1 Introduction

Education, Education, Education. With this slogan the British Prime Minister Tony Blair set out his priorities for office in 2007. Indeed, many governments have now formulated the need for greater education spending and try to facilitate international exchange. The idea is that education is an investment that pays off in the long run through higher economic growth on a path towards a "knowledge society". Economists, for a long time, have tried to capture the effect of education on growth and introduced the idea into a series of models, which go back to the Solow model. While 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 et al. (1992), they have not yet attempted to embrace international education. However, international education has left the ivory tower and is becoming a mass phenomenon which can impact economic growth.

Multiple interesting transformations are linked with this development. On the one hand it is engaging to ask whether the productivity of international education is large enough to justify the promotion of exchanges. Here, Economics faces the problem that its standard trade theory seems incompatible with models for international growth. The one casually assumes countries with different factor endowments trading different goods, while the other focuses on the "production" as a whole. More fundamentally, trade theory tends to be static and "non accumulative" and is therefore regarded as part of total factor productivity in growth models. Human Capital, however, is accumulating and should thus be treated differently.

2 Areas of Analysis

This paper believes that international education has a positive effect on human capital. Economic theory lends many possible arguments for this assumption. From a Ricardian perspective one might suggest that different countries benefit from specialising on certain branches of education and that it is efficient if the internationally most talented students in this subject area can attend these courses. Current observation even hints that countries like the UK specialise in education in general and view it like an export good. While this probably explains a fair share of the rise of international education it does not explain the growing number of exchange programmes.

Over the last years European universities have truly participated in globalisation. Most universities now aim at a diverse international student population and try to find many different partner universities for exchange programmes. Such exchanges do not only take place within the industrialised countries, but even go to those parts of the globe which cannot be suspected to have specialised in education as an export good. On the other hand exchanges within the same country tend to be rare. This paper believes that the cultural experience which students make in these exchanges increases their economic productivity. The fact that firms often want applicants to have international experience lends further legitimacy to the argument.

Cultural exchange can be economically beneficent. It seems plausible that when people exchange their traditional views and approaches for the first time, their marginal productivity of learning is high. Moreover, knowledge about different cultures can promote social communication skills and self-awareness. Naturally, these arguments still lack the empirical backing, which will be difficult to obtain as it is difficult to measure an individual's productivity and trace it back to specific events. Independent of the necessary empirics this paper will propose ways on how to integrate the potential effect of international education into growth models.

Another visible effect concerns student movements. Some part of the international student population is expected to stay in the foreign 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 places benefit from educational globalisation? While it may be different to calculate the precise educational productivities, these questions can be answered from this paper's analysis. Similarly, countries subsidising many foreign students like the Netherlands query whether the expected benefits exceed the monetary 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 and in face of deficient empirics, Economics would be well advised to present some conceptual ideas.

As a starting point the basic models of Romer (***), Lucas (1988) and Mankiw et.al. (1992) are used and altered to include international education, thereby covering two influential endogenous growth models as well as a well recognised exogenous model. The changed models are solved for their steady state and examined about their response to changes in the variables named above. Furthermore, an optimal investment in capital, domestic education and international education will be found.

3 Modelling the effects of international education on economic growth

Different models attempt to explain the effect of education on economic growth and can be adjusted to also include the effects of international education. The following section aims to demonstrate how the effects of international education can be included in a variety of different growth models. Following from the set-up of the models, different results will be achieved. The first two models based on Romer and Lucas are examples of endogenous growth models since they produce long run growth through the endogenous accumulation of production inputs. The last model, which is an adjusted version of a model by Mankiw, Romer and Weil, puts the focus back on classical growth models. However, this paper does not aim to produce empirical tests to produce a winning model which best matches evidence. It will merely suggest what the parameters introduced could look like from the surveyed literature.

3.1 The Original Romer Model

The original model by Paul Romer suggests that output, capital and technology accumulate as a Cobb-Douglas function. The labour force is split into two parts, which are used in the production of output and in the production of ideas. Within this setup Romer discovers that there is no simple steady state as output per capita is always growing. Therefore, Romer starts to investigate the change of the steady state growth rate to see whether one can indentify cases where it converges to a constant. It turns out that a convergence point for the growth rate exists whenever the sum of the productivities of capital and ideas in the production of ideas is smaller than one. The following model will show a comparable approach including international education. While the results are similar concerning the accumulating factors, the model finds some interesting differences for the growth rate's steady state.

3.2 International Education based on simplified version of Romer's R&D model

In the model the amount of output produced depends on capital and effective labour. The production function is a Cobb-Douglas function with constant returns to scale and decreasing returns with regard to the two production factors A and K. The respective shares of capital and labour that are used to produce output are called v_K and v_L.

$$Y = [u_K \times K]^\alpha \times [u_L \times AL]^{1-\alpha}$$

Labour augmenting technology is then accumulated as follows.

$$\dot{A} = [\psi(1 - u_K) \times K]^\beta \times [\psi(1 - u_L)(1 - i) \times L]^\rho \times [\psi(1 - u_L)i \times L]^\phi \times [A]^{\theta\,1}$$

Therefore, the part of capital and labour not employed in production is used to improve the state of technology. However, the important difference to the original Romer model is that labour augmenting technology is not only produced by capital, technology and domestic education, but also through international education. The technology accumulation equation is consequently a Cobb-Douglas function which consists of four parts. No assumptions are made about the returns to scale of the production function, but it is assumed that $\beta + \theta < 1$ which is necessary to obtain constant steady state growth rates in an endogenous growth model. Relaxing the assumption of decreasing returns with respect to the two accumulating inputs of A would result in ever increasing output growth. Moreover, it is important to note that $(1 - v_L)$ and $(1 - v_K)$ are now the shares of labour and technology which are used up in education. The parameter i reflects the share of students in international education.

Moreover, it is assumed that the returns from international education are higher than returns from domestic education. For now, we rely on the qualitative reasoning pointing towards greater international efficiency. In the empirical section additional quantitative evidence will be quoted. To keep things simple it is defined that the productivity of international education is equal to the productivity of domestic education plus some international effect ε. It therefore holds that:

$$\phi = \rho + \epsilon$$

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[1]   Due to the fact that international education is an on its own, in this input Cobb-Douglas function it is not possible to get back to the original Romer model just by plugging i=0. However, this is inevitable if domestic and international education need to be included with different levels of productivity. While this is principally undesirable, it does not pose any acute problems in situations when international education exists.

Further on, in this model we assume implicitly that the share of international education is the same in all countries and that the quality of education is identical across countries. These assumptions may be problematic when looking at a wider range of countries. However, when investigating Western Europe they may be a reasonable starting point.

Finally the coefficient ψ is what we call the "Holland Effect". It measures to which extent a country can benefit from other countries using up their capital and labour to educate its labour force. Clearly, if many German students decide to study in the Netherlands, then the Netherlands are using part of their resources to train the German workforce. If the Netherlands are sending less students to Germany, ψ would be larger than 1 for Germany and smaller than 1 for the Netherlands. The formal definition of ψ will use the Netherlands as an example:

$$\psi = \frac{(DN) - (\frac{cU}{cT}ND + \left(1 - \frac{cU}{cT}\right)DN)}{DD + DN} + 1$$

The first letter refers to the nationality and the second to the country where university education takes place. The character D stands for Dutch and N stands for Non-Dutch. Additionally, the terms cU and cT represent the cost of university education and total education, respectively. A few points need to be stressed with respect to this definition. The main idea stems from cost benefit analysis. The first term DN represents Dutch students which are educated in a different country. This can be seen as a benefit from international education for the Netherlands. Along these lines the second term $(\frac{cU}{cT}ND + \left(1 - \frac{cU}{cT}\right)DN)$ represents the costs to a specific country. It is important to include the cost fractions here as the respective students gain only their university education in a different country. Hence, the Netherlands are still paying a share of the education of their own students which go to university in another country. Equivalently, the Netherlands only pay the university education of the foreign students. These costs and benefits are then taken as a share of the Dutch labour force to attain a number between -1 and 1. The fraction is then incremented by one to achieve an appropriate scale, which can be used in the human capital accumulation equation.

As usual, capital is accumulated through investments which need to equal savings in the economy. Existing capital is depreciating at a rate δ.

$$\dot{K} = sY - \delta K$$

To solve for the steady state growth of the model it is necessary to first compute the growth rates of the two endogenous variables and then determine when both these growth rates are constant. Dividing both sides of the technology accumulation equation by A yields the growth rate of technology.

$$g_A = [\psi(1 - u_K) \times K]^\beta \times [\psi(1 - u_L) \times (1 - i) \times L]^\rho \times [\psi(1 - u_L)i \times L]^\phi \times [A]^{\theta - 1}$$

Applying an equivalent operation and dividing both sides of the capital accumulation equation by K yields an expression for the growth rate of capital. Afterwards, the production function can be plugged into this expression.

$$g_K = s \times u_K^\alpha \times [K]^{\alpha - 1} \times [u_L \times AL]^{1 - \alpha}$$

The growth rates will tend to be constant if the growth rates of the growth rates are zero. Taking logs and derivatives gives the following two conditions.

$$g_{g_A} = 0 = \beta \times g_K + (\rho + \phi) \times g_N + (\theta - 1) \times g_A$$

$$g_{g_K} = 0 = (1 - \alpha) \times (g_A + g_N - g_K)$$

The two lines can be graphed in a $g_A - g_K$ space to produce a phase diagram as shown below. All locations on the blue line refer to points in which the change in the growth rate of g_A is zero, while the red line includes all the combinations for which g_K are constant.
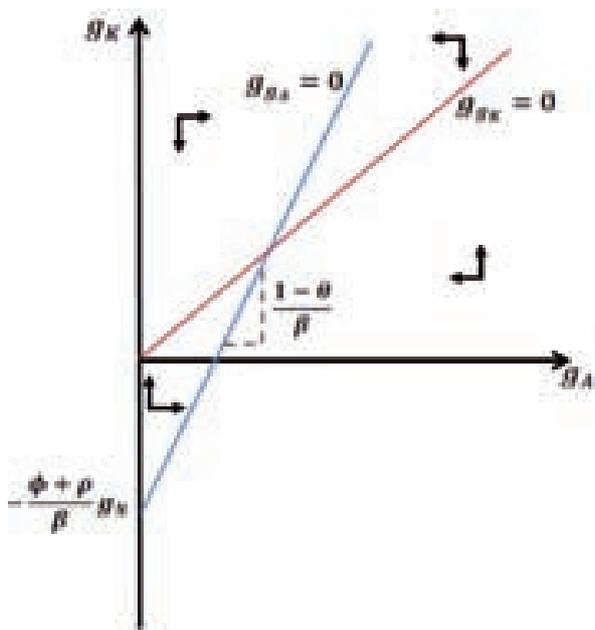
The arrows show that if g_A is larger than on the blue line, the growth of g_A will be negative because θ is smaller than one and vice versa. Additionally, if g_K is larger than displayed by the red line, the growth of g_K is negative and vice versa. Combining these two findings it follows that the two growth rates are converging to a long run equilibrium at the crossing point of the two lines. However, this only holds true as long as $\beta + \theta < 1$, which is exactly in line with the assumption we made with respect to the endogenous character of the growth of technology and capital.

If the prerequisite holds and the model is converging, it is possible to uniquely determine the growth rates of technology and capital.

$$g_A = \frac{\beta + \rho + \phi}{1 - \theta - \beta}$$

$$g_K = \frac{1 - \theta + \rho + \phi}{1 - \theta - \beta}$$

To be able to analyse the effect of international education on long-run growth it is important to compare these findings with the results of the original model by Romer. The difference in the long run growth rates of the two models results from the fact that domestic and international education have dissimilar returns. As long as it is assumed that international education has higher returns than domestic education the steady state growth of both capital and technology will be higher exactly due to this factor. The same holds true for the long-run growth rate of output, which is equal to:

$$g_Y = \frac{\beta + \rho + \phi}{1 - \theta - \beta} + \alpha.$$

Therefore, changes in the productivity of international education have a growth effect and not a level effect. This implies that increases in the productivity of international education have a permanent impact in this model. To illustrate this, the phase diagram on the left shows the mechanism after a permanent increase in ε. The new equilibrium involves higher growth rates. Additionally, the model allows to analyse the effects of an increase in international education itself. This will be measured by an increase in the parameter i. Unlike with changes in the productivity such a shock has only consequences for the short-run. In the short-term the growth rates g_A and g_K should increase, but in the long-run the economy converges back to the old equilibrium growth rates. This finding is again illustrated in the figure below.

Finally, the influence of the "Holland Effect" can be analysed. Just as the changes in i, also changes in ψ have a level effect. That means a worsening of the terms decreases g_A and g_K in the short-run, but does not alter equilibrium growth. Consequently, in this model international education is always favourable for a country when considering its long-run growth performance. However, if ψ is sufficiently small, international education can result in shortrun losses.
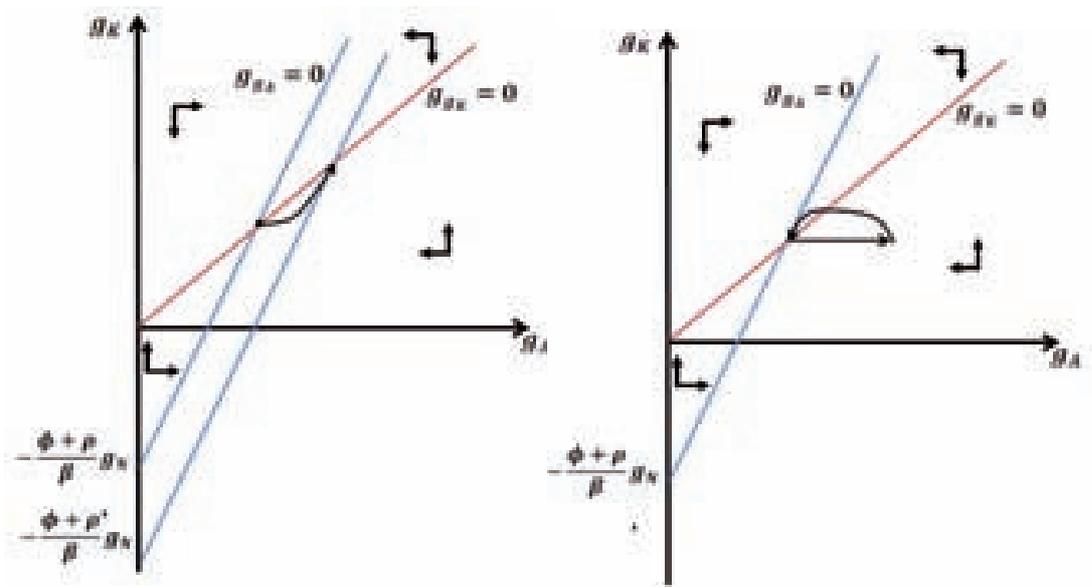
3.3 The Original Lucas Model

One of the most influential endogenous growth models was formulated in Lucas' paper "On the Mechanics of Economic Development", which introduced education as a driving force for growth. Lucas assumed that education contributed to human capital and split the work force among those who are accumulating human capital and those who are working. While Romer's focus is more on R&D, Lucas specifically investigated the effects of education. The production function consists of capital and effective labour, which is the work force augmented by its level of human capital. Additionally, the term v_L is again used to represent the proportion of workers contributing to output. Capital is accumulated to savings and diminishes at the depreciation rate δ. This implies:

$$Y = [K]^{\alpha}[u_L hL]^{1-\alpha}$$

$$\dot{K} = sY - \delta K$$

3.4 International Education based on Lucas

Starting from this, the original Lucas model needs to be changed to allow for international education. First, it is important to clarify the effects that international education can have. Naturally, education improves the level of human capital and thus contributes to h. Again, it is assumed that international education provides some extra benefit over domestic education. Therefore, the productivity of domestic education is called ρ while for international education ϕ is used, which exceeds ρ by a positive ε. Again, the "Holland Effect" is added to the model. To keep the model simple it is no longer assumed that capital is needed in accumulation of human capital and the following accumulation functions are constructed:

$$\dot{h} = \psi(1 - u_L) \times [i \times \phi\,(1 + \eta) + (1 - i) \times \rho]\ \times h$$

$$\dot{L} = \dot{L_D} + (1 - u_L) \times i \times \eta\ \times L$$

The flood of different parameters may cause confusion at first, which will be countered by spelling out the above argument. Initially, it must be noted that human capital reproduces itself. A boost in the level of h will also increase $\dot{h}$, thereby starting a cycle which does not run into diminishing returns. Human capital thus accumulates linearly with a particular coefficient. As in the model based on Romer this coefficient takes into account the proportion of the workforce in education ($1 - u_L$), the "Holland Effect" ψ and the productivity of education ρ or ϕ. Additionally, the net flow of international students as a share of the total amount of international students is added to the model. This new variable η is defined as:

$$\eta = \frac{NDD - DNN}{ND + DN}$$

The first letter corresponds to the nationality (Dutch, Nondutch) and the second to the country of university education. A third letter is added which explains in which country the respective student will be working once university is finished. Knowing this helps to understand the last term in the square bracket. We assume that a portion of those students, who benefit from international training, decide to stay in the foreign country. Naturally, this functions as a give and take. Some of the domestic students decide to stay abroad, while some of the foreign students coming in remain in the domestic economy. Thus, the real change of the labour force is equal to the change of the initially domestic labour plus the net flow of students.

These gains or losses of students also affect the accumulation of human capital and are included in the last expression in the square bracket. Note that this second effect is the real extension to the previous model based on Romer. Including labour flows from international education allows to analyse a second effect which can redirect the discussion to a completely new course.

As already in the Romer model we assume that education has the same quality in all countries and also that the international effect is the same as well as the share of international students. Additionally, a new assumption follows from the introduction of labour flows. We assume that there are no labour flows which are unrelated to international education. Even though this is truly unrealistic it should not bias the results as long as the focus is on international education. Dividing by h and L, respectively, one finds that:

$$g_h = \psi(1 - u_L) \times [i \times \phi\,(1 + \eta) + (1 - i) \times \rho]$$

$$g_N = n + (1 - u_L) \times i \times \eta \qquad where \; n = \frac{\dot{L_D}}{L}$$

Now that we have formulated a model it is possible to find a steady state. By definition, in steady state it holds that:

$$\left(\frac{\dot{K}}{hl}\right) = 0$$

Taking this derivative implies:

$$\frac{sY - \delta K}{hL} - \frac{K}{hL}\,(g_h + g_N) = \; 0$$

Plugging in the production function and solving this for the steady state yields a level of capital per effective worker of:

$$\frac{K}{hL}^{*} = \left(\frac{s}{\delta + n + (1 - u_L) \times i \times \eta + \psi(1 - u_L)[\rho + i \times \epsilon + i \times \eta \times \phi]}\right)^{\frac{1}{1-\alpha}} * u_L$$

This steady state has a number of interesting implications. On the one hand, it is not surprising to see that the savings rate has a positive level effect while the rate of depreciation and population growth has the opposite. However, there is a fascinating interplay between the educational factors. This becomes clear when the level of output per worker is considered:

$$\frac{Y^*}{L} = \left(\frac{s}{\delta + n + (1 - u_L) \times i \times \eta + \psi(1 - u_L)[\rho + i \times \epsilon + i \times \eta \times \phi]}\right)^{\frac{\alpha}{1-\alpha}} * u_L * h$$

In steady state, output per effective worker is solely growing because of advancements with respect to education. Therefore, the growth rate is equal to the growth rate h, namely:

$$\psi(1 - u_L) \times [\rho + i \times \epsilon + i \times \eta \times \phi]$$
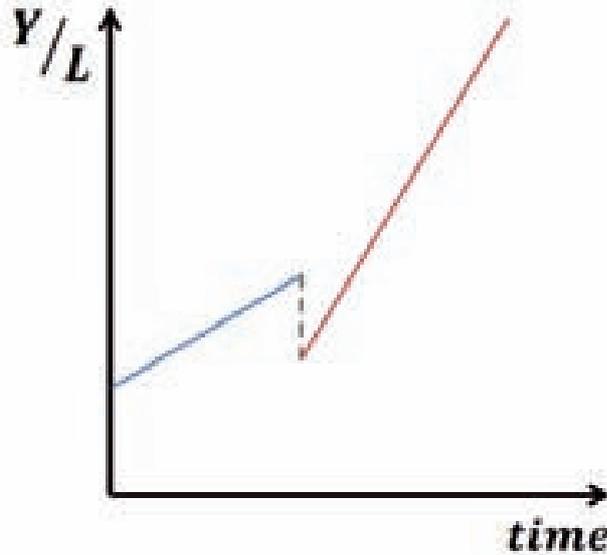
Now a fall in the share of people contributing to output v_L decreases both factors of the steady state. However, it also increases the rate of steady state growth. The developments after this shock are displayed in the graph to the left. An equivalent effect is achieved when the parameters associated with international education shift. An increase in ε or η or a decrease in ψ will then lead to a similar reaction.

However, compared to a rise of v_L the drop of the steady state is smaller and the growth effect is less pronounced. The effect of the parameter i is more difficult to analyse as it depends on other parameters as well. More international education changes the growth rate of human capital by the additional international productivity and the net inflow factor ($\Delta i \times \psi(1 - u_L) \times (\epsilon + \eta\phi)$).

This effect is ambiguous. It depends on the values of ε, η and ψ. Not surprisingly, this shows that a country stops to benefit from international education once net migration develops into a brain drain, which is large enough to counter the positive effects from higher international productivity. How can a country benefit from productivity gains if it loses its students to foreign countries? Also, it is important whether international education is balanced which is reflected by ψ. If, however, $\psi \times \phi \times (1 + \eta) > \rho$, then we obtain the result displayed in the graph above.

If the above condition does not hold, an increase in i will cause the steady state to jump and grow slower afterwards. Hence, the net movements of the student population and the Holland Effect play an important role in this model. Overall international education is still a positive sum game due to the international effect ε. However, a negative η and a negative ψ can decrease even long-run growth compared to the case without international education.

So what are the conditions for a country to overall benefit from international education when it is compared to the domestic education. In order to find this condition it is necessary to compare the growth rate of output per worker, which follows from the original Lucas model with the growth rate in this adjusted model. It can be found that international education is beneficial if:

$$\rho < \psi \times (\rho + i\varepsilon + i\eta\phi)$$

This paper decides to distinguish three rather extreme cases. In the first case $\psi = 0$, which means that a country uses up all its labour force working in education to train foreign students, while foreign countries do not train any domestic students. In this case international education can only be beneficial if $\rho < 0$; a funny condition which suggests that domestic education would have to be harmful. Still, this makes sense as we look at a case where the whole nation decides to educate foreigners rather than domestic students. This can only be optimal if domestic education is actually destroying human capital.

The second case assumes that $\psi = 1$. In this case the costs of international education are evenly split among the different countries. This case turns out to be beneficial when $0 < i\varepsilon + i\eta\phi$. If net labour flows are zero, each country can benefit with the amount of international students times the higher efficiency of international education. However, as soon as η becomes negative it is possible that a country loses due to negative net labour flows.

Finally, a third case simulates the scenario in which a country educates their own labour force with the help of another country. Therefore $\psi = 2$ and it follows that international education will be advantageous if $0 < \rho + 2i\varepsilon + 2i\eta\phi$. Compared to the previous case the country hence gains an additional $\rho + i\varepsilon + i\eta\phi$. The first two effects are independent of the net labour flows and thereby constitute a pure gain. However, the importance of η is also increased by a factor of two. This makes sense as more students of the respective country are educated abroad and a negative η would lead to a higher share of the labour force migrating to their country of education.

3.5 Education in a model of Mankiw, Romer and Weil

The last paper from Gregory Mankiw, David Romer and David Weil "takes Robert Solow seriously" (MRW 1992 pp. 1). The authors, who were students of Robert Solow, aim to show that their teacher's classical growth model still fits well with the empirical facts once it is augmented by human capital. Thus, the authors let human capital accumulate in exactly the same way that Solow proposed for physical capital. They define an own human capital savings rate and assume that depreciation is the same as for physical capital. The productivity of both types of capital together is taken to be less than one and hence the model arrives at a steady state. This paper now augments the Solow model for international education. It uses the same technique as in Mankiw, Romer and Weil (1992), defining a new savings rate and taking depreciation to be the same as for physical capital. Additionally, it will use the insights gained in the previous models.

3.6 International Education based on the Mankiw, Romer and Weil Model

While the first extension to the model by Romer allowed modelling the higher efficiency of international education, the second model based on Lucas additionally allowed including effects due to labour movements. However, leaving opportunity costs aside, none of these models takes into consideration one of the main arguments against international education. International education is costly, not only because it occupies one part of the labour force, but also because it needs investment.

The model developed by Mankiw, Romer and Weil exactly takes this aspect of education into account. However, what distinguishes this model from the two models discussed above is that it is not an endogenous growth model, but rather based on classical growth theory and the Solow Model. By introducing human capital as a third input to the production function it is apparent that savings are split between investments in capital and human capital. In order to allow for steady state growth in output per worker Mankiw, Romer and Weil include a labour augmenting technology term. However, this term is assumed to grow at a constant and exogenous rate of g_A. Similarly, labour is constantly growing at the rate g_N.

$$Y = K^\alpha \times H^\beta \times (AL)^{1-\alpha-\beta}$$

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Our model uses the same capital accumulation equation as Mankiw, Romer and Weil. However, the human capital accumulation needs to be modified to take international education into account as well. Again, we include the respective productivities of domestic and international education ρ and ϕ, which are defined as before. As in the Lucas model, international education increases the human capital stock if more foreign students become part of the domestic labour force than domestic students are lost to other countries. Therefore the net labour movement parameter η is included. We arrive at:

$$\dot{K} = s_K Y - \delta K$$

$$\dot{H} = s_{HD} Y \times \rho + \psi(1+\eta) \times s_{HI} Y \times \phi - \delta H$$

The steady state is reached when both, capital per effective worker and human capital per effective worker are constant. This requires the following two conditions to be satisfied.
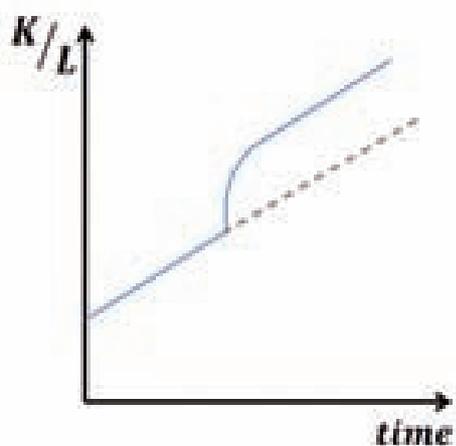
$$\frac{\dot{K}}{AL} = s_K \frac{Y}{AL} - \frac{K}{AL} \times (g_A + g_N + \delta) = 0$$

$$\frac{\dot{H}}{AL} = \rho \times s_{HD} \frac{Y}{AL} + \phi \times s_{HI} \times \psi \times (1+\eta) \times \frac{Y}{AL} - \frac{H}{AL} \times (g_A + g_N + \delta) = 0$$

Solving these two conditions with respect to capital per effective worker and output per effective worker gives the respective two steady state levels.

$$\frac{K^*}{AL} = \left(\frac{s_K^{1-\beta}[\rho \times s_{HD} + \phi \times s_{HI} \times \psi \times (1+\eta)]^\beta}{g_A + g_N + \delta} \right)^{\frac{1}{1-\alpha-\beta}}$$

$$\frac{H^*}{AL} = \left(\frac{s_K^{\alpha}[\rho \times s_{HD} + \phi \times s_{HI} \times \psi \times (1+\eta)]^{1-\alpha}}{g_A + g_N + \delta} \right)^{\frac{1}{1-\alpha-\beta}}$$

In this steady state capital per effective worker is constant and hence capital per worker is just growing at the rate of technological progress. As the rate of technological progress is exogenous in the Mankiw, Romer and Weil model it is thereby also independent of international education.

Thus, in this model international education has a level effect, but no growth effect. This finding is different from the results of the previous two endogenous growth models which predict growth effects due to international education. The graph on the left illustrates the consequences of an increase in international education on capital per worker. However, in order to obtain a path as positive as this, several conditions need to be met.

A closer look at the parameters reveals their impact on the steady state of the economy. Just as in the original model a higher amount of savings results in a higher level of capital and human capital per effective worker. This finding still applies as the savings rate has only been split and therefore also higher investments in international education increase the steady state. The interpretation of the variables η and ε now claims greater importance. The effect of international education on human capital becomes more pronounced if more of the international students decide to stay in the foreign country they were educated in. Thus, positive η will increase the steady state level, while a negative η can decrease the steady state level compared to the original Mankiw, Romer and Weil model. To get a complete overview of the benefits of international education we compare our model to the MRW model. The effect of international education on the steady state income per effective worker will only be positive for a country if:

$$\rho \times (s_{HD} + s_{HI}) < \rho \times s_{HD} + \phi \times \psi(1 + \eta) \times s_{HI}$$

The left hand side of this equation expresses human capital accumulation in a model without international education. It is a slight paraphrase of what Mankiw, Romer and Weil find in there steady state so that the parameters of our model can be included. As the model only includes domestic education, all savings have the same productivity ρ. The right hand side of the equation is payoff with international education as it can be found in the steady state above. Solving this expression yields that:

$$0 < (\rho + \epsilon) \times \psi(1 + \eta) - \rho$$

Again, three different cases are distinguished. First, a country is assumed to use up all their resources to educate foreign students ($\psi = 0$), it can only benefit from international education if $0 < -\rho$. This is a familiar condition which carries the same intuition as in the Lucas model. The second case refers to the situation where a country neither benefits nor loses in terms of their investments into education. This implies that the costs of educating internationals is equal to the benefits from other countries educating domestic students.

Then, $\psi = 1$, which leads to the condition that $0 < \varepsilon + \phi \times \eta$. This means that in the case of zero net labour movements ($\eta = 0$) all countries benefit from international education by the international effect ε. International education is once more a positive sum game. Despite the fact that we find a level instead of a growth effect this is exactly in line with the findings from the models based on Romer and Lucas. In the case where η is not zero and there are labour flows associated with international education it is possible that international education can decrease the steady state of a certain country. However, this can only happen if $\eta < -\frac{\varepsilon}{\phi}$. The smaller the difference between ε and ρ, which implies that international education is much more effective than domestic, the lower can be the net labour flows for a country in order to still benefit from international education.

In the last case it is assumed that $\psi = 2$ which means that a country can double its investments into its labour force as lots of their students are educated internationally. In that case this country benefits from international education if $0 < + \varepsilon + \phi \times (1 + 2\eta)$. Comparing this to the $\psi = 1$ case before one notes that a one is added within the brackets and η is multiplied with 2. This means that international education pays off in more cases. However, the importance of η is increased. This finding is intuitive as the fact that lots of students are educated in a foreign country makes a the domestic country more dependent on the question whether those students come back once their education is over.

One of the main advantages of the set-up of the Mankiw, Romer and Weil Model is that it allows to calculate the marginal returns on investments into capital, domestic human capital and international human capital. As none of these savings parameters has a growth effect, one can simply start with the steady state level of output per effective worker, which is given by:

$$\frac{Y}{AL}^* = \left(\frac{s_K^{\alpha} [\rho \times s_{HD} + \phi \times s_{HI} \times \psi(1 + \eta)]^{\beta}}{(g_A + g_N + \delta)^{\alpha + \beta}} \right)^{\frac{1}{1 - \alpha - \beta}}$$

Differentiating with respect to S_K, S_{HD} and S_{HI} yields three partial derivatives. It can be argued that within an economy savings should be invested into the assets with the highest yield. Therefore, in equilibrium the marginal returns of capital, domestic human capital and international human capital should be equal. Then, it must hold that:

$$\alpha * \frac{\rho \times s_{HD} + \phi \times s_{HI} \times \psi(1 + \eta)}{s_K} = \beta * \rho = \beta * \phi * (1 + \eta)$$

Note that this condition is very intuitive. α gives the productivity of capital, while β gives the productivity of human capital. In the equation α is multiplied with $\frac{\rho \times s_{HD} + \phi \times s_{HI} \times (1+\eta)}{s_K}$. The purpose of this fraction is to determine the relative weights of investments into capital and human capital. As both production inputs run into diminishing returns themselves, this term is necessary when the marginal returns are considered. Knowing this, the equation says that the return of capital needs to equal the return of human capital through domestic education. This return also depends on ρ. Additionally, these two should also be equal to the productivity of international human capital. However, this productivity does not only depend on the efficiency in international education ϕ, but also on the net amount of international students which stay in a specific country, namely η. These insights suggest that countries which are relatively bad in keeping hold of their international students should invest less in international education as their benefits are smaller.

4 Summarising International Education in all models

The adjustment of the different models in this section has led to various results. In order to clear up with the different predictions the following table has been constructed. However, the differences in the effects caused by changes in the variables can be explained by the set-up of the respective model. As the models based on Romer and Lucas are endogenous growth models, they produce long-run growth which depends on the international education. Contrary the Mankiw, Romer and Weil adjustments are based on the Solow model. Thereby only level effects can be found with respect to that model. Additionally, not all the findings should be taken as definite. The model based on Romer's R&D model makes an unrealistic assumption considering labour flows which is relaxed in the other models. Moreover, the Lucas model takes into account the impact of the labour force, which is dropped in the Mankiw, Romer and Weil model. However, the last allows to analyse international education from an investment perspective. Thus, all models have their advantages and downsides and were build up in an attempt to model the different effects international education can have.

Parameter	Effect	Romer	Lucas	MRW
i	Level	Positive	Ambiguous	n/a
	Growth	o	Ambiguous	n/a
ε	Level	o	Negative	Positive
	Growth	Positive	Positive	o
η	Level	n/a	Negative	Positive
	Growth	n/a	Positive	o
ψ	Level	Positive	Negative	Positive
	Growth	o	Positive	o

What is striking is that international education itself does not produce clear cut results. While the effect is positive in Romer, it is ambiguous in Lucas. Hence, the main question whether international education is positive for a country or not remains for the last, empirical section to be answered. However, what can be concluded even under this general set-up are the effects of the variables ε, η and ψ. Increases in all these variables cause positive developments in the respective country. This finding is in line with the general intuition one has with respect to these variables. That is increases in the efficiency of international education, net labour inflows of educated students as well as resource gains caused by the foreign education of labour force should and do improve a countries economic situation.

5 International education and its effect on the Dutch growth perspective

The goal of the previous section was to focus on how international education can be included into the existing models of growth theory. These models have not been empirically tested, yet. While this section will not perform any type of statistical tests of the models either it attempts to find real life values for the different parameters by examining other research. After this is done it is the possible to simulate the effects international education has on the long run growth perspective of a certain country. Given some of the assumptions we made in the models, the focus of this analysis will clearly be a European one. Additionally, whenever necessary we further limit our analysis to the case of the Netherlands. This makes sense for two main reasons. First, the authors of this paper are currently based in Maastricht. Second, due to the fact that the Netherlands are educating lots of foreign European students, it is open to much more doubt whether international education is beneficial for the Netherlands than it is for other countries. Whenever data is unavailable for a certain parameter we will assume different reasonable values and point out different cases.

5.1 Empirics on the "Holland Effect" ψ

To assess the variable ψ two different types of data are needed. Firstly, numbers on foreign students who get educated in the domestic country and vice versa are relevant. Secondly, the costs of university education as well as the total costs of education need to be estimated. Dealing with the second type of data we use a study which has recently been donein Germany. The Berlin Forschungsinstitut für Bildungs- und Sozialökonomie tried to estimate the costs of education in Germany in 2009. They find that the cost of pre-school education is roughly 10,000 Euro per child in Germany. Additionally, they estimate the total costs of schooling (after prep-school until the high-school diploma) to be about 65,000 Euro per child. As the total costs per person which occur until a university degree is achieved sum up to 100,000 Euro on average, the remaining 25,000 can be associated to university education. This means that university makes up for 25% of total schooling costs. Even though these numbers originate from Germany it is reasonable to assume

that the share of university education in the Netherlands will be close to what we observe in Germany. Plugging the numbers into the formula for ψ one can show that

$$\psi = \frac{0.25(DN - ND)}{DD + DN} + 1$$

What remains to be done is to investigate the amount of international students which study in the Netherlands as well as the amount of Dutch students who leave the country for their higher education. The Netherlands' Organization for International Cooperation in Higher Education (Nuffic) offers a statistic about these numbers. As published on their website there were roughly 76,000 international students enrolled in the Netherlands in 2009. With almost 20,000 students by far the largest share came from Germany. Moreover, 5000 students came from China and Belgium ranks third with 2500 Belgians who were studying in the Netherlands. Additionally, Nuffic estimates the number of Dutch students studying abroad at 41,250. With 4,550 the largest share of these Dutch students went to the United Kingdom. On rank two and three 3,450 students go to Belgium, while 2,200 study in Germany. What is striking at first sight is the unequal balance with Germany as ten times more Germans study in the Netherlands than Dutch study in Germany. However, while this most certainly biases the public perception of the costs and benefits which occur to the Netherlands it does not necessarily mean that the Netherlands cannot gain from international education. In total there are about 580,000 students in the Netherlands (The Chronicle of Higher Education, 2010). This means that the main conclusion which can be drawn is that ψ may be estimated as 0.986, which means that the Netherlands only use 98.6% of their investments to get their own nationals educated. However, to be really able to judge whether these 1.4 percent are forgone it is important to include η in the discussion. This is because investments in students who are non-Dutch but stay in the Netherlands after their university education definitely add to economic growth.

5.2 Empirics on the net flow variable η

It is hard to find publicly available data to answer the question how many students are staying abroad once they finished their education there. In 2006, Osterbeek and Webbink in a discussion paper for the Dutch Bureau for Economic Policy Analysis found that studying abroad increased the probability to live abroad by 15 to 17 percent. There is also

data available on how many international students study in the Netherlands and how many Dutch students study in a different country. In a European context it is reasonable to assume that as many international students decide to stay in the Netherlands as Dutch students decide to stay abroad. The following table therefore plots different probabilities to stay abroad together with the corresponding η and the change in the labour force they would cause in the case of the Netherlands.

Probability to stay	η	Change in L
0.01	0.002964	348
0.02	0.005928	695
0.05	0.014819	1,738
0.1	0.029638	3,475
0.2	0.059275	6,950
0.5	0.148188	17,375

We can see that as long as the assumption that the probability to stay is equal between countries holds the Netherlands will always have a positive η. Moreover, the higher the probability the higher will also be the η. However, η needs to be sufficiently positive in order to make up for the losses from ψ. Consequently, a later section will combine the different values for η with the models and check their implications for the Netherlands in all our models.

5.3 Empirics on the share of international students i

Reusing the numbers of section 3.3 gives a share of international students which is equal to 13.1%. Even though the Netherlands always point out the international character of their educational system, this number is not extraordinary high if compared with other European countries. Germany, for example, has a share of international students of 11.8% which is fairly close to the Dutch one (Statistisches Bundesamt Deutschland, 2010). This also means that the assumption of an equal i among the different European countries is not that unrealistic, after all, and no large biases should be caused by the set-up of the model.

5.4 Thoughts on the efficiency of education ρ

Several papers discuss the effect of education on economic growth. Most of them find it problematic to distinguish between the impact of education and the returns from other factors like family status and relations. Indeed, Dennison in his 1968 paper used an arbitrary factor of one third to translate wage differentials into differences of years of education. Since then, a large amount of literature has arrived at varying conclusions ranging from returns of 1.2 percent to 10.1 percent as summarised in Johnes and Johnes (2004).

Unfortunately, it is difficult to use these findings for our modelling parameter ρ. This is because the actual return on the investment into human capital is a function of several variables, one of which is ρ. Additionally, the factor share i.e. the exponent of human capital is important. Mankiw, Romer and Weil find that human capital in their model has a factor share of on third, which in our model based on MRW implies $\beta = \frac{1}{3}$.

However, even with this factor share given the actual return of education in the growth model will vary widely. Nonetheless, with this data it is possible to demonstrate how ρ behaves in MRW if we assume a certain human capital return. Therefore, recall that the production function in MRW is:

$$Y = K^{\alpha} H^{\beta} (AL)^{1-\alpha-\beta}$$

Now assume that human capital increases and must bring a return of r. Then :

$$\frac{Y_2 - Y_1}{Y_1} = r$$

Alternatively:

$$\frac{\left(K^{\alpha} \times H_2{}^{\beta} \times (AL)^{1-\alpha-\beta} - K^{\alpha} \times H_1{}^{\beta} \times (AL)^{1-\alpha-\beta}\right)}{K^{\alpha} \times H_1{}^{\beta} \times (AL)^{1-\alpha-\beta}} = r$$

This implies:

$$\left(\frac{H_2 - H_1}{H_1}\right)^{\beta} = r \quad where \ (H_2 - H_1) = s_H Y_1 \times \rho - \delta H_1$$

Substituting and rearranging these terms one finds that:

$$\rho = \left(r^{\frac{1}{\beta}} + \delta\right) \times \frac{H_1}{s_H Y_1}$$

Naturally, it is unlikely that all variables are fixed except of ρ. Moreover, it will be the return variable, which will fluctuate most. However, this small calculating exercise shows what factors ρ depends on other things being equal. First, you can see that the factor share is important. The greater the factor share β the lower ρ needs to be to achieve the same return r. On the other hand, the higher the depreciation δ the larger ρ must be, ceteris paribus. Also, the relationship between the stock of human capital and the investment into human capital is relevant. The smaller the investment is compared to the stock of human capital the larger ρ would have to be to assure the same return. This is logically appealing, as returns tend to diminish when the human capital stock rises.

Given that the return of education constantly changes, it is difficult to quantify ρ from empirical observation returns. However, it happens that there is one case where both variables are constant. When the MRW model reaches a steady state we find that the returns of each type of investment must be equal. There, the return of domestic education is determined by $\beta * \rho$. Taking β as one third like in MRW and the equilibrium return of education as 6.5 percent this implies:

$$\rho = 0.065 \times 3 = 0.195$$

Although it is nice to have a quantitative expression for a model's parameter, the estimate above should be used with caution, as it is largely the result of an educated guess derived from one model in equilibrium and relying on a series of assumptions.

5.5 Empirics on the international factor ε

When investigating the general returns of international education, ε is the most fundamental parameter. It determines whether international education is a positive sum game and hence lends important advice to policy makers deciding about the promotion of international education. Compared to returns of general education there is even less testable evidence. However, a discussion paper by Osterbeek and Webbink (2006) found that studying abroad has a return which is 6.3 percent greater than studying at home. Although, these results are not biased due to the clever set up by the two authors, they are statistically insignificant. According to Osterbeek and Webbink this is because of a too small sample size. Unfortunately, their evidence is the only empirical study we are

aware of. Therefore, we will use the 6.3 percent and test for implications in our model. If international education is 6.3 percent more productive than domestic education it must be that:

$$\phi = \rho + \epsilon = 1.063\,\rho$$

And thus:

$$\epsilon = 0.063\,\rho$$

With the help of this result it is now possible to make some final remarks about the nature of our models. The next section will present under what conditions international education is beneficial.

5.5.1 The effect of international education on the Netherlands in Romer

In order to determine whether international education has a positive or negative effect on the Netherlands it would be necessary to compare our adjusted Romer model to the original one. However, due to the set-up of the model this is not possible. What can be said
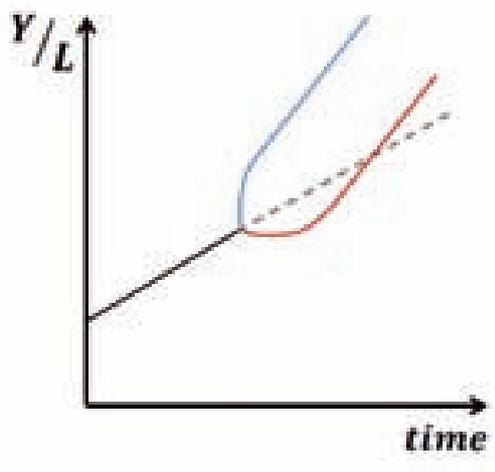
is that the introduction of international education will have an ambiguous level effect in those countries that have a ψ smaller than one and a positive effect if ψ is larger than one. This is because an increase in ψ as well as i increases output growth in the short-run. As the Netherlands have a $\psi = 0.986$, the short-run effect will be ambiguous. However, with respect to the long-run growth perspective of the country equilibrium growth will be increased according to the model based on Romer.

Exactly these developments are displayed by the graph. It shows the ambiguous effect in the short-run, with the blue line assuming a positive and the red line assuming a negative effect as well as the increased equilibrium growth rate in the long run. Unfortunately, this only holds true as long as international education is really more efficient than domestic education. Additionally, the model does not yet take into account net labour flows or monetary investments in education.
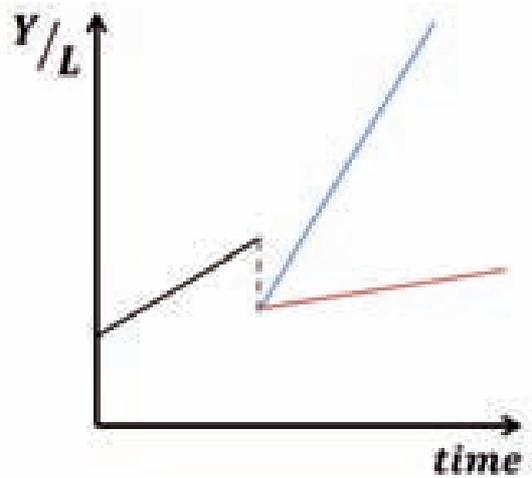
5.5.2 The effect of international education on the Netherlands in Lucas

From the previous discussion of the Lucas model we quote the condition under which international education is positive for a country:

$$\rho < \psi \times (\rho + i\epsilon + i\eta\phi)$$

It is not necessary to use an approximation for ρ as the factor cancels out. Plugging in all other estimates one finds that the Netherlands would benefit from international education as long as η exceeds 0.0427, which implies a probability to stay in a foreign country of more than 14.4%. As the Netherlands educate more international students than Dutch students go abroad a positive probability to stay in a foreign country will lead to labour inflows into the Netherlands. More precisely, it is necessary that about 5000 more foreign students decide to stay and work in the Netherlands than Dutch students decide to stay abroad. Otherwise the effect of international education predicted from the Lucas model will be negative for the Netherlands. The positive η is necessary to cancel the "Holland Effect".

However, as long as ρ and η are positive for the Netherlands, the short-run level effect will always be negative. This results if the denominators of the original and the adjusted Lucas model are compared. If the values of the parameters are plugged into this inequality it always works the following way.

$$\rho < i\eta + \psi(\rho + i\epsilon + i\eta\phi)$$

Thus, the following graph displays the developments after international education is introduced to the Lucas model. Thereby the red line shows the effects if η is not sufficiently high and the growth effect is negative, while the blue line displays the case where η is high enough and international education is beneficial.

5.5.3 The effect of international education on the Netherlands in Mankiw, Romer, Weil

For the MRW model it is important to recall that the condition for a positive international education effect is:

$$0 < (\rho + \epsilon) \times \psi(1 + \eta) - \rho$$

Again, it is not necessary to fill in an estimate for ρ. Instead, one finds that in MRW the effect of international education will be positive for the Netherlands as long as η exceeds -0.0459. Given that the Netherlands most likely have a positive η this is not problematic
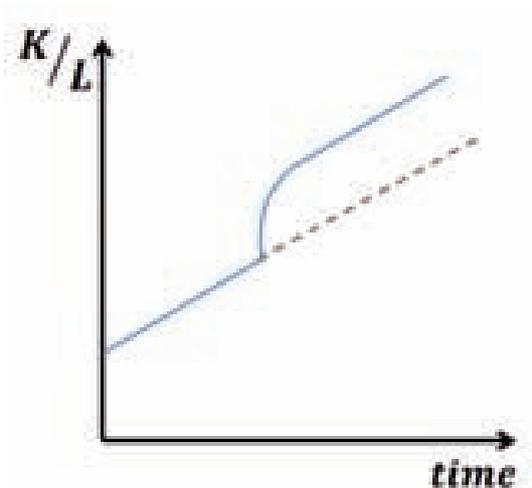
and international education has the positive level effect shown in the diagram on the left. However, one limitation is that the model assumes that international education is simply a matter of investment rather than of choice. The parameter i does not exist in the MRW based model. Thus, although the effect is positive, the real benefits may be smaller than the MRW model suggests. Realistically, they are limited by the proportion of citizens choosing to study abroad.

6 Conclusion

The current literature has so far not made any attempts to integrate the increasing share of international students into the existing theoretical framework of growth theory. However, even though the integration we present is straightforward, the models do need empirical testing which is beyond the scope of this paper. Additionally, the theoretical conclusions from the models are mixed. While it can be shown in all the models that international education is a positive sum game as long as it is assumed to be more effective, not all countries necessarily gain from it. The variables ψ and η attempt to measure costs and benefits of international education and thereby allow to include effects which can have a negative impact for a country. Those states which lose lots of students to other nations in the process of international education as well as countries which use up much of their resources to educate a foreign labour force are the potential losers of international education. However, luckily these two effects balance in a way that states which educate lots of foreigners will also tend to be among the nations that should achieve a larger inflow of foreigner graduates into their labour force.

For the Netherlands the evidence from the models does not allow for a simple conclusion. While the analysis based on Romer's R&D model as well as the model by Mankiw, Romer and Weil concludes that the Netherlands benefit from international education, the adjusted Lucas model imposes some further restrictions. Even though the Romer model is the most complex in the way it model economic growth, its results do not have the same validity as those of the other two models. This results from the set-up of the model in which the variable η has been left out. In the other two models the conclusions mainly depend on the question whether a country manages to convince foreign graduates to stay. Mankiw, Romer and Weil treat international education as an investment and as such it only pays out if students later add to economic output. In this point the Mankiw, Romer and Weil model and the Lucas model impose similar conditions.

The authors of this paper believe that the Netherlands are able to benefit from international education. However, this does not necessarily mean that they are benefiting at the moment, already. Some models show negative short-run level effects of international education, while the long-run growth is mainly positive. The relevant question continues to be whether the Netherlands can convince foreign students to stay and create output after their graduation.

Therefore, not international education should be questioned as it offers the country an excellent chance to expand its labour force with young and talented graduates. Rather effective policies should be set up which increase what we called η.

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