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Higher Education Policy, Graduate Taxes and Wealth Distribution

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Abstract

This thesis intends to shed light on the possible effects of higher education policy reforms on the distribution of wealth, specifically the comparison of a grant and loan based model with a free tertiary education one. A novel alternative for financing such a reform is examined: a tax on the labor income of higher education graduates. The analysis is based on a quantitative OLG life cycle model, with heterogeneous agents, intergenerational links, incomplete financial markets, endogenous education decision, and general equilibrium in the determination of wages. Preliminary results indicate a more equitable distribution of wealth and a general increase in assets, explained by a significant increase in enrollment, graduation and a smaller wage premium for higher education. However, there are still important caveats to these results.

May 24, 2017

"The most valuable of all capital is that invested in human beings"
Alfred Marshall, 1890

1 Introduction

Higher education policy is very diverse throughout the world. For example, the U.S. and Norway take radically different approaches in financing tertiary studies.[1] While the U.S. relies heavily on tuition fees and 64% of the tertiary education expenditure comes from private sources (as opposed to public), this figure drops to 4% in the case of Norway. In this country tuition costs are fully covered by the Ministry of Education and Research and on top of that students are given financial support for their living expenses, but these policies result in a much heavier budget burden for the government. Under the framework proposed by Ansell (2008), the former would correspond to the Anglo-American system of higher education, and the latter to the Scandinavian system. Ansell argues that partisan politics is the main reason behind each country's choice of the regent system. But what are the economic effects of choosing one over the other?

This question becomes especially relevant in the case of Chile, which is currently in transit from the Anglo-American to the Scandinavian system. And since differences in higher education are a mayor source of heterogeneity in expenditure and income for households, then we could expect significant distributional changes coming from a reform which would change the entire system. But, as government expenditure increases, steady state budget balance requires an additional form of revenue. An innovative proposal which has not been extensively analyzed in the literature is imposing a tax on the beneficiaries of such a system: the graduates. And the selectivity of this tax could induce even further distributional change.

This thesis thus intends to answer the question: *Which would be the long term effects of implementing universal free higher education, financed with a proportional tax on graduates' rents, on the distribution of wealth in Chile?*

For this task I will build an overlapping generations model with agents who decide whether to enter higher education or not, and will be heterogeneous in a number of relevant dimensions (age, assets, an idiosyncratic productivity shock, higher education, ability and parent's economic situation). Financial markets will be incomplete and thus liquidity

[1] The difference between higher and tertiary education varies between countries. In this work, I use both indistinctly to mean all forms of formal education after secondary, be it vocational or general.

restrictions relevant. Inter-generational links will be a key feature, through parent-child ability correlation and inter-vivos transfers. The government will have a tax and higher education funding policy subject to change in the policy experiments. The cost and quality of higher education will be exogenous and constant, as modeling this aspect is not part if the objectives of this investigation. And finally, the economy is small and open, and thus subject to an exogenous international interest rate, but wages of different types of labor (which will be imperfect substitutes) are determined endogenously in general equilibrium.

This model is based strongly on the work of Abbott et al. (2013), yet much simpler and more parsimonious. The methodology will be to first calibrate the model for Chilean data computing the steady state equilibrium before the policy. Then, alter the model structure to represent the policy reforms (education gratuity and tax on graduates) and compute a new steady state. This comparison will provide the long term effects of the policy.

I hypothesize that three main and interesting mechanisms will alter the steady-state distribution of wealth because of the reform. First of all, agents with high ability but little transfers from parents will cease to be financially constrained, and will enter and graduate from higher education. This will increase the proportion of labor that is skilled, and drive down the wage premium, reducing income and wealth inequality. Second, the graduate tax could provide a strong disincentive to opt for higher education, especially if dropout rates are high. This mechanism works in the exact opposite direction of releasing financial constraints, increasing wealth inequality.

Third, I will argue that inter-vivos transfers to pay for a child's studies are uncertain expenses, that induce precautionary savings, all of which disappears once tuition fees are set to zero. This means that savings will diminish, for the wealth group that is subject to this uncertainty. Is this an economically relevant mechanism? Keynes (1936) might say so, as it incorporates two of the eight savings motives mentioned in his work, which are summarized in Browning & Lusardi (1996). Namely, the *precautionary savings* motive against uncertain future expenses (the first in Keynes' list), and the *life cycle* motive: "To provide for an anticipated future relation between the income and the needs of the individual or his family different from that which exists in the present, as, for example, in relation to old age, **family education, or the maintenance of dependents**".

In order to investigate this matter, the rest of this work will proceed as follows. In section 2, the academic literature concerning methodology and the underlying economic mechanisms is reviewed. The following section completes the background of this thesis by providing context, statistics and stylized facts about Chile. Then, section 4 explains the mechanisms at work in the hypothesis using a theoretical toy model, while section 5 details the full-blown quantitative model. Section 6 discusses the estimation methodology and results, while section 7 warns the limitations of these results. Finally, section 8 concludes.

2 Literature

The frontline papers which are most closely related to my work, are those of Abbott et al. (2013), Krueger & Ludwig (2016), Bohaceck & Kapicka (2010), Johnson & Keane (2013) and Garriga & Keightley (2007). They study outcomes of educational policies in general equilibrium OLG Bewley models with intergenerational links.

Heterogeneous agent models with incomplete markets and idiosyncratic earnings risk are very useful in characterizing earnings and wealth distributions, as they include the concept of precautionary saving dependent on individual liquidity constraints. Bewley (1977), Huggett (1993), Aiyagari (1994) and Krussel & Smith (1998) are some of the most influential papers that popularized these so-called Bewley models. Over-lapping generations and life cycle models go as far as the foundational paper by Samuelson (1958) and even further, but their application in Bewley models was popularized by Ríos-Rull (1995) and Huggett (1996) to investigate intergenerational wealth accumulation.

Regarding the two intergenerational links I will use, it is useful to discuss each one separately. Inter-vivos transfers[2] are shown to be sizable (20% of aggregate wealth, and almost as large as inheritances) in the U.S. by Gale & Sholz (1994). Moreover, these authors as well as Kotlikoff & Summers (1981) support the hypothesis that wealth accumulation is mostly an intergenerational phenomenon, as opposed to the importance of the life cycle stressed most strongly by Modigliani (1988). Consensus in the literature has favored the estimate of Gale & Scholz who find that intergenerational wealth transfers are responsible for 60% of total wealth accumulation, as stated by De Nardi (2004).

Inter-vivos tranfers are also one of the mechanisms which would explain the relevance of parental income and wealth in college attainment, as documented by Belley & Lochner (2007). And Becker & Tomes (1979) note that the first of intergenerational transfers is payment for the child's education: monetary transfers for other reasons usually happen

[2] Transfers between the living, as opposed to bequests, in this case from parent to child.

after this has been taken care of. This is highly related to the long standing debate of liquidity constraints in education, initiated by Becker (1964) who argued for their existence and relevance. However, modern evidence tends to favor the opposite in the U.S., as Cameron & Heckman (1998), Keane (2002), Garriga & Keightley (2007), Bohaceck & Kapicka (2010) all favor the hypothesis that financial constraints play a relatively minor role in tertiary educational decisions. The evidence for Chile will be reviewed in section 3.

But, if inter-vivos transfers can't explain intergenerational correlation in education attainment (evidence presented in section 3 of this work), then parent-child correlation in ability is the next alternative in line. Sacerdote (2002) and Plug & Vijverberg (2003) present evidence for correlation in innate ability, which means genetics is relevant. Restuccia & Urrutia (2004) later build on this and add acquired ability, the accumulation of which happens at primary and secondary education, and is also highly correlated between generations of the same household. For this reason, most modern OLG models studying educational policy feature this variable and its intergenerational correlation.[3] In the highly parsimonious model I will use, ability is defined as the human capital accumulated up to the point of completing secondary education, understanding human capital in the classical and broad sense given by Becker (1962). Ability is also a crucial heterogeneous state variable because the enrollment increase of educational policies may consist of lower ability students, which would be more likely to drop out. Therefore ignoring this dimension biases upwards educational attainment estimations, as noted by Cameron & Heckman (1998) and Akyol & Athreya (2005).

The second heterogeneity in human capital I model is between skilled and unskilled labor: those that attained higher education (HE) and those that did not. And as this is a macro model intended to evaluate country-wide policy change, I model general equilibrium in wage determination. A growing number of authors implement this aspect[4] and a big question arises: How much of the increase in enrollment due to education subsidies found in partial equilibrium holds for the general equilibrium case? Because if education subsidies increase the share of labor that is skilled, then the corresponding wage premium will fall, which is a disincentive towards education, known as the Stiglitz (1982) effect. Interestingly, this is not a settled matter. A tuition subsidy mostly affects the wage premium in Heckman et al. (1998b) and makes little difference for college attendace, the opposite result in Lee (2005), and a midpoint in the case of Johnson & Keane (2013).

[3]Examples are Garriga & Keightley (2007), Bohaceck & Kapicka (2010), Abbott et al. (2013), Krueger & Ludwig (2016)

[4]Heckman et al. (1998a,b,c), Lee (2005), Lee & Wolpin (2006), Johnson & Keane (2013), Abbott et al. (2013), Krueger & Ludwig (2016).

The key in the different results is the elasticity of substitution between the different kinds of labor[5] (higher for Lee) and the structure of the model's labor market, which is the main contribution of Johnson & Keane who may have the most reliable estimate.[6]

Moving onto more of my model's characteristics, the tax structure effects have a vast literature even in Bewley models alone, notable examples are Chamley (1986) and Judd (1985) and linked to education are Heckman, Lochner & Taber (1998c) and Krueger & Ludwig (2016).[7] The latter characterize the optimal degree of income tax progressivity and tertiary tuition subsidy, and find both policies to be complements by negating education decision distortions, and substitutes in providing social insurance. Their work and literature review demonstrate how interrelated both policies are, implying they should be modeled together, as is done in this thesis. However, the graduate tax I will use is quite rare in academic literature and nonexistent in Bewley Models (up to my knowledge), which is one of the aspects that differentiates my work from any other done previously. It is relevant to analyze this policy reform in a Bewley Model because they are arguably the best at characterizing wealth distributions.

Nevertheless, the previous literature on graduate taxes has interesting things to say. The two most influential papers addressing it make opposing policy recommendations. García-Peñalosa & Wälde (2000) argue that it achieves efficiency and equity considerations while at the same time diminishes the lifetime income risk of educational investment, but Greenaway & Haynes (2003) make practical arguments such as potential brain drain[8] to prefer income-contingent loans. On the same side are Espinoza & Urzúa (2015) who provide the previous arguments and more, for example those who don't graduate will receive the benefit of gratuity but won't have to pay taxes, causing graduates to pay more in taxes than what they save in gratuity.[9]

[5]See Katz & Murphy (1992) or Borjas (2003)

[6]They make distinctions of up to 160 types of labor, differentiating by education, gender, age and occupation, and argue that this characterization is relevant because it reveals wage premium patterns that are much more complex than those usually studied by the literature. They base this structure on Kambourov & Manovskii (2004a,b, 2005) among others who argue that occupation may be a better measure of skill than education. Unfortunately to make my model parsimonious it will have to miss out on that richer structure, and is subject to the pertinent criticism.

[7]Most of these models incorporate endogenous labor supply, which is relevant as taxes may distort the labor/leisure decision. Unfortunately my model will not incorporate such a feature in the pursuit of simplicity. This means my results might be biased as a graduate tax could diminish labor supply from this group.

[8]They also mention the long time needed to achieve steady state in the tax collection, and the impossibility in the UK to tie this tax reform to the education reform intended

[9]This will be the only argument against graduate taxes that my model will be able to incorporate due to its simplicity. Refer to the mentioned investigation for the rest of the criticism and thus shortcomings of this thesis.

Parallel to the extensive line of study presented, the literature on explaining the wealth distribution has made extensive use of Bewley models. De Nardi (2015) makes a fine review of these papers, broadly qualified into five categories: High earnings risk for top earners would explain abnormally high saving rates for the wealthy, as in Castañeda et al. (2003); entrepreneurship and borrowing constraints are the key according to Quadrini (2000); Krussell & Smith (2008) propose heterogeneity in patience, the richer being more patient; Hubbard et al. (1995) explains the bottom of the distribution with social insurance policies; and De Nardi (2004) herself models intergenerational links, but only through bequests and productivity inheritance. None of these authors consider higher education expenses as a significant savings motive, and none of the literature mentioned in the previous paragraphs focuses on the effects on the wealth distribution. The purpose of my investigation is to join these two separate strands of literature, using graduate taxes as a means of financing the reform, and in the Chilean context which would be specially suitable as argued the next section.

3 Chilean Context

3.1 Benchmarks

A rough comparison of some interesting present statistics for Chile and three benchmarks is presented in the following table.[10] The U.S. is included for its Anglo-American system of higher education, and Norway for its Scandinavian system. The OECD is included as the only average of countries available for most of these statistics.

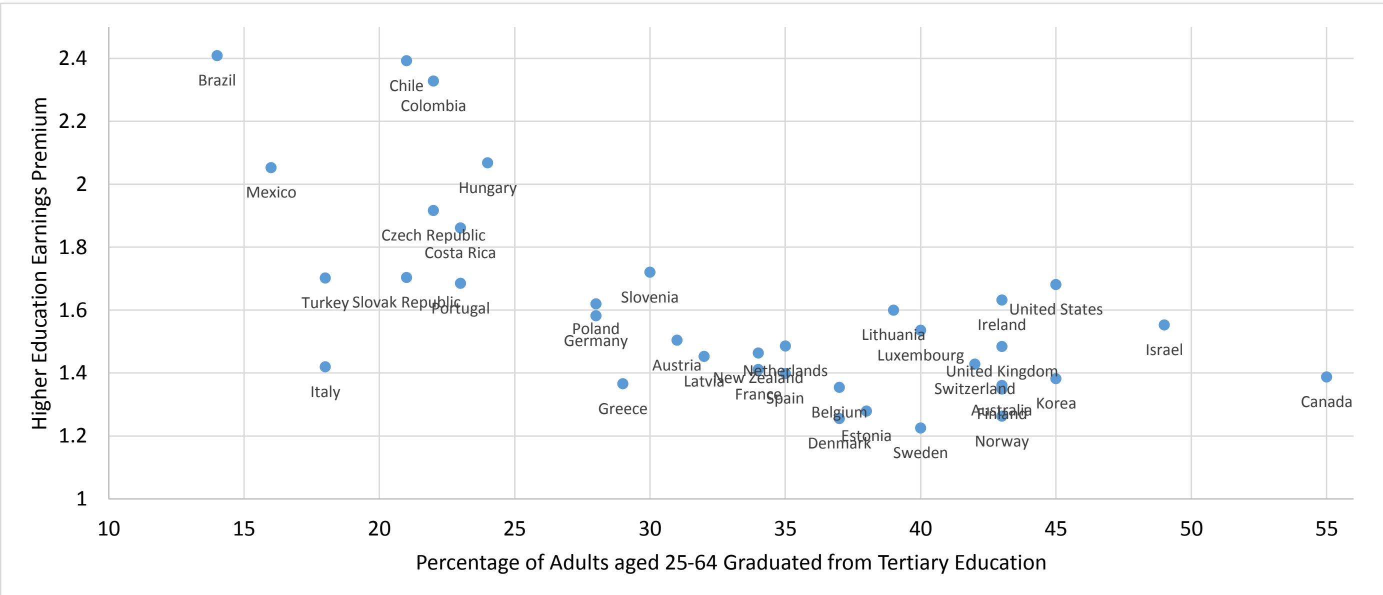
Table 1: Relevant Statistics

	Chile	**USA**	**Norway**	**OECD**
Household Disposable Income Gini	0.465	0.394	0.252	0.318
Household Wealth Gini	0.777	0.801	0.633	
Public Expenditure on H.E. as % of GDP	1.0%	1.0%	1.5%	1.1%
Private Expenditure on H.E. as % of GDP	1.4%	1.7%	0.1%	0.5%
Adults Graduated from H.E.	21%	45%	43%	42%
H.E. Earnings Premium	2.39	1.68	1.26	1.55
Parent Child Schooling Correlation	0.60	0.46	0.35	
Parent Child Schooling β_s	0.64	0.46	0.40	

[10]Appendix A provides detailed definitions of each of the variables presented, as well as the year for each pair of country-variable.

The first two rows are merely motivational as they indicate present distributional outcomes in income and wealth. The third and fourth rows manifest the resemblance of Chile with the U.S. in its high proportion of higher education expenditure that is covered by privates, corroborating Chile's current system as the Anglo-American. This is relevant because higher education expenditures are a significant part of some household's expenditures, and will induce precautionary savings if uncertain.

But why is Chile more interesting to study than the U.S. for the question at hand? The first half of the answer is given by the next two rows: it has a small proportion of higher education graduates among 25-64 year-olds, and very high earnings premium (which refers to the times labor earnings is higher for HE graduates than secondary graduates). These two variables suggest that general equilibrium effects might be substantial in Chile for educational policies, i.e. the earnings premium might be reduced in a greater degree. The following chart[11] illustrates the situation of the OECD countries and some of its partners.



The second half of the answer is provided by Hertz et al. (2007) who studied the correlation coefficient of parent and child years of schooling for a number of countries, as well as the regression coefficient of

$$s_1 = \alpha + \beta_s s_0 + \epsilon$$

Where s_1 are the child's years of schooling and s_0 the parents'. Those two measures are the seventh and eight rows of Table 1 respectively. Both evidence significantly larger

[11]Source: Own elaboration based on OECD data.

intergenerational correlation in educational attainment in Chile than its benchmarks. In fact Chile's correlation ranks higher than any country that is not Latin American, a country group that far outranks all others. And this can only be explained through intergenerational links between parent and child of some kind. The links that could take credit for this result are many, but the model of section 4 covers the two most covered by the literature as the best candidates in explaining this stylized fact: inter-vivos transfers and inheritance of cognitive and non-cognitive skills. And such strong intergenerational correlation in education strongly suggests tighter links, or an environment which amplifies their effects. Either way, they make Chile a more interesting country to investigate, because higher importance of inter-vivos transfers in determining the child's education could induce higher precautionary savings.[12]

3.2 Stylized Facts

This subsection intends to deal specifically with Chilean data. First, savings and wealth accumulation behavior is crucial to the mechanism, and a succinct review of facts is in order. The best recent data is provided by the *Encuesta Financiera de Hogares* (EFH) 2014, a survey intending to characterize household financial balances in detail. First off, 26% of households surveyed declared to have saved the past twelve months, and this figure becomes 17% for low income households, 27% for mid-income, and 45% for high income, suggesting that savings increases with income.[13] This same sharp correlation is also observed when comparing savings and education: 38% of university and 61% of post-graduate households saved the last month, in comparison with 16% and 21% of primary and secondary education ones respectively.[14]

Gallego & Butelmann (2000, 2001) perform a more extensive, though slightly outdated, analysis of savings in Chile, and find the same patterns. They state that savings rate are mostly determined by transitory income, but also by education, permanent income, and the age profile in a way that is consistent with the life cycle theory. Interestingly, education is correlated positively with savings even after controlling for permanent income, suggesting a pure effect from educational attainment. Also, if a wider definition

[12] One may notice that the measures presented cover all levels of schooling, from primary through tertiary, and that the results may not hold when analyzing solely tertiary education, the object of this investigation. Appendix A presents evidence countering this concern. The measures presented here were chosen for their simplicity over those presented in the appendix.

[13] These figures and the following do not consider obligatory savings: those destined for the Chilean pension system of AFP's.

[14] Educational attainment corresponds to the education attained by the person of reference in the household, which is determined by the Canberra Group standards, and usually will result in the household member with the highest income.

of savings is used and investment in human capital and durable goods expenditures are incorporated, only 27% of total savings falls under the standard definition, 39% corresponds to human capital investment and the rest to durable goods, using 1997 data.

Back to the EFH 2014, our next interest are wealth statistics. The EFH analyzes net wealth (assets minus liabilities) without considering funds from obligatory savings: available net wealth. The distribution is highly skewed, as is expected from a high Gini: The mean wealth is 42 million CLP, and percentiles 25, 50, 75 and 90 are 1, 18, 44 and 98 million CLP respectively.[15] Both wealth mean and median are increasing in household income group, age group, and educational attainment.

Moving on to mainstream educational indicators, a key piece of data in this analysis will be through dropout rates. An exact figure is not possible to find because higher education desertion is a complex phenomenon[16], where a single student may stop studying temporarily and resume in later years, may switch between educational programs, or between educational institutions. Causes of dropping out may be several as well: financial constraints, vocational issues, poor academic performance, and many others. A reasonable figure to follow seems to be the second year institutional retention rate[17], which was 56,7% for the Chilean cohort entering the system in 2008[18]. This means that of these students, 56,7% remained in the same educational institution at the end of their second year of studies. Some may drop out in the following years, making this an upwards-biased estimation of the long run the retention rate (though Stratton et al. (2008) points out that most of the dropping out occurs within the first two years). But at the same time a student may have changed the institution but still pursue a degree in higher education, making this a downwards-biased estimation of the system-wide retention rate. The author of this investigation did not find a better estimation of such a rate.

Our final topic is regarding financial constraints for education in Chile: three modern studies address the issue of estimating their existence and relevance for tertiary educational attainment. Alfonso (2009) and Rojas et al. (2016) both use indirect approaches derived from the intuitions of Carneiro & Heckman (2002)[19] and find that financial con-

[15]The EFH has over-representation of high income groups in its sample in order to better study this group due to its high heterogeneity. This implies that the wealth distribution is not completely representative of the Chilean population.

[16]A good analysis is provided by the *Serie Evidencias: Deserción en la Educación Superior en Chile* by the Chilean Ministry of Education in 2012.

[17]A retention rate is the opposite of a dropout rate.

[18]Comisión de Financiamiento para la Educación Superior (2012)

[19]Alfonso (2009) estimates the effect of current income on college enrollment with logistic regressions, controlling for relevant variables (mainly long run variables including measures of permanent income).

straints are not a significant determinant of higher education enrollment. Only Rojas et al. find some evidence suggesting a role for financial constraints in HE graduation, i.e. access to credit is restricted to students once they are attending HE, instead of at the moment of enrollment. Opposite to these studies is Solis (2015), who uses a regression discontinuity study[20] and finds loan access implies an increase of nearly 20 percentage points in enrollment in the first, second and third year of college, representing relative increases of 100%, 200% and 400%, respectively. These increasing figures support Rojas' finding that credit constraints are relevant for graduation, even if they were not for enrollment.

Thus, the small available literature on this matter is divided, and the authors do not provide criticisms of each other in their works. It is my opinion that Solis uses a more rigorous empirical methodology than both other authors, minimizing possible bias and providing a more reliable estimation. He also presents survey answers indicating that a significant number of potential students declare they did not enroll in higher education due to financial constraints. However, it must be noted that formally, this matter is unsettled.

4 Theoretical Model

This section will introduce a highly simplified version of the quantitative model in order to obtain theoretical results and explain the mechanisms at work in the hypothesis as simply as possible. The initial structure will represent the present steady state of the economy. The structure will then incorporate the policy intervention of universal free higher education financed by graduate taxes, and its effects on steady state equilibrium will be discussed.

She argues that the presence of liquidity constraints would imply that current income would play a role in college enrollment. As she finds no such effect, she concludes financial constraints are not significant. Rojas et al. (2016) take a different approach and calculate higher education returns for students who attended HE and those at the margin of attending. The intuition they follow from Carneiro & Heckman (2002) is that if the returns of the latter group are larger than those of the former one we could be in presence of unobservable barriers to higher education access, such as credit constraints. They do not find this for college enrollment. It is the opinion of this thesis' author that their approach is not very trustworthy, as college rates of return are quite difficult to estimate correctly, especially for those at the margin.

[20]This is enabled because the *Crédito con Aval del Estado* and *Fondo de Crédito Solidario* loan programs are only given to students with a national admission test score above a specific cutoff. Solis studies the difference between students directly below and above the cutoff.

4.1 Initial Steady State

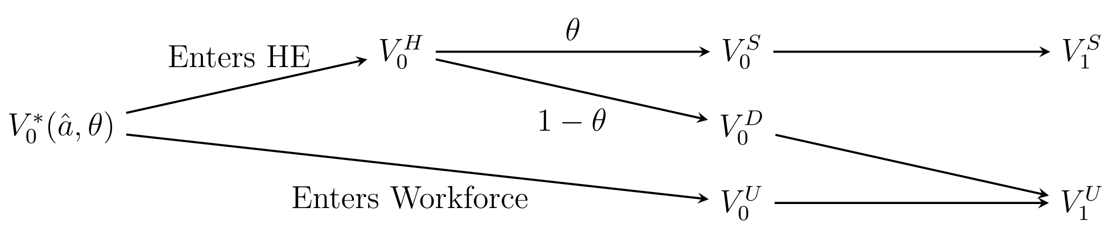
In this economy there are no aggregate shocks, and there are two overlapping generations denoted by $j = 0, 1$ in every period (period subscripts will be omitted for simplicity). Each generation is comprised of a continuum of individuals (also called agents or households) of measure one. At any point in time, every agent in $j = 1$ is the parent of a child in $j = 0$, and will choose to transfer assets to him or not. It is useful to think of $j = 0$ as the period starting after high school graduation and covering the first half of adult life, and $j = 1$ as the second half, up to retirement.

Agents are assumed to have a utility function based on consumption $u(c)$, which is differentiable and complies $u'(c) > 0$ and $u''(c) < 0$. Utility discount factors and interest rates are omitted from this model for the sake of parsimony: agents can freely transfer resources from $j = 0$ to $j = 1$ and value both consumption levels equally. However, they are liquidity constrained and may not borrow, following market incompleteness as in a standard Bewley Model.

Working agents are classified into either skilled or unskilled labor, where the latter completed higher education and perceive a wage of w^S, higher than the unskilled wage w^U. Both are assumed constant, and thus this section deals with a partial equilibrium problem. The consequences of this will be discussed later.

Additionally to being heterogeneous in age and education, agents will differ in the transfers they receive at the onset of their adult life $\hat{a}$, the assets they choose to save the first half of their lives a_1, and their probability of graduating higher education should they choose to enter: θ. This variable is considered a measure of cognitive and non-cognitive ability, and the population distribution follows $\theta \sim f_\theta > 0$ if $0 < \theta < 1$.

The following timeline represents the life-cycle of any agent:



So the agent begins its adult life with value and state variables $V_0^*(\hat{a}, \theta)$, and must decide whether to enter higher education or not. Now, $\hat{a}$ may only take two value in this model:

it is either zero, or the cost of higher education ϕ. Therefore,

$$V_0^*(\hat{a},\theta) = \begin{cases} \max \{ \underbrace{\theta V_0^S + (1-\theta)V_0^D}_{V_0^H} , \ V_0^U \} & \text{if} \quad \hat{a} = \phi \\ V_0^U & \text{if} \quad \hat{a} = 0 \end{cases}$$

Which means that the child may not choose if he did not receive a transfer, as he may not borrow. We will consider financially constrained the agents for whom $V_0^H > V_0^U$, but $\hat{a} = 0$. That is, it would be optimum for them to enter education, but they did not have the chance to do so.

But if an agent received the transfer, chose to enter HE, and graduated successfully, he will face the following problem:

$$V_0^S(\theta) = \max_{c_0,a_1} u(c_0) + \mathbb{E}_\theta[V_1^S(a_1,\theta_C)]$$

Subject to:

$$c_0 + a_1 = w^S(1-\Delta)$$
$$c_0, a_1 \geq 0$$
$$\theta_C \sim \Gamma_\theta(\theta_C|\theta)$$

Here, the agent received a transfer of $\hat{a} = \phi$, and spent it on education. Also, it spent a fraction Δ of its time in higher education, while he worked the rest receiving a wage of w^S per unit of time (which is one model period). Also, the agent knows its own θ, but does not know its child's ability, which follows a distribution $\Gamma_\theta(\theta_C|\theta)$ reflecting intergenerational persistence in ability. This is why θ is a relevant state variable in $j = 0$, it contains information regarding θ_C, which will be directly relevant in $j = 1$.

All agents in $j = 0$ face the liquidity constraint and θ conditional distribution, but may have different value functions and budget constraints. The dropouts' problem is very similar, only perceiving wage as unskilled labor:

$$V_0^D(\theta) = \max_{c_0,a_1} u(c_0) + \mathbb{E}_\theta[V_1^U(a_1,\theta_C)]$$

Subject to:

$$c_0 + a_1 = w^U(1-\Delta)$$

It must be noted that the dropout spent Δ of his time educating himself, but still earns the unskilled wage. Δ is the only difference from the case of the agent who enters the workforce immediately, as he works the entire period:

$$V_0^U(\theta) = \max_{c_0,a_1} u(c_0) + \mathbb{E}_\theta[V_1^U(a_1, \theta_C)]$$

Subject to:

$$c_0 + a_1 = w^U$$

The dropouts and unskilled face almost the same problem, except for the lower income in the first period for the dropout. Therefore, we can assert that for any given value of $\theta \in (0,1)$, $V_0^U(\theta) > V_0^D(\theta)$. This relevant in order to construct our next result. Specifically, if we add the assumption that $\forall\theta$, $V_0^S(\theta) > V_0^U(\theta)$ (which intuitively would happen if the wage premium was high enough to compensate the time spent studying), then we obtain our first result:

Lemma I: *For an agent starting the life cycle, given $\hat{a} = \phi$, $\exists\bar{\theta} \in (0,1)$:*

- *If $\theta > \bar{\theta}$, then $V_0^H(\theta) > V_0^U(\theta)$, the agent will study.*
- *If $\theta < \bar{\theta}$, then $V_0^H(\theta) < V_0^U(\theta)$, the agent will enter the workforce.*

And particularly

$$\bar{\theta} = \frac{V_0^U(\bar{\theta}) - V_0^D(\bar{\theta})}{V_0^S(\bar{\theta}) - V_0^D(\bar{\theta})}$$

Proof: The result is easily obtainable clearing θ from a condition of indifference between the two alternatives

$$\bar{\theta}V_0^S + (1-\bar{\theta})V_0^D = V_0^U$$

Where $V_0^e = V_0^e(\bar{\theta})$ for $e = S, D, U$.

Lemma I indicates that agents with high enough ability will choose to educate themselves, and agents with low ability will not. The particular threshold will be determined by the value functions, but it is sure to be between 0 and 1 based on the relations between the initial value functions, leaving a positive fraction of agents both above and below the threshold.

Next up is $j = 1$. Skilled workers continue perceiving the same wage, and now both dropouts and unskilled workers from $j = 0$ face the same problem of unskilled workers in $j = 1$ as shown in the timeline. Generalizing for $e = S, U$:

$$V_1^e(a_1, \theta_C) = \max_{c_1, \hat{a}} u(c_1) + \xi \cdot \mathbb{H}(\hat{a}, \theta_C)$$

Subject to

$$\begin{gathered} c_1 + \hat{a} = w^e + a_1 \\ c_1 \geq 0 \\ \hat{a} \in \{0, \phi\} \end{gathered}$$

Where

$$\mathbb{H} = \begin{cases} 1 & if \quad \hat{a} = \phi \quad \& \quad \theta_C > \bar{\theta} \\ 0 & if \quad \text{otherwise} \end{cases}$$

As was stated before, the child's ability is a relevant state variable, because it will influence the indicator $\mathbb{H}$, which indicates if the child will attend higher education if the parent transfers. And should both things happen, the parent will obtain an amount ξ of utility as a form of paternalism (more on this parameter is explained in the quantitative model, where it will be used as well). Here, the liquidity constraint is not explicit, but we may notices that a parent may not acquire debt to pay for a high-ability child's education. This means parents may want to increase a_1 in order to avoid this situation: precautionary savings.

We may also take another approach in this matter: from first order conditions we may obtain the following Euler equation:

$$\begin{aligned} u'(c_0) &\geq \mathbb{E}_\theta[u'(c_1)] \\ &> \quad \text{if} \quad a_1 = 0 \\ &= \quad \text{if} \quad a_1 > 0 \end{aligned}$$

Notice that the right hand side is a weighted average of the case where the parent will find it optimum to transfer (high ability child), and the opposite:

$$\mathbb{E}_\theta[u'(c_1)] = \pi(\hat{a} = \phi) u'(c_1|_{\hat{a}=\phi}) + (1 - \pi(\hat{a} = \phi)) u'(c_1|_{\hat{a}=0})$$

Uncertainty has the following effect: if the expense on $\hat{a}$ is uncertain, that adds more volatility to the values c_1 might take (higher difference between consumption among different states). Given the concavity of the utility function, by the Jensen Inequality more volatile consumption in the future raises the value of the right hand side of the Euler equation (this is because marginal utility increases by more in the states where c_1 is lower, than the decrease in the states where c_1 is higher, thanks to decreasing marginal utility). Therefore, agents that are not liquidity constrained (given by $a_1 > 0$) will seek to save more, decreasing consumption today and increasing tomorrow, which lowers the left hand side and raises the right hand side of Euler and balances the equation. In other words, increasing the uncertainty of expenses and thus the uncertainty of future consumption is equivalent to imposing a distorting wedge on the Euler equation such as ζ:

$$u'(c_0) \geq \zeta \mathbb{E}_\theta[u'(c_1)]$$

It is also relevant to notice that this mechanism may not affect some agents. In particular, given a low enough wage for unskilled labor and low ξ, it may be that $\pi(\hat{a} = \phi) = 0$. That is, some parents may not find it optimum to transfer to the child, no matter how high his ability, and so no uncertainty is present. Intuitively, this could happen with lower-income households. Unfortunately, the author has not been able to obtain sharp theoretical results in this aspect, nor closed form solutions for the policy functions of this equilibrium. The next section will eliminate uncertainty in order to obtain sharper results in other aspects, leaving precautionary savings results as they are.

4.2 Removing Uncertainty of θ_C

This section will assume that θ_C is observable from $j = 0$, but nothing else will change from the model. Thus, arguably the only difference between this section and the previous, are precautionary savings. We will use the closed form solutions that we will find in this equilibrium, compare them to the closed form solutions from the next section (implementing free HE financed by the graduate tax) and argue that the difference is a fair approximation of what would happen if we would compare sections 4.1 and 4.3 (the only element missing would be precautionary savings).

First, the structure of the problems that agents face changes as follows. It will be useful to generalize for $e = U, D, S$, where $w^D = w^U$, $\Delta^S = \Delta^D = \Delta$ and $\Delta^U = 0$. Then,

$$V_0^e(\theta_C) = \max_{c_0, a_1} u(c_0) + V_1^e(a_1, \theta_C)$$

- $c_0 + a_1 = w^e(1 - \Delta^e)$
- $c_0, a_1 \geq 0$

$$V_1^e(a_1, \theta_C) = \max_{c_1, \hat{a}} u(c_1) + \xi \cdot \mathbb{H}(\hat{a}, \theta_C)$$

- $c_1 + \hat{a} = w^e + a_1$
- $c_1 \geq 0$
- $\hat{a} \in \{0, \phi\}$

As there is no uncertainty, the Euler equation is now $u'(c_0) \geq u'(c_1)$. If he can, the agent will try to obtain equal marginal utility $u'(c_0) = u'(c_1) \Rightarrow c_0 = c_1 \equiv c$. Let's conjecture that the agent is not liquidity restricted and can achieve this result. Then, using the budget constraints it is easy to obtain the closed form solutions:

$$c^* = \frac{(2 - \Delta^e) w^e}{2} - \frac{\hat{a}}{2}$$
$$a_1^* = \frac{\hat{a} - \Delta^e w^e}{2}$$

Where c^* and a_1^* are unconstrained solutions, and remember that $\hat{a}$ may take values 0 or ϕ. If $a_1^* < 0$, then the agent will be liquidity constraint, and instead his solutions will be

$$a_1 = 0$$
$$c_0 = w^e(1 - \Delta^e)$$
$$c_1 = w^e - \hat{a}$$

But, it is entirely possible for the agent to be unconstrained, and to save. In fact that is a useful result we will use later:

Lemma II: *There exist values of ϕ, w^e, Δ^e, ξ such that $\int a_1 > 0$.*
Proof: See appendix B

This is important because, as we will see in the next section, the policy experiment yields $\int a_1 = 0$ no matter the values of these parameters, which means wealth accumulation is equal or (more probably) smaller in the policy experiment. We will dive into this discussion in the next subsection.

4.3 Policy Experiment

The policy imposes $\phi = 0$, and so inter vivos transfers cease to exist in this model. On the other hand, a proportion τ over graduates' income is levied as the graduate tax that finances this reform. For those who choose to enter HE and successfully graduate, the problem becomes:

$$V_0^S = \max_{c_0} u(c_0) + V_1^S(a_1)$$

- $c_0 + a_1 = w^S(1-\Delta)(1-\tau)$
- $c_0, a_1 \geq 0$

$$V_1^S = u(c_1)$$

- $c_1 = w^S(1-\tau) + a_1$
- $c_1 \geq 0$

Where $\xi \cdot \mathbb{H}$ has become completely irrelevant for the problem, because the child's education decision is not influenced by transfers. This also means that θ_C ceases to be a state variable. This has a trivial closed form solution, by Euler: $u'(c_0) \geq u'(c_1)$, and should the constraint be active $u'(c_0) > u'(c_1)$ and $a_1 = 0$.

If $u'(c_0) = u'(c_1)$, then $c_0 = c_1$, and this results in $a_1 < 0$ because $w^S(1-\Delta)(1-\tau) < w^S(1-\tau)$. Then, the solution is:

- $c_0 = w^S(1-\Delta)(1-\tau)$
- $a_1 = 0$
- $c_1 = w^S(1-\tau)$

On the other hand, for dropouts

$$V_0^D = \max_{c_0} u(c_0) + V_1^U(a_1)$$

- $c_0 + a_1 = w^U(1-\Delta)$
- $c_0, a_1 \geq 0$

$$V_1^U = u(c_1)$$

- $c_1 = w^U + a_1$
- $c_1 \geq 0$

Which implies $c_0 = w^U(1-\Delta)$, $a_1 = 0$, $c_1 = w^U$ by the same argument as with graduates.

Finally, for those who enter immediately as unskilled labor:

$$V_0^U = \max_{c_0} u(c_0) + V_1^U(a_1)$$

- $c_0 + a_1 = w^U$
- $c_0, a_1 \geq 0$

$$V_1^U = u(c_1)$$

- $c_1 = w^U + a_1$
- $c_1 \geq 0$

Which results in $c_0 = c_1 = w^U$, $a_1 = 0$. Then, for the whole economy, we can reach the following conclusion:

Lemma III: *Implementing free higher education with graduate taxes yields* $\int a_1 > 0$ *independent of the choice of parameters.*

The proof is the previous analysis, and lemmas II and III together enable us to formulate the following proposition:

Proposition I: *There exist values of* ϕ, w^e, Δ^e, ξ *such that the policy reform results in a disincentive to savings. Also, there are no values of said parameters for which the opposite is true.*

Proposition I suggests is merely a consequence of the timing of the expenses during the life cycle, coupled with liquidity constraints. In the initial steady state, agents save in their early years to pay a large amount during the late period of their lives, even if not for themselves. On the other hand, paying for education through the graduate tax spreads out this expense throughout the life cycle, eliminating a reason to save.

The final piece of analysis we might make in this context of policy reform is the government budget constraint. Define Q_0^S as the amount of agents of age $j = 0$ who are graduates, Q_1^S those of $j = 1$ and Q_0^S the dropouts. Then, in order to completely finance free higher education through graduate taxes of rate τ, the government must satisfy:

$$\phi(Q_0^S + Q_0^D) = \tau w^S [Q_0^S(1-\Delta) + Q_1^S]$$

In steady state equilibrium the amount of graduates is constant over time, so $Q_0^S = Q_1^S \equiv Q^S$. For simplicity lets define $Q_0^D \equiv Q^D$, then we can obtain an intuitive result:

$$\tau w^S(2-\Delta) = \phi\left(1 + \frac{Q^D}{Q^S}\right)$$

If we define the dropout rate as $\delta = {}^{Q^D}/_{(Q^D+Q^S)}$,

$$\tau w^S(2-\Delta) = \phi\left(\frac{1}{1-\delta}\right)$$

This equation shows the total amount paid in taxes throughout the life of a higher education graduate on the left hand side. The total benefit he receives from free higher education is ϕ, the cost of education itself, but since $Q^D > 0$ and $\delta > 0$ by construction (every agent who enters higher education has a probability smaller than 1 of graduating, which means the probability of dropping out is greater than zero), the amount paid in taxes is greater than the benefit received. This is because graduates are not only paying for their own education, but are also paying for dropouts, who won't pay taxes, by definition. And this mechanism is stronger, the higher the dropout rate. Also,

$$\tau = \frac{\phi}{w^S(2-\Delta)}\left(\frac{1}{1-\delta}\right)$$

This second equation is a different approach on the same problem: the tax rate that the government must apply in order to achieve budget balance is grows if the dropout rate is higher. And since we are studying long-run steady states in this work, this condition must be satisfied. Therefore, intuitively we might think that in a context of high dropout rates, graduate taxes might provide a disincentive to opting for higher education, because of the very high rates needed to have a balanced budgets.

4.4 General Equilibrium

So far theoretical consequences of the policy reform include a fall in precautionary savings, life cycle savings, and an uncertain effect over educational attainment (depending on liquidity constraints and dropout rates). But it is fundamental to include general equilibrium concerns in the discussion, since changes in wages may alter income and wealth distributions, as well as educational attainment decisions.

For example, suppose a high number of agents were liquidity constrained regarding education, and the graduate tax rate is reasonable. Then the increase in enrollment given by students previously financially constrained could prevail, and given that they are high ability students they will probably graduate. This means the amount of unskilled labor will diminish and the contrary for skilled labor, and given general equilibrium that will lower the wage premium for skilled workers.

Now we can say something about the income distribution. If we categorize unskilled labor as low earners and skilled labor as high earners, then four facts contribute to lessen income inequality. This is first due to the higher proportion of high earners, and also to the higher wages of low earners (thanks to their increasing scarcity). But it is also due to both lower wages and higher taxes of high earners, whose disposable income might fall substantially.

And finally what would happen to the distribution of wealth? First off, it should mimic the changes in the income distribution, as these two variables will be correlated for the reasons given previously. Richer households could face a substantial decrease in their wealth, and poorer households might enjoy a moderate increase. But now the precautionary savings motive for education disappears, as there is no uncertainty in educational expenses. This means that wealth diminishes for households previously affected by this motive, who will in turn consume a greater fraction of their available resources instead of saving, shaping the wealth distribution accordingly.

Such would be a favorable scenario for the policy reform, but what if most agents were not financially constrained? And if high dropout rates result in a very high graduate tax rate? Maybe graduates would diminish, increasing the wage premium and increasing income and wealth inequality: the results are reversed. That is why proper modeling and calibration is necessary: in order to quantify these concerns. We address this issue in the rest of this investigation.

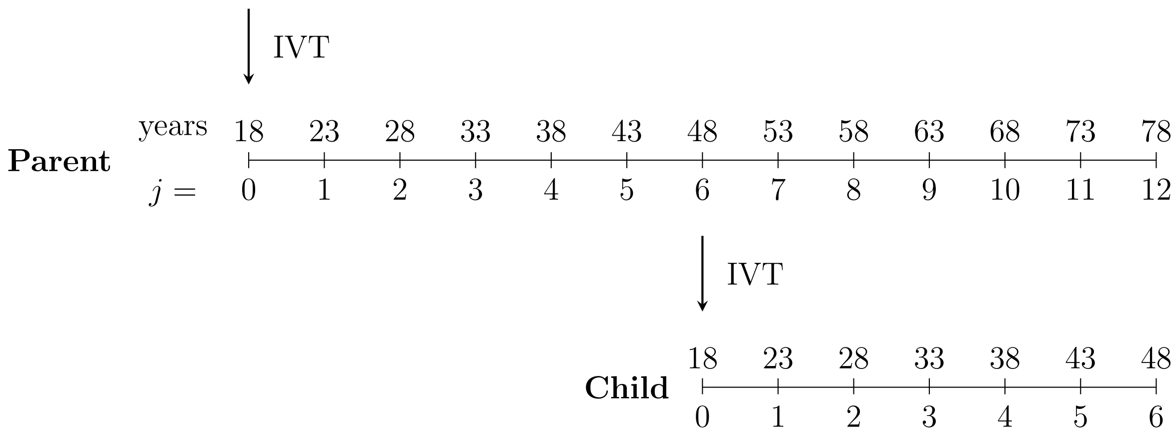
5 Quantitative Model

This model will follow the toy model presented previously in spirit, mostly building a more realistic life cycle profile and incorporating the general equilibrium concerns. There are no aggregate shocks, therefore the economy will be described in steady state and without time subscripts

5.1 Preliminaries

Time is discrete and continues forever, but since there are no aggregate shocks and the economy is always described in steady state, time subscripts will be omitted. A period in the model corresponds to five years. The economy is populated by 13 overlapping generations, where each generation is a continuum of measure one of individuals (also called agents or households). Each generation corresponds to period $j \in \{0, 1, ..., J\}$ of the life cycle. At each date a new cohort of measure one enters the economy, and another one leaves, making the model's age distribution stationary. The first period of life in the model ($j = 0$) corresponds to age 18 and the last one ($j = J = 12$) to age 78, after which agents pass away.

Individuals beginning adult life choose between entering higher education or entering the workforce. Should they opt for education, the entirety of $j = 0$ is spent studying, and in $j = 1$ they enter the workforce. All individuals proceed to work the following periods of the life cycle up until $j^{RET} = 9$, when they retire and spend the following four periods without labor income. Thus, the three stages of the life cycle are education (which is optional), work and retirement. However, $j = 6 = j^{IVT}$ is arguably the most important age of the life cycle in this model, as parents make an inter-vivos transfer to their children, who have just started their own life cycle at $j = 0$. We illustrate with the following diagram regarding a parent and its child:



Next, individual preferences over consumption c are simple:

$$u(c) = \frac{c^{1-\gamma}}{1-\gamma}$$

Where γ is the relative risk aversion coefficient. This utility refers to a specific age of the individual and time of the model. Individuals discount utility at a rate of β for each period.

A representative firm produces the final good with aggregate capital K (which depreciates at a rate δ), aggregate human capital $\mathcal{H}$, and exogenous and constant total factor productivity A:

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

Workers are classified as skilled labor if they completed tertiary education, and unskilled if they did not. The former's aggregate labor input is H^S and the latter's H^U, and they are aggregated together as imperfect substitutes with shares s^S and s^S respectively, with constant elasticity of substitution, governed by $0 < \rho < 1$:

$$\mathcal{H} = \left[s^U \left(H^U\right)^{\rho} + s^S \left(H^S\right)^{\rho}\right]^{1/\rho}$$

Financial markets are incomplete: agents can buy risk-free bonds at the international interest rate, but cannot buy state-contingent insurance against individual labor-income risk. The economy is small and perfectly open in capital markets, therefore aggregate capital need not equal aggregate household assets. Also, households are liquidity constrained: they may not borrow, which means their assets cannot be negative.

The government will run a pension system which pays a benefit p to retirees, financed by unspecified sources.[21]

5.2 Life Cycle

The life cycle of an individual consists of three stages: education, work, and retirement, which we describe in this same order.

5.2.1 Education

The education stage is entered if the individual decides to attain higher education. Individuals make this decision at the onset of the first period of adult life, in $j = 0$, and this has two outcomes for $j = 1$: either graduating and becoming skilled labor, or dropping out and becoming unskilled labor.

[21]This is only because I have not calibrated income, consumption and capital taxes yet. Once I do, pensions will be payed though the resourced levied by those means. And pensions p are the same for all only to simplify the model in the retirement period, which is not fundamental for my analysis.

Parental resources matter for the education decision of the child in two ways. First, during the education period a child receives education-conditional cash transfers from their parents. Specifically, a child receives $\hat{a}$ conditional on going to higher education, and $\tilde{a}$ if it enters the workforce, both variables chosen by the parents before the education decision is made (note how the parent may influence the education decision: this is intentional).

Now, when the individual turns 18 at the beginning of $j = 0$, it knows about $\hat{a}$, and its ability $\theta \in \Theta$, Θ discrete. This parameter represents cognitive and non cognitive competence, both innate and acquired through primary and secondary education, and its distribution for each individual depends on parental characteristics as will be described later. The value for this individual depends on its education choice:

$$V_0^*(\hat{a}, \tilde{a}, \theta) = \max\{V_0^H(\hat{a}, \theta), \mathbb{E}_z[V_0^U(\tilde{a}, \theta, z_0)]\}$$

Where V_0^* is the value it will obtain before it makes the decision, V_0^H if it chooses to attend higher education and V_0^U if it does not and enters the labor market as an unskilled worker. This last value function will be described in the next stage of the life cycle, for now it is enough to say that z is an idiosyncratic productivity shock not known to the student before it makes the decision to enter the working stage of its life. The value function of choosing education is as follows:

$$V_0^H(\hat{a}, \theta) = \max_{c_0, a_1} u(c_0) + \beta \left[\kappa(\theta)\mathbb{E}_z[V_1^S(a_1, \theta, z)] + (1 - \kappa(\theta))\mathbb{E}_z[V_1^U(a_1, \theta, z_1)]\right]$$

Subject to

$$c_0 + a_1 + \phi = \hat{a}$$
$$c_0, a_1 \geq 0$$

At this point some explanations from the previous problem are necessary. First, students may fail their education and end as drop outs, entering the workforce the following period as unskilled labor. The probability of passing tertiary education is κ and it depends on ability θ, with higher ability individuals being more likely to obtain their degree.

Finally, ϕ is the cost of tertiary education. It would be desirable in the future to understand ϕ as net of grants, and thus a function of ability and parental economic status. it would also be desirable to include subsidized government loans. These aspects will be discussed later.

5.2.2 Work

The value function of a working individual may be presented accurately for ages $j \in \{0, ..., J^{RET} - 2\}$, excluding j^{IVT} and $j^{IVT} - 1$, and for both education groups $e \in \{U, S\}$ (considering a skilled worker may only begin this stage at $j = 1$):

$$V_j^e(a_j, \theta, z_j) = \max_{c_j, a_{j+1}} u(c_j) + \beta \mathbb{E}_z[V_{j+1}^e(a_{j+1}, \theta, z_{j+1})]$$

Subject to

$$\begin{gathered} c_j + a_{j+1} = y_j + a_j(1 + r) \\ y_j = w^e \varepsilon_j(\theta, z_j) \\ c_j \geq 0,\ a_{j+1} \geq 0 \\ z_{j+1} \sim \Gamma_z^e(z_{j+1}|z_j) \end{gathered}$$

Labor income is denoted by y_j, which can be decomposed by its components. First is the wage for the appropriate education group w^e, which will be determined in general equilibrium as the marginal productivity of that type of human capital. Second, the amount of efficiency units provided by a unit of labor, $\varepsilon_j(\theta, z_j)$. Notice that these are contingent on age, ability and the productivity shock. Skilled workers provide more efficiency units, as well as those with higher ability and a better productivity shock, and the age effect intends to follow a life cycle profile of earnings. Also, the productivity shock z follows a discrete-state Markov process that induces persistence given by Γ_z^e. The first productivity shock, when the individual in a new worker, is taken from the stationary distribution of z.

Two more special cases should be detailed. First, before retiring (in period $j = j^{RET} - 1 = 8$) the constraints are the same but the value function will be:

$$V_8^e(a_8, \theta, z_8) = \max_{c_8, a_9} u(c_8) + \beta V_9^R(a_9)$$

Where $V_j^R(a_j)$ is the value function of the retiree and will be explained in the next stage. The other special case is in $j = j^{IVT} - 1 = 5$, before inter-vivos transfers are made. The value function becomes

$$V_j^e(a_j, \theta, z_j) = \max_{c_j, a_{j+1}} u(c_j) + \beta \mathbb{E}_{z,\theta}[V_{j+1}^e(a_{j+1}, \theta, \theta_C, z_{j+1})]$$

Where the difference is that next periods value function is uncertain regarding the child's ability θ_C, which will become a state variable. This change is quite important as stated in section 4. The parent also knows the probability distribution of his child's ability:

$$\theta_C \sim \Gamma_\theta(\theta_C|\theta)$$

This distribution, along with the parent's problem in j^{IVT} will be explained in detail in the next subsection, referring to intergenerational linkages.

5.2.3 Retirement

During the retirement stage, agents do not work or study and thus dedicate all of their time to leisure. They receive pension payments p and may not borrow from the financial market. Including all of this, the retiree's value function is as follows:

$$V_j^R(a_j) = \max_{c_j, a_{j+1}} u(c_j) + \beta V_{j+1}^R(a_{j+1})$$

Subject to

$$c_j + a_{j+1} = p + a_j(1+r)$$
$$c_j, a_{j+1} \geq 0$$

And $V_{13}^R = 0$

5.3 Intergenerational Linkages

Parents are linked to their child through both the transmission of ability θ and monetary transfers $\hat{a}$ and $\tilde{a}$. Let us denote θ_C the ability of the child, and for the parent θ. θ_C follows a probability distribution Γ_θ conditional on the parent's ability, that is:

$$\theta_C \sim \Gamma_\theta(\theta_C|\theta)$$

The realization of the child's ability happens at age 18, the first period of its life cycle, and before both the educational choice and the inter vivos transfer. The determination of $\hat{a}$ comes next, and will be the result of the optimal decision of the parent in period $j = j^{IVT} = 6$, which will be a special period in the working stage, as the parent solves

$$V_j^e(a_j, \theta, \theta_C, z_j) = \max_{c_j, a_{j+1}, \hat{a}, \tilde{a}} u(c_j) + \beta \mathbb{E}_z[V_{j+1}^e(a_{j+1}, \theta, z_{j+1})] + \omega V_0^*(\hat{a}, \tilde{a}, \theta_C) + \xi \cdot \mathbb{H}(\hat{a}, \tilde{a}, \theta_C)$$

Subject to

$$c_j + a_{j+1} + \mathbf{a} = y_j + a_j(1+r)$$
$$y_j = w^e \varepsilon_j(\theta, z_j)$$
$$c_j, \hat{a}, \tilde{a}, a_{j+1} \geq 0$$
$$z_{j+1} \sim \Gamma_z^e(z_{j+1}|z_j)$$

As the ability of the child has already been determined, it becomes a state variable relevant for the parent's decision. The amount of the inter vivos transfer becomes a control variable, where $\mathbf{a}$ corresponds to $\hat{a}$ if the child is induced to enroll in higher education, and $\tilde{a}$ if not. Note that the parent knows all the information necessary (θ_C) to be able to discern perfectly which amounts of $\hat{a}$ and $\tilde{a}$ will induce which decision on part of its offspring. And this is expressed through $\mathbb{H}$, which is an education decision indicator that takes a value of 1 when the child decides to attend education, and zero otherwise.

The parent cares about its child through two relevant channels. $V_0^*(\hat{a}, \tilde{a}, \theta_C)$ is the value of the child and its state variables, and ω is a parameter reflecting the altruistic desire for the child's well being, the first channel. The second one is the paternalistic desire for the child to go to tertiary education, quantified in ξ. This parameter is added to parental utility if the indicator $\mathbb{H}$ becomes one, that is if the child decides to get educated, which happens if $V_0^T(\hat{a}, \theta_C) > \mathbb{E}_z[V_0^U(\tilde{a}, \theta_C, z_0)]$. Abbott et al. (2013) argues that this parameter is key to producing realistic results in terms of higher education student characteristics, namely the high presence of low ability-high wealth students.

5.4 Stationary Equilibrium

The model is solved numerically to characterize the stationary equilibrium allocation. Given age heterogeneity and finite lives, this model entails $J+1$ overlapping generations. Stationarity implies that we study an equilibrium such that the cross-sectional allocation of state variables for any given cohort of age j is invariant over the sequence of time periods $t \in \{t_0, t_1, ...\}$. In the following definition, it will be useful to consider $s_j \in S_j$ as the vector of state variables for an individual of age j.

Formally, a **stationary recursive competitive equilibrium** for this economy is a collection of: (i) decision rules for tertiary education $\mathbb{H}(s_0)$, consumption $c_j(s_j)$, wealth $a_{j+1}(s_j)$ and inter-vivos transfers $\hat{a}(s_j)$ & $\tilde{a}(s_j)$; (ii) value functions $V_j^H(s_j)$, $V_j^U(s_j)$, $V_j^S(s_j)$, $V_j^R(s_j)$; (iii) aggregate capital and labor inputs K, H^U, H^S; (iv) prices w^U and

w^S such that:

1. Given w^U and w^S, the decision rules $\mathbb{H}(s_0)$, $c_j(s_j)$, $a_{j+1}(s_j)$, $\hat{a}(s_j)$ & $\tilde{a}(s_j)$ solve the respective household problems, and $V_j^H(s_j)$, $V_j^U(s_j)$, $V_j^S(s_j)$, $V_j^R(s_j)$ are the associated value functions.

2. The representative firm optimally chooses factors of productions, and input prices equate their marginal products,

$$\begin{aligned} r + \delta &= F_K(K, \mathcal{H}) \\ w^e &= F_{H^e} \text{ for } e \in \{U, S\} \end{aligned}$$

3. The labor market clears for each kind of human capital. That is, for each individual i:

$$H^U = \int_{e=U} \varepsilon_i \, di$$
$$H^S = \int_{e=S} \varepsilon_i \, di$$

An element is missing: the government budget constraint. But since the model presented does not have taxes yet, this is pending on this update. Note that the goods and capital markets need not clear, since this is a small open economy.

5.5 Policy Experiment

The policy reform to be evaluated in this investigation is the implementation of free higher education, completely financed with graduate taxes. In the model presented, this results in very simple changes that have very important implications. First, the cost of education, *phi*, is now zero. Agents who choose education face the same value function V_0^H, but the resource constraint loosens to $c_0 + a_1 = \hat{a}$. For the agents who manage to graduate, in their working stages they will also have to pay the graduate tax τ: their budget constraint will be

$$c_j + a_{j+1} = (1 - \tau)y_j + a_j(1 + r)$$
$$y_j = w^S \varepsilon_j(\theta, z_j)$$

No other part of the agents' life cycle problems will change: unskilled workers will not pay the graduate tax, and inter-vivos transfers will continue to occur due to parental altruism. However, the government budget constraint for this policy must be satisfied, and this model that requires that in equilibrium:

$$\phi \int_{j=0} \mathbb{H}_i \; di = \tau w^S \int_{e=S} \varepsilon_i \; di$$

Where remember that agents are in a continuum: the left integral measure the amount of agents of the initial period that choose to enter higher education (times the cost, equals the government expenditure) and the right integral adds all the efficiency units of skilled labor. The aggregate efficiency units times the skilled wage equals the tax base, and times the tax rate equals the government revenues from the graduate tax. The tax rate is chosen by the government in order to comply with this restriction in steady state equilibrium.

6 Estimation

6.1 Methodology

The intention of this investigation is to simulate a policy reform and produce an estimation of its effects on various moments of interest. The estimation of the initial steady state (before the reform) must resemble the economy investigated in these moments of interest in order for the simulation to be valid. Therefore, the strategy pursued consists of first calibrating the model so that the initial steady state resembles the Chilean economy and higher education system. Then, with the parameter values resulting from the previous calibration, a new steady state will be calculated that will incorporate the policy reforms mentioned in subsection 5.4. The differences in the moments of interest can be interpreted as an estimation of long-run effects of the policy.

The calculation of the general equilibrium initial steady state is done with the following computational algorithm:

1. Posit a guess for aggregate skilled and unskilled human capital, H^S and H^U. These guesses will imply specific wage levels w^S and w^U.

2. Posit a guess for the initial value function $V_0^*(\hat{a}, \tilde{a}, \theta)$

3. Solve through induction the agents problems from $j = 12$ to $j = 0$, obtaining numberical estimates of the value functions. Note that a previous guess of V_0^* is needed to solve the problem in $j = 6$.

4. Solving the problem in $j = 0$ will yield a new estimate for V_0^*. If the new V_0^* is too different from the previous guess, use it as a new guess and repeat step 3. Otherwise, continue.

5. Posit a guess for the aggregate distribution of inter-vivos transfers for n agents. n will be the number of agents simulated.

6. Simulate the life cycles of the n agents, using the policy functions obtained in step 4. Note that this needs a guess for the distribution of inter-vivos transfers. The agents must have random idiosyncratic shocks, ability and graduation according to the structure detailed in section 5.[22]

7. Step 6 yields a new distribution of inter-vivos transfers. If the new distribution is too different from the previous guess, use it as a new guess and repeat step 6. Otherwise, continue.

8. Completing step 7 means the partial equilibrium has been found, but this results in new levels of aggregate human capital. if these levels are too different from the guess, update the guess, obtain new wages and return to step 2. Otherwise, a fixed point has been achieved and the general equilibrium has been found.

The model is calibrated with data from various sources, specifically to match observed income gini, household wealth gini, higher education attainment rate, dropout rate, and wage premium over high school graduates. The full calibration strategy is detailed in appendix C.

Once the model is calibrated, the post-reform general equilibrium must be calculated. This is done adding one more loop to the previous algorithm, because a guess must be posited on the tax rate, which will be used to calculate a general equilibrium. If the government budget is not balanced (revenue and expenditure can be easily calculated), the tax rate must be updated and a new general equilibrium must be calculated. Once a general equilibrium with a balanced budget[23] is achieved, the calculation of the post-reform steady state equilibrium is complete, and results can be obtained. We present these in the next subsection.

[22]This means shocks must use their transition matrix, as well as ability which must consider the intergenerational link.

[23]Note that a perfectly balanced budget is impossible to achieve, a threshold for acceptable levels of budget imbalance must be used.

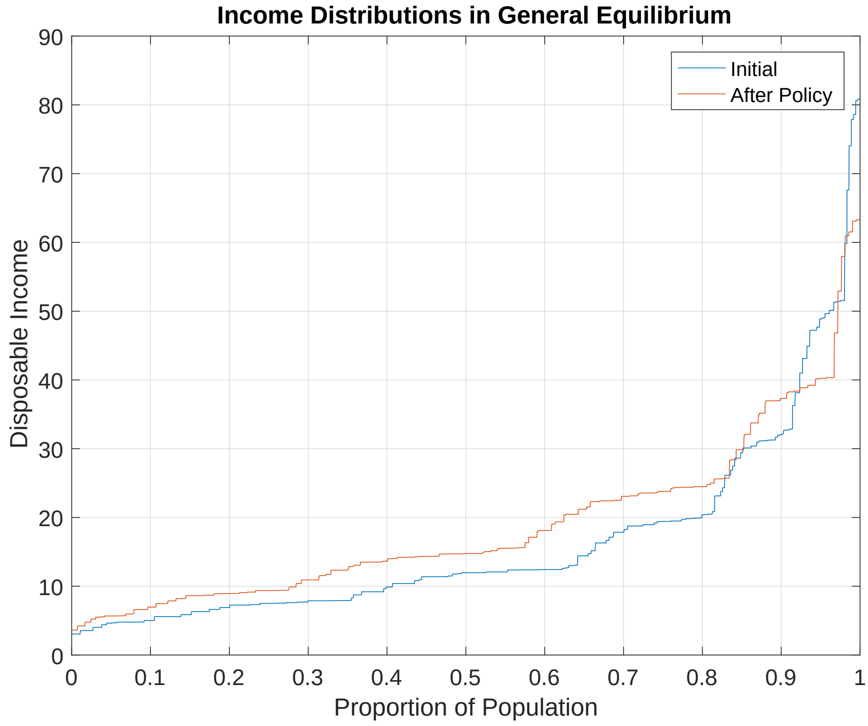
6.2 Results

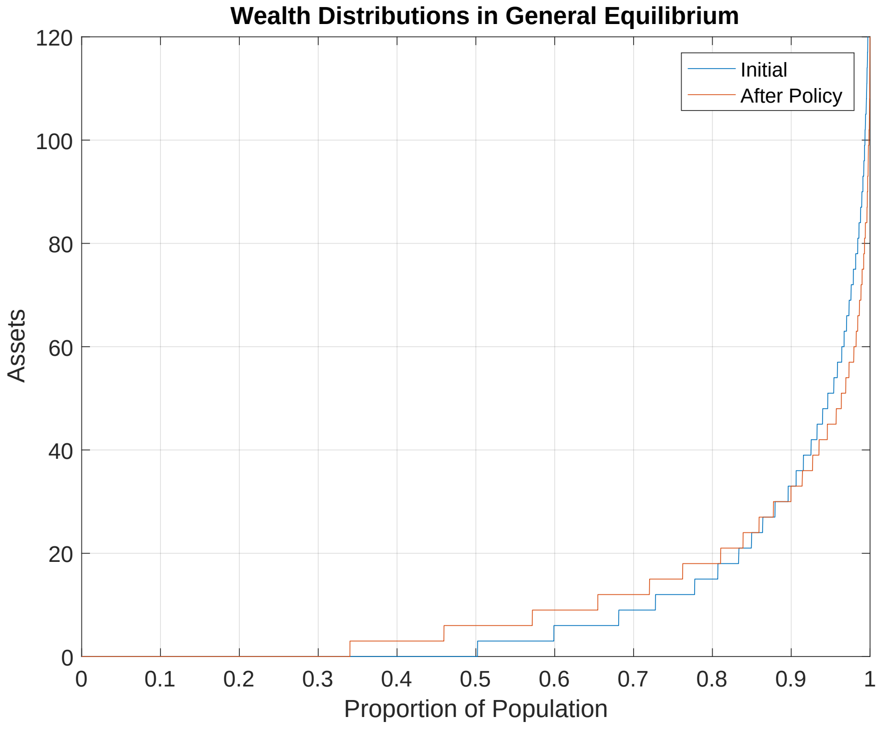
The following table presents the main moments of interest in each steady state equilibrium:

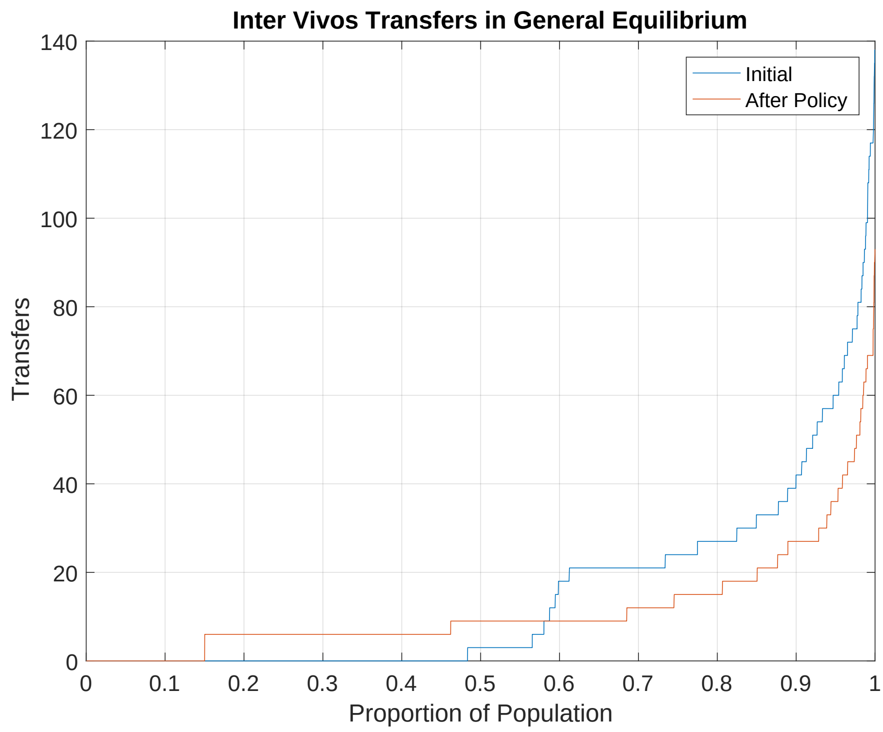
	Before Policy	**After Policy**
Disposable Income Gini	0.4057	0.334
Wealth Gini	0.7629	0.6539
Aggregate Assets	10.22	11.24
HE Earnings Premium	2.5162	1.8566
HE Entering Rate	40.29%	85.42%
Dropout Rate	43.72%	49.13%
HE Population Attainment	22.59%	43.23%
Graduate Tax		10.66%

Where the earnings premium is defined as w^S/w^U, the times the skilled wage per efficiency unit is higher than the unskilled wage. The entering rate is the percentage of individuals in $j = 0$ who opt for education. Of these individuals, the percentage who end up as dropouts is given by the dropout rate. And finally HE attainment represents skilled labor as a percentage of the total individuals in any given generation.

The full distribution of income, assets (same as wealth in this model) and transfers can be observed as well:


Income Distributions in General Equilibrium
Disposable Income
Proportion of Population
Initial
After Policy
0
10
20
30
40
50
60
70
80
90
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Wealth Distributions in General Equilibrium
Assets
Proportion of Population
Initial
After Policy
0
20
40
60
80
100
120
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1



6.3 Discussion

From the previous results we have a preliminary answer to the thesis question: the distribution of wealth presents a significant decrease in inequality, driven both by an increase in the assets of the middle percentiles of the distribution and a decrease in the case of the top percentiles.

We can analyze this result from several aspects. First of all, the HE entering rate increased dramatically, and even though the dropout rate increased as well (which we can attribute to lower-ability individuals entering the system), the percentage of HE graduates in the population increased. This sets off the general equilibrium effects: the wage premium lowers significantly, and it is both due to higher wages of unskilled labor and lower wages of skilled labor. It also suggests that a very significant amount of individuals are financially constrained at the beginning of their life cycle.[24]

These effects become clear when we observe both income distributions.[25] After the policy reform, earnings increase for the lowest 9 deciles approximately, while they decrease for

[24] And this is considering a lower wage premium. A partial equilibrium

[25] One may notice both distributions are not very smooth, they present significant bumps which cause the distributions to intersect in several points. The author attributes this to insufficiently large grids for idiosyncratic shocks and ability: both have three possible values and have large effects on efficiency units. Abrupt jumps in the distribution may correspond to a higher category of any of these state variables.

most of the top decile. The former can be attributed to higher unskilled wage and more skilled labor, and the latter to lower skilled wage and the graduate tax, as the measure presented is disposable income. This lends credit to the hypothesis that changes in the income distribution will be in part mimicked by the wealth distribution.

Another reason why assets increased in the middle percentiles of the distribution may be due to transfers. Transfers are much smoother as there is not a large expense in $j = 0$ as was before. This means a significantly greater percentage of the population realizes a transfer to their children, for which asset accumulation is necessary to smooth consumption. And the decrease in large transfers is consistent with smaller intertemporal wealth accumulation for the richest.

The precautionary and life cycle savings arguments seem to have little or no weight in this result, as aggregate assets increase in the case of the policy reform, as well as assets for the majority of the population. This may be because they have no weight compared to the general equilibrium effects on educational attainment and wage premium, which are especially large in these results.

All of these results must be interpreted with caution, as the analysis has built on several strong assumptions which will be discussed in the following section.

7 Limitations

In the author's opinion, the strongest assumption on which the model builds so far, is that there are no loans or grants for potential higher education students. This may strongly bias the results obtained, because these two policy instruments are targeted specifically at liquidity constrained high school graduates, significantly reducing the number of persons afflicted by this problem (remember section 3.2, the literature is not settled whether there is a significant number of liquidity restricted potential students). If financial constraints are small or nonexistent, increases in educational attainment should be negligible. And this might be the case if we model loans and grants targeted at students from low income backgrounds: the increase in educational attainment and decrease in wage premium would probably be much smaller than what section 6 suggests.

Another strong assumption is that the marginal cost of higher education ϕ is constant, and the educational supply is infinitely elastic (anyone who decides to study can, instead of only the best scores of an admission test or similar). This is only reasonable if we are studying long-term dynamics, which is the case of this investigation. In such a case, following an increase in educational demand, actual institutions might grow and new institutions might sprout. And comparing two overlapping-generation steady states means that after the reform, all generations must be different from those present in the initial steady states, therefore these changes could only occur after many decades. That is why this is a long term model that is not useful for analyzing short term effects of educational policies, only the general direction and destination of the variables studied.

More important limitations lie with the methodology instead of the model. It is the authors opinion that the calibration exercise is generally lacking, for many reasons. First and foremost, the graduation probability and its relation with ability, $\kappa(\theta)$, is fundamental to the model as it strongly influences educational decisions, and the approach taken to construct it should build more strongly in literature and data. Second, θ itself should have a larger grid (more possible values) for smoother reactions to the policy reform. This has not been done yet because it entails significant costs on computational time of the model. Third, the income process should build on data from the country that is being analyzed, Chile. Fourth, the general calibration strategy could use more refined techniques, such as a simulated method of moments estimation, which Abbott et al. use, in order to reach the targets better.

Back to the model limitations, it is inevitable to notice that modeling all higher education as a single process with the same cost in time and resources and the same outcome in wages is a powerful abstraction from reality, where there is much heterogeneity between different kinds of higher education institutions and programs. However, this would be a very complex problem to solve, and it is difficult to ascertain in which way the results would be different, should it be solved. A first guess is provided by Espinoza & Urzúa (2015): the educational choice would be distorted in the detriment of short and lucrative programs and favoring long and expensive programs. This misallocation could imply a decrease in total factor productivity or aggregate human capital.

These same authors also document a number of potential undesirable consequences of a graduate tax, most of which are not modeled because they would be extremely difficult to do so. They are mostly practical concerns, such as brain drain: students could obtain free higher education in Chile and then migrate to other countries where the tax would not be applied. Also, students could drop out just before graduating in order to avoid the tax while obtaining considerable knowledge from higher education, which could be valuable for employers resulting in a higher wage despite not graduating. Note that the presented model assumes that a dropout will inevitably receive compensation as unskilled labor, which is a limitation.

8 Conclusions

As was lengthily argued in the previous section, the results presented should be treated with considerable caution. However, it is the author's opinion that a piece of the results is stronger than the whole: *Should the policy reform increase significantly the number of graduates in the economy, the wealth distribution will experience a considerable decrease in inequality, both through the increase of assets in poorer households and decrease in richer households.* That is because the assumptions underlying this conclusion are not as strong: mainly imperfect substitution between human capital types and a substantial initial wage premium as is the case of Chile. The implicit assumption that a great number of agents are liquidity restricted from attending higher education is much stronger, and that is what drive the educational attainment result obtained, which is questionable.

Two next steps are intended to be taken soon: First to model and program state subsidized loans (and possibly grants) in an intent to fix the main caveat of financial constraints. And second, trying to make a better calibration exercise wherever it is possible regarding time constraints. Also, some alternative scenarios could be computed: a partial equilibrium steady state where the policy reform is implemented but wages do not change, an alternative government budget constraint such as only paying for graduates but not dropouts with the graduate tax (in an attempt to quantify the disincentive to education this might produce), and many others.

As for further work, the author's opinion is that a short-term model featuring an inelastic educational supply could be built. Then, short term effects of the policy would probably not have large consequences on educational attainment or the wage premium, but possibly a better allocation of ability into higher education through the elimination of liquidity constraints. Another alternative could be diving into the heterogeneity of educational supply. A simple approach could be to differentiate between short term vocational programs from technical institutions, and longer general programs from universities. Later, institution or program heterogeneity in quality could play a role as well. And lastly, the theoretical toy model might hold some promise if worked more thoroughly.

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Appendix

A Section 3 Data

A.1 Data Definitions and Sources

- *Household Disposable Income Gini*: Income distribution data refer to the total population and are based on equivalised household disposable income, i.e. disposable income (after taxes) adjusted for household size. The Gini coefficient takes values between 0 (where every person has the same income), and 1 (where all income goes to one person). 2013 data for Chile, 2014 for the USA, 2013 for Norway, and the OECD average includes country data between 2012 and 2014 according to data availability. Source: *Income Inequality Update, November 2016,* OECD

- *Household Wealth Gini*: Data corresponds to the year 2000 for all three countries. In the case of the USA, the Survey of Consumer Finances 2001 is used. With Norway, the Income and Property Distribution Survey. And finally, the authors argue that there was no available data for Chile and constructed the wealth distribution by regression-based imputations. Provided by Davies et al. (2011).

- *Public Expenditure on H.E. as % of GDP*: Public expenditure on tertiary educational institutions, as % of GDP. Public expenditure figures presented here exclude undistributed programmes. Including public subsidies to households attributable to educational institutions, and direct expenditure on educational institutions from international sources. In the case of Chile, not including international sources. Year of reference is 2013 for USA and Norway, 2014 for Chile. OECD average includes 2012, 2013 and 2014 as years of reference. Source: Table B2.3 Education at a Glance (2016).

- *Private Expenditure on H.E. as % of GDP*: Private expenditure on tertiary educational institutions, as % of GDP. Net of public subsidies attributable to educational institutions. Year of reference is 2013 for USA and Norway, 2014 for Chile. OECD average includes 2012, 2013 and 2014 as years of reference. Source: Table B2.3 Education at a Glance (2016).

- *Adults Graduated from H.E.*: Percentage of 25-64 year-olds that have attained tertiary education, either short-cycle tertiary, bachelor's degree, or higher. Data classification refers to ISCED 2011. Year of reference is 2015 for USA and Norway, 2013 for Chile. OECD average includes 2013, 2014 and 2015 as years of reference. Source: Table A1.2 Education at a Glance (2016).

- *H.E. Earnings Premium*: Relative earnings of full-time full-year workers. 25-64 year-olds with income from employment; upper secondary education = 1. For USA, Index 100 refers to the combined ISCED levels 3 and 4 of the educational attainment levels in the ISCED 2011 classification. The indicator is based on the data collection on education and earnings by the OECD LSO (Labour Market and Social Outcomes of Learning) Network that takes account of earnings from work for individuals working full-time full-year as well as part-time or part-year during the reference period. For further methodology details, see Education at a Glance 2016 pages 122-123. Year of reference is 2014 for USA and Norway, 2013 for Chile. OECD average includes 2010, 2012, 2013 and 2014 as years of reference. Source: Table A6.1 Education at a Glance (2016).

- *Parent Child Schooling Correlation*: Sample correlation between years of schooling of parent on child are taken for each five-year birth cohort, and then averaged across cohorts. Years of schooling are taken from survey data from each country, survey year is 1998-1999 for Chile, 1998 for Norway and 1994-2000 for USA. See Hertz et al. (2007) for further details and advantages of this methodology.

- *Parent Child Schooling* β_s: Bivariate regressions (of the kind shown in section 3) between years of schooling of parent on child are run for each five-year birth cohort, and then the regression coefficients β averaged across cohorts. Years of schooling are taken from survey data from each country, survey year is 1998-1999 for Chile, 1998 for Norway and 1994-2000 for USA. See Hertz et al. (2007) for further details and advantages of this methodology

A.2 Intergenerational Correlation of Education

As stated in section 3, it may concern the reader that while the last two variables evidence intergenerational correlation of education in general, they do not specifically represent intergenerational correlation of tertiary education. A more indirect measure is now presented for Chile and its benchmarks:

	Chile	**USA**	**Norway**	**OECD**
T.E. attainment given S.E. parents	37%	33%	38%	39%
T.E. attainment given T.E. parents	77%	61%	65%	67%
Difference	40%	28%	27%	28%

How to read this table: In Chile, among 25-44 year-old non-students whose parents have upper secondary education and whose parents are both native-born, 37% attained tertiary education. On the other hand, among 25-44 year-old non-students whose parents have tertiary education and whose parents are both native-born, 77% attained tertiary education. Parents' educational attainment should be understood as the highest level of education of either parent.

In this case, a rough measure of intergenerational correlation in tertiary education (TE) is the increase in the proportion of adults attaining TE education if their parents attained TE instead of SE. Using a frequentist approach of probability, it could be interpreted as the increase in the chances of attaining TE if parents attained TE. If this increase is zero, that would mean parent's background does not influence child educational attainment at all, the opposite if the increase were 100%.

The third row gives such increase. It is significantly higher in Chile than in all benchmarks, indicating a higher intergenerational correlation, specifically in tertiary education. Recall that we are using the terms higher education and tertiary education indistinctly to mean all forms of formal education after secondary, be it vocational or general.

But even this indicator may be criticized as too rough to provide an accurate depiction of intergenerational correlation in TE. For further analysis, see Sapelli (2009a) who studies intergenerational mobility in Chile. In particular, his graph 7d shows significant and increasing persistence in TE attainment. Sapelli attributes this increase in persistence to financial constraints not at the time of college entry of the child, but at the time of his birth, thus suggesting the importance of early interventions in education. That would translate into a higher correlation of ability θ between parent and child in our model. Regardless, other studies find that financial constraints are significant in Chile, as shown in section 3.

B Mathematical Proofs

Proof of Lemma II: In order for $a_1^* = \frac{\hat{a}-\Delta^e w^e}{2} > 0$, first it is necessary that $\hat{a} = \phi$ (because if $\hat{a} = 0$ then necessarily $a_1^* < 0$).

Two conditions must be met for $\hat{a} = \phi$ to be optimum:

$$\begin{aligned} \theta_C &\geq \bar{\theta} \\ u\left(c^*|_{\hat{a}=\phi}\right) + u\left(c^*|_{\hat{a}=\phi}\right) + \xi &\geq u\left(c_0^*|_{\hat{a}=0}\right) + u\left(c_1^*|_{\hat{a}=0}\right) \end{aligned}$$

$c^*|_{\hat{a}=\phi}$ can be obtained from the results previous to lemma II, while $c_0^*|_{\hat{a}=0}$ and $c_1^*|_{\hat{a}=0}$ are the liquidity restricted consumption levels, which were also obtained (the individual would like to borrow because income in $j = 0$ is smaller). Thus, the second condition becomes:

$$2u\left(\frac{w^e(2-\Delta^e)-\phi}{2}\right) + \xi \geq u\left(w^e(1-\Delta^e)\right) + u\left(w^e\right)$$

Where we can observe that if $\phi < w^e(2-\Delta^e)$ for some e, when $\xi \to \infty$ this condition is met because $u(c)$ is a finite number $\forall c$.

Regarding the firs condition, remember from lemma I that $\bar{\theta} < 1$, and $f_\theta > 0$ if $0 < \theta < 1$, then $\exists \theta > \bar{\theta}$.

After meeting the condition $\hat{a} = \phi$, the last condition needed is

$$\frac{\phi - \Delta^e w^e}{2} > 0 \Rightarrow \phi > \Delta^e w^e \tag{1}$$

If this is fulfilled for some e, then $a_1 > 0$, the agent saves.

C Calibration

Several parameters of the model are taken directly from Abbott et al.: the CES parameter governing the elasticity of substitution between skilled and unskilled human capital, ρ, is 0.7. They estimated this parameter from the Current Population Survey 1968-2001. Altruism $\omega = 0.27$ is an average of their altruism towards sons and altruism towards daughters, 0.29 and 0.25 respectively. They calibrated this parameter using the simulated method of moments (SMM). I attempt to use the same persistence of idiosyncratic shocks as theirs: I use the average of the annual persistences ϱ they present for high school graduates and college graduates, to the power of five (reflecting a five year period in my model), which yields 0.8303. I build a discrete markovian process using the Tauchen function, which maps my AR(1) shock process into a transition matrix and three shock values. The share of capital in the production function α is 0.33, the utility function CRRA parameter $\gamma = 2$ and the time discount factor β is $0.944^(5/2) = 0.8658$, taking care of their two year period model versus my five year periods. They choose this value two replicate an annual capital/product ratio of 4.

I also use their same cognitive ability transition matrix, Γ_θ, using the first quintile, the middle three and the fifth as my possible values for θ. The matrix is available upon request, but is quite standard in persistence of cognitive ability, specially in the first and fifth quintiles. Finally, I use their same age profile, taking care to match my five-year periods. The age profile is also standard (increasing at decreasing rates) and available upon request.

Annual depreciation is drawn from Penn World Tables data, taking an average of the years 2000-2015, resulting in an annual estimate of 4.11%. The international exogenous interest rate comes from the same average of years of the real interest rate presented by the World Bank data, which is 3.08%. In a five year period, these values become 18.93% and 20.62% respectively.

The cost of education ϕ and pensions p are what sets the scale in this model. *phi* is chosen to match the average direct private costs faced by Chilean students who would enter and complete tertiary education in 2011, data by Education at a Glance 2016, OECD, and amounts to 13,359,000 CLP. Therefore, *phi* = 13.259 and the unit of measure in goods will be equivalent to a million CLP. From the Chilean *Superintendencia de Pensiones*, the average pension in January 2011 was around 175,000 CLP, which translates into 10.515 million CLP in five years, the value of p.

That leaves the following parameters to be chosen in order to calibrate the model:

- The share parameters s^S and $s^U = 1 - s^S$ will be obtained from a condition arising from general equilibrium. Given that wages equal marginal productivity of each kind of human capital, the wage premium has to be:

$$\frac{w^S}{w^U} = \frac{s^S}{s^U}\left(\frac{H^U}{H^S}\right)^{1-\rho}$$

  Given that in Chile $\frac{H^U}{H^S} \approx 4$ (given around 20% of the population are tertiary graduates), $\frac{w^S}{w^U} \approx 2.5$, and $\rho = 0.7$, it must be that $\frac{s^S}{s^U} \approx \frac{5}{3}$. I choose $s^S = 0.65$ and $s^U = 0.35$ as reasonable approximations.

- TFP A will be used to manage the magnitude of both wages, and provide reasonable results comparing with ϕ and p.

- Paternalism ξ will induce more transfers conditional on education, $\hat{a}$, and thus deliver higher educational attainment.

- Shock volatility σ_z is used to increase income volatility, which increases the income gini.

- The ability-efficiency profile $\varepsilon(\theta)$ can be made more volatile to produce the same effect as σ_z with the income gini. However, σ_z usually decreased the wealth gini, while a more volatile $\varepsilon(\theta)$ did not. This was intentionally used to target both measures of inequality.

- The graduation probabilities $\kappa(\theta)$ can be calibrated in various ways. I assumed they followed a normal distribution with μ_κ and σ_κ, using both moments to target the dropout rate.

The calibration targets and the achieved results in the model's steady state general equilibrium are presented in the following table

Moment	**Target Value**	**Model Value**
Wage Premium	2.39	2.52
HE Population Attainment	21%	22.6%
Dropout Rate	43,3%	43.7%
Income Gini	0.465	0.406
Wealth Gini	0.777	0.763

All targets come from the values presented in section 3. The target dropout rate is simply the opposite of the opposite of the second year institutional retention rate, for the reasons argued in said section. The resulting values of the parameters are:

- $A = 12$

- $\xi = 0.07$

- $\mu_\kappa = 0.5$

- σ_κ

- $\sigma_z = 0.3$

- $\varepsilon(\theta)$ is constructed so that low ability decreases efficiency units by 50%, and high ability raises them by 50%.