economic impact of a change in non-cognitive abilities that could be achieved by an educational policy.

There are some limitations to our findings. An important concern would the sample size in the individual groups. Especially, in the group that stays in Maastricht before going abroad that serves as a control group the lowest observations available for a given trait is 34. While the main result that going abroad groups obtain a more inward Locus of Control and lower Neuroticism appears to be strong despite the low sample size, more subtle points might have been lost. For example, it would have been interesting to see how students with different personality profiles ex-ante were affected by the treatment. The study focussed on a treatment effect for a group who committed themselves to go abroad and, thus, does not comment on the effect of international education for groups that do not want to go abroad.

The results help to explain why international education has become increasingly popular as it has become more easily attainable. It also suggests an explanation for the observed international-experience wage premium (Oosterbeek & Webbink, 2006) that goes beyond a pure signalling effect. This is also relevant for international communities like the European Union who encourage students to go abroad hoping to a achieve more integration between its members. The results may hint that there is an economic dividend to policies enabling students to such policies. Our analysis suggests that studying in another European country has the same effect on student personality than going away even further.

Non-cognitive abilities have received much attention in recent years. If cognitive and non-cognitive abilities are indeed important complements and non-cognitive skills can be affected by public policy, then, investment into cognitive as well as non-cognitive abilities would be a logical step. Going abroad seems to have an effect on the personal development of young adults and, thus, may be a way of investing in personality.

3.8 Appendix

3.8.1 Locus of Control Statements

1.

a) Children get into trouble because their parents punish them too much.
b) The trouble with most children nowadays is that their parents are too easy with them.

2.

a) Many of the unhappy things in people's lives are partly due to bad luck.
b) People's misfortunes result from the mistakes they make.

3.

a) One of the major reasons why we have wars is because people don't take enough interest in politics.
b) There will always be wars, no matter how hard people try to prevent them.

4.

a) In the long run people get the respect they deserve in this world.
b) Unfortunately, an individual's worth often passes unrecognised no matter how hard he tries.

5.

a) The idea that teachers are unfair to students is nonsense.
b) Most students don't realize the extent to which their grades are influenced by accidental happenings.

6.

a) Without the right breaks one cannot be an effective leader.
b) Capable people who fail to become leaders have not taken advantage of their opportunities.

7.

a) No matter how hard you try some people just don't like you.
b) People who can't get others to like them don't understand how to get along with others.

8.

a) Heredity plays the major role in determining one's personality.
b) It is one's experiences in life which determine what they're like.

9.

a) I have often found that what is going to happen will happen.

b) Trusting to fate has never turned out as well for me as making a decision to take a definite course of action.

10.

a) In the case of the well prepared student there is rarely if ever such a thing as an unfair test.
b) Many times exam questions tend to be so unrelated to course work that studying in really useless.

11.

a) Becoming a success is a matter of hard work, luck has little or nothing to do with it.
b) Getting a good job depends mainly on being in the right place at the right time.

12.

a) The average citizen can have an influence in government decisions.
b) This world is run by the few people in power, and there is not much the little guy can do about it.

13.

a) When I make plans, I am almost certain that I can make them work.
b) It is not always wise to plan too far ahead because many things turn out to be a matter of good or bad fortune anyhow.

14.

a) There are certain people who are just no good.
b) There is some good in everybody.

15.

a) In my case getting what I want has little or nothing to do with luck.
b) Many times we might just as well decide what to do by flipping a coin.

16.

a) Who gets to be the boss often depends on who was lucky enough to be in the right place first.
b) Getting people to do the right thing depends upon ability, luck has little or nothing to do with it.

17.

a) As far as world affairs are concerned, most of us are the victims of forces we can neither understand, nor control.
b) By taking an active part in political and social affairs the people can control world events.

18.

a) Most people don't realize the extent to which their lives are controlled by accidental happenings.
b) There really is no such thing as "luck."

19.

a) One should always be willing to admit mistakes.
b) It is usually best to cover up one's mistakes.

20.

a) It is hard to know whether or not a person really likes you.
b) How many friends you have depends upon how nice a person you are.

21.

a) In the long run the bad things that happen to us are balanced by the good ones.
b) Most misfortunes are the result of lack of ability, ignorance, laziness, or all three.

22.

a) With enough effort we can wipe out political corruption.
b) It is difficult for people to have much control over the things politicians do in office.

23.

a) Sometimes I can't understand how teachers arrive at the grades they give.
b) There is a direct connection between how hard 1 study and the grades I get.

24.

a) A good leader expects people to decide for themselves what they should do.
b) A good leader makes it clear to everybody what their jobs are.

25.

a) Many times I feel that I have little influence over the things that happen to me.
b) It is impossible for me to believe that chance or luck plays an important role in my life.

26.

a) People are lonely because they don't try to be friendly.
b) There's not much use in trying too hard to please people, if they like you, they like you.

27.

a) There is too much emphasis on athletics in high school.
b) Team sports are an excellent way to build character.

28.

a) What happens to me is my own doing.
b) Sometimes I feel that I don't have enough control over the direction my life is taking.

29.

a) Most of the time I can't understand why politicians behave the way they do.
b) In the long run the people are responsible for bad government on a national as well as on a local level.

The NEO-FFI Big 5 questions are licensed and therefore cannot be made available in this appendix.

Chapter 4

Personality and Field of Study

Selection and Personality Change.

4.1 Abstract

Choosing to study a particular subject at university considerably changes the set of employment possibilities later in life. Personal preferences and interests could, therefore, be expected to drive subject choice initially, but they could also change as a result of the specialisation. Using new data from over 23,000 German students we find that study choice is influenced by personality differences. We find significant selection into study fields along the Big 5 personality traits and a comprehensive set of economic preferences. However, the personality measures do not show mean or standard deviation changes as a result of studying a certain subject. If personality plays a role in subject choice and students stick to that choice due to the opportunity costs of switching, a sizeable portion of personality based job sorting may take place just before entering university.

4.2 Introduction

The choice of a university subject has important implications for later life. Students often find it attractive to look for a job linked to their subject specialisation, either because a university specialisation increases their productivity in that area or (at least) because it signals interest, commitment and maybe talent for it. Once on the job they acquire more specific human capital making it even less attractive to switch to other areas. The skills that are obtained at university through specialisation are an entry card to professions in which many people choose to stay for all their working life, as the cost of switching becomes too high. This makes the choice of a university subject, that is arguably at the beginning of the described trajectory, a significant personal decision.

Electing a field is a free choice that is yet subject to financial, regional and personal constraints. In a world with perfect information and foresight, high school graduates would compare all subjects' costs and benefits given their specific capabilities and a large vector of personal preferences. A decision without such perfect information must be based on perceptions, both of oneself and of the subject, that are also likely to be influenced by personal characteristics. Thus, if personality plays a role in subject choice and students tend to stick to that choice due to the opportunity costs of switching, a sizeable portion of personality based job sorting may take place not right after, but just before entering university.

In this paper we investigate the link between personality and field of study. We want to know whether students majoring in different university subjects have different personality profiles and whether profiles change over the course of study. We investigate these questions using a new data set that consists of more than $23,000$ German students who took part in the study "Fachkraft 2020". Students were asked to provide details on their study field and took a comprehensive personality tests. They answered fifty questions from the International Personality Item Pool (IPIP), of which ten at a time were used to construct the Big 5 character traits Openness, Conscientiousness, Extraversion, Agreeableness and Emotional Stability (Goldberg et al., 2006).[1] Moreover, we elicited the economic traits Impatience, Risk Aversion, Trust, Altruism and Positive and Negative Reciprocity through a set of survey items that were designed by Falk, Becker, Dohmen, Huffman, and Sunde (2014) to most closely track the results of incentivised experiments. In our analysis we compare students at the start of their university career to students further down the road. We find that both the Big 5 and the economic traits play an important role when students choose their subject, but that the initial selection of personality profiles within fields remains unaffected by the length of study. This is true for the average personality profile of a study as well as the spread of personality profiles within one study field.

While previous studies have estimated the impact of personality on variables like the optimal length of education, the actual choice of study is mostly left out. The few studies that try to estimate the effect exclusively focus on either the selection into study programs or the change in personality due to studying a specific subject (Rutkowski and Domino (1975), Boone, van Olffen, and Roijakkers (2004), Lüdtke, Roberts, Trautwein, and Nagy (2011), Schurer, Kassenboehmer, and Leung (2015)). If these studies find significant effects, the causality between the field of study and personality remains

[1]Emotional Stability is the inverse of the trait Neuroticism, which is an item of other versions of the Big 5.

unclear. The selection into a certain study track can be influenced by the personality of students. Once enrolled, the study track might then change the personality of students. It is, therefore, essential to model these two effects simultaneously to get an understanding of the inter-linkages between personality and study field. Moreover, these studies are also limited to either the Big 5 personality scores or economic personality traits. Jackson, Thoemmes, Jonkmann, Lüdtke, and Trautwein (2012) investigate both selection and personality change for military training in Germany. They find little change, but considerable selection.

As part of our analysis we present a 10 by 11 table (Table 4.3) that summerises the relation between the ten subject areas and eleven personality traits. Frey and Meier (2005) find in a large sample that economics students contribute less to a good course than students of other faculties independent of whether they were freshmen at university. From this Frey and Meier (2005) conclude that the more selfish character traits of economics students were likely to be the outcome of a selection process. Our evidence supports this viewpoint. We find that business and economics students differ significantly in almost all domains compared to the broad average of students: They show less Trust and Altruism, less Positive and more Negative Reciprocity. They are less risk averse and more patient, are less aggreeable and open while being more conscientious and extraverse. On the effect of studying economics the only change we find is actually an increase in Altruism and (weakly significant) in Agreeableness.[2] The strongest individual selection result is on the positive relationship between studying Pedagogy or Psychology and being agreeable.

Psychologist offer a range of explanations for why students might select into subjects which fit their personality. Rutkowski and Domino (1975) find a link between personality and study skills. With a certain set of study skills students might, then, choose subjects in which they can benefit from their specific set of skills. More generally, the tendency to select environments which suit ones personality is well known in psychology and referred to as a proactive person-environment transaction. Along these lines Balsamo, Lauriola, and Saggino (2012) find evidence for a link between two Big 5 personality scores and major choice. Similarly, locus of control has been related to study field selection (Boone et al., 2004).

With respect to changes in personality psychologists differentiate between four different types. On a person level, intra-individual changes refer to changes in the personality scores, while ipsative changes are defined as changes in the relative weights of the different domains. On a group level, mean-level changes refer to a shifting of the group mean and rank order changes refer to a change in the ranking of different participants with respect to their personality (Roberts & DelVecchio, 2000). Group-level changes are our first

[2]For details please refer to Table 4.4.

criterion to determine the link between personality and study fields in this paper. An ongoing shift of the distribution of personality scores of a certain subject as a result of studying this subject would be equivalent to changes in the mean level. Additionally, we propose a second measure for change in personality as the dispersion of the distribution of personality scores within one subject may change over time. This effect is not widely described in the psychology literature. Theoretically it can occur without a change in the mean or the rank order. As a result, the average personality does not change, but the longer students study, for example, the closer they could move to the mean personality of their study field. A combination of the two effects is also possible.

The next section outlines the data used. Thereafter, we explain the methodology used in this paper and present the various results. Finally, a last section concludes.

4.3 Data

The data originates from the German student study "Fachkraft 2020". It is collected biannually by the authors and Studitemps GmbH via the Studitemps student network called Jobmensa. Jobmensa is the largest network for student jobs and internships in Germany with currently more than 400, 000 users. In this paper we use data from the second and the fourth round which took place between 01.03.2013 - 14.03.2013 and 11.03.2014 - 27.03.2014 respectively. The survey was collected online and was incentivised by giving participants the chance to win Amazon vouchers with a total value of 1000 Euro for round two and 2000 Euro for round four.[3] The entire Jobmensa network was invited to participate via a first email and a reminder email one week later. The average time needed to complete the full questionnaire was 37 minutes for round two and 39 minutes for round four.

During round two a total of 15, 878 students and during round four a total of 21, 728 students participated in the questionnaire. Since participation in the personality test was made explicitly voluntary[4] and some observations had to be excluded[5] the analysis uses 10, 155 observations from round two and 12,985 from round four. Most students participate in only one round so that the panel dimension of the dataset is small. For this study we will ignore the

[3]Five Amazon vouchers of 200 Euro for round two and one 500 Euro Amazon voucher, five 100 Euro Amazon vouchers and twenty 50 Euro Amazon vouchers for round four.

[4]The personality test came in an extra section after the core questionnaire. Students were informed that they had finished, but that they would help research and double their chances to win the lottery if they went on to do the personality test.

[5]Study field with a too small sample size, age below 16 or above 30, age at entry into higher education larger 25 years or semesters studied larger 20

panel dimension and treat the data as a repeated cross-sectional set.[6]

As noted, the personality test included the fifty item IPIP Big 5 personality test as well as a module for economic personality traits developed by Falk et al. (2014). The IPIP test is scored on the five dimensions: Openness, Conscientiousness, Extraversion, Agreeableness and Emotional Stability. The economic traits included in the module are Impatience, Risk Aversion, Trust, Altruism and Positive and Negative Reciprocity. All different personality scores are standardised for the analysis. Study fields are clustered into ten categories: Business and Economics, Communication and Media, Engineering, Language and Culture, Law, Math and Computer Science, Medical Science, Natural Sciences, Pedagogy and Psychology as well as Social Sciences. These fields cover all students that participated in the survey except those studying Sport or Theology, which were dropped due to a small sample size.

It can be argued that the sample is not necessarily representative for German students as the data was collected through a student job network. Comparing observable characteristics of the sample to another German student survey called "Sozialerhebung" we cannot find large differences[7].[8] This is not only true for demographic variables, but also holds for the share of students that ever had or currently has a job. The "Sozialerhebung" is collected systematically on a university level and is funded by the German government (Middendorff, Apolinarski, Poskowsky, Kandulla, & Netz, 2013). Table 4.1 shows selected descriptive statistics for the two rounds of data collection that are used for this research and the "Sozialerhebung" respectively.

Variable	round two	round four	Sozialerhebung
Age	21.9	23.0	24.4
Semester studied	4.6	5.7	5.1
Age at university entry	19.6	20.2	21.9
Male-Female ratio	37% / 63%	40% / 60%	42% / 58%
Share of working students	60.4%	63.3%	62%

Table 4.1: Descriptive Statistics

4.4 Methodology

With a total of eleven different personality traits and ten study tracks which we use in our analysis it is highly likely to obtain significant associations by

[6] A total of 2455 students participated in both questionnaires

[7] See also Hartmann, Thiel, and Seegers (2013)

[8] The somewhat larger difference in age and entry age is mainly driven by the fact that we chose to drop students older than 30 years and students with an entry age above 25 in our sample.

chance. To avoid misinterpretations, we do not study each of the possible links between study tracks and personality traits separately, but focus on the share of the significant coefficients and the distribution of the p-values instead. If the results were only obtained due to sampling variation, the distribution of p-values would asymptotically converge to a uniform distribution. Hence, finding a distribution with a higher density for lower p-values suggests an effect of the respective explanatory variables.

To shed more light on the direction of causality, the personality based selection into study tracks as well changes in personality due to the study track are estimated simultaneously. If personality change caused by a particular study field happens over time, it should be the case that students at the very beginning of their study have not yet changed. Comparing such students across study fields, then, allows to look at selection effects. Next, as long as the different student cohorts are sufficiently similar, students in higher semesters can be compared to students in earlier semesters within the same subject. We attribute the differences between these students to a change in personality as a result of studying a certain subject.

A problem arises when trying to estimate three effects simultaneously: age at entry into higher education, getting older and studying longer. Ideally, one would like to differentiate between the effect of a student getting older and that of a student studying a certain subject. However, age at entry into higher education is an important control variable for two reasons. First, if personality changes over time it is vital to control for the starting age. Second, age at university entry carries a lot of information about students.[9] Keeping age at university entry means that the model can no longer differentiate between getting older and studying longer.[10] Therefore, we define the age effect as the average effect of studying longer across all subjects. If a subject deviates from this age effect one can argue for study field specific personality change.

We propose a model in equation 4.1 in which personality (P) is explained by study field dummy terms (F) and interaction terms between study field dummies and the semesters studied (S). Note that the constant as well as a general semester effect is left out. Hence, the procedure is equivalent to estimating separate regression models for each study field. Additionally, we use controls variables (C) to test for stability. These are gender, age at entry into higher education[11], the grade point average of the student as well as the highest parental degree for social status[12]. Individuals and study fields are

[9] Conscientious students, for example, are likely to start studying earlier.

[10] Every variable is a linear combination of the other two.

[11] age at entry into higher education is demeaned as the constant would otherwise measure the personality of a student with a hypothetical entry age of zero years.

[12] the variable is included in the models in quantitative terms, but consists of four ordinal categories: higher education, meister degree, vocational education and no (known) education after compulsory schooling

labeled i, and j respectively. The regression is repeated for each of the Big 5 and six economic traits.

$$P_{ij} = \sum_j \beta_j F_{ij} + \sum_j \gamma_j F_{ij} S_i + C_{ij} + \epsilon_{ij} \tag{4.1}$$

The dummy terms measure personality if semesters studied is equal to zero. Therefore, we can speak about a significant selection effect if the coefficient of the study field dummy (β_j) is significantly different from the weighted average (μ) of the dummy terms of all other study fields ($k \neq j$). Equivalently, a study field leads to a change in personality if its interaction effect between field and semesters studied is significantly different from the weighted average interaction effect. To decide about the significance we construct a t-statistic as follows:

$$t = \frac{\beta_j - \mu(\beta)_{all\ k\neq j}}{\sqrt{se_j^2 + \mu(se)^2_{all\ k\neq j}}} = \frac{\beta_j - \sum_{k\neq j} \frac{\beta_k n_k}{n-n_j}}{\sqrt{se_j^2 + \sum_{k\neq j} (\frac{se_k n_k}{n-n_j})^2}} \tag{4.2}$$

Additional to mean level changes in the personality of a certain study field the spread distribution of personality can change. Even if average personality stays the same throughout the course of a study it could be true that the standard deviation changes. A decrease in its dispersion, for example, could result from students getting closer to the mean personality of their field by studying longer. To see whether this effect can be found we formulate a new model in terms of squared differences between individual and average study field personality rather than only personality itself. By definition this difference is dependent on the study field. However, the effect of studying longer on this mean deviations does not need to be the same for different study fields. Therefore we estimate a equation 4.3 in which this effect is as well dependent on the study field. The same set of control variables as before is used.[13]

$$(P_{ij} - \bar{P}_j)^2 = \sum_j \delta_j F_{ij} + \sum_j \phi_j F_{ij} S_i + C_{ij} + \epsilon_{ij} \tag{4.3}$$

[13]gender, age at entry into higher education, grade point average of the student and highest parental degree for social status

4.5 Results

4.5.1 Selection and Mean Level Change

Using the full set of control variables and estimating the regression in equation 4.1 for each of the eleven traits shows that 53 out of the 110 study field dummy terms are significantly different from the weighted average of the remaining dummy terms. Moreover, only eight out of 110 interaction terms between study field and semesters studied show significant deviations from the weighted average of the interactions. Hence, there is strong evidence in favour of selection into study tracks based on personality. Given the significance level of 5%, however, the few significant findings where study fields change personality are likely to have emerged by sampling chance. Therefore, we cannot find evidence that differences in personality between study fields are generally changing during the course of a study program. Our results, thus, indicate that the differences in personality originate from the selection of students into study fields.

This finding is robust across different specifications of the model. Table 4.2 reports the number of significant deviations for the selection and change effect in different model specifications. Type I models use the full set of control variables, while type II models use age at entry into higher education as the only control variable. Models of specification III include no control variables at all. From the table it can be seen that leaving out some of the control variables increases the share of significant findings. However, the increase in the number of significant change effects is too small to argue for a general effect. Table 4.2 also reports the significance of the control variables. Note that each of the eleven traits is regressed separately. Each control variable appears, therefore, in eleven regressions per model specification.

Similar conclusions can be drawn based on the distribution of p-values that result from testing one coefficient against the weighted average of all other coefficients. Figure reffig:spc1 shows a histogram of the p-values of both, the selection as well as change effect for different model specifications. Note that if scores are drawn randomly from a t-distribution their p-values follow a uniform distribution. Hence, the strong clustering of points supports selection into study fields, while the rather uniform pattern rejects the idea of study field specific personality change. This is supported by the results of testing for a uniform distribution explicitly.[14] Still, the distributions for the change effects are somewhat denser at lower p-values and indeed for speci-

[14]Categorizing the p-values in 50 categories of equal size allows the application of a chi-square test for homogeneity to test whether the distributions are indeed uniform. For the distributions of the p-values in the selection case all specifications lead to a rejection of a uniform distribution with p-values below 0.01. In the change case a uniform distribution in specifications I to III cannot be rejected at p-values of 0.86, 0.52, 0.87 respectively.

fication III 58% of the p-values are lower than 50%. Moreover, half of the significant change effects can be found in Altruism and Openness throughout all specifications. Nevertheless, we do not want to argue that the data allows to detect a general pattern in favour of study field based personality change.

Overall, it can be said that the Big 5 personality traits inform a little more on the personality based selection of study fields than the economic traits. However, it should be noted that each of the Big 5 domains carried information from ten separate questions, while each economic trait only comprised two. Depending on the model specification the ranking of significant effects differs. Still, Agreeableness and Conscientiousness seem to be most important for the selection of study fields. Extraversion and Openness show significant selection parameters for at least half of the study fields. The importance of Emotional Stability vanishes as more control variables are added. In the group of economic traits Altruism, Impatience and Trust are most decisive. Risk aversion, Negative and Positive Reciprocity are significant less than 40% of the time. The differences in the selection effects for these traits are picked up strongly by the control variables.

Trait	Specification I		Specification II		Specification III	
	Selection	Change	Selection	Change	Selection	Change
Altruism	6/10	2/10	7/10	2/10	7/10	2/10
Impatience	6/10	0/10	5/10	0/10	6/10	0/10
Neg. Reciprocity	2/10	0/10	4/10	0/10	4/10	0/10
Pos. Reciprocity	3/10	1/10	5/10	1/10	5/10	1/10
Risk Aversion	3/10	1/10	5/10	2/10	6/10	2/10
Trust	6/10	0/10	6/10	1/10	6/10	1/10
Agreeableness	7/10	1/10	10/10	1/10	9/10	1/10
Conscientiousness	7/10	0/10	7/10	1/10	7/10	1/10
Extraversion	6/10	1/10	6/10	1/10	6/10	1/10
Emotional Stability	2/10	0/10	6/10	0/10	7/10	0/10
Openness	5/10	2/10	5/10	3/10	5/10	3/10
Total	53/110	8/110	66/110	12/110	68/110	12/110

Control Variables	Specification I	Specification II	Specification III
Entry Age H.E.	6/11	7/11	-
Gender	9/11	-	-
GPA	6/11	-	-
Parental Edu.	9/11	-	-

Table 4.2: Share of significant deviations of the selection and change effects as well as share of significant control variables for different model specifications

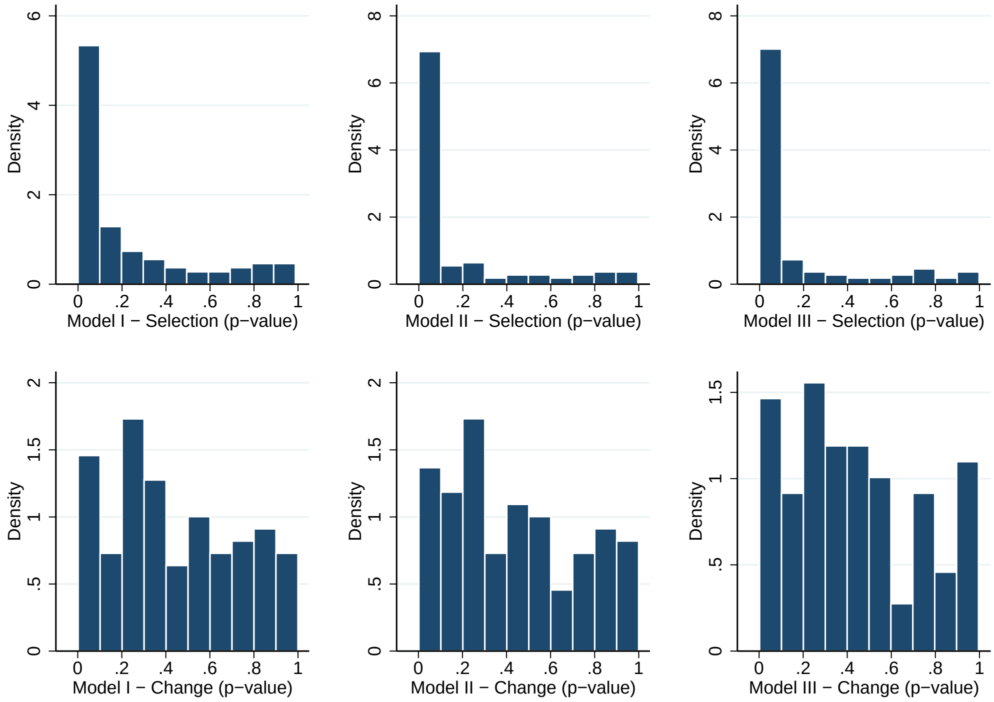

Figure 4.1: Distribution of the p-values of the selection and change effects for different model specifications

4.5.2 Personality Profiles

Next, we can investigate which personality traits are important for which study field. Here, we use the model specification with the full set of control variables. Table 4.3 and 4.4 show the t-scores of the selection and change effects respectively for all combinations of study fields and personality traits. We suggest caution when interpreting the change effects as the few significant results are likely to have been obtained by chance. Therefore we will not elaborate on them and they are merely shown for completeness. With respect to selection, we see more significant effects. Students who decide to study Pedagogy or Psychology differ from the average student in that they show greater Positive Reciprocity, are more impatient, risk averse, trusting, agreeable and open, but less conscientious. Social Sciences attract students who are more altruistic, impatient, trusting, agreeable and use more Positive Reciprocity, but are less conscientious than the average student. Students with positive mean deviations for Altruism, Conscientiousness and Emotional Stability and negative mean deviations for Impatience, Agreeableness and Extraversion select into Engineering. Law students can be characterized by significantly negative t-scores for Altruism, Trust and Agreeableness as well as significantly positive t-scores for Negative Reciprocity, Conscientiousness and Extraversion. Communication and Media students are more extraverse and open, but less altruistic and risk averse. Selection effects for students in Math and Computer Science show negative deviations in Impatience, Agreeableness and Extraversion. Future medical scientist select into their field based on high Altruism, Trust and Conscientiousness. Natural Sciences are chosen by students who are trusting, but not agreeable, conscientious or extraverse. The study field Language and Culture shows positive mean deviations for Impatience and Openness and negative mean deviations for Conscientiousness and Emotional Stability. Finally, Business and Economics students are low on Altruism, Impatience, Positive Reciprocity, Risk Aversion, Trust, Agreeableness and Openness and high on Negative Reciprocity, Conscientiousness and Extraversion. We want to stress that while these effects are significant they are mean effects. Personality per se is a not a very strong predictor of an individual's choice of study field.[15]

[15]A multinomial logit regression estimating the chosen study field given the Big 5 and six economic personality traits leads to a correct prediction in 24% of the cases.

	Altr.	Impat.	N.Rec.	P.Rec.	Risk Av.	Trust	Agree.	Consc.	Extra.	Emot.	Open.
Pedagogy/Psych.	1.14	3.10***	-1.53	4.15***	2.76***	2.33**	8.15***	-2.49**	0.82	-0.01	2.66***
Social Sc.	2.80***	4.25***	-0.27	2.82***	0.88	2.00**	3.87***	-4.93***	0.17	-1.61	1.36
Engineering	3.61***	-3.32***	-1.32	-1.70*	-1.28	0.19	-4.00***	3.52***	-3.03***	2.28**	-3.75***
Law	-4.08***	0.40	2.30**	-1.89*	1.41	-4.57***	-2.36**	1.86*	2.36**	-1.57	0.18
Communic./Media	-2.03**	1.44	-0.39	-0.03	-3.02***	0.08	1.04	-0.90	2.54**	-0.22	3.62***
Math/Comp. Sc.	1.42	-2.29**	-1.66*	-1.23	1.35	0.40	-2.60***	0.52	-3.16***	1.32	-1.45
Medical Sc.	2.03**	-1.17	-1.23	0.72	0.03	2.34**	1.66*	2.79***	0.46	0.59	1.19
Natural Sc.	-0.64	-0.13	-0.58	0.69	1.27	2.29**	-2.09**	-2.68***	-3.95***	-0.14	1.00
Language/Culture	1.43	5.50***	0.94	1.00	1.37	0.30	0.80	-4.98***	-1.12	-3.97***	3.80***
Business/Econ.	-5.26***	-4.47***	2.52**	-2.89***	-2.63***	-3.89***	-2.05**	5.02***	4.45***	1.59	-3.60***

Table 4.3: t-scores of the selection effect for all study field and trait combinations using the full set of control variables

	Altr.	Impat.	N.Rec.	P.Rec.	Risk Av.	Trust	Agree.	Consc.	Extra.	Emot.	Open.
Pedagogy/Psych.	-0.34	-1.13	-0.44	-1.58	-0.46	1.27	-1.18	0.88	1.61	0.88	-0.64
Social Sc.	-2.15**	0.80	0.77	-1.05	0.00	-0.02	-0.89	-0.60	0.42	-0.14	3.12***
Engineering	-1.15	0.96	-0.02	-0.86	0.23	-0.07	0.35	-0.86	1.02	-0.07	-0.31
Law	1.60	-1.69*	1.08	2.25**	-1.78*	0.06	1.10	0.08	1.01	0.35	1.84*
Communic./Media	1.30	0.93	-1.11	0.47	0.61	0.95	-0.82	-0.71	-1.34	-0.79	0.23
Math/Comp. Sc.	-0.50	1.42	0.33	-0.34	-0.37	-0.45	0.40	-1.20	-2.45**	-1.34	-0.59
Medical Sc.	-1.05	-0.29	1.13	-0.53	2.18**	-1.87*	-2.04**	-1.94*	-1.36	-1.08	-1.79*
Natural Sc.	0.13	0.18	-0.56	0.20	0.89	-1.92*	-0.38	1.06	-0.60	-0.67	-3.05***
Language/Culture	-0.78	-1.24	0.07	1.04	-0.15	0.15	0.47	1.22	1.19	0.96	0.58
Business/Econ.	2.56**	-0.54	-0.56	0.88	-0.73	1.07	1.67*	1.16	-0.20	1.03	0.23

Table 4.4: t-scores of the change effect for all study field and trait combinations using the full set of control variables

Counting the overlaps between study fields in terms of significant positive, significant negative and no significant deviation also allows us to analyse whether students selecting into them are similar. However, this only considers the direction, but not the size of the effect. Table 4.5 shows the amount of overlaps for the different study field combinations. With eight agreements respectively, Pedagogy / Psychology and Social Sciences as well as Math / Computer Science and Natural Sciences are most similar. The least overlap exists between Language / Culture and Business / Economics for which none of the effects point in the same direction.

	PP	SS	EN	LA	CM	MC	MS	NS	LC	BE
Pedagogy / Psych.	*	8	1	1	3	3	4	5	6	1
Social Sc.		*	3	3	2	4	7	6	5	1
Engineering			*	3	3	7	5	5	4	4
Law				*	6	6	5	6	2	6
Communic. / Media					*	5	5	4	5	4
Math / Comp. Sc.						*	5	8	5	3
Medical Sc.							*	7	5	2
Natural Sc.								*	5	2
Language / Culture									*	0
Business / Economics										*

Table 4.5: Overlap in effect direction (negative, positive, no significant difference) for the eleven traits between study fields

4.5.3 Change in Dispersion

In the preceding analysis no mean change in personality as a result of studying could be found, but it could be that the distribution of traits changes in other ways. For example, students could become more similar over the course of their study. We estimate equation 4.3 type regression models in which the deviation between an individuals personality and the average personality of the respective study field is explained by studying longer. Again, this regression is repeated for the Big 5 personality traits and the six economic traits. To test for stability we vary the set of control variables that are included in the two models. Once more this leads to three different types of models. Type I models use the full set of control variables, type II models uses entry age as the only control variable and type III models use no controls.

There are no signs of a general trend in the deviation between individual and study field mean personality. Across type I models only eleven out of 110 coefficients reveal significant changes in the standard deviation of the personality distribution over time. Moreover, from those eleven significant coefficients four point towards a reduction in standard deviation while seven show a significant increase. This picture is also robust across different formulations of the models as shown in Table 4.6. We can also see from Figure 4.2 that the p-values show no clear clustering and seem to follow a uniform distribution.[16]

Nevertheless, it should be noted that for each of the traits respectively the coefficients point in the same direction. For no trait both a reduction in the standard deviation of some fields and an increase for other fields could be observed. For Altruism and Emotional Stability the results are above what one would expect at the 5% significance level, with three out of ten study fields showing a lower standard deviation in Altruism and four out of ten study fields showing a larger standard deviation in Emotional Stability for later semesters. Generally, however, there is little evidence that students approach to or depart from the personality mean of their subject over the course of their study.

Trait	Specification I		Specification II		Specification III	
	Significant	R : I	Significant	R : I	Significant	R : I
Altruism	3/10	3:0	3/10	3:0	3/10	3:0
Impatience	0/10	0:0	0/10	0:0	0/10	0:0
Neg. Reciprocity	2/10	0:2	2/10	0:2	2/10	0:2
Pos. Reciprocity	0/10	0:0	0/10	0:0	0/10	0:0
Risk Aversion	1/10	0:1	2/10	0:2	2/10	0:2
Trust	0/10	0:0	0/10	0:0	0/10	0:0
Agreeableness	0/10	0:0	0/10	0:0	0/10	0:0
Conscientiousness	0/10	0:0	0/10	0:0	0/10	0:0
Extraversion	0/10	0:0	1/10	0:1	0/10	0:0
Emotional Stability	4/10	0:4	4/10	0:4	4/10	0:4
Openness	1/10	1:0	1/10	1:0	1/10	1:0
Total	11/110	4:7	13/110	4:9	12/110	4:8

Control Variables	Specification I	Specification II	Specification III
Entry Age H.E.	4/11	5/11	-
Gender	6/11	-	-
GPA	5/11	-	-
Parental Edu.	5/11	-	-

Table 4.6: Share of significant changes in the deviations between individual and study field mean personality including the direction (R - reduction, I - increase) for different model specifications

[16]The null hypothesis of a uniform distribution cannot be rejected for each of the three models at p-values of 0.76, 0.48 and 0.13 respectively

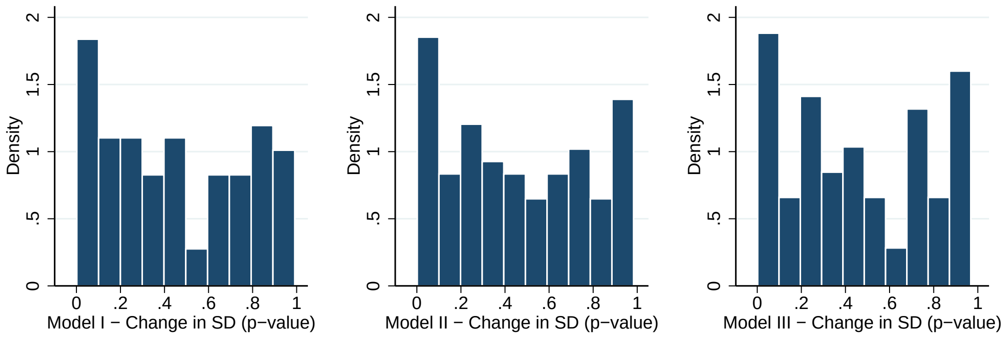

Figure 4.2: Distribution of the p-values of the deviations between individual and study field mean personality

4.6 Conclusion

Personality is an important driver of labour market outcomes. Past research has focused on the effect of personality on job sorting (Dohmen & Falk, 2010). This decision, however, is driven by the earlier subject choice. Understanding the link between personality and study field is therefore crucial in understanding job sorting. Moreover, it is conceivable that studying a certain subject affects the personality of students. If this was the case it would be valuable to know whether such changes are favourable with respect to the student's future in the labour market. The personality of an agent defines the environment under which he can operate comfortably. If a certain subject appeals to students with specific personality traits this may be because of its particular combination of teaching style, level of abstractness or degree of human interaction. Knowing about student personalities could therefore also help to improve current education programs by designing them to accommodate their particular group of students or by explicitly targeting new groups of students. For example, study programs attracting extravert students may benefit from greater interactiveness. Countries aiming at increasing the share of students in the natural sciences may devise new programs targeting different student pools.

In this paper we study the relationship between the personality of students and their field of study. Personality is measured by the Big 5 personality traits as well as six economic traits. A simultaneous analysis allows to disentangle the selection into a study field due to a certain personality from the effect of studying a certain subject on the personality. We find strong evidence for selection into study tracks based on personality, where in the estimated models 53 out of 110 selection coefficients deviate significantly from the weighted average. We cannot confirm a change in personality as a result of studying a specific subject. Only eight out of 110 change coefficients differ significantly from the weighted mean. Moreover, we also do not find a change in the standard deviation of personality as a result of studying a certain field. Out of 110 coefficients only four point towards a reduction in standard deviation while only seven point towards an increase. The findings are robust with respect to various control variables.

Chapter 5

International Education and Economic Growth

5.1 Abstract

In recent years international student mobility has increased. While net hosting countries are in a better position to win highly educated students for their labour force, they face the additional cost of providing the education. In much of continental Europe these costs are not levied on students, but are borne by the national tax payers, making them an active topic of debate. Borrowing some fundamental equations from the Lucas growth model, this paper addresses the question whether countries benefit from educating international students. We derive conditions under which international education has a positive effect on economic growth, overall and in each specific country. Based on empirically motivated parameter values to calibrate our two-country model we find that international student mobility increases steady state growth for both countries on average by 0.013 percentage points. A small country that is favoured by the inflows of a larger country could experience an extra growth of 0.049 percentage points. The benefits from international education increase when a country tunes its education and migration policy.

5.2 Introduction

Education is generally viewed as an important determinant for economic growth. In recent years, international mobility of students in higher education has increased substantially and further growth is expected. This raises the question how the international flows of students will affect economic growth in general and in particular how it will affect it in those countries that either receive or send many students.

The aim of this paper is to develop an endogenous growth model that incorporates the international mobility of students and to calibrate the model to investigate potential growth effects of internationalisation in higher education. We do this by constructing a two-country model, in which a fraction of the students in higher education studies abroad, around the human capital accumulation equation from Lucas (1988). We assume that the host country pays the direct costs of the university education. In the literature we look for plausible values for the parameters and the uncertainty of these estimates. Based on these we simulate potential growth profiles for countries that send or receive students. Our main findings are that total growth of both countries together always increases in steady state. Countries that receive a large group of foreign students who stay after their study will have a larger than average steady state growth rate. At the same time countries that receive a net surplus of students face an immediate negative shock in income when internationalisation increases. Receiving a large share of international students, thus, leads to a lower income at first but will benefit the country in the long run. This payback period is shorter if the fraction of foreign students that stay is larger. An international labour market that easily adopts home-educated foreign students, therefore, complements access for international students to the universities.

The question how internationalisation in higher education affects economic growth has important policy implications in the debate about the European market for higher education. While in countries like Australia, the US and the UK foreign students pay a fee that covers the costs of higher education, this is not true for European students that want to study in another European country. The Bologna agreement has created a common market for higher education in Europe comparable to the common market that already exists in the Anglo-Saxon World. There is, however, one main difference between the two models. Whereas in Anglo-Saxon countries tuition fees differ between locals/nationals and foreigners (in the US they even differ between in-state and out-of-state students and in addition between US and foreign students), this difference does not exist in Europe. Freedom of settlement in Europe implies that all European students must be treated the same and hence pay the same tuition fees as domestic students. For the Netherlands, for example, this implies that all European students pay the Dutch tuition fee of about 1.800 Euros per year. For Germany this means that all European students can study for free at a number of German universities. Governments are therefore confronted with the question whether they should promote the inflow of foreign European students or should make it less attractive for foreign European students to study in their country, and perhaps encourage their own students to study abroad.

This paper is related to literature about the returns to education and endogenous growth. Economists have been capturing the effect of education on economic growth into a series of growth models, which go back to the Solow growth model. These models manage to capture a broad range of the features associated with education, such as positive externalities and opportunity costs included in Lucas (1988) or the necessary monetary investment in Mankiw, Romer, and Weil (1992). Research shows that an investment in education can be a profitable: in his overview of empirical research McMahon (2004) finds that the private rate of return on education is around 10 percent while the social rate of return is around 17 percent for OECD countries. Empirical evidence confirms the positive effect of education on economic growth. The key driver of this relation is the positive relation between education and productivity (Mankiw et al., 1992).

The paper also relates to the literature on student mobility. Existing endogenous growth models assume that graduates stay in the country after finishing their studies. But with increasing globalisation and increasing (student) mobility, graduates do not automatically stay in the country in which they have been educated. This does not only hold for European students: in particular the BRIC countries[1] have been very active in changing the brain drain into a brain gain by attracting natives who have been educated abroad, back to their home-country. On the other hand, part of the international student population is expected to stay in the host country. This changes human capital as well as the labour force in a given country and consequently leads to interesting growth effects. What happens when the net flow of students for a country is negative? Do all countries benefit from educational globalisation? These questions can be answered from the analysis of this paper. Similarly, countries subsidising many foreign students query whether the expected benefits exceed the cost of providing the education. With many students able to move to their desired place of study, educational protectionism could soon be a matter of debate.

The analysis in this paper evaluates the assumption that studying abroad may benefit some students. This could be either because the quality of universities in another country is better in general, or because the match between student and university may improve. Internationalization could also enhance economic productivity because of the cultural experience that students obtain in foreign education as argued by Mechtenberg and Strausz (2008): "The development of multi-cultural skills are seen as indispensable in a European Union that strives for full economic integration while preserving the diversity of its cultures" (p. 110, Mechtenberg and Strausz (2008)). We contribute to this literature by showing the relevance of the added value of international education for economic growth. In addition we take both the sending and the receiving country into account and discuss the relation between internationalisation of education and internationalisation of the labour market via

[1] The term refers to Brazil, Russia, India and China.

migration.

This paper is organised as follows. Section 2 presents the model. In section 3 we discuss the parameter values that we use to simulate the model. The results of the simulation are presented in section 4. Section 5 concludes.

5.3 The Model

5.3.1 Basic equations

Our model represents a "Solow style" simplification of the Lucas model[2] (Lucas, 1988). To model international flows of students we extent the model by introducing a second country called Foreign, whose variables are marked by asterisks. Our domestic county is called Home. Production in the model takes place in a similar fashion as in the original Lucas Model where output depends on capital and effective workers. The latter consist of the total labour force L times the share of workers v and the stock of human capital h:

$$Y = K^{\alpha} (vhL)^{(1-\alpha)} \tag{5.1}$$

Investment into physical capital is derived from a constant savings rate s and depreciates at a constant rate δ:

$$\dot{K} = sY - \delta K. \tag{5.2}$$

As in the Lucas model, education is necessary for the creation of human capital. Imagine a world where there exist three different types of individuals: Workers (vL), students (uL) and teachers ($(1-u-v)L$). Students can either receive their education domestically with productivity ρ, or they can go abroad and receive foreign education. The productivity of such international education ϕ is the sum of the domestic productivity in the foreign country ρ^* and an international premium ϵ. Similarly, ϕ^* is the sum of the domestic productivity ρ and the international premium for foreign students ϵ^*. The term productivity in this context refers to the rate at which students accumulate new human capital. This parameter could be heterogeneous among students.

[2] Lucas (1988) calculates the savings rate endogenously. We assume a constant savings rate as in Solow (1956). This simplification was inspired by the high quality teaching material from Christopher D. Carroll, that is available online.

We assume that the productivities of education are exogenous. This is a limitation to the model as the rate of internationalisation could have an effect on the productivities. The direction of this effect, however, is so far not determined and could be positive as well as negative. For this reason and to keep the model simple we assume the productivities to be fixed. The growth of human capital is described as:

$$\dot{h} = hu\left((1-i)\rho + i(1-\lambda)\phi + Ri^*\lambda^*\phi^*\right),$$
$$\text{where } R = \frac{u^*L^*}{uL}; \phi = \rho^* + \epsilon \text{ and } \phi^* = \rho + \epsilon^*. \tag{5.3}$$

The structure of this equation is same as in Lucas' model. In fact, when setting the percentage of students that study abroad i equal to zero, the equation gives back Lucas' equation where $\dot{h} = hu\rho$. The difference here is the term $((1-i)\rho + i(1-\lambda)\phi + Ri^*\lambda^*\phi^*)$, which is a weighted average of the different educational productivities. The first element $(1-i)\rho$ weighs the domestic productivity of education by the percentage of Home students enrolling in domestic education. The second term $i(1-\lambda)\phi$ looks at the percentage of Home students that decide to obtain education in the foreign country at productivity ϕ and return to the Home. Since it can be expected that students will only study abroad when they benefit from this we assume that $\phi = \rho^* + \epsilon > \rho$ and $\phi^* = \rho + \epsilon^* > \rho^*$. It is a feature of our model that students who obtain education in the other country might not return to their country of origin. The parameter λ captures this probability to stay. The second term, therefore, only includes those international students in Home's human capital growth that also return to the country. The last element considers the international students from the foreign country that decide to study and stay in Home. It is additionally weighted by the relative size of the two countries student populations $R = \frac{u^*L^*}{uL}$. This is important because if, for example, Foreign was four times the size of Home and had the same values for i and u, Home would see four times more students coming into the country than leaving it for education. Overall, this equation introduces productivity differences and the concept of brain drain and brain gain to human capital formation.

The original Lucas model does not explicitly distinguish between teachers and students. A fraction u of the workforce is not working in the productive sector but puts effort in learning. This fraction u includes both students and teachers, while ρ is the productivity of teachers and students together. In our extension we need to distinguish students from teachers, since we assume that teachers always come from the Home country, while students might also come from the Foreign country. Our fraction u therefore only refers to the fraction of students in the population and is thus lower than u in the Lucas model. Moreover, our ρ refers to the productivity of students in learning and will therefore be larger than ρ in the Lucas model which refers to students and teachers.[3]

A necessary condition for students to accumulate any human capital is the availability of teachers. While students and teachers produce human capital together, we assume that only students can store human capital. Moreover, we take as given that at any point in time there exists the same ratio between teachers and students θ in both countries. This assumption enables us to effectively account for the costs of education and to leave out teachers from the human capital accumulation equation. Assuming that both countries have the same teacher student ratio, θ, we define the share of workers as anybody who is neither a student nor a teacher. As a result, the costs of education per student will be very similar in the two countries. The share of workers in the population is then given by

$$v = 1 - u - u\theta\left(1 - i + Ri^{*}\right).$$

Student migration has a direct effect on the population size in both countries. We look at two different scenarios with respect to the balancing of migration flows. In the first scenario we assume that the population size of both countries is constant. Consequently, the growth in the population through channels other than student migration (the birth rate or migration of unskilled workers) has to counterbalance the student migration flows. In the second scenario we will assume that student mobility will cause changes in the population size of the two countries. Here we assume all other causes of population growth to be absent. Consequently the country that net receives most students will face a population growth while the other country will face a reduction in its population.

5.3.2 Solution

To be in steady state, capital per effective capita needs to be constant.

$$\begin{aligned}\frac{\dot{K}}{hL} &= 0 \\ \Rightarrow s\frac{Y}{hL} &= \frac{K}{hL}\left(\delta + g_h + g_L\right).\end{aligned}$$

This leads to an output per capita of:

[3] All labour that is required to build and maintain the universities is counted as teachers in this model.

$$\frac{Y}{L} = h\left(\frac{s\left(1-u-u\theta\left(1-i+Ri^*\right)\right)^{\frac{1-\alpha}{\alpha}}}{\delta+u\left((1-i)\rho+i(1-\lambda)\phi+Ri^*\lambda^*\phi^*\right)}\right)^{\frac{\alpha}{1-\alpha}}.$$

Even though this expression may seem complex at first sight its interpretation is simple. All items which are listed in parentheses are constant. Therefore, output per capita grows at the same rate as the human capital stock given by

$$g_h = u\left((1-i)\rho + i(1-\lambda)\phi + Ri^*\lambda^*\phi^*\right).$$

Restricting student migration to balance in steady state requires an additional steady state condition. Ignoring other types of migration, the change in the Home labour force is the difference between the inflow of international foreign students who decide to stay in Home after education and the outflow of the respective Home international students who decide to stay in Foreign:

$$\dot{L} = L^*u^*i^*\lambda^* - Lui\lambda$$

Since in the steady state the labour force is required to be constant it follows that

$$L^* = \frac{Lui\lambda}{u^*i^*\lambda^*}.$$

Plugging this condition into the equations above allows us to solve for the steady state level and growth of Home if student migration is in balance.

5.3.3 The Effects of International Education

Ultimately, this paper seeks to analyse under what conditions international education is beneficial for a country using steady state output per capita without internationalisation in higher education as a benchmark. Generally, two types of effects are conceivable. In the long run, growth effects that lead to a change in growth of output per capita in steady state are of greatest interest. They generally follow from changes in the human capital accumulation equation. In the short run, level effects also affect growth rates, resulting in a lower steady state of capital per effective capita, but their impact on the growth rate is not permanent. In that spirit, level effects lead to short term increases or decreases in the growth rate while growth effects prevail in steady state. To investigate both we compare the steady state levels and growth without international education with those which include international education.

Starting with the case in which migration flows balance as a whole we can derive necessary conditions for internationalisation in higher education to be beneficial. We reproduce each country's steady state growth equation for convenience. Home and Foreign respectively, will experience steady state growth equal to:

$$\begin{aligned} g_h &= u\left((1-i)\rho + i(1-\lambda)\phi + Ri^*\lambda^*\phi^*\right) \\ g_h^* &= u^*\left((1-i^*)\rho^* + i^*(1-\lambda^*)\phi^* + \frac{1}{R}i\lambda\phi\right). \end{aligned}$$

To examine how international education affects the overall growth rate in both countries we can aggregate the growth rates. Assuming that output per capita in both countries is comparable, their respective population sizes can be used as weights. International education increases total growth in the countries if the following holds:

$$\begin{aligned} \frac{Lu\rho + L^*u^*\rho^*}{L+L^*} < \frac{Lug_h + L^*u^*g_h^*}{L+L^*} \\ \Rightarrow i\rho + i^*R\rho^* < i\phi + i^*R\phi^*. \end{aligned}$$

Economic theory would predict that students only go abroad if it is more productive. If this assumption holds, it is beneficial for both countries together to open up for international students. The question remains, however, whether both countries separately benefit from internationalisation. Home will experience an increase in its growth rate if:

$$u\rho < u\left((1-i)\rho + i(1-\lambda)\phi + Ri^*\lambda^*\phi^*\right).$$

$Ri^*\lambda^*\phi^*$ is always positive. This is not necessarily true for $(-i)\rho + i(1-\lambda)\phi$ which is positive only if

$$\rho < (1-\lambda)\phi.$$

Hence, the domestic productivity must be lower than the international productivity times the share of students that returns to Home. If this term is negative it has to be sufficiently small to make the steady state growth rate positive. A negative growth rate is only possible in either Home or Foreign, but not in both. In general, the country that receives and keeps the smaller share of foreign students faces a lower growth rate.

The steady state growth rates determine the effects of internationalisation in the long run. In the short run, however, matters can turn out very differently. Immediately after the introduction of international student flows, the only effect is that the country that receives more students needs more teachers, while the other country needs fewer teachers. Since we assume the same teacher to student ratio in both countries, this implies that the aggregate short run effect is zero. For each country individually, however, this direct effect might be positive or negative depending on whether more or less members of the labour force are required for teaching.

$$s(1-u-u\theta)^{\frac{1-\alpha}{\alpha}} < s\left(1-u-u\theta(1-i+Ri^*)\right)^{\frac{1-\alpha}{\alpha}}$$
$$\Rightarrow i < Ri^*.$$

To investigate the effects of internationalisation on growth if students migration leads to changes in the population of both countries a similar analysis is informative. The steady state growth rate in the home country is now equal to

$$g_h = u((1-i)\rho + i(1-\lambda)\phi + i\lambda\phi^*)$$

Growth in both countries together is higher with international education if the following holds true.

$$\frac{Lu\rho + L^*u^*\rho^*}{L+L^*} < \frac{Lug_h + L^*u^*g_h^*}{L+L^*}$$
$$\Rightarrow \rho + \frac{\lambda}{\lambda^*}\rho^* < \phi + \frac{\lambda}{\lambda^*}\phi^*.$$

Again, this assumes that output per capita is comparable in the two countries so that population sizes can be used as weights. The term will always be positive if international students are rational and hence $\rho < \phi$. Moreover, a country is able to benefit individually from internationalisation in higher education if it holds that.

$$u\rho < u((1-i)\rho + i(1-\lambda)\phi + i\lambda\phi^*)$$
$$\Rightarrow \rho < \phi + \frac{\lambda}{1-\lambda}\epsilon. \tag{5.4}$$

This condition is always met if $\rho < \phi$. Moreover, we can see that in the long run, when migration is balanced, the growth rate increases with the productivity of education of domestic students in the foreign country. A certain share of these students returns to Home after graduation. Additionally, Home benefits by the international premium that Home students in Foreign gain. This effect increases if more foreign students decide to stay in Home after education.

Finally, we can have a look at the level effects in the case where student migration balances.

$$s(1-u-u\theta)^{\frac{1-\alpha}{\alpha}} < s\left(1-u-u\theta(1-i+\frac{\lambda}{\lambda^*}i)\right)^{\frac{1-\alpha}{\alpha}};$$
$$\Rightarrow \lambda < \lambda^*$$

This means that if student flows balance the level effect is no longer dependent on the actual student inflow but on the probability that those students stay in the country. If the probability that home students stay abroad is smaller than the probability that foreign students stay in Home, the level effect is positive in the home country.

5.4 Empirics

5.4.1 Parameter Callibration

In order to apply the model it is essential to evaluate its parameters empirically. The exact share of international students depends on the country at hand. Within the model the internationalisation rate i is measured in terms of the share of students which are educated in a foreign country. A broad comparison of those rates of internationalisation is possible with the help of a yearly assessment by Eurostat. According to their measurement, internationalisation within Europe averages 2.9 percent (Statistical Office of the European Communities, 2012). However, given that not all international students register in the foreign country, the Eurostat figures are likely to be under-reported. This becomes visible at the example of the Netherlands, for which Nuffic collects data on a university level. While Eurostat reports that 2.3 percent of the Dutch students go abroad, Nuffic (2011) reports a rate of internationalisation of 7.1 percent. Since the Netherlands are below the European average in terms of outgoing students in (Statistical Office of the European Communities, 2012), the simulations are done for international shares between 5 and 10 percent.

Data quality is weaker when it comes to the probability to stay in a foreign country after graduation. In a recent paper, Bijwaard (2010) suggests that male study related migrants have a chance of 19 percent to stay in the Netherlands. For female students the chance is estimated at 26 percent. The values fluctuate strongly between different countries of origin. Moreover, these figures might be over reported. The data includes only students who register in the Netherlands and these have a higher probability to stay than students which do not even register in the first place. Hence, the probability to stay used in the simulations is somewhat lower and equal to 15 percent.

To estimate the share of students in the labour force as measured by the model we consider the working population only. Eurostat data shows that men in Europe work between 40 and 46 years over their lifetime, while women work 36 to 44 years (Brugiavini & Peracchi, 2005). Moreover, university education is supposed to require three to four years for a Bachelor and four to six years for a Master degree. In reality even more time may be needed to finish university. Combining this information with the European target that 40 percent of the population should hold a university degree allows to calculate scores for the population share of students. These range between roughly 2.5 percent and 7.5 percent, and hence, 5 percent will be used in the simulations.

Values for the teacher to student ratio θ can be found on the basis of data published by the European Commission. Currently, there is a total of roughly 19 million students in Europe, while higher education institutions employ 1.5 million staff members. Hence, θ should be close to 8 percent. This number neglects workers that work on buildings and equipment for the university sector.

Suppose there was no international education. Setting $i = i^* = 0$, the human capital accumulation equation would reduce to $\dot{h} = hu\rho$ as in the original Lucas model. The parameter ρ, then, represents the growth of the human capital stock. In a sense, it is the return on human capital for every unit of human capital each time period. To evaluate plausible values for ρ we make use of the vast literature estimating real returns to education. In their influential review paper, Psacharopoulos and Patrinos (2004) estimate the social return on investments into education to be 10.8 percent. In the context of our model every unit invested in human capital grows with rate ρ and every one percent increase in human capital results in a $(1 - \alpha)$ percent increase in output. To obtain an estimate for ρ we hence use that

$$r_{edu} \approx \rho(1 - \alpha)$$

Setting $r_{edu} = 10.8$ and $\alpha = \frac{1}{3}$ gives an estimate for ρ at 15.75 percent. The return in human capital that is specific to international education is given by ϵ. This variable is important as it determines the extra learning gains from international education. Unfortunately, not much conclusive evidence exists on whether international education holds a return premium. However, several empirical studies have shown that students spending time abroad have benefited in terms of improved language skills and better cultural understanding (Sutton & Rubin, 2004; Freed, 1995). Many verbal accounts, moreover, suggest that students undergo some personal development when going abroad. International experience, indeed, catches a wage premium in the labour market, but currently it is uncertain how much of it is attributable to selection (Oosterbeek & Webbink, 2006). Applying the same approximation as above $\epsilon = 0.02$ implies a rate of return premium of about 1.3 percent.

5.4.2 Simulations

The model as formulated can be calibrated to fit many different pairs of countries. Whenever we compare our findings to an economy with purely domestic higher education, we name this economy "'Lucas"'. Whenever we do this, we mean that we are comparing our results to the simplified version of the Lucas model rather than with the original. In the following section we will consider a pair that has the same parameter values except for size, where we assume that the labour force of the foreign country is initially four times larger. This setup roughly resembles the cases of Germany and the Netherlands. All parameter values used lie within the ranges established in the previous section:

Model Parameter	Value
α	$\frac{1}{3}$
s, δ	0.1
θ	0.08
u	0.05
i	0.1
ρ, λ	0.15

Table 5.1: Parameter values used for callibration.

Imagine this two-country world and suppose that international education does not carry any premium. Given that all parameters are identical with the exception of population size, we should expect to see a great surplus of students entering the small country every period of time. Since all students have the same probability to stay, the small country then faces a positive migration of well-qualified students as compensation for the initial increase in the cost of education. Figure 5.1 plots the development of both countries' income per capita relative to what it would have been without international education. The left panel assumes that the population size of both countries remains the same, and thus that student migration is offset by exogenous factors. The small country represented by the thick line initially starts off at a lower income per capita level. This decrease in GDP per capita equals -0.084 percent. However, since it enjoys a larger growth rate, it reaches the no-internationalisation level of income within only four periods. Thereafter, brain gain leads to constantly higher levels of income than under the non-international *Lucas regime* and to 0.034 percent faster growth in steady state.

Table 5.2 gives additional comparative statics for this scenario relative to the domestic education economy, which, under our parameters for u and ρ, grows at 0.75 percent in steady state. If more students of the home country study abroad ($i = 0.15$) the extra steady state GDP-growth decreases. When the mobility of foreign students increases ($i^* = 0.15$) the steady state growth rate increases. A simultaneous increase in both mobility rates is more advantageous for the smaller than for the larger country. The same is true for the percentage students that stay in the country of study. An increase of the fraction of students that remain abroad negatively influences the growth rate, but the smaller country benefits more from a higher percentage of stayers than the larger country.

The right panel of Figure 1 shows what happens if the population size of both countries starts to change due to student mobility. Since for the Home country GDP growth is now accompanied by a population growth Home needs much more time to recover from its initial drop, and GDP per capita will grow slower. The reason for this is that the capital stock only adjusts gradually to the increased population size. If an increase in the number of workers would be accompanied by an extra investment in capital, the growth patterns would look more like in the first panel. Figure 2 shows what happens in the very long run. With a constant increase in population the smaller country becomes larger and larger. This means that the mobility flows become more equal. The smaller country has more students and, therefore, also more students will study abroad. Eventually, the differences in population size will disappear and the growth effects vanish. It should be stressed that this result is a consequence of having constant and equal parameter values for u, i, λ and ρ. If one country, for example, has a higher internationalisation rate, country sizes will not fully equalise in the long run.

Thus far, in the Figures we have only considered the purely distributional effects of international education. Figure 5.3 repeats the simulation assuming an international premium of two percent corresponding to about 1.3 percent greater returns to education. This corresponds to the penultimate row in table 5.2. Relative growth rates of both countries increase across scenarios such that in either scenario both countries benefit from international education. Economic growth in the home country increases from 0.034 percentage points to 0.049 while for the foreign country a lower growth of $-.0085$ turn into a faster growth of 0.0044. Based on these parameters economic growth in the smaller country would increase with 0.049 percentage points while GDP per capita would increase with 0.0044 percentage points. The average annual extra growth in both country therefore equals 0.013 percentage points.

This shows that at the most plausible values of the parameters international education is beneficial for both countries. Naturally, policy makers can attempt to increase their share of the overall gains, by targeting variables like the probability to stay through migration policy or by making it easier for foreign students to start studying. Even if no international premium exists, international education may be mutually beneficial. This is, for example, the case when one country has a higher productivity in educating students than the other country; a relationship we may see between a more and a less developed country. Under the assumption that only students from the less developed country want to study and stay in the more developed country, international education is universally beneficial as shown in Figure 5.4. Here, the less developed country benefits as the higher human capital of the students returning from the developed country outweighs the human capital loss from brain drain. The developed country loses in the short run due to the higher costs of education, but quickly recovers and gains from the inflow of talented students later on.

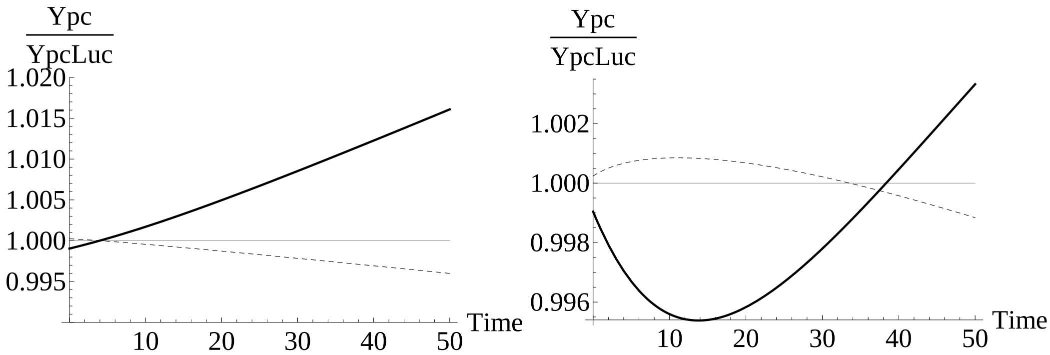

Figure 5.1: Base Scenario without Labour Adjustments (Left), with Labour Adjustment (Right)

5.5 Conclusions

In this paper we developed an endogenous growth model to investigate the effects of internationalisation in higher education on economic growth. In aggregate, assuming that individual students only go abroad when that is beneficial to them, in the long run internationalisation is always beneficial for the two countries together. The distribution of the gains, however, depends on a variety of parameters like the rate of internationalisation and the probability to stay in a foreign country. While there are cases in which both countries gain, it is also possible that one country loses.

	NL			DE	
Rel. to Lucas	Init. Δ (%)	Recov. in (t)	SS Gr.(%)	Init. Δ	SS Gr.
Base L. exog.	-0.084	4.00	0.034	0.021	-0.0085
$i = 0.15$	-0.070	4.00	0.028	0.017	-0.0071
$i^* = 0.5$	-0.141	4.00	0.056	0.035	-0.014
$i = i^* = 0.15$	-0.126	4.00	0.051	0.032	-0.013
$\lambda = 0.2$	-0.085	4.50	0.030	0.021	-0.0075
$\lambda^* = 0.2$	-0.085	2.75	0.049	0.021	-0.012
$\lambda = \lambda^* = 0.2$	-0.085	3.00	0.045	0.021	-0.011
$\rho = \rho^* = 0.2$	-0.085	3.00	0.034	0.021	-0.0085
$\rho = \rho^* = 0.1$	-0.085	6.00	0.034	0.021	-0.0085
$\epsilon = \epsilon^* = 0.02$	-0.085	2.75	0.049	0.021	0.0044
$\epsilon = \epsilon^* = 0.05$	-0.085	1.75	0.070	0.021	0.014

Table 5.2: Comparative Statics for the left panel of Figure 5.1. The first column gives the Initial Change of Output per Capita relative to Lucas. In the second column we give the time it needs to reach the Lucas' level of output per capita again. The third column has the changes in the steady state growth rate due to internationalisation in percentage points.

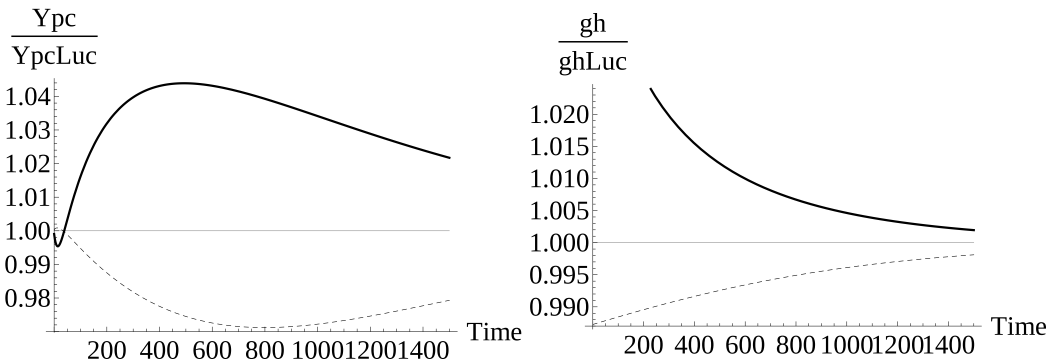

Figure 5.2: Long Run adjustment of per Capita Income and Human Capital relative to Lucas when Labour is Endogenous.

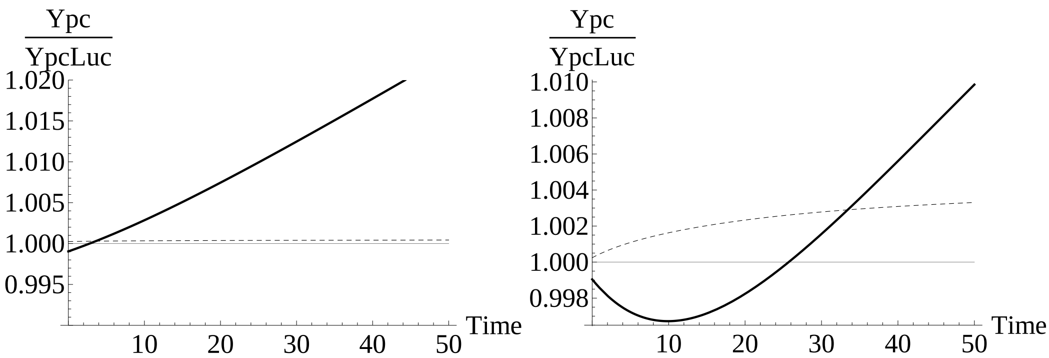

Figure 5.3: Scenario with $\epsilon^* = 0.02$ without Labour Adjustments (Left), with Labour Adjustment (Right).

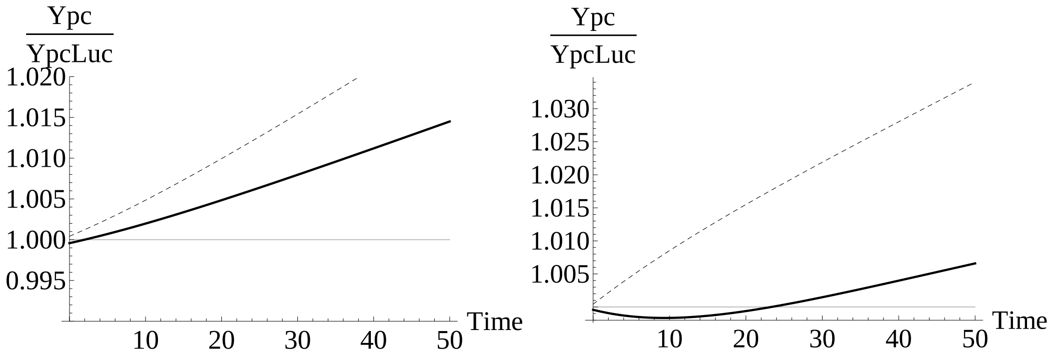

Figure 5.4: Case where countries are unsymmetric in most parameters except size: $\rho = 0.2, \rho^* = 0.1; i = 0, i^* = 0.2; \lambda^* = 0.2$.

This implies that there can be two obstacles for the internationalisation of university education. First, countries that emphasise short run effects in their decision making might try to limit access for foreign students. The reason for this lies in the costs of education which lowers short term output. Second, an unequal division of the benefits of internationalisation might hamper international cooperation. When a large fraction of graduates leaves the country after studying there, net receiving countries may find it more difficult to benefit from international education. At the opposite extreme, if a substantial fraction of the students stays in the country of study, it will be attractive for each individual country to promote foreign students to study in their country. This could lead to a rat race in which countries attempt to get an as large as possible share of the flow of international students. Considering long-term growth, a country benefits if it attracts many foreign students who stay in the country. A policy to open up universities for foreign students is therefore complementary to a policy to make the labour market attractive for these foreign students.

Concluding remarks

All mistakes are my own.

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