REDISTRIBUTIVE EFFECTS OF GOVERNMENT GRANTS FOR HIGHER EDUCATION

by

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Abstract

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Education is one of the key determinants of an individual's income and inequality in income within a society. It is typical for modern governments to intervene in the market for higher education, adjusting tuition fees and engaging more people to obtain a degree. However, the lower inequality as a result of this policy may be costly in terms of efficiency losses within the economy.

This study analyzes the tradeoff between productivity and inequality under different modes of higher education financing by the government using an OLG model with heterogeneity in age, innate ability, and education level. The baseline model with merit-based grants is calibrated to resemble the economy of Ukraine in 2019. Several alternative policy programs are considered: pure private education, a diversified system, need-based grants, and pure public education.

Numerical simulations show that pure private education leads to higher productivity only in the long run. All the other policies are effective in reducing income inequality both in the short and long run. The advantage of need-based grants over a diversified system is that they provide a higher incentive for parents to partially finance the higher education of their children. On the other hand, need-based grants lead to the withdrawal of some high-ability students from universities, while a diversified system does not have such an effect.

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ACKNOWLEDGEMENTS

This thesis is a product of all the knowledge I accumulated during 2 years on the Master's program in Economic Analysis at KSE. I am thankful to all of my teachers, who shared a portion of their human capital with me.

Even the harder part for me was to place myself on the map of the economic field of study realizing what stands within my circle of interest. In this process, two teachers played a key role. The first is professor Maksym Obrizan, my thesis advisor. His Macroeconomics III course covered Overlapping Generations models and inspired me to delve deeper into this topic, discovering what they are capable of. Professor Sergii Kiiashko and his Macroeconomics IV continued to nurture my passion for macroeconomic modeling. I am grateful to both of them for the advice they regularly provided to me in the process of writing this thesis.

Among the people out of academia, family is the most important for me. My mom, dad, and elder brother Yurii have continuously supported and believed in me, even during the most difficult periods of my life. And last, but not the least, special mentions to the members of all the running communities I participated in: Pace Run Club in Chernivtsi, Nike Run Club in Kyiv, and Adidas Runners in Vienna. Our joint runs have always helped me recover intellectually, keeping a healthy study-life balance.

Chapter 1

INTRODUCTION

One of the most fundamental sources of income and wealth inequality in the economy is heterogeneity in wages caused by the difference in skills that are required for a particular type of employment. The existence of the skill premium is an essential incentive for people to accumulate human capital, which is the main driver of overall economic growth. Thus, the total amount of investment in education has important macroeconomic implications. The most usual way for the government to intervene in the process of human capital accumulation is to provide public education. Adam Smith in Wealth of Nations described the impact of public education on wage differentials and people's incentives to obtain education. Even back then, in the XVIII century, he recognized that the public provision of education in certain professions attracts more people into that field and shrinks their prospective skill premiums (Spengler, 1977).

The recent empirical evidence confirms that an increase in the educational attainment rate on every level (primary, secondary, tertiary) is associated with mitigating income inequality from both ends of the distribution. The income level of richer people is lowered, whereas the poorest members of the population earn more than before (Abdullah, Doucouliagos, and Manning 2015). The most natural explanation of this phenomenon is labor supply spillover from low-skilled to high-skilled jobs and the subsequent decrease in the skill premium.

In this context, the government subsidization of education services is considered a mechanism to bolster human capital accumulation and fight inequality. Although primary and secondary education is provided by the government for free almost universally, the differences in state financing of higher education persist. The size of government expenditures on tertiary education relative to the country's GDP varies from 0.1% to 2.4%. The correlation of this indicator with the pre-tax Gini index, one of the measures of income inequality in the economy, is moderate, but significant (Appendix A). In the sample of 146 countries with different levels of development, the US is placed in the middle, while Ukraine stands among the countries with the highest expenditures on tertiary education and the lowest income inequality: Sweden, Norway, and Denmark (Figure 1).

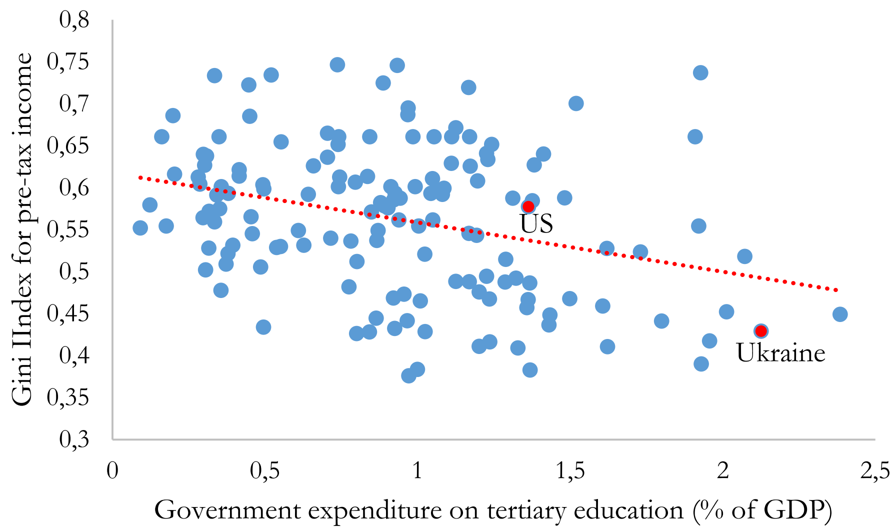

Figure 1. Government expenditure on tertiary education in % of GDP and Pre-Tax Gini Index by country in 2014

Source: Our World in Data, World Inequality Database

Most of the theoretical studies concentrate on two extreme cases: pure private vs. universal public higher education. However, there are multiple policies possible in between those extreme opposites. One of them is providing full-covered grants for higher education to part of the students. Those grants can be provided on a merit basis, subsidizing the smartest students, or a need basis, subsidizing the poorest.

From the Soviet times, Ukraine has inherited a merit-based binary system, according to which part of the students who got the highest scores on entry exams are exempt from tuition fees, while the rest of the students finance the total cost of higher education provision with their tuition fees (Erfort, Erfort, and Zbarazskaya 2016). The expediency of the current system is questionable, taking into account the very low returns to education in Ukraine (Gorodnichenko and Sabrianova 2005), which may be a direct result of the current system of education financing. Although even the tuition fees of the students who did not qualify for a full merit-based grant cover the costs of their education only partially, significant steps in better matching the fees with the tuition costs have been taken in the last few years (Ministry of Education and Science, 2020).

Although need-based financing schemes are also present in Ukraine for some categories of the population, the most significant step in this direction was taken only recently. Because of the Russian invasion, students from temporarily occupied or war zone areas have been allowed to continue their studies at the government's expense (Ministry of Education and Science 2022). This policy can be considered as an example of the need-based financing of higher education. Although the war makes the Ukrainian economy highly unstable, the case of more extensive provision of higher education on a need basis raises questions about the possible impact of such a policy.

This study aims to assess the impact of merit-based and need-based grants on income and wealth inequality in the Ukrainian economy. With this purpose, the Overlapping Generations model (OLG) is built and calibrated to match the Ukrainian economy before the war as closely as possible. First, the current binary merit-based system of higher education financing is modeled. Then, the following policy changes are considered:

Case 1. Tuition fees are set for everybody and they reflect the full cost of higher education. This is the case of pure private higher education.

Case 2. Tuition fees are completely abolished, and the higher education becomes free for everybody. This is a case of pure public higher education, an opposite policy to Case 1.

Case 3. The binary merit-based system is canceled, and the diversified system of financing is adopted instead. Every student has to pay such a share of per-student costs so that the total government expenditure on higher education is the same as before the policy change.

Case 4. Instead of the binary merit-based system, the analogous need-based system of higher education funding is implemented. The same share of the students is provided with free education, but those are the ones from the poorest families.

Universally free higher education is expected to be the most powerful driver of income and wealth equalization, while the need-based system should deliver the results which are in between free education and merit-based financing. However, the impact of those policies will probably be relatively mild, given the recent low values for the Gini index and skill premium in Ukraine. In contrast to this, abolishing government grants is expected to raise income inequality and return to education. However, there are two opposite effects arising from this policy. On one hand, it will be costlier for the smartest students to study. On the other hand, the tuition fees of the students who paid them before the policy change are lower. The aggregate impact would depend on what effect is stronger.

Taking into account the positive correlations between a person's innate ability, education, and income, and the intergenerational correlation between a parent's and a child's innate ability (Anger and Heineck 2010), it is more probable for a smart student who qualifies for a merit-based grant to come from a rich family which can finance the student's higher education on its own. Thus, the educational attainment among the smartest students should not be modified much by this policy, whereas the tuition fee discounts for the rest could be a more powerful incentive to enter a university. As a result of an increase in overall educational attainment, income and wealth inequality may be lowered even further. The abolishment of government support of any kind (Case 4) is expected to drive inequalities the highest.

This study is organized as follows. Chapter 2 presents theoretical and empirical literature relevant to the topic. Chapter 3 describes the OLG model used for the calibration and policy simulations. In Chapter 4, the process of the model's calibration following the data from Ukraine is described step-by-step. Chapter 5 discusses the results of the policy changes simulated in the model. Chapter 6 concludes.

Chapter 2

LITERATURE REVIEW

The relevant literature for our research can be divided into two main categories: OLG models with income heterogeneity government subsidization of higher education; alternative models which directly consider merit-based and need-based student aid. The study of Abbott et. al. (2013) is the only one which fits into both categories.

2.1. OLG models

The most basic setting for income heterogeneity modeling is presented in Heer and Maußner (2009). In their OLG model, households are different in productivity due to both heterogeneous innate ability and idiosyncratic shocks. Moreover, the productivity of agents depends on their age. It accounts for intergenerational heterogeneity in wages observed in the real world due to the accumulation of experience by workers. Both permanent and stochastic components of individual productivity include only 2 possible states (lower and higher). Each year of work/retirement is modeled separately, so there are 70 periods in total: 45 for work and 25 for retirement. Although the high number of periods makes this model computationally complex, this setting does not cover the issue of education choice by individuals in their early stages of life.

In the most fundamental theoretical study of human capital accumulation, Glomm and Ravikumar (1992) consider pure private vs. public education financing. They use the overlapping generations framework (OLG) to show that public provision of education reduces income disparities more quickly. In their model, the parents care both for their own and the future welfare of the children

– the so-called dynastic utility function, first described by Becker and Barro (1988). In the model of Glomm and Ravikummar, as in most of the papers that followed after, the financing of education for the youth is provided through bequests in the case of the pure private education market. De la Croix and Lubrano (2009) use a similar approach in comparing pure public vs. private education systems. They conclude that under the system of public education financing, the inequality in income is lowered because it is easier for students from poorer families to obtain an education and catch up. De la Croix and Michel (2004) consider an alternative channel of human capital – when parents decide to make some effort to educate their children themselves. A similar mechanism of home education as an alternative to pure private or public forms is later used by Viaene and Zlicha (2008).

In Stantcheva's (2015) model, Barro-Becker intergenerational transfers of wealth from parents to children are used in both ways: as investments throughout the parents' life, and bequests. Her study is even more multidimensional: she solves for an optimal education subsidy together with the degree of income and bequest taxation and discusses whether education expenses should be tax-deductible. She shows that the optimal subsidy for education is non-zero. Moreover, the presence of credit constraints, which could be even more relevant for Ukraine than for developed economies, tends to raise the optimal subsidy rate.

In the papers of Prettner and Schaefer (2016), and Imoto (2022), the historically observed income inequality dynamics are studied through the OLG framework with the higher education choice. Prettner and Schaefer consider only the case of the U-shaped Kuznets curve for inequality and explain it through the gradual attainment of the rich, the middle-class, and the poor in higher education. Imoto shows that different scenarios are possible, depending on whether education is a normal or a luxury good. Although both papers consider only the case of pure private financing of higher education, Prettner and Schaefer recognize that the provision of education publically could act as a smoothing factor in inequality dynamics. Viaene and Zlicha (2009) develop an extensive OLG model with the heterogeneity in innate ability to study a similar issue – persistent cross-country differences in income. They show directly in the model that it is possible to lower inequality by providing public education, sustaining the rate of technological progress.

The most comprehensive study on the impact of government loans and grants for higher education is done by Abbott et. al. (2013). Calibrating the model for the US data, the authors state that the most efficient instrument for improving welfare is merit-based grants. However, they indicate the presence of a crowding-out effect from such grants: merit-based aid is often received by students from richer families whose parents are ready to finance their education on their own. The model proposed by Leighton (2017) is mostly based on Abbott et. al. (2013). Although it simplifies the model and does not consider government grants, concentrating on pure private vs. public higher education instead, it retains its crucial elements, such as heterogeneity in innate abilities, a correlation between an individual's earnings and innate ability, and intergenerational correlation between innate abilities of a parent and a child.

2.2. Alternative models for merit- and need-based government grants

The studies of Colas, Findeisen, and Sachs (2021) concentrate primarily on the effect of need-based student grants. They implicate that government subsidies on education should target students from the poorest families. It is the most efficient both for boosting aggregate human capital growth and income redistribution. Therefore, the higher the opportunities for the student to be self-financed by his family, the lower the education subsidy she should receive from the government. Singel and Stone (2002), opposite to the abovementioned research, consider the effect of merit-based student aid separately. By fitting the bivariate probit model to the US data, they indicate that such grants make the problem of income inequality worse because the main beneficiaries of non-need-based student aid tend to be students from financially-able families.

The following studies consider the impact of merit-based and need-based grants simultaneously, or a combination of both. Yang (2018) finds that both modes of higher education financing have a mitigating effect on income inequality. However, in the case of need-based aid, the marginal increase in educational attainment is significantly higher, so the redistributive effects are stronger in this case. Hadavand (2018) states that separate merit-based and need-based grants are more effective in income redistribution than the combination of both policies and need-based grants are more effective in reducing inequality compared to merit-based ones. Minaya, Agasisti, and Bratti (2021) come to a similar conclusion in their empirical research on Italian students. They indicate the harmful effect of strengthening the merit component for being qualified for need-based student grants on education attainment. Although they do not consider the issue of income inequality directly, the negative effect of such policy change can be extrapolated from the leading discouragement of poorer students from obtaining an education.

The study of Erfort, Erfort, and Zbarazskaya (2016) mentioned earlier is devoted exclusively to Ukraine. They compare the current binary system of higher education financing with the model of diversified financing (MDF), according to which all the students have to pay tuition fees. They show that the transition to MDF is appropriate for Ukraine because it could attract more financing per-student and higher wages for the teaching staff at universities, and therefore increase the quality of the education services. Although they manage to incorporate the measure of the quality of education, which is another relevant matter for Ukraine, their modeling approach is more simple and unorthodox than in other papers mentioned in this chapter. Thus, it is difficult to compare their implications with ones delivered in other papers.

The study of Põder and Lauri (2021) considers the consequences of the completely contrary policy in Estonia, another post-soviet country that once transitioned from the binary system. In 2013, Estonia abolished tuition fees for everybody. They analyze econometrically how this policy change has altered the educational attainment in the country and its determinants. Their conclusion is counterintuitive: the provision of higher education completely for free has not improved the educational equity in the country. Although it marginally increased the chances of the current students from rural areas to graduate, it did not improve overall education attainment among the disadvantaged groups of the population. They suggest that the merit-based admission mechanism which takes place after abolishing tuition fees could hinder the positive effects of the reform. They mention alternative reasons for this phenomenon might come from the information asymmetries and the difficulty to combine full-time study with work.

It is worth mentioning that among the OLG literature presented in this chapter, part of it is purely theoretical and devoted to developing abstract, but universally applicable mathematical identities. In some of them, numerical simulations are conducted as well. However, to analyze the country-specific context of the higher education system, the more complicated model that can be solved only numerically may be preferred, as in the case of Abbott et. al. (2013) for the US and Leighton (2017) for Chile. The model for Ukraine developed in the next chapter is inspired by the abovementioned papers but also includes some specificities of the binary system currently set in the country.

Chapter 3

THE MODEL

The model combines the features of Abbott et. al. (2013) and Leighton (2017). The length of the period in the OLG model is 5 years, as in Leighton (2017), which is a sufficient tradeoff between the simplest 3-period models and the 60-period one presented by Heer and Maussner (2009). For the sake of simplification and consistency, the share of every cohort in the population is equal, the agents' life expectancy is deterministic, and college graduates (equivalent to Junior Bachelor or Junior Specialist degree in Ukraine) are excluded.

The value functions embedded in this model are similar to Leighton (2017). The key simplification is that the intergenerational transfers of parents are unconditional to the education obtained by a child. Instead of implementation of graduate tax, income tax or subsidization shares are modified to maintain the government expenditures at the same level as before. The pension payment mechanism is slightly modified as well.

3.1. Agents

All n agents live 11 periods, 5 years each. At the beginning of period 1, an agent is 17 years old, which is the usual age for a high school graduate in Ukraine. At the end of period 11, an agent is 72 years old, which corresponds to the average life expectancy in Ukraine for males and females. Agents maximize their discounted lifetime utility in every period by consuming and saving:

$$\max_{c_t, k_{t+1}} E_t \left(\sum_{t=1}^{11} \beta^{t-1} u(c_t) \right) \tag{1}$$

Where $u(c_t)$ is a utility function from consumption with a constant relative-risk aversion:

$$u(c_t) = \frac{c_t^{1-\eta}}{1-\eta} \tag{2}$$

The consumption and savings are non-negative in each period ($c_t, k_t \geq 0$).

The agents (households) in the OLG model are heterogeneous in their income. Agents are exposed to idiosyncratic shocks in their productivity every period, which are persistent in time through the AR(1) process with shocks normally distributed around zero:

$$\begin{gathered} z_t = \rho_z z_{t-1} + \epsilon_t, \\ \epsilon_t \sim N(0, \sigma_\epsilon^2) \end{gathered} \tag{3}$$

Where ρ_z is persistence coefficient, ϵ_t stands for normally distributed shocks with a standard deviation σ_ϵ.

The households' wages for the low-skilled (with secondary education) and high-skilled labor (with higher education) obtained in each period of working can be expressed as:

$$w_t^{L,H} = w^{L,H} \varepsilon_t^{L,H}(\theta, z_t) \tag{4}$$

Where w is a wage rate for low-skilled or skilled labor per efficiency unit. The efficiency unit ε_t for different kinds of labor is conditional on innate ability θ and productivity shocks z_t:

$$\varepsilon_t^{L,H} = e^{\psi\theta + p_t^{L,H} + z_t} \tag{5}$$

Where ψ is higher education premium, $p_t^{L,H}$ is an aged premium reflecting the productivity dynamics of the agent throughout his life. The term $\psi\theta$ implies that return to higher education is smaller for individuals with lower innate ability even if they graduate successfully.

Contrary to z_t, θ is defined at the beginning of an agent's life and does not change thereafter. The process of assigning particular θ to the agent is described in more detail in section 3.1.3.

The mechanism by which households make decisions during the different periods of their lifetime is realized through value functions. In period 1 (17-21 years), they first face the following value function when they need to decide whether to enter a university or begin to work right after graduation from high school:

$$V_1(\theta, k_P) = \max\{\tilde{V}_1^H(\theta, k_P), E(V_1^L(\theta, k_P, z_1))\} \tag{6}$$

Where k_P is a transfer from a parent, and z_1 is an individual idiosyncratic shock in an agent's productivity if he decides to work.

3.1.1. Higher education

If an agent decides to enter a university, his value function is:

$$\begin{aligned}\tilde{V}_1^H(\theta, \tilde{k}) = \max_{c_1, k_2} \frac{c_1^{1-\eta}}{1-\eta} \\ &+ \beta\left(\left(1-\vartheta(\theta)\right)E\left(V_2^H(\theta, k_2, z_2)\right)\right. \\ &\left. + \xi(\theta)E\left(V_2^L(\theta, k_2, z_2)\right)\right)\end{aligned} \tag{7}$$

Where $\xi(\theta)$ can be interpreted in two ways. Leighton (2017) frames it as a probability that a student drops out of the university which is conditional on his innate ability. If he drops out of period 1, he should enter a labor market for workers with secondary education in the next period, as if he did not decide to obtain an education at all. If he graduates from the university successfully, he can enter a market for skilled labor.

In the context of the Ukrainian labor market, in which the problem of overeducated workers taking low-skilled jobs is common (Kupets 2015), $\vartheta(\theta)$ can also stand for the mismatch risk – a probability that the agent will not find a suitable high-skilled job after graduation. In both cases, the conditional probability on the level of innate ability is justified. However, accounting for the microdata used for the calibration, the former interpretation is more suitable.

The value function above is subject to the constraint:

$$k_P = c_1(1 + \tau_c) + k_2 + \phi(1 - s_\phi) \tag{8}$$

Where τ_c is a value-added tax rate, ϕ is the full cost of higher education, and s is a share of the costs subsidized by the government. We assume that the government sets such a threshold $\tilde{\theta}$ in the ability level to provide a share of the students s_θ merit-based grants. If the agent's ability is higher than the threshold value ($\theta > \tilde{\theta}$), he qualifies for a merit-based grant from the government which fully covers his tuition cost. It corresponds to $s = 1$, so the budget constraint becomes:

$$k_P = c_1(1 + \tau_c) + k_2 \tag{9}$$

However, we let $s_\phi \geq 0$ for those who do not manage to qualify, so the government can at least partly subsidize the costs of higher education for everybody. It corresponds to the current situation in Ukraine where tuition fees paid by the students are significantly lower than the government expenditure per-student. $s_\phi = 0$ corresponds to the case of pure private financing of higher education.

3.1.2. Work

If the agent did not enter the university and start working from period 1, his value function is:

$$V_1^L(\theta, \tilde{k}, z_1) = \max_{c_1, k_2} \frac{c_1^{1-\eta}}{1-\eta} + \beta E\left(V_2^L(\theta, k_2, z_2)\right) \tag{10}$$

Which is constrained by:

$$w_1(1-\tau_w) + k_P = c_1(1+\tau_c) + k_2 \tag{11}$$

Where τ_w is a personal labor income tax rate, w_1 is labor income in period 1.

In period 1, no matter what decision the agent makes, the only savings available to him come from the intergenerational transfer from his parent. For all the further periods, only his savings k_t are available to him.

For $t \in \{2,3,4,5,6\} \cup \{8,9\}$, the value function looks the same for both kinds of workers:

$$V_t^{H,L}(\theta, k_t, z_t) = \max_{c_t, k_{t+1}} \frac{c_t^{1-\eta}}{1-\eta} + \beta E\left(V_{t+1}(\theta, k_{t+1}, z_{t+1})\right) \tag{12}$$

Subject to:

$$w_t(1-\tau_w)+k_t\big(1+r(1-\tau_k)\big)$$
$$=c_t(1+\tau_c)+k_{t+1} \tag{13}$$

Where r is a gross real interest rate, τ_k is a capital gain tax rate.

At the beginning of period 7, the agent is 47 years old, and it is time for him to transfer some funds for his 17-year-old child's good. His value function is slightly modified:

$$V_7(\theta,\theta_C,k_7,k_C,z_7)$$
$$=\max_{c_7,k_8,k_C}\frac{c_7^{1-\eta}}{1-\eta}+\omega V_1(\theta_C,k_C) \tag{14}$$
$$+\beta E\big(V_8(\theta,k_8,z_8)\big)$$

Where θ_C is a level of a child's innate ability conditional to the parent's ability, and ω measures the degree of the parent's altruism. Let θ_C depend on θ the following way:

$$\theta_C=\rho_\theta\theta+\vartheta,$$
$$\vartheta\sim N(0,\sigma_\theta) \tag{15}$$

Where ρ_θ is a parent-child innate ability correlation, ϑ is a normally distributed random shock with a standard deviation σ_θ. The assignment of a specific ability level to the child resembles the AR(1) process of idiosyncratic productivity shocks. The fundamental difference is that innate ability is assigned only once – at the beginning.

This setting lets the agent derive utility for himself directly from his child proportionally to ω. So the agent faces a tradeoff between consumption, intergenerational transfer, and saving for his good:

$$w_7(1-\tau_w) + k_7\big(1 + r(1-\tau_k)\big) = c_7(1+\tau_c) + k_8 + k_C \tag{16}$$

The parent's altruism is unconditional on the child's education choice and depends only on the level of utility. This level depends on the income expected from the child given the intergenerational correlation on ability.

3.1.3. Retirement

Period 9 is the last one in which the agent works. After that, he retires in period 10, when he/she is 62 years old. It reflects the in-between value of male (65 years) and female (60 years) retirement ages in Ukraine. Starting from that, he can live only on the savings he accumulated before. His value function is then:

$$V_{10}^{H,L}(k_{10}) = \max_{c_{10},k_{11}} \frac{c_{10}^{1-\eta}}{1-\eta} + \beta V_{11}(k_{11}) \tag{17}$$

Subject to:

$$k_{10}\big(1 + r(1-\tau_k)\big) + b = c_{10}(1+\tau_c) + k_{11} \tag{18}$$

Where b is a pension received by a retiree.

Period 11 (67-72 years) is the last for the agent, and he does not leave a bequest for the child. The value function for this period is simply:

$$V_{11}^{H,L}(k_{11}) = \frac{c_{11}^{1-\eta}}{1-\eta} \tag{19}$$

Subject to:

$$k_{11}\big(1 + r(1-\tau_k)\big) + b = c_{10}(1+\tau_c) \tag{20}$$

The public pension system in Ukraine is solidarity-based, so the payments to the retirees depend only on the wage levels of the current workers, not on the retirees' savings. In the model, the pension benefit period is expressed as a share of an expected representative worker's wage throughout life. So the base wage does not include idiosyncratic shocks but contains the agent's ability premium and mean age premiums throughout his life:

$$b = s_b^{H,L}\overline{w} \tag{21}$$

$$\overline{w} = w^{L,H}e^{\psi\theta+\frac{1}{8}\sum_{i=2}^{9}p_t^{L,H}} \tag{22}$$

Where s_b shows the share of the average wage $\overline{w}^{H,L}$ paid to the retiree. In Ukraine, the value of s_b depends on the total labor market experience of an individual. There is no unemployment in our model, so individuals work continuously. The only difference is when their experience begins. Those who decided to work after school are expected to have 5 more years of experience at the end than the university graduates and dropouts. However, we will use 40 years of experience to estimate pensions for both types of labor. There are 2 reasons behind this decision. First, it simplifies the process of value function iteration that is applied to solve the model. Second, it reflects the higher prevalence of informal employment among the low-skilled labor in Ukraine (Lehmann and Pignatti 2018). This type of employment does not count as a labor market experience in calculating retirement benefits.

3.2. Production

There is no heterogeneity among the firms in this model. There is a multi-level production function in the economy. The aggregate level looks like a usual Cobb-Douglas function:

$$Y = AK^{\alpha}H^{1-\alpha} \tag{23}$$

Where Y is a gross domestic product, A is the total factor productivity, K is the total accumulated physical capital, H is the total human capital, α is the elasticity of production to physical capital.

The aggregate capital is equal to the savings accumulated by each agent:

$$K = \sum_{t=2}^{9}\sum_{j=1}^{n_t} k_{tj} \tag{24}$$

A nested measure for human capital is derived from a CES production function:

$$H = (\mu(H^H)^{\gamma} + (1-\mu)(H^L)^{\gamma})^{\frac{1}{\gamma}} \tag{25}$$

Where μ is a CES weight parameter which stands for the share of the skilled labor force in total labor income, H^H and H^L are total human capital generated by the workers with secondary and tertiary education correspondingly, γ is a constant elasticity of substitution parameter. It can be easily shown that in terms of this specification, the education premium diminishes when the human capital generated by workers with higher education relative to workers with secondary education grows (Appendix B).

Total human capital for two types is calculated as the total efficiency units of every individual with a correspondent education:

$$H^H = \sum_{t=2}^{9} \sum_{j=1}^{n_t^H} \varepsilon_{tj}^H \tag{26}$$

$$H^L = \sum_{t=1}^{9} \sum_{j=1}^{n_t^L} \varepsilon_{tj}^L \tag{27}$$

Where n_t^H, n_t^L are numbers of workers with higher and secondary education who live in period t.

3.3. Government

The government performs several functions in this model: collecting taxes, subsidizing higher education, supplying the oldest with pension payments, and spending the unused tax revenues for government consumption G. The latter is necessary to balance the budget:

$$\sum_{t=1}^{9}\sum_{j=1}^{n_t}\left(w_{tj}\tau_w + rk_{tj}\tau_k + c_{tj}\tau_c\right) = \sum_{j=1}^{n^H}\left(s_\theta\phi + (1-s_\theta)s_\phi\phi\right) + \sum_{t=10}^{11}\sum_{j=1}^{n_t} b_{tj} + G \qquad (28)$$

Where s_θ is a share of n^H students with a merit-based full-cover grant.

In our exercise, it is assumed that G, which stands for all the government expenditures other than education subsidies and pensions for retirees, remains unchanged after the policy change.

3.4. Policy reforms

If the government changes the mechanism of higher education financing on the steady state, the government expenditures are altered, keeping G constant. Thus, the income tax rate τ_w is correspondingly altered to provide a proper increase in government revenue after each of the policy changes.

If the government abolishes tuition fees for everybody, $s_\phi = 1$, and his budget constraint becomes:

$$\sum_{t=1}^{9}\sum_{j=1}^{n_t}\left(w_{tj}\tau_w + k_{tj}\tau_k r + c_{tj}\tau_c\right) = \sum_{j=1}^{n^H}\phi + \sum_{t=10}^{11}\sum_{j=1}^{n_t} b_{tj} + G \tag{29}$$

The income tax rate is altered:

$$\tau_w = \frac{\sum_{j=1}^{n^H}\phi + \sum_{t=10}^{11}\sum_{j=1}^{n_t} b_{tj} + G - \sum_{t=1}^{9}\sum_{j=1}^{n_t}\left(k_{tj}\tau_k r + c_{tj}\tau_c\right)}{\sum_{t=1}^{9}\sum_{j=1}^{n_t} w_{ij}} \tag{30}$$

If the government forfeits all grants and subsidies for higher education, it corresponds to $s_\phi = 0$, and the budget constraint is:

$$\sum_{t=1}^{9}\sum_{j=1}^{n_t}\left(w_{tj}\tau_w + k_{tj}\tau_k r + c_{tj}\tau_c\right) = \sum_{t=10}^{11}\sum_{j=1}^{n_t} b_{tj} + G \tag{31}$$

The income tax thus becomes:

$$\tau_w = \frac{\sum_{j=1}^{n^H} \phi + \sum_{t=10}^{11} \sum_{j=1}^{n_t} b_{tj} + G - \sum_{t=1}^{9} \sum_{j=1}^{n_t} \left(k_{tj}\tau_k r + c_{tj}\tau_c\right)}{\sum_{t=1}^{9} \sum_{j=1}^{n_t} w_{ij}} \tag{32}$$

Suppose that the government abolishes merit-based grants, but it would like to keep the total higher education expenditures constant, assuming that the demand for higher education remains constant., although it may alter after the policy change. Then, it has to adjust the share of subsidization (s_ϕ^*), so that the next identity is true:

$$s_\phi^* \phi = s_\theta \phi + (1 - s_\theta) s_\phi \phi \tag{33}$$

By rearranging the parameters, we have:

$$s_\phi^* = s_\phi^* + s_\theta \left(1 - s_\phi\right) \tag{34}$$

When $0 < s_\phi < 1$ and $0 < s_\theta < 1$, the adjusted subsidization share is higher than the former ($s_\phi^* > s_\phi$).

Then the government budget constraint becomes:

$$\sum_{t=2}^{9}\sum_{j=1}^{n_t}\left(w_{tj}\tau_w + k_{tj}\tau_k r + c_{tj}\tau_c\right) = \sum_{j=1}^{n^H} s_\phi^* \phi + \sum_{t=2}^{9}\sum_{j=1}^{n_t} b_{tj} + G \tag{35}$$

Adjusting the subsidization share s_ϕ^* is done simultaneously with adjusting for the new income tax rate until both the government budget is balanced and the aggregate level of subsidies remains the same as in the initial model.

If the government decides to provide complete support to the poorest instead of the smartest, there are potentially multiple options to choose from as a measure of the student's welfare. Suppose that the government can observe the level of savings each adult parent accumulated.

Then, the budget constraint is similar:

$$\sum_{t=1}^{9}\sum_{j=1}^{n_t}\left(w_{tj}\tau_w + k_{tj}\tau_k r + c_{tj}\tau_c\right) = \sum_{j=1}^{n^H}\left(s_k\phi + (1 - s_k)s_\phi\phi\right) + \sum_{t=10}^{11}\sum_{j=1}^{n_t} b_{tj} + G \tag{36}$$

Where s_k is the share of the students with the need-based grant. It is set at such a level that the aggregate subsidies are the same, similar to the policy change described in 3.4.3, and updated together with τ_w.

Chapter 4

CALIBRATION

4.1. Exogenous parameters

To estimate agents' productivity dynamics through their lifetime, microdata on Ukrainian employees from the State Statistics Service of Ukraine is used (Appendix C). The earnings function is estimated by Weighted Least Squares (WLS) using the weights from the microdata for a better representation of the whole population of Ukraine:

$$\ln w = \beta_0 + \beta_1 educ + \beta_2 age + \beta_3 age^2 + \beta_4 age * educ + \beta_5 age^2 * educ \tag{37}$$

Where $educ$ is a binary variable that is equal to 1 if an employee has higher education, and 0 if not, age is measured in years.

The curves derived from the regression are shown in Figure 2. According to the curves, the most noticeable difference between Ukraine and the US is an exceptionally low age premium for workers with secondary education. The peak of their hourly earnings happens much more quickly – around the age of 30, and after that their wages decrease with age. Although the curve for the Ukrainian employees with higher education looks more usual, their age premiums are still lower, than the estimations of Abbott et. al. (2019) for the US.

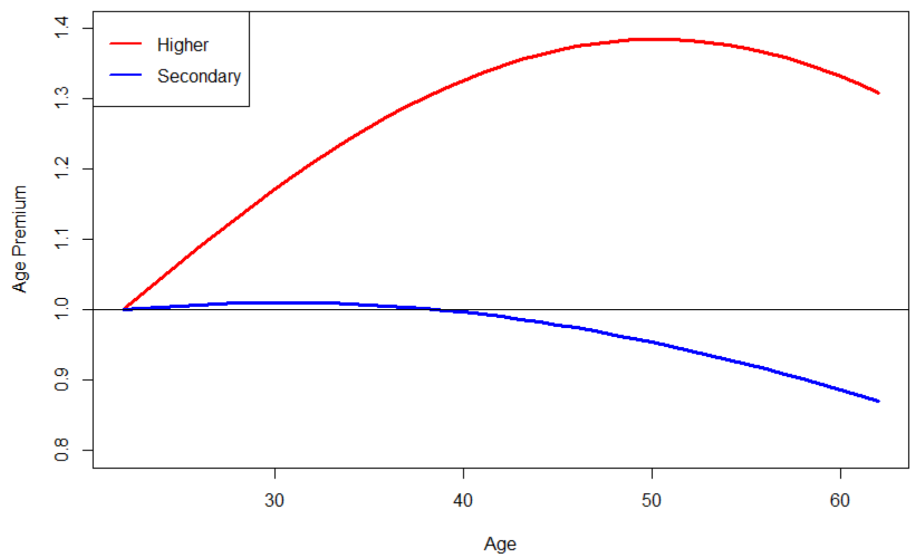

Figure 2. Wage dynamics in Ukraine by education and age

The age premium vectors for every period $t = 2, \ldots, 9$ derived from the regression estimates are:

$$p^H = (0.000 \quad 0.111 \quad 0.209 \quad 0.289 \quad 0.347 \quad 0.379 \quad 0.383 \quad 0.359)$$

$$p^L = (1.000 \quad 1.008 \quad 1.010 \quad 1.004 \quad -0.010 \quad -0.030 \quad -0.058 \quad -0.091)$$

In Table 1, the tax rates that are applied in the economy of Ukraine are chosen. Both labor and capital income tax rates, which are 18% also include a 1.5% military tax. According to the Ministry of Finance, education expenditures per student were 63,000 UAH for the students fully financed by the government and 38,000 UAH for those who paid tuition fees. Thus, the state still covers 60% of the tuition costs for the latter, and the full cost of a 5-year higher education program is 315,000 UAH.

The CRA value in the utility function is estimated for Ukraine by Gendelman and Hernández-Murillo (2015). The CRA coefficient estimated for Ukraine is unusually low compared to the estimates used in the literature, but this may be plausible to generate high wealth heterogeneity. Macroeconomic variables come from Penn World Tables – a database of the Groningen University. We estimate the 5-year discount rate β using the real internal rate of return for Ukraine from PWT (1.52%) and following the approach of Ahmed, Haider, and Iqbal (2012), but also accounting for the presence of capital taxes in the model:

$$\beta = \frac{1}{1 + r(1 - \tau_k)} \tag{38}$$

From the weighted Ukrainian microdata, it is estimated that the share of high-skilled labor in total labor income is almost exactly 2/3. We cannot use this value for the CES weight parameter μ, as its equivalence with income shares is relevant only for the Cobb-Douglas production function, for which the elasticity of substitution is exactly zero (Thöni 2015). Nevertheless, this value proved to be suitable during the calibration exercise. On the other hand, the different value for the elasticity of substitution is used. Behar (2010) indicates that the elasticity of substitution between high-skilled and low-skilled developing countries is close to 2, and this value can be applied to the various macroeconomic models. It corresponds to $\gamma = 0.5$ in our CES production function for labor.

Unfortunately, it is not possible to estimate the behavior of individual wage shocks in Ukraine properly using a static, one-period dataset. Thus, the persistence coefficient for wage shocks is obtained from Carneiro et. al. (2021). They estimate yearly wage persistence in Portugal for male and female labor separately. For our model, the average persistence between two sexes is raised to the fifth power to better represent persistence in more aggregate 5-year periods. The intergenerational correlation in ability is set at 0.5, according to Anger and Heineck (2010) who researched the relationship between the IQ level of parents and their children.

Table 1. Parameters defined using external sources

Parameter	Value	Source
τ_w	0.195	State Tax Service of Ukraine
τ_k	0.195	
τ_c	0.2	
s_b	0.4	Pension Fund of Ukraine
ψ	1.321	State Statistic Service of Ukraine (2016)
ϕ	0.315	Ministry of Finance of Ukraine
s_ϕ	0.6	
η	0.44	Gendelman and Hernández-Murillo (2015)
β	0.928	Groningen Growth and Development Centre
α	0.442	
r	0.076	
γ	0.5	Behar (2010)
ρ_z	0.619	Carneiro et. al. (2021)
ρ_θ	0.5	Anger and Heineck (2010)

It is worth clarifying that there are two approaches regarding the interest rate in this model. In Abbott et. al. (2013), it is endogenously defined by the marginal product of capital derived from the production function, which is the case of the closed economy. In simulating the economy of Chile, Leighton (2017) uses the small open economy approach in which it is given exogenously and does not change with the quantity of capital in the country. The former approach is fairly used for the US as not as much closed economy, as a large open economy. However, the latter approach suits better for the magnitude of the Ukrainian economy in the world.

The rest of the parameters, the value of which has been defined during the process of calibration, are represented in Table 2. The parameter for parental altruism is much higher than in Abbott et. al. (2013). This can be explained by its strong dependency on the particular risk-aversion coefficient used in the utility function. Because a different η for Ukraine found in literature is used, there is a need to modify the value of ω as well, so that the intergenerational transfers would not be too low or too high.

Table 2. Parameters adjusted to fit targets

Parameter	Value	Parameter	Value
A	2.5	$\bar{\xi}$	0.4
μ	0.667	σ_{ξ}	0.25
ω	0.8	σ_{ϵ}	0.5
ψ	1.2	σ_{θ}	0.5

In a couple of columns on the right of Table 2, there are standard deviations for the normal distributions of dropout probability (σ_{ξ}), productivity shock (σ_{ϵ}), and innate ability (σ_{θ}). Whereas the latter two are defined so that their means were at zero, we have to assume the mean dropout probability for the agent with a median innate ability ($\bar{\xi}$).

The parameters on the right-hand side are needed to generate productivity shocks (z_t) and innate ability levels (θ). Both z_t and θ can be approximated with Markov-chain transition matrices using Tauchen (1987) method. A detailed explanation of how it was used to approximate the AR(1) productivity process and normal distributions for the ability vector and the corresponding dropout probabilities is given in Appendix D.

Heer and Maussner (2009) show that only three discrete shocks are enough to model real-life income heterogeneity. Furthermore, even though there are only 3 possible shocks in each period, they generate 19,683 (3^9) possible combinations of shocks through the lifecycle of the agent who works from the first period, and 6,561 (3^8) shocks for the agent who decided to study at the university at the beginning of his life. By using 5 shocks instead of 3, the number of combinations becomes much higher – 1,953,125 (5^9) and 390,625 (5^8). That might be problematic for modeling the steady state values for the aggregate economy. Therefore, only 3 discrete states are modeled, and they are:

$$Z = (-0.4294 \quad 0 \quad 0.4294)$$

The corresponding transition matrix between the different states of productivity shocks is:

$$P^Z = \begin{pmatrix} 0.5407 & 0.2910 & 0.1683 \\ 0.3338 & 0.3324 & 0.3338 \\ 0.1683 & 0.2910 & 0.5407 \end{pmatrix}$$

The approximation vector for the innate ability contains 5 discrete states:

$$\Theta = (-0.9062 \quad -0.3708 \quad 0 \quad 0.3708 \quad 0.9062)$$

The probability to be dropped out of the university for the corresponding states of innate ability are:

$$\Xi = (0.7204 \quad 0.5311 \quad 0.4000 \quad 0.2689 \quad 0.0796)$$

The transition matrix, which defines the probabilities of the child having a certain state of innate ability given that her parent has a particular state, is:

$$P^\Theta = \begin{pmatrix} 0.3554 & 0.3484 & 0.1954 & 0.0863 & 0.0145 \\ 0.1824 & 0.3176 & 0.2708 & 0.1795 & 0.0497 \\ 0.1008 & 0.2546 & 0.2892 & 0.2546 & 0.1008 \\ 0.0497 & 0.1795 & 0.2708 & 0.3176 & 0.1824 \\ 0.0145 & 0.0863 & 0.1954 & 0.3484 & 0.3554 \end{pmatrix}$$

Given those parameters, the baseline model and the economy after policy changes are simulated in MATLAB using the algorithm described in Appendix E.

4.2. Baseline model estimates

In the baseline setting, the merit-based system is modeled according to which students from the 4th and 5th quintile of the innate ability distribution do not pay for their tuition, while the rest of the students pay 189,000 UAH, which is still only 60% of the real tuition cost for the government (315,000 UAH).

The model is calibrated to correspond to the targets observed in the Ukrainian economy (Table 3). The mean wage is used for the same year as the tuition cost for consistency. The yearly mean wage (139,159 UAH) is then multiplied by 5 to correspond to the 5 years. Gini indices are taken from the most recent World Inequality Database estimates for 2021. The graduation rate is calculated as the number of students who graduated with a bachelor's degree in 2021 (180,675) divided by the number of students who entered a bachelorship in 2017 (264,448). The dropout rate then is simply the opposite of the graduation rate.

Table 3. Target values for calibration

Indicator	Simulation	Target	Source
Mean labor earnings	0.666	0.697	Minfin
Income Gini (pre-tax)	0.5016	0.43	World Inequality Database
Wealth Gini	0.6156	0.75	
Labor with higher education	50.1%	51.7%	State Statistic Service of Ukraine (2016)
Dropout rate	32.5%	31.7%	State Statistic Service of Ukraine (2017)

Although the model resembles the share of labor with higher education and dropout rates, the Gini values for income and wealth distributions are noticeably further from their targets. In defense of the results, it is worth saying that the data source for the Gini income index in Ukraine is given the lowest reliability score by WID, so there is a possibility of underestimation in the empirical estimate. The issue with the underestimated wealth Gini is more universal in the literature of heterogeneous OLG models (Heer and Maussner, 2009). It might be difficult to capture the real-world disparities in wealth, especially when the Gini values are shaped mostly by several of the richest people in the country.

In Figure 3, the Lorenz curves for income and wealth distribution are built from the simulation of heterogeneous agents' lifecycles. The vertical line corresponds to perfect equality. In this case, it is visible that wealth is distributed more unequally than income because the corresponding Lorenz curve is further from the perfect equality line. The set of parameters and approximations of random variables used in the model let us build a fairly smooth Lorenz curve for income, whereas the shape of the Lorenz curve for wealth depends more on the interval and precision of the capital grid. It can also be noticed that for approximately 30% of the adult population, the savings are zero. This is also a realistic outcome, according to which people with the lowest income spend everything on consumption and cannot afford to transfer part of their savings to further periods of life.

In contrast to the deterministic Ramsey problem, we do not have only one pre-determined path for consumption and savings because the agents are exposed to unexpected changes in their level of income, so they adjust their consumption-savings tradeoff according to the shock that happened in the current period. Figure 4 represents the mean values of savings calculated for the agents in a particular quintile of innate ability.

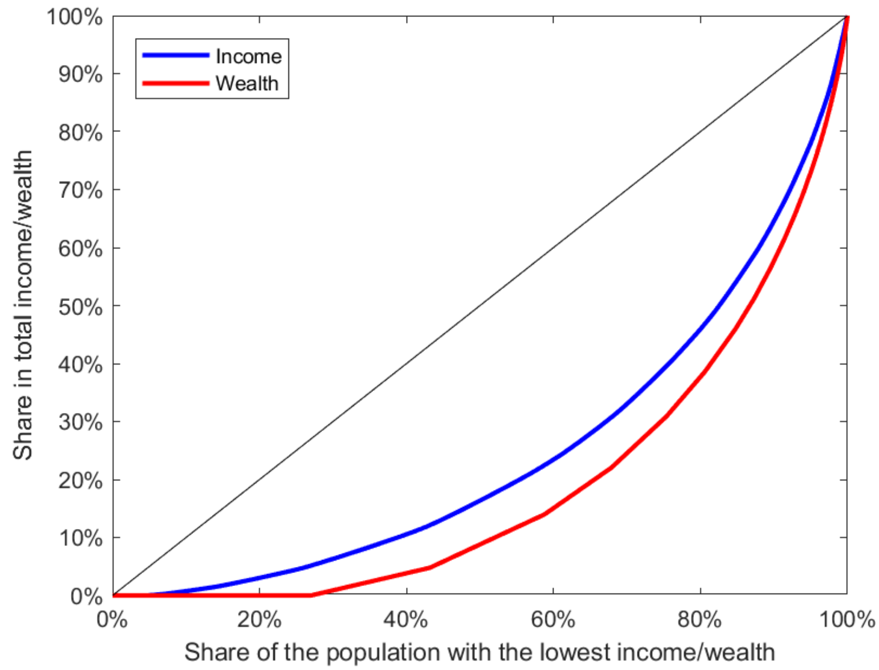

Figure 3. Lorenz curves for income and wealth distribution in the model

By looking at savings paths, we can recognize key events in the agent's life which structurally change the trend in savings accumulation. The capital at the age of 17 is equivalent to the size of the intergenerational transfer received from the parents. It can be spent for both consumption and education. We can see that most of the agents in 1st and 2nd quintiles might have not enough money to enroll at the university even when they would like to do that. On the other hand, the smartest (and the richest) of the youth spend much more capital than their education costs, so at the age of 22 (period 2) all the groups have relatively low savings.

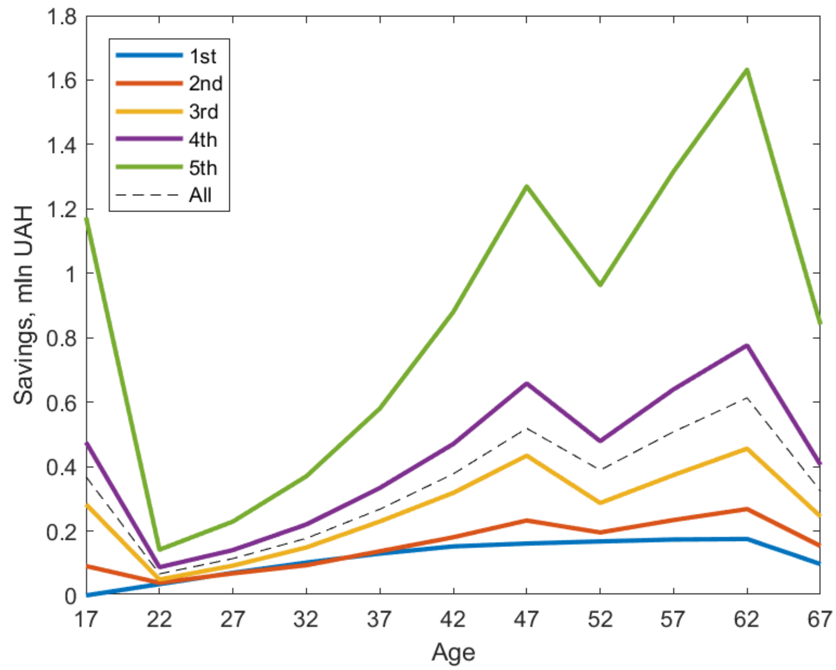

Figure 4. Mean Savings by age and innate ability quintile

From the age of 22 to 47, all the agents accumulate capital. Their savings, besides playing a traditional precautionary role, stand also as a base for an intergenerational transfer which happens when a parent is at the age of 47. Parents from the 1st ability quintile do not have higher education to boost their income and savings. Furthermore, according to our transitional matrix for innate ability, they do not expect that their children manage to obtain the university diploma successfully. As a result, they do not transfer any money to their children. For all the other quintiles, we can a sharp drop in savings the magnitude of which itself depends on the level of savings accumulated before. After that, the savings are accumulated again because they are still needed to smooth consumption through life accounting for a drop in income when the agents retire at the age of 62.

In Figure 5, we can see the monetary value of agents' consumption on average. The chosen coefficient η in the utility function for Ukraine, although unusually low for macroeconomic modeling, is enough to generate a consumption smoothing effect. We can see that consumption for all of the ability groups is fairly flat, with a slight upward convex trend. We can also see the reason why smarter agents spend most of their transfer in the very first period between ages 17 and 22. Enrolling at the university, most of them lock the opportunity to each income from the beginning, so they use their transfer to maintain consumption at a level similar to the following periods when they work.

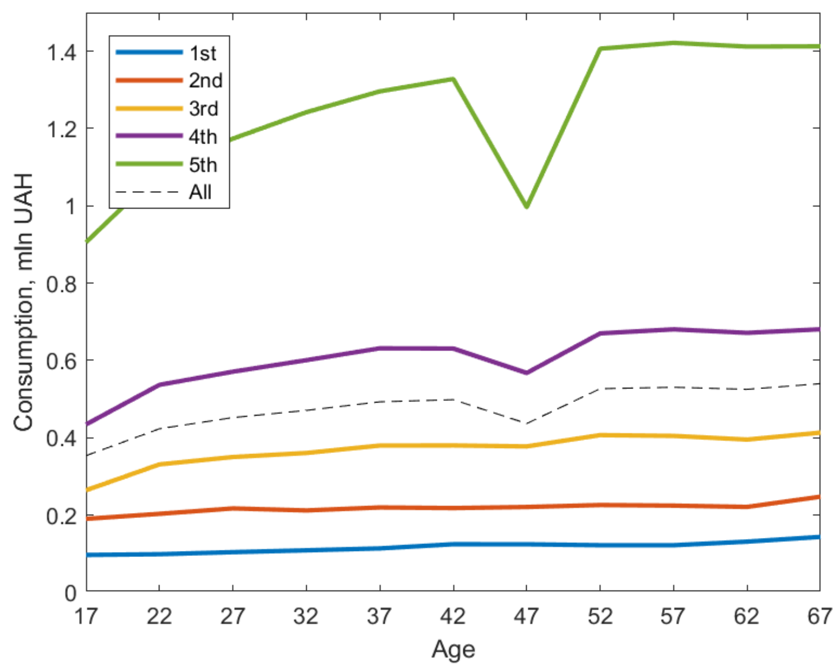

Figure 5. Mean consumption by innate ability quintile

The only period which abrupts the trend is when an agent transfers a sum of money to his child. Agents are altruistic in the sense that they also benefit from the expected lifetime utility of their children given the current transfer. Thus, they are ready to drop consumption temporarily. After that, they restore consumption at the usual level.

After calibrating the baseline model, it is modified for each policy change considered and the new equilibria are found. Chapter 5 discusses changes in the model's endogenous variables that arise after the simulations are completed.

Chapter 5

POLICY SIMULATIONS

5.1. Recalibrating the model

All the policy change scenarios are simulated on the base of the initial steady-state economy with the binary system of higher education according to which full-cover grants are awarded to the smartest students. Both partial and general equilibria are found. In partial equilibrium, only taxes rates (and subsidies for Cases 3 and 4) are updated to balance the government budget, but the factor prices are left the same as before the policy change. It corresponds to the case when the labor has already reacted to the changes in the value of education for them and moved between different labor markets, but the market itself has not adjusted to the new quantities of human capital. In general equilibrium, both the government budget and labor prices are adjusted.

Unfortunately, our model cannot properly display how the changes in the variables happen dynamically, from one period to another. One reason is that the distinct periods represent fairly wide time intervals (5 years). Another reason is the complicated iterative algorithm for finding a steady state. After the policy change, a lot of the model's aggregate variables and their distribution in heterogeneous society need to be sequentially readjusted. However, we could assume that the rational agents can calculate all the necessary adjustments simultaneously, but the labor market reaction is more deferred. In this case, partial equilibrium represents what happens 5 years after the policy change, when the first cohort of students under new conditions graduated from universities. Let the general equilibrium of the economy represent the long run with an indefinite time frame.

For the following policy changes, the aggregate education subsidies are fixed at the previous level in addition to the procedure of balancing the budget. This is done to better access the macroeconomic changes from the qualitative modification of the education financing system rather than a simple increase/decrease of the financing in monetary terms. In the case of a diversified system, it also means that the subsidization share should also be adjusted properly. Under the old system, the students without a full-cover grant paid 40% of the tuition cost (126,000 UAH). Keeping subsidies for higher education equal (13.6 Billion UAH) and abolishing merit-based grants, students can pay only 18% of costs (56,700 UAH). Thus, the students that used to qualify for a grant start paying, while the rest benefit from lower tuition fees.

Before analyzing how a switch in the criterion for qualifying for a grant impacts the economy, some clarifications should be made. Before that policy change, the students from the 4th and 5th ability quintile were eligible for a grant. This parameter was exogenous to the model because it was defined before the life cycle simulations. However, need-based grants need values for the distribution of wealth within the society, which is a final result of simulation and changes every time the model is altered.

Let k_s be a threshold for a student's savings which are equivalent to intergenerational transfers at the beginning. Thus, in the case of a binary system with need-based grants, we adjust it every time, so that the aggregate subsidies are the same as before. In our final setting, $k_s = 0.8$ mln UAH. This can be fairly considered high value. But the reason for it being high is that the students from the 1st and 2nd ability quintile do not want to enroll in a university anyway, accounting for their low probability to graduate and a relatively small boost in wages for them in case of graduation.

In subsections 5.1 and 5.2, the numerical results of the policy simulations are presented and their implications are discussed.

5.2. Aggregate outcomes

The aggregate indicators presented in Tables 4 and 5 are measured in different units. Some of them are difficult to interpret in absolute terms, for example, unit-wages and human capital. Thus, the model's output is shown in terms of change to the baseline model of merit-based grants. The values presented are relative changes. The exceptions are the share of labor with higher education, dropout rate, and income tax rate, which are given in terms of absolute percentage change. For income and wealth Gini, absolute changes in indices are shown since percentage changes are not interpretable for them. The absolute values of the given indicators are presented in Appendix F.

Almost all of the changes are lower in magnitude in partial than in general equilibrium. However, we can still observe how the new financing policies impact the demand for education and the whole economy before the new labor market equilibrium is set.

Pure private higher education policy has the strongest and the most negative impact on the economy in the short-run. Less people enter and graduate from universities, thus we observe the flow from high-skilled to low-skilled human capital. Skill premium, which can be considered the measure of both return to education and income inequality, increases by 6%, while the changes in income Gini are the opposite, but less significant. The output drops mildly, by less than 1%, because the disruption in human production factors is mitigated by the increase in aggregate savings, which in our model are always equal to the physical capital used in the production function. Therefore, setting tuition fees equivalent to the full price of higher education is a lose-lose policy, as it worsens both the level of productivity in the economy and income inequality.

Table 4. Economy of Ukraine in partial equilibrium under various systems of higher education financing

Indicator	Education financing			
	Pure private	Diversified	Binary need-based	Pure public
w^L	-	-	-	-
w^H	-	-	-	-
K	+2.3%	-0.5%	-0.3%	-1.3%
H^L	+21.0%	-3.1%	+3.6%	-8.9%
H^H	-10.5%	+1.4%	-1.8%	+4.0%
Y	-0.9%	-0.0%	-0.4%	-0.2%
Skill premium	+6.0%	-2.3%	-2.2%	-5.7%
τ_w	-0.3%	+0.5%	+0.7%	+0.5%
Labor with higher education	-8.6%	+1.2%	-0.8%	+4.9%
Dropout rate	-4.7%	+0.4%	+0.1%	+2.3%
Mean wage	-3.6%	+0.3%	-0.7%	+1.0%
Income Gini	-0.001	-0.001	-0.003	-0.003
Wealth Gini	+0.004	0.000	-0.001	+0.002

The impact of the opposite policy, pure public higher education, mostly leads to mirrored results. Some people that used to work after graduation from high school start to prefer entering the university. Changes in both skill premium and income Gini indicate that the income distribution became more equal. Although mean wages are somewhat higher, any possible surpluses from the redistribution of labor between high- and low-skilled segments are canceled out by decreased savings. As a result, public education serves as an income equalizer in the short run, even though its impact on total productivity is inconclusive.

Although two alternative policies in the middle are simulated in such a way that the educational expenses on education are the same, both of them are costlier to implement, as we can imply from the increases in tax rates. A diversified system leads to a slight improvement in tertiary attainment and share of labor with higher education, whereas implementing need-based instead of merit-based grants surprisingly leads to a lower share than before. Both inequality measures support the hypothesis that the mentioned policy changes equalize income distribution. Need-based grants lead to lower output in the short run than before, but the impact of a diversified system is inconclusive since the changes are less than 0.1% in magnitude.

Table 5. Economy of Ukraine in general equilibrium under various systems of higher education financing

Indicator	Education financing			
	Pure private	Diversified	Binary need-based	Pure public
w^L	-1.6%	-0.2%	-0.9%	+1.1%
w^H	+11.4%	-2.1%	+0.7%	-3.6%
K	+15.6%	-3.4%	+0.2%	-0.6%
H^L	+17.8%	-2.1%	+2.4%	-6.6%
H^H	-9.0%	+0.9%	-1.2%	+3.0%
Y	+5.0%	-1.4%	-0.1%	-2.1%
Skill premium	+15.4%	-3.7%	-2.1%	-8.9%
τ_w	-2.5%	+1.1%	+0.6%	+1.4%
Labor with higher education	-6.7%	+1.2%	+0.2%	+3.7%
Dropout rate	-2.6%	+0.4%	+0.4%	+1.9%
Mean wage	+4.1%	-1.5%	-0.3%	-1.9%
Income Gini	+0.016	-0.004	-0.001	-0.009
Wealth Gini	+0.010	-0.002	-0.002	-0.002

In comparison to partial equilibrium, the impact of pure private education on income inequality is much clearer. The increase in skill premium is much higher, and income Gini is higher now as well. The influence on the higher education share is still negative, but slightly mitigated. Some people discouraged from obtaining a degree in the short run are now willing to do that because the unit-wages for high-skilled labor finally increased. GDP is now higher by 5%. Although people pay for higher education themselves, the boost in productivity is strong enough to encourage even higher savings than before. Thus, pure private education leads to the highest productivity and income inequality in the long run, as was assumed.

The direction and magnitude of public education policy, in the long run, is also well observed. Skill premium and income Gini decrease, together with the total output. However, the changes are much lower in magnitude in comparison to pure private mode. It can be considered as both an advantage and a drawback. If the primary aim of the state is to fight inequality, public education can mitigate it for relatively small losses in productivity. In principle, the government could go further and make education subsidized by providing scholarships that are higher in value than the cost of education, attempting to set even lower income inequality, but such a policy is out of the scope of this thesis.

The impact of diversified mode of education financing on income inequality, in the long run, is very similar to what was observed in the short run, but somewhat stronger. However, both mean wage and output are lower in the long run. The main drawback of this policy is that both unit wages are lower than before, so decreased inequality might have happened just because the drop in wages of high-skilled people is stronger. At the same time, the unit wages of high-skilled labor unexpectedly increase under the system of need-based grants as opposed to low-skilled labor, but the change in skill premium is still negative. This is possible only if the average productivity levels of two labor groups changed oppositely. The main advantage of the need-based grants over the diversified system is that the level of savings/capital is higher, canceling out the negative effects on output.

Figures 6 and 7 visualize changes in the level of inputs and outputs in the economy, in partial and general equilibrium correspondingly. The visualizations show more clearly that changes in human-capital components of the input have a canceling-out nature, so their aggregate impact on the level of output is negligible. Therefore, the level of physical capital is the only significant determinant of changes in output in our model. Both variables move proportionally in all cases. As can be noticed, changes in the level of accumulated physical capital are higher in magnitude for all modes of general equilibrium except for the binary need-based system.

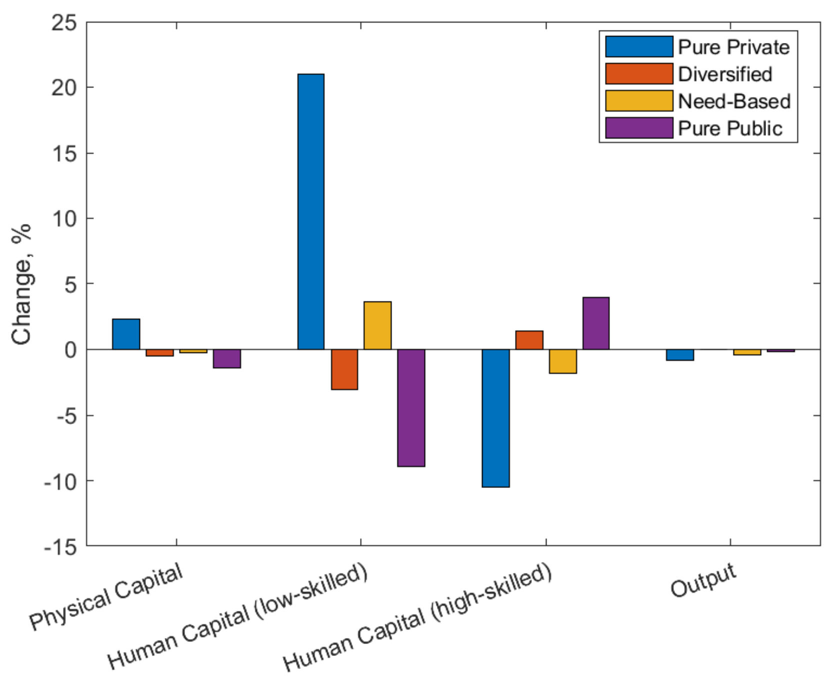

Figure 6. Changes in production factors and output (partial equilibrium)

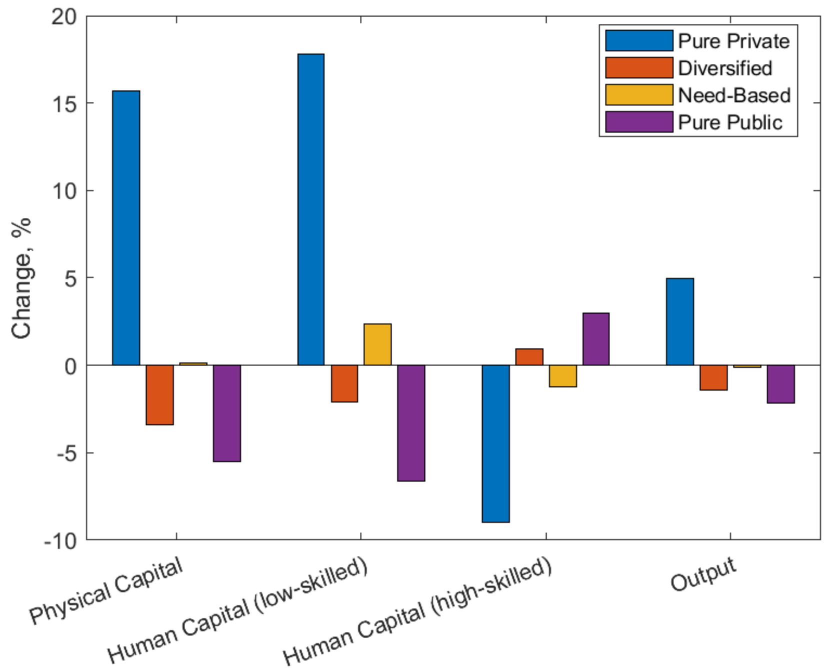

Figure 7. Changes in production factors and output (general equilibrium)

Figures 8 and 9 present a similar visualization, but now changes in skill premium are decomposed instead. In Figure 8, there are no bars representing changes in unit-wages which corresponds to the fixed labor costs in partial equilibrium. However, skill premium is an object to change even in the short run because different education policies still can influence the structure of labor in the economy by encouraging or discouraging particular groups of the population to obtain a higher education degree. Together with a unit-wage, an individual's productivity level influences the total wage they receive. Thus, skill premium is positively related to the productivity of high-skilled labor and negatively to the productivity of low-skilled labor.

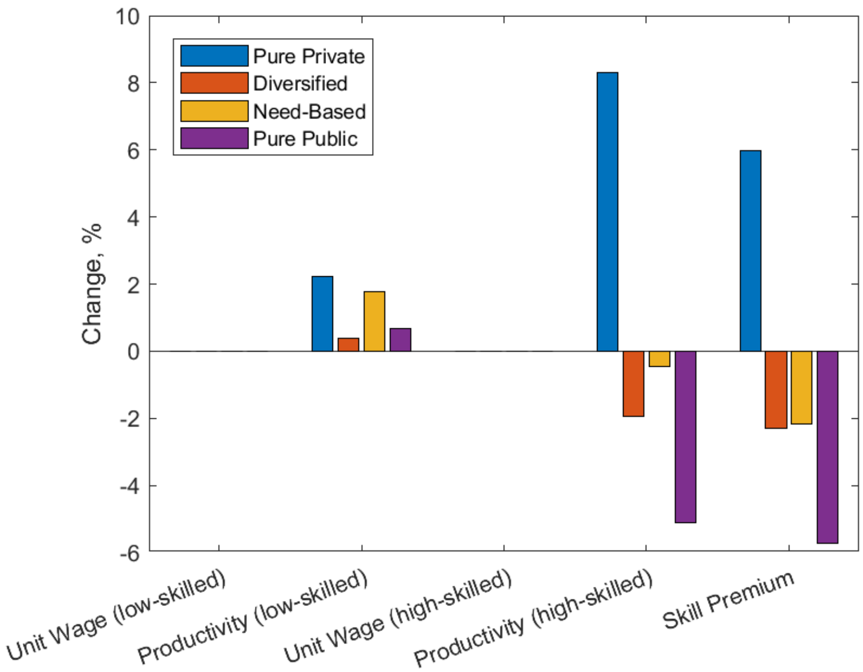

Figure 8. Decomposition of changes in wages (partial equilibrium)

Figure 8 shows that, similarly to human capital levels, productivities move in opposite directions to each other, but not in the case of pure private higher education. This policy increases the productivity of both groups, but the high-skilled labor productivity increases much stronger, leading to a higher skill premium. Pure public education leads to slightly higher productivity within the low-skilled labor segment, but the losses of high-skilled labor productivity are much more severe. Both diversified and need-based policies decrease skill premiums in the short run, but the sources of that effect are slightly different. In the case of diversified policy, it happens mainly because of the drop in high-skilled productivity, whereas need-based policy leads to a more significant increase in low-skilled productivity, heightening the wages of this labor segment.

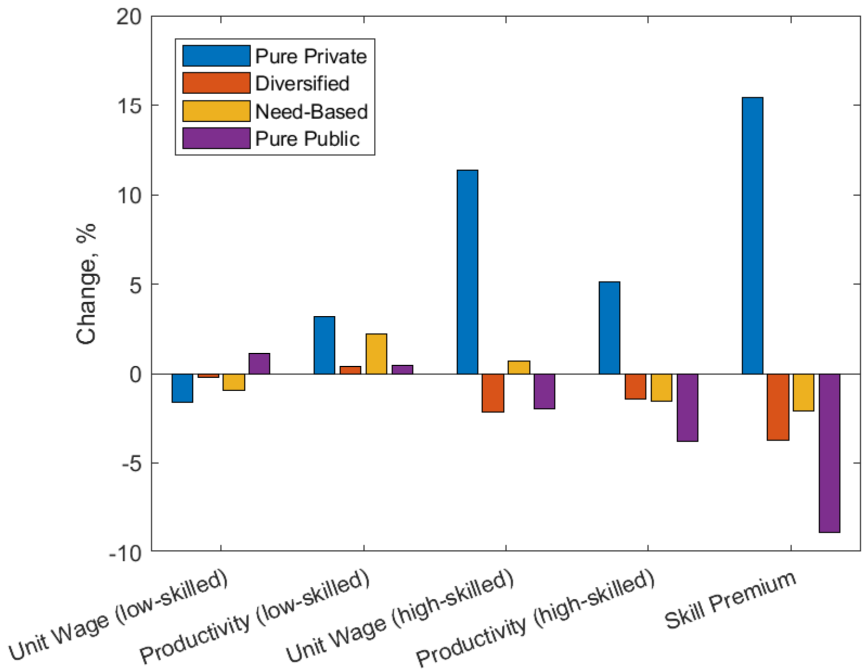

Figure 9. Decomposition of changes in wages (general equilibrium)

Figure 9 shows that changes in the productivities of both labor segments in general equilibrium are very similar. However, unit wages are allowed to adjust in the long run, so they also contribute to changes in the skill premium. In the case of pure private education, a spike in high-skilled unit wages leads to an even higher degree of inequality than before. Changes in unit wages under a diversified system, which are very similar to what happens under pure public financing, contribute to lower inequality, whereas the effect of need-based grants is the opposite. Nevertheless, the mitigating impact of need-based policy is sustained in the long run.

All of the information provided by the simulations is summarized in Table 6. Changes in output 0.2% in magnitude or less are considered as inconclusive. As an inequality measure, both skill premium and income Gini are accounted for. There is only one observance of conflict between two measures (pure private education in the short run), but the change in income Gini is only -0.001 which is also negligible.

Table 6. Aggregate impact of education policy changes on the economy

Policy	Short run		Long run	
	Output	Inequality	Output	Inequality
Pure private	-	+	+	+
Diversified	?	-	-	-
Need-based	-	-	?	-
Public	?	-	-	-

The aggregate effects studied in the current section might not provide a full picture of income and wealth redistribution within the economy. The main advantage of the heterogeneous macroeconomic model is the possibility to observe the impact of some policies on different categories of the population. The next section delves deeper into this issue.

5.3. Decomposition of outcomes by ability and education

The results of the simulations are presented in a similar way to the previous section. All the indicators, except for the share of higher education, are shown in terms of percentage changes relative to the baseline policy and visualized. All the values of tertiary attainment, income, consumption, and utility within different population groups are shown in absolute terms in Appendix G.

Figures 10 and 11 visualize the impact of education policies on the share of the population holding a higher education degree. Although both shares of higher education and tertiary attainment can be studied separately within our model, they always move proportionally. The only difference is that the share of people holding a degree is also influenced by the corresponding dropout probability. So even when all of the people from some ability quintile decide to enter the university, the share of those who graduated successfully is lower, as Tables 16 and 17 in Appendix G show.

Both in partial and general equilibrium, a population from the 1st (lowest) ability quintile does not enter the university at all under any policy of those studied. The main obstacle for them is a dropout rate that is too high to guarantee an expected payoff high in terms of lifetime utility which is high enough for them to enroll. Nevertheless, calibrating the model using different parameters can make it theoretically possible.

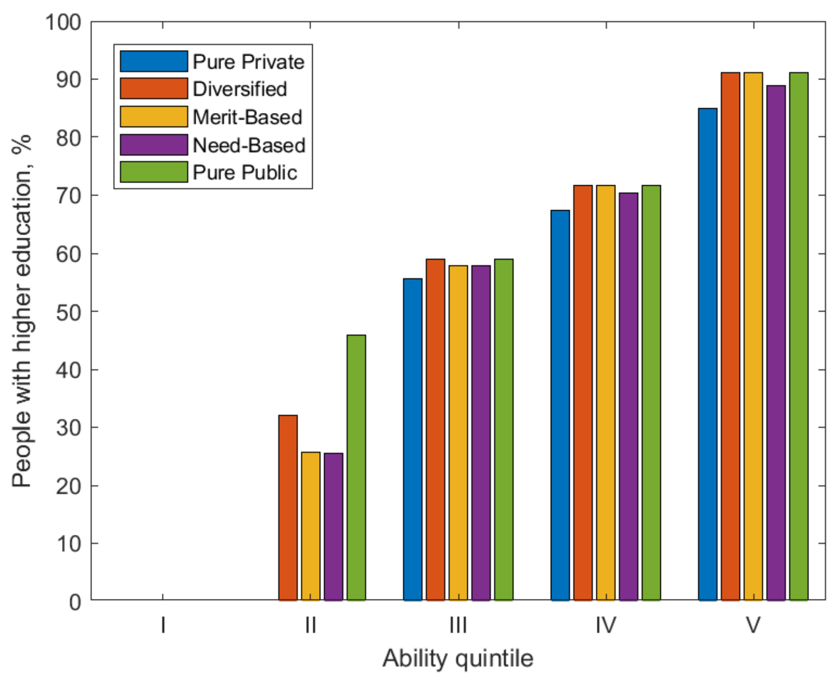

Figure 10. Share of people with higher education (partial equilibrium)

In all cases, both in partial and general equilibrium, the differences in tertiary attainment among the 3rd, 4th, and 5th innate ability quintiles are minimal. Tertiary attainment among those groups is close to the maximum (see Table 17 in Appendix G), so the share of people with higher education among them is mostly defined by the exogenously given dropout probabilities. Almost the whole effect of the policies in our model is directed to the 2nd quintile, as their higher education share deviates the most.

Furthermore, can see that the column that corresponds to the share of people with higher education among the 2nd ability quintile under pure private education policy is missing in Figure 10. It means that in partial equilibrium, the rising cost of education together with fixed unit wages discourage all the people from this segment from entering a university. When the government covers the whole cost of tuition, the effect is vice versa.

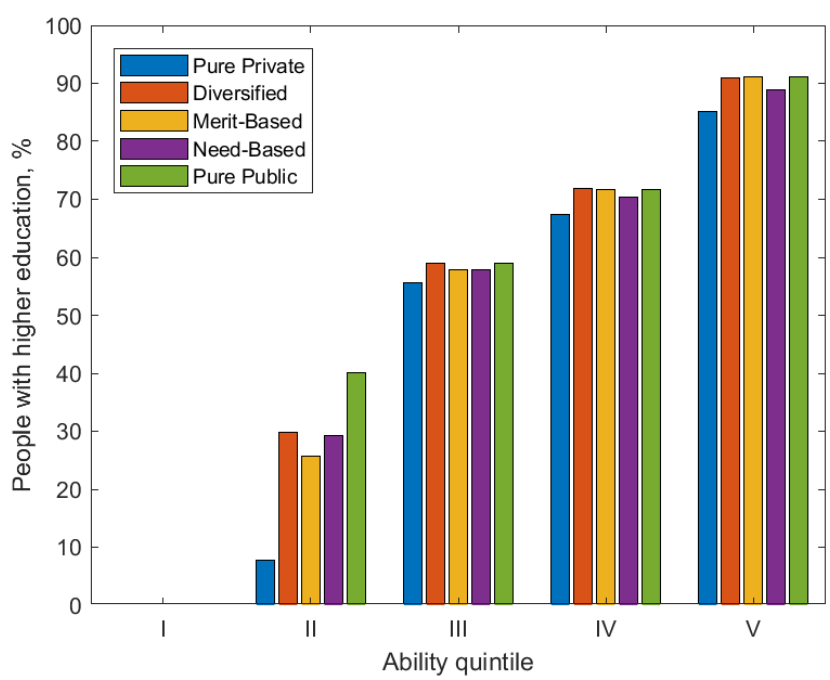

Figure 11. Share of people with higher education (general equilibrium)

The enrolment is slightly higher under the diversified system as well. Merit-based grants are not available for the 2nd quintile, so they are forced to partially pay for their tuition if they wish to enroll. But when the merit-based grants are abolished and all the population groups share part of the tuition costs equally, it is equivalent to the discount for the people from the 2nd quintile.

The policy of merit-based grants has a similar effect to the one described above on the university enrollment of the 2nd quintile, but only in the long run. However, under this policy, we can also observe changes in the shares of the quintiles with higher innate abilities. Enrolment of the 4th and 5th quintiles is the lowest both in partial and general equilibrium. This is not a surprising outcome, recalling the fact that this policy leads to the more expensive education for "the smartest" students.

Figures 12 and 13 show changes in the number of average transfers that the parents leave to their children. Although the child's innate ability has a stochastic nature, we calibrate the model so that in the steady state, the transfer an individual from a particular ability quintile receives is equal to what they give to their children later. Monetary values of transfers are available in Figure 4 and Table 18 in Appendix G.

The 1st quintile is not presented because no transfers take place among this population group. The same thing happens to the 2nd quintile under pure private higher education in the short run. Discouragement from higher education together with the absence of the parents' financing leads to a vicious circle making it impossible for them to study during the 1st period in the model. In the long run, we also observe a significant drop in transfers among this population group, but they are not crowded out completely. Pure private education policy has the opposite effect on the transfers among the higher ability quintiles. They still want to study, but education becomes more expensive for them, so the parents decide to leave more money for their children's good.

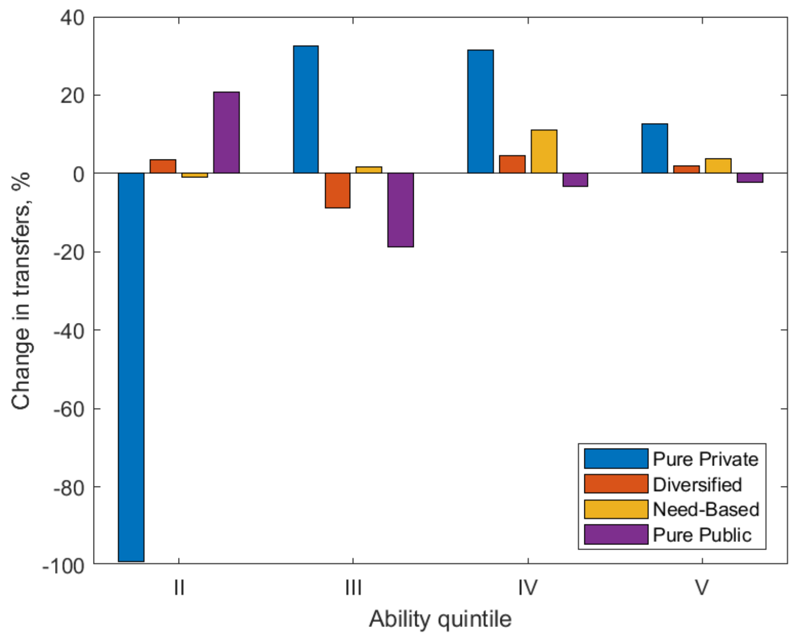

Figure 12. Change in parent-child transfers (partial equilibrium)

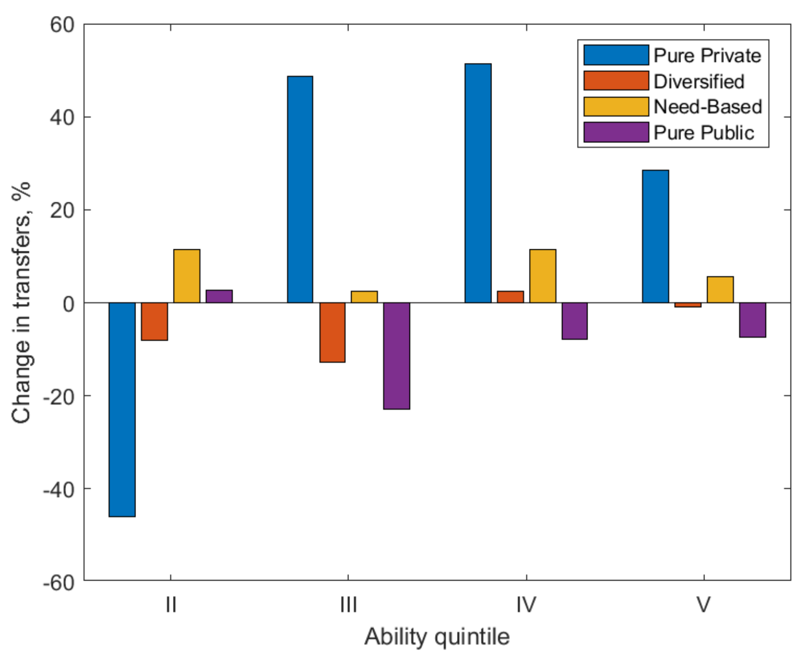

Figure 13. Change in parent-child transfers (general equilibrium)

Pure public education has an opposite, but considerably weaker effect on transfers. It increases the sum of transfers among the 2nd quintile. Even though they can study for free now, they still should sacrifice 5 years for studying at the university instead of starting to work immediately. Thus, the parents leave more money than before so that their children can benefit from higher education later in life. The impact of public education on the transfers is the most negative among the 3rd quintile and it sustains even in the long run.

Interestingly, diversified and need-based policies have the opposite effects on transfers. It is especially noticeable in general equilibrium (Figure 13). The transfers are slightly decreased among the 2nd and 3rd quintiles, while changes among the 4th and 5th quintiles are positive but much less significant. At the same time, the policy of need-based grants is the only one which leads to improvements in the number of transfers among all the population groups. The drivers of this improvement might be different. For example, transfers increase for the 4th and 5th quintile as a result of higher tuition fees for them. Somewhat paradoxically at first glance, the increase among the 2nd quintiles probably comes from the fact that education became cheaper for them, so the parents agree to finance at least part of it.

Figures 14 and 15 show the effect of the policies on the lifetime consumption of the individuals. Besides different innate ability quintiles, we now also separate individuals by the level of education obtained. In Appendix G, both the amounts of income and consumption are available. It should be noted that it represents only the impact on the people who remained in the same category before and after a policy change. Among those who decided to enroll or withdraw from the university, obtaining an education is better under any type of policy (Tables 21, 22).

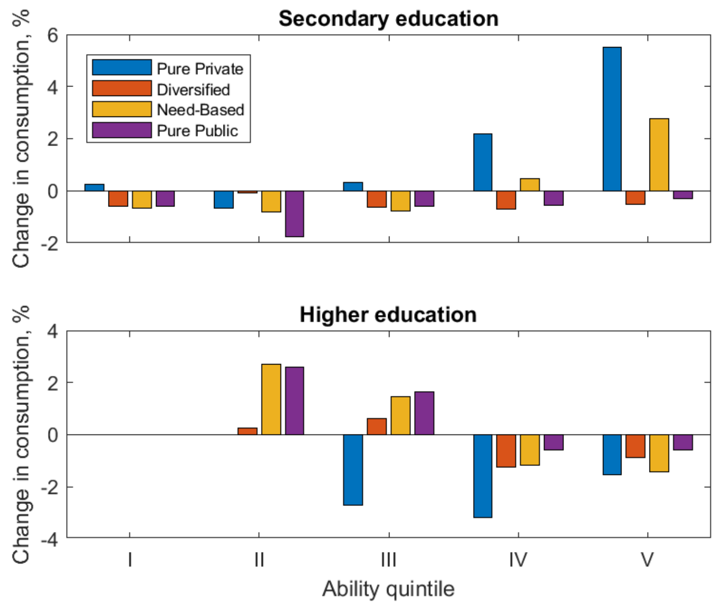

Figure 14. Change in consumption (partial equilibrium)

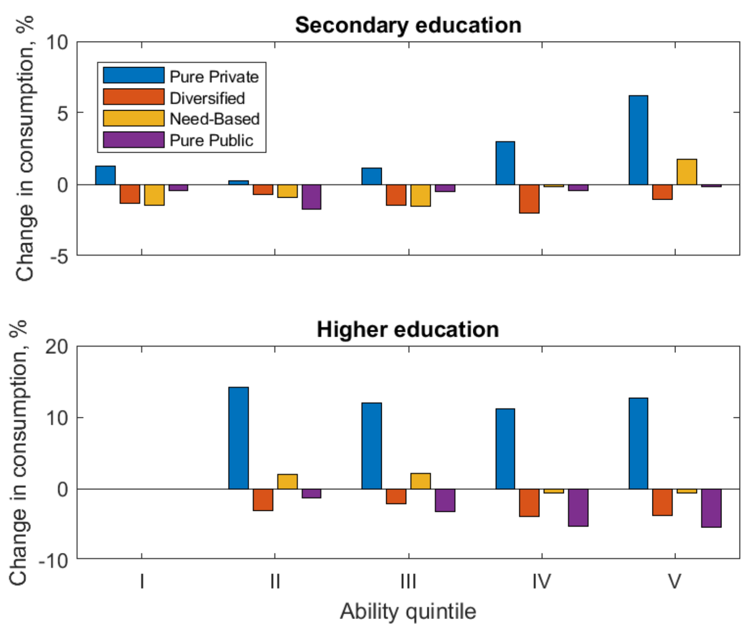

Figure 15. Change in consumption (general equilibrium)

As Figure 14 shows, all the policies lead to a decrease in consumption in partial equilibrium among the people with secondary education. In the case of private education and need-based grants, the opposite happens among the 4^{th} and 5^{th} quintiles which have only secondary education, but those groups represent only a small share of the population. This result resembles a lot the decrease in aggregate GDP in Section 5.2. However, 2^{nd} and 3^{rd} quintiles with higher education benefit from all the policies in the short run.

In the long run, only pure private higher education leads to improvement in consumption among the people with secondary education, even though their unit wages fall. Consumption is higher for both education groups under this policy. Pure public and diversified systems have similar negative effects on the consumption of all groups. However, the policy of need-based grants demonstrates a beneficial externality again. It not only leads to higher enrolment among the 2^{nd} and 3^{rd} quintiles but also increases consumption among the people of the same innate ability who were already enrolled before. This could be the result of the fact that education is provided to them for free, so they spend less at the beginning of their lives redistributing part of the money to consumption.

Alternatively, we can observe the welfare levels under different policies directly from the values of their utility functions. It has little sense to measure the magnitudes of changes, but we can use the values to rank the preferences for the policies by various population groups. Tables 7 and 8 present those rankings, derived from utility values in Tables 23 and 24 (Appendix G).

The preferences of people with secondary education in the short and the long run are consistent. They prefer pure private education the most, while pure public education or need-based grants are the worst for them. This can be interpreted as follows. Because they do not obtain higher education in any case, they cannot benefit from free education, but they share the burden of increased income taxes with everybody else. The pure private system, on the contrary, leads to the lowest tax rate, so they can benefit from it.

Table 7. Policies ranked by preferences (secondary education)

Education financing					
(Partial eq-m)	Pure private	Diversified	Binary merit-based	Binary need-based	Pure public
I	1st	3rd-4th	2nd	5th	3rd-4th
II	3rd	2nd	1st	4th	5th
III	1st	4th	2nd	5th	3rd
IV	1st	5th	3rd	2nd	4th
V	1st	5th	3rd	2nd	4th
(General eq-m)	Pure private	Diversified	Binary merit-based	Binary need-based	Pure public
I	1st	4th	2nd	5th	3rd
II	1st	3rd	2nd	4th	5th
III	1st	4th	2nd	5th	3rd
IV	1st	5th	3rd	2nd	4th
V	1st	5th	3rd	2nd	4th

On the other hand, the preferences of the population with higher education vary considerably. Under a purely private system, education becomes more expensive for everybody, but the income cannot be adjusted appropriately yet. However, due to the higher wages of the high-skilled labor in the long run, pure private education policy turns from the least favorite into the most favorite. The rankings confirm that the people from the 2nd and 3rd quantiles are the main beneficiaries of the need-based grants policy.

Table 8. Policies ranked by preferences (higher education)

Education financing					
(Partial eq-m)	Pure private	Diversified	Binary merit-based	Binary need-based	Pure public
I	-	-	-	-	-
II	-	3rd	4th	1st	2nd
III	5th	3rd	4th	1st	2nd
IV	5th	4th	1st	3rd	2nd
V	5th	3rd	1st	4th	2nd
(General eq-m)	Pure private	Diversified	Binary merit-based	Binary need-based	Pure public
I	-	-	-	-	-
II	1st	5th	3rd	2nd	4th
III	1st	4th	3rd	2nd	5th
IV	1st	4th	3rd	3rd	5th
V	1st	4th	2nd	3rd	5th

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Chapter 6

CONCLUSIONS

In this thesis, the redistributive effects of changes in the government policy of higher education funding were investigated on the macroeconomic level. For this purpose, an OLG model with heterogeneous agents was calibrated for the Ukrainian economy and the corresponding simulations were conducted.

As it was suggested in the preliminary hypotheses, pure private higher education leads to higher productivity and income inequality in the long run, while the effect of universal government funding is the opposite. However, the desired impact is not achieved in the short run, before the labor markets for low- and high-skilled labor adjust to the new equilibrium.

The analysis of the policy on an aggregate level showed that abolishing merit-based grants to implement a diversified system of education financing or grants on a need basis leads to results similar to the case of pure public higher education: increase in the tertiary attainment and lowering income inequality at the cost of productivity losses. Nevertheless, among the two policies suggested, making everybody pay the same tuition fee while keeping education expenditures equal leads to more significant aggregate effects.

Observing the impact of policies on different population groups uncovered the advantages and disadvantages of the policies on a deeper level. The superior feature of the diversified system over the need-based grants is that it encourages students from poorer population groups to enroll in a university, but does not lead to the withdrawal of students from richer families. On the other hand, the policy of need-based grants is more effective in stimulating family financing of children's higher education among all the population groups. A median person in terms of income and innate ability benefits more from the need-based policy than from a diversified system of paying for education.

The recommendation of a particular education policy depends on the primary target of the government and the appropriate time horizon for the policy to deliver the desired results. If the main aim is to boost the level of productivity in the economy, setting maximum tuition fees for everybody is justifiable only in the long run. If the government aims to tackle inequality and/or increase tertiary attainment among certain groups of the population, the policies suggested are effective in both short-term and long-term horizons.

One of the main limitations of the macroeconomic model used in the study is its steady-state nature. It shows the effects of the policy in the absence of other disruptions in the economy. That is the main reason the generalizability of the model's results and implications on the current Ukrainian economy, which is currently in a state of war, is limited. Nevertheless, the main implication should still hold. If the current tuition fee is too high for some population groups, reducing its cost at the expense of less vulnerable segments has a positive net effect on the level of enrollment. However, the risk of losses in productivity and the withdrawal of the smartest students after abolishing merit-based grants have to be accounted for.

With enough computing power, the model can be improved further. Smaller steps on the capital grid, shorter lengths of the periods, and endogenizing labor supply and cost of higher education should lead to more precise numerical results of the policies' effects. Further research can be concentrated on analyzing alternative policies, for example, implementing merit-based and need-based grants simultaneously or subsidizing education by providing scholarships to some or all of the students.

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APPENDIX A

Table 9. Regression summary for Figure 1

	Dependent variable:
	Gini
GE_Tertiary	-0.0587***
	(0.0147)
Constant	0.6174***
	(0.0155)
Observations	146
R^2	0.0999
Adjusted R^2	0.0936
Residual Std. Error	0.0849 (df = 144)
F Statistic	15.9782*** (df = 1; 144)
Note:	*p<0.1; **p<0.05; ***p<0.01

APPENDIX B

Combining two levels of the production function, we get:

$$Y = AK^{\alpha}(\mu(H^H)^{\gamma} + (1-\mu)(H^L)^{\gamma})^{\frac{1-\alpha}{\gamma}}$$

The firm's profit function then looks like this:

$$\max_{K,H^H,H^L} \pi = AK^{\alpha}(\mu(H^H)^{\gamma} + (1-\mu)(H^L)^{\gamma})^{\frac{1-\alpha}{\gamma}} -$$

$$(r+\delta)K - w^H H^H - w^L H^L$$

The FOCs are:

$$\begin{cases} \dfrac{\partial \pi}{\partial K} = \alpha A K^{\alpha-1}(\mu(H^H)^{\gamma} + (1-\mu)(H^L)^{\gamma})^{\frac{1-\alpha}{\gamma}} - (r+\delta) = 0 \\ \dfrac{\partial \pi}{\partial H^H} = \mu(1-\alpha)AK^{\alpha}(H^H)^{\gamma-1}(\mu(H^H)^{\gamma} + (1-\mu)(H^L)^{\gamma})^{\frac{1-\alpha-\gamma}{\gamma}} - w^H = 0 \\ \dfrac{\partial \pi}{\partial H^L} = (1-\mu)(1-\alpha)AK^{\alpha}(H^L)^{\gamma-1}(\mu(H^H)^{\gamma} + (1-\mu)(H^L)^{\gamma})^{\frac{1-\alpha-\gamma}{\gamma}} - w^L = 0 \end{cases}$$

Which gives the usual optimality conditions:

$$r = \alpha A K^{\alpha-1}(\mu(H^H)^{\gamma} + (1-\mu)(H^L)^{\gamma})^{\frac{1-\alpha}{\gamma}} - \delta = \frac{\partial Y}{\partial K} - \delta$$

$$w^H = \mu(1-\alpha)AK^{\alpha}(H^H)^{\gamma-1}(\mu(H^H)^{\gamma} + (1-\mu)(H^L)^{\gamma})^{\frac{1-\alpha-\gamma}{\gamma}} = \frac{\partial Y}{\partial H^H}$$

$$w^L = (1-\mu)(1-\alpha)AK^{\alpha}(H^L)^{\gamma-1}(\mu(H^H)^{\gamma} + (1-\mu)(H^L)^{\gamma})^{\frac{1-\alpha-\gamma}{\gamma}} = \frac{\partial Y}{\partial H^L}$$

The wage disparity (per efficient unit) can be expressed as:

$$\frac{w^H}{w^L} = \frac{\mu(1-\alpha)AK^{\alpha}(H^H)^{\gamma-1}(\mu(H^H)^{\gamma} + (1-\mu)(H^L)^{\gamma})^{\frac{1-\alpha-\gamma}{\gamma}}}{(1-\mu)(1-\alpha)AK^{\alpha}(H^L)^{\gamma-1}(\mu(H^H)^{\gamma} + (1-\mu)(H^L)^{\gamma})^{\frac{1-\alpha-\gamma}{\gamma}}} = \frac{\mu}{1-\mu}\left(\frac{H^H}{H^L}\right)^{\gamma-1}$$

APPENDIX C

Table 10. Weighted mean hourly wages of Ukrainian employees by education and age group

Age in years	Education			
	Secondary		Higher	
	N	Mean	N	Mean
less than 25	1568	27.12	1312	37.87
25-34	5892	29.88	11425	47.71
35-44	9164	28.33	11137	56.13
45-54	11865	26.62	8758	53.10
55-60	5677	25.91	3819	51.73
60-64	2683	23.43	2241	49.59
65 and older	1562	21.77	1909	46.60
Total	38411	27.10	40601	51.35

Source: Microdata from the State Statistics Service of Ukraine for 2016.

Note: In the "secondary" category, both "full general secondary" and "vocational" education categories from the original data are included. In the "higher" column, there are only employees of the "full higher" category, which corresponds to the current Master or former Specialist level in Ukraine.

Table 11. WLS Regression summary for the Mincer equation in Ukraine

	Dependent variable:
	log(wage)
educ	-0.324680***
	(0.062845)
age	0.009069***
	(0.002061)
age^2	-0.000149***
	(0.000023)
age * educ	0.031928***
	(0.002907)
age^2 * educ	-0.000259***
	(0.000032)
Constant	3.025188***
	(0.044743)
Observations	79,012
R^2	0.1548
Adjusted R^2	0.1548
Residual Std. Error	4.0172 (df = 79006)
F Statistic	2,894.32*** (df = 5; 79006)
Note:	*p<0.1; **p<0.05; ***p<0.01

APPENDIX D

Using the Tauchen method for discrete approximations of continuous distributions

1. Define the (odd) number of the discrete values i so that the median value corresponds to the center of the normal distribution, and the further values stand for the less probable outcomes. For example, there are 3 possible states for a probability shock z_{it}:

$$Z = (z_{1t} \quad z_{2t} \quad z_{3t})$$

and 5 values for an agent's innate ability θ_i:

$$\Theta = (\theta_1 \quad \theta_2 \quad \theta_3 \quad \theta_4 \quad \theta_5)$$

2. Choose the (symmetric) quantiles which are represented by the discrete states from the set of possible values. In the generation of productivity shocks, 3 states stand for the 1st, 2nd (median), and the 3rd quartile:

$$z_{it} = N(0.25i)\sigma_\epsilon$$

Where $N(\dots)$ is the function for the standard score of the normal distribution.

5 states of an innate ability are defined as 10th, 30th, 50th, 70th, and 90th percentile of the normal distribution:

$$\theta_i = Z\big(0.1 + 0.2(i-1)\big)\sigma_\theta$$

Note that the standard normal distribution is only the starting point and the quantiles should be multiplied by the corresponding standard deviation of the distributions.

3. Calculate the middle points between the neighboring discrete states of the distribution. This is done to represent the calculations at the next step more

conveniently. For example, the midpoints for innate ability states are calculated as:

$$\bar{\theta}_{i,i+1} = \frac{\theta_i + \theta_{i+1}}{2}$$

4. Calculate the probability of state j occurring conditionally to the state i happened before. This is needed to complete $i \times i$ transition matrices for the Gauss-Markovian process. We keep following the calculations for θ only, but they are identical in case of productivity shocks.

For $j = 1$, the closest state to the left tail of the distribution, the formula is as follows:

$$P_{i1}^{\theta} = N\left(\frac{\bar{\theta}_{1,2} - \rho_\theta \theta_i}{\sigma_\theta}\right)$$

Probabilities for $j = 2,3,4$ are calculated similarly:

$$P_{ij}^{\theta} = N\left(\frac{\bar{\theta}_{j,j+1} - \rho_\theta \theta_i}{\sigma_\theta}\right) - N\left(\frac{\bar{\theta}_{j-1,j} - \rho_\theta \theta_i}{\sigma_\theta}\right)$$

For $j = 5$, the closest state to the right tail of the distribution, the probability is:

$$P_{i5}^{\theta} = 1 - Z\left(\frac{\bar{\theta}_{4,5} - \rho_\theta \theta_i}{\sigma_\theta}\right)$$

5. Calculate the steady-state probabilities for each state which will be used in the agents' lifecycle simulations:

$$P_i^{\theta} = \frac{\sum_{j=1}^{5} P_{ij}^{\theta}}{5}$$

The shorter version of this procedure involving only the first 2 steps is applied to model 5 dropout probabilities for the corresponding states of the innate ability. The only modification is a non-zero median value for the probability $\bar{\xi}$.

APPENDIX E

Algorithm for solving the model

1. Set up the values for all exogenous parameters.

2. Set up the values for endogenous factor prices: wage rate for workers with secondary (w^L) and higher education (w^H), and in the case of a closed economy – a real return on capital (r). For the first iteration, a guess is needed.

3. Applying the Tauchen method, calculate values for the discrete states of idiosyncratic shocks (z_t), innate ability (θ), and dropout probabilities (ξ). In addition, calculate transition matrices for z_t and θ.

4. Set up a capital grid with a discrete number of points which is used in value function iteration.

5. Find the optimal intergenerational transfers k_C, iterating through all the possible values of θ, k_7, k_8, z_8. To solve the problem, you need a guess the lifetime values of the child $E\left(V_1(\theta_C, k_C)\right)$.

6. Iterate the main value function through different θ, t, z_t, k_t, k_{t+1}, starting from the last period $t = 11$ and going back to the beginning of life. This procedure returns the optimized value functions for each period $V_t(\theta, k_t, z_t)$. If the received $E\left(V_1(\theta, k_1)\right)$ differ from the initial values used to solve the iterative problem in Step 5, go back and reiterate it using new values.

7. Simulate the lifecycles of n agents. In contrast to value function iteration in Step 6, we iterate value functions starting from $t = 1$ and use the obtained policy functions to decide between consumption, savings, and intergenerational transfers. The agents should have different θ and ξ at the beginning of life and z_t in each period t distributed according to Tauchen processes. At the first

iteration, we have to guess how much each agent receives at the beginning from a parent (k_1). In the process, we receive the corresponding k_C from the same agent as a parent. If k_1 and k_C are different, reiterate Step 7 using k_C as a new input for k_1. Repeat the process until the convergence of parent-child transfers.

8. Calculate equilibrium wage rates for low-skilled and high-skilled labor using the aggregate values for human capital with secondary (H^L) ad higher (H^H) education. For a closed economy, the new interest rate is also to be obtained. If equilibrium factor prices differ from the initial values used in iterative procedures, do one of the following:

- If the baseline model before policy intervention is calibrated, go back to Step 2 using new factor prices as inputs. Repeat the process until the factor prices converge. Only then the general equilibrium is found.
- If the effects of policy change are being analyzed, update the income tax rate to balance the government budget and go back to Step using the same factor prices. When the income tax rate does not need to be updated anymore, partial equilibrium after the intervention is found. In the case of particular policy changes, there is also a need to update the aggregate sum of subsidies together with the tax rate.
- To calculate general equilibrium after the policy change, go back to Step 2 using new factor prices, income tax rate, and subsidies. Only when all the values converge, the general equilibrium is found.

9. If the initial state of the economy is simulated, and the obtained values in the general equilibrium significantly differ from their targets, go back to Step 1 and alter some of the exogenous parameters to get closer to the target values. One may also need to go back to Step 4 and change the interval of the capital grid and the number of the points on it to find an optimal tradeoff between the model's complexity and computation time.

APPENDIX F

Table 12. Case 1: Pure private higher education

Indicator	Baseline model	After policy change		Δ	
		Partial eq-m	General eq-m	Partial eq-m	General eq-m
w^L	0.436	-	0.429	-	-1.6%
w^H	0.562	-	0.626	-	+11.4%
K	0.3726	0.3813	0.4311	+2.3%	+15.6%
H^L	0.4639	0.5612	0.5464	+21.0%	+17.8%
H^H	1.1296	1.0109	1.0282	-10.5%	-9.0%
Y	1.5005	1.4876	1.5751	-0.9%	+5.0%
Skill premium	2.565	2.718	2.961	+6.0%	+15.4%
τ_w	19.5%	19.2%	17.0%	-0.3%	-2.5%
Labor with higher education	50.1%	41.5%	43.4%	-8.6%	-6.7%
Dropout rate	32.4%	27.7%	29.8%	-4.7%	-2.6%
Mean wage	667	643	697	-3.6%	+4.1%
Income Gini	0.502	0.501	0.518	-0.001	+0.016
Wealth Gini	0.616	0.620	0.626	+0.004	+0.010

Table 13. Case 2: Pure public higher education

Indicator	Baseline model	After policy change		Δ	
		Partial eq-m	General eq-m	Partial eq-m	General eq-m
w^L	0.436	-	0.441	-	+1.1%
w^H	0.562	-	0.541	-	-3.6%
K	0.3726	0.3674	0.3521	-1.3%	-0.6%
H^L	0.4639	0.4225	0.4331	-8.9%	-6.6%
H^H	1.1296	1.1746	1.1635	+4.0%	+3.0%
Y	1.5005	1.4976	1.4685	-0.2%	-2.1%
Skill premium	2.565	2.418	2.337	-5.7%	-8.9%
τ_w	19.5%	20.0%	20.9%	+0.5%	+1.4%
Labor with higher education	50.1%	55.0%	53.8%	+4.9%	+3.7%
Dropout rate	32.4%	34.7%	34.4%	+2.3%	+1.9%
Mean wage	667	674	654	+1.0%	-1.9%
Income Gini	0.502	0.499	0.493	-0.003	-0.009
Wealth Gini	0.616	0.618	0.614	+0.002	-0.002

Table 14. Case 3: Diversified system

Indicator	Baseline model	After policy change		Δ	
		Partial eq-m	General eq-m	Partial eq-m	General eq-m
w^L	436	-	435	-	-0.2%
w^H	562	-	550	-	-2.1%
K	0.3726	0.3708	0.3599	-0.5%	-3.4%
H^L	0.4639	0.4497	0.4543	-3.1%	-2.1%
H^H	1.1296	1.1456	1.1403	+1.4%	+0.9%
Y	1.5005	1.4999	1.4794	-0.0%	-1.4%
Skill premium	2.565	2.506	2.470	-2.3%	-3.7%
τ_w	19.5%	20.0%	20.6%	+0.5%	+1.1%
s_ϕ	60.0%	82.0%	82.0%	+22.0%	+22.0%
Labor with higher education	50.1%	51.3%	51.3%	+1.2%	+1.2%
Dropout rate	32.4%	32.8%	32.8%	+0.4%	+0.4%
Mean wage	667	669	657	+0.3%	-1.5%
Income Gini	0.502	0.501	0.498	-0.001	-0.004
Wealth Gini	0.616	0.616	0.614	0.000	-0.002

Table 15. Case 4: Binary system with need-based grants

Indicator	Baseline model	After policy change		Δ	
		Partial eq-m	General eq-m	Partial eq-m	General eq-m
w^L	436	-	432	-	-0.9%
w^H	562	-	566	-	+0.7%
K	0.3726	0.3716	0.3732	-0.3%	+0.2%
H^L	0.4639	0.4807	0.4750	+3.6%	+2.4%
H^H	1.1296	1.1091	1.1157	-1.8%	-1.2%
Y	1.5005	1.4944	1.4985	-0.4%	-0.1%
Skill premium	2.565	2.509	2.512	-2.2%	-2.1%
τ_w	19.5%	20.2%	20.1%	+0.7%	+0.6%
Labor with higher education	50.1%	49.3%	50.3%	-0.8%	+0.2%
Dropout rate	32.4%	32.5%	32.8%	+0.1%	+0.4%
Mean wage	667	662	665	-0.7%	-0.3%
Income Gini	0.502	0.499	0.501	-0.003	-0.001
Wealth Gini	0.616	0.615	0.614	-0.001	-0.002

APPENDIX G

Decomposition of the model's aggregates by ability quintile and education

Table 16. Share of labor with higher education

Education financing					
(Partial eq-m)	Pure private	Diversified	Binary merit-based	Binary need-based	Pure public
I	0.0%	0.0%	0.0%	0.0%	0.0%
II	0.0%	32.0%	25.7%	29.2%	40.1%
III	55.6%	59.0%	57.9%	57.9%	59.0%
IV	67.4%	71.7%	71.7%	70.3%	71.7%
V	85.1%	91.1%	91.1%	88.9%	91.1%
(General eq-m)	Pure private	Diversified	Binary merit-based	Binary need-based	Pure public
I	0.0%	0.0%	0.0%	0.0%	0.0%
II	7.8%	29.8%	25.7%	29.2%	40.1%
III	55.6%	59.0%	57.9%	57.9%	59.0%
IV	67.4%	71.8%	71.7%	70.3%	71.7%
V	85.1%	91.0%	91.1%	88.9%	91.1%

Table 17. Tertiary attainment

Education financing					
(Partial eq-m)	Pure private	Diversified	Binary merit-based	Binary need-based	Pure public
I	0.0%	0.0%	0.0%	0.0%	0.0%
II	0.0%	72.7%	57.6%	57.4%	98.0%
III	92.4%	98.1%	96.2%	96.3%	98.1%
IV	92.3%	98.3%	98.3%	96.3%	98.3%
V	92.2%	98.9%	98.9%	96.5%	98.9%
(General eq-m)	Pure private	Diversified	Binary merit-based	Binary need-based	Pure public
I	0.0%	0.0%	0.0%	0.0%	0.0%
II	20.2%	63.9%	57.6%	62.6%	88.8%
III	92.4%	98.1%	96.2%	96.2%	98.1%
IV	92.3%	98.3%	98.3%	96.2%	98.3%
V	92.3%	98.7%	98.9%	96.5%	98.9%

Table 18. Parent-child transfers (thsd. UAH)

Education financing					
(Partial eq-m)	Pure private	Diversified	Binary merit-based	Binary need-based	Pure public
I	0.0	0.0	0.0	0.0	0.0
II	0.8	92.8	89.7	88.9	108.3
III	373.8	257.4	282.3	287.0	229.6
IV	624.7	496.3	475.0	528.0	458.9
V	1322.0	1198.1	1174.0	1218.9	1146.4
(General eq-m)	Pure private	Diversified	Binary merit-based	Binary need-based	Pure public
I	0.0	0.0	0.0	0.0	0.0
II	48.5	82.5	89.7	100.0	92.2
III	419.4	246.3	282.3	289.0	217.4
IV	718.5	486.2	475.0	529.3	437.2
V	1508.2	1163.2	1174.0	1240.8	1086.4

Table 19. Mean income (23-62 years, secondary education, thsd. UAH)

Education financing					
(Partial eq-m)	Pure private	Diversified	Binary merit-based	Binary need-based	Pure public
I	193.2	193.2	193.2	193.3	193.2
II	324.5	326.7	325.1	324.9	324.0
III	472.2	471.9	472.1	472.1	471.9
IV	688.4	684.0	684.3	685.4	684.0
V	1162.5	1140.6	1140.5	1148.5	1140.6
(General eq-m)	Pure private	Diversified	Binary merit-based	Binary need-based	Pure public
I	190.6	192.9	193.2	191.6	195.3
II	318.6	326.6	325.1	324.3	325.6
III	465.0	470.6	472.1	467.7	477.1
IV	677.6	681.3	684.3	679.2	691.3
V	1143.2	1138.0	1140.5	1137.3	1153.2

Table 20. Mean income (23-62 years, higher education, thsd. UAH)

Education financing					
(Partial eq-m)	Pure private	Diversified	Binary merit-based	Binary need-based	Pure public
I	-	-	-	-	-
II	-	510.3	516.3	516.2	514.2
III	807.2	804.2	804.3	804.5	803.9
IV	1252.8	1252.0	1252.6	1251.9	1252.1
V	2377.7	2378.3	2378.2	2377.7	2377.3
(General eq-m)	Pure private	Diversified	Binary merit-based	Binary need-based	Pure public
I	-	-	-	-	-
II	599.4	496.3	516.3	511.4	500.0
III	900.2	786.8	804.3	810.2	773.1
IV	1398.2	1225.7	1252.6	1260.3	1204.4
V	2652.3	2325.8	2378.2	2395.0	2285.3

Table 21. Mean consumption (secondary education, thsd. UAH)

Education financing					
(Partial eq-m)	Pure private	Diversified	Binary merit-based	Binary need-based	Pure public
I	117.8	116.8	117.5	116.7	116.8
II	198.4	199.5	199.7	198.1	196.2
III	287.9	285.2	287.0	284.8	285.3
IV	419.8	407.9	410.8	412.7	408.5
V	710.4	670.0	673.4	692.0	671.4
(General eq-m)	Pure private	Diversified	Binary merit-based	Binary need-based	Pure public
I	119.0	115.9	117.5	115.8	117.0
II	200.2	198.2	199.7	197.9	196.2
III	290.3	282.7	287.0	282.5	285.6
IV	422.9	402.6	410.8	410.1	408.9
V	715.2	666.3	673.4	685.2	672.3

Table 22. Mean consumption (higher education, thsd. UAH)

Education financing					
(Partial eq-m)	Pure private	Diversified	Binary merit-based	Binary need-based	Pure public
I	-	-	-	-	-
II	-	273.0	272.3	279.7	279.4
III	418.0	432.3	429.6	435.8	436.6
IV	662.5	675.7	684.3	676.4	680.4
V	1279.4	1287.9	1299.5	1281.1	1291.7
(General eq-m)	Pure private	Diversified	Binary merit-based	Binary need-based	Pure public
I	-	-	-	-	-
II	311.0	263.9	272.3	277.8	268.7
III	480.9	420.2	429.6	439.0	415.8
IV	760.3	657.2	684.3	680.0	648.0
V	1464.7	1251.2	1299.5	1291.0	1229.7

Table 23. Mean utility (secondary education)

Education financing					
(Partial eq-m)	Pure private	Diversified	Binary merit-based	Binary need-based	Pure public
I	0.5331	0.5304	0.5321	0.5300	0.5304
II	0.7159	0.7182	0.7188	0.7155	0.7115
III	0.8829	0.8782	0.8812	0.8775	0.8783
IV	1.0912	1.0713	1.0766	1.0807	1.0732
V	1.4650	1.4082	1.4144	1.4430	1.4126
(General eq-m)	Pure private	Diver-sified	Binary merit-based	Binary need-based	Pure public
I	0.5359	0.5280	0.5321	0.5276	0.5308
II	0.7196	0.7156	0.7188	0.7150	0.7115
III	0.8871	0.8738	0.8812	0.8734	0.8789
IV	1.0958	1.0629	1.0766	1.0771	1.0737
V	1.4706	1.4051	1.4144	1.4350	1.4137

Table 24. Mean utility (higher education)

Education financing					
(Partial eq-m)	Pure private	Diversified	Binary merit-based	Binary need-based	Pure public
I	-	-	-	-	-
II	-	0.8538	0.8523	0.8672	0.8653
III	1.0838	1.1057	1.1014	1.1127	1.1121
IV	1.4044	1.4208	1.4314	1.4232	1.4264
V	2.0305	2.0388	2.0493	2.0331	2.0424
(General eq-m)	Pure private	Diversified	Binary merit-based	Binary need-based	Pure public
I	-	-	-	-	-
II	0.9193	0.8375	0.8523	0.8638	0.8467
III	1.1730	1.0880	1.1014	1.1173	1.0821
IV	1.5178	1.3989	1.4314	1.4272	1.3880
V	2.1904	2.0060	2.0493	2.0417	1.9868