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Entrepreneurship, College and Credit: The Golden Triangle

Roberto M. Samaniego* Juliana Yu Sun†

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Abstract

We develop a model to evaluate the aggregate impact of college finance in an environment with entrepreneurship. The calibrated model captures the stylized fact that entrepreneurs with college are more common and more profitable in the US. The calibration indicates this is mainly because higher labor earnings allow college educated agents to ameliorate credit constraints if and when they eventually become entrepreneurs. Changes in financing constraints on entrepreneurs can thus affect college attendance, and changes in financing constraints on college can affect entrepreneurship rates as well.

1 Introduction

Education and entrepreneurship are important determinants of the wealth of nations. Education represents the accumulation of human capital, whereas entrepreneurship is key for accounting for patterns of financial capital accumulation – for example, in the United States

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entrepreneurs account for a disproportionate share of the wealthiest households. In addition, the accumulation of capital through both education and entrepreneurship are thought to be limited by borrowing constraints. This is one reason why, around the world, higher education is often at least partially subsidized.[1]

Empirical work shows that entrepreneurs in developed economies disproportionately come from among the college-educated, who also appear to make more profitable entrepreneurs.[2] This suggests that the incentives to go to college and to become entrepreneurs are intertwined. If so, financing constraints on *either* of these two activities may affect both human *and* financial capital accumulation. However, prior work has not studied the extent of these interactions.[3] There has also been no work trying to explain *why* entrepreneurs are more likely to be college educated. Is it because the college educated are more likely to make better entrepreneurs, or is it because they are wealthier? Also, what are the welfare implications of public financing of higher education in an environment where education and entrepreneurship might interact?

This paper studies the impact of education finance when both college education and entrepreneurship experience borrowing constraints. We develop a general equilibrium model featuring both, and argue that the true impact of either form of financing constraint on aggregate outcomes cannot be assessed in isolation: the interactions among them are key to understanding the impact of financing constraints on aggregate outcomes, as well as the role of entrepreneurship and education in the determination of aggregate outcomes. That is, financing constraints on entrepreneurship affect the decision to become educated

[1] Regarding the disproportionate share of entrepreneurs among the wealthy see Diaz-Gimenez et al. (1997) and Cagetti and de Nardi (2006). On borrowing constraints, see Becker (1975) regarding education and Evans and Jovanovic (1989) regarding entrepreneurship. Regarding the inalienability of human capital see Hart and Moore (1994). See for example Myers and Rajan (1998) regarding the difficulty of using physical or financial capital as collateral.

[2] See Bates (1990), Parker and van Praag (2006) and Mondragon-Velez (2009).

[3] The related literature either does not have entrepreneurs or does not have college education, see for example Cagetti and de Nardi (2006) and Lochner and Monge-Naranjo (2011). Terajima (2006) develops a general equilibrium model with both entrepreneurs and college, but there are no financing constraints.

– specifically, the decision to attend college – and financing constraints on education affect entrepreneurship rates, as well as aggregate outcomes. This paper is the first to study the joint impact of college education and entrepreneurship in a general equilibrium framework with financing constraints.

To understand these interrelations, consider the following – see Figure 1. Borrowing limits on entrepreneurs have been shown to account for the otherwise puzzling fat right tail in the US wealth distribution, since the difficulty of raising external funds gives entrepreneurs a powerful incentive to accumulate wealth – see Cagetti and De Nardi (2006). The empirical literature on the other hand delivers mixed results on the importance of financing constraints for entrepreneurship rates and entrepreneurial returns, in part because of problems identifying finance separately from ability variables, see Holtz-Eakin et al (1994), Hurst and Lusardi (2004), Blanchflower (2009), Buera (2009) and Jensen et al (2014) for contrasting views. However, even if one concludes that financing constraints are not key determinants of entrepreneurship rates or entrepreneurial scale, Bates (1990), Parker and van Praag (2006) and Mondragón-Vélez (2009) and others find that a disproportionate share of entrepreneurs is college-educated, indicating that education could be a key potential determinant of entrepreneurial skill. If agents are barred from attending college by the inability to borrow, then financing constraints may significantly lower the number of entrepreneurs even if *no agents report* being unable to take advantage of an entrepreneurial opportunity because of financing constraints. Similarly, reductions in the profitability of entrepreneurship due to borrowing constraints may disproportionately lower the return to college, so that financing constraints lead some agents to find it optimal not to go to college even when no agent reports that borrowing constraints limit them from going to college. Such interrelations may imply that studies of entrepreneurship that ignore education (and vice versa) fail to identify key channels through which borrowing constraints affect labor market and aggregate outcomes. This also implies that the impact of public financing of college may be difficult to evaluate without considering its impact on entrepreneurial activity. Finally, are the college-educated more likely to become entrepreneurs because they make better entrepreneurs, or because the college educated have higher wealth and are therefore less constrained? This matters for the answers to all the other questions. If college educated entrepreneurs are intrinsically more productive, then subsidizing education would not just increase the stock of human capital but would also raise productivity. Even if not, any benefits from subsidizing education would depend on whether they significantly relax financing constraints on would-be entrepreneurs.

We develop a general equilibrium model to analyze the role of borrowing constraints in agents' human capital investment decisions and occupational choices. Borrowing constraints arise because of a limited enforcement constraint: agents may default on their loans, in which case they are subject to punishment. While no default occurs on the equilibrium path, the extent to which agents can borrow is endogenously limited by the possibility of default.[4] In the model, agents have labor market ability, and also an entrepreneurial ability process, each of which may be affected by education. We then calibrate the model to match data on the wealth distribution, occupational choice and college attendance in the US. The calibration process matches model statistics to those of US data, pinning down the key parameters of the model that govern the returns to different activities and thus the educational and occupational choice decisions. The calibrated model also replicates basic features of the US wealth distribution, as well as the fact that agents with low labor market ability are less likely to go to college.

FIGURE 1 ABOUT HERE

In the calibrated model, we find that college-educated entrepreneurs are as productive as the uneducated. In addition, they are equally likely to have entrepreneurial opportunities. Small changes in the values of the parameters governing entrepreneurial opportunities and

[4] See Quadrini (2000), Cagetti and de Nardi (2006, 2009) and Buera et al (2011) for models with similar constraints.

productivity cause large changes in the matched statistics (such as the relative income and prevalence of enterprises run by people with or without college), indicating that the finding is robust.[5] Thus, both the returns to labor and the returns to potential entrepeneurship encourage investment in education, but the main reason for the latter factor is that education tends to generate more potential wealth for would-be entrepreneurs, and that the wealthy are more likely to become educated. This finding is consistent with Aghion et al (2016) who find that children of wealthy parents are more likely to become educated and to become inventors (defined as people who register a patent), but that this is mainly because of agent type rather than an independent effect of either wealth or education.[6]

This finding has important consequences for our subsequent questions regarding the impact and interrelationships between different types of financing constraint. To answer the questions posed earlier, we find that:

- financing constraints on education have a large impact on the composition of entrepreneurship. Disallowing agents from borrowing for college lowers the share of college educated agents from 29 to 12%, and the share of educated entrepreneurs drops from 41 to 18 percent, although entrepreneurs with college are disproportionately profitable (as college financing constraints make college more of a privilege of the wealthy). It also lowers entrepreneurship rates modestly from 7.5 to 7.20 percent.

- tightening financing constraints on entrepreneurship lowers the number of entrepreneurs from 7.5 to about 4 percent. This lowers the differences in the profitability of entrepreneurship across educational groups, since the relative lack of entrepreneurs implies that the wealth distribution is flatter.

[5] When we matched the model statistics assuming no support for college whatsoever in the benchmark economy, we found the same. On the use of calibration as an econometric tool see Kydland and Prescott (1996) and Cooley (1997) inter alia.

[6] While this relates to inventors rather than entrepreneurs, patenting should be the subset of entrepreneurial activity most likely to display a strong independent relationship with higher education, yet they do not find one.

- both kinds of constraints have significant aggregate impact. For example, disallowing agents from borrowing for *college* lowers GDP by 14 % in the steady state equilibrium. Disallowing agents from borrowing for *entrepreneurship* lowers GDP by 36%.[7]

Our policy experiments indicate other important interactions between credit constraints on education and entrepreneurship. For example, depending on assumptions about the extent to which college subsidies are "passed through" into higher college prices, we find that subsidizing education can increase income and welfare by more than double the impact of removing credit constraints on education. This is because the subsidies allow households not to deplete their wealth on a college education, so young college-educated agents may start their firms earlier or at a larger scale. Above a 70 percent subsidy rate, the policy becomes mainly redistributive (rather than relaxing any financing constraints) and above that rate income and welfare deteriorate. Education grants only for agents who cannot afford college by themselves have a uniformly increasing impact on income and welfare, although they are less powerful than subsidies. Finally, it turns out that in terms of income and welfare, the US college financing scheme is equivalent in terms of GDP and welfare (relative to a world with no support at all) to a pure college subsidy rate of around 30 percent of cost, or a need-based grant rate of about 50 percent. This provides, for the first time we believe, a sense of where the intensity of support for college in the US lies in the spectrum of possibilities.

We underline that the purpose of this paper is to study entrepreneurship in a developed economy context. Specifically, the model is calibrated to match statistics for the United States. A different approach to calibration would be appropriate to a developing country context, where self employment rates are extremely high (Gollin 2002) – specifically, we could introduce more values of entrepreneurial productivity. However that would significantly increase the computational cost in what is already a complex model. See Castro and Ševčik

[7] These may seem like large numbers, but they are generated by matching the wealth distribution of the US, which is fat-tailed in part due to the presence of some highly wealthy entrepreneurs. Notably the model matches this feature of the data even though it is not a calibration target.

(2016) for current work along those lines. Also, as pointed out in Poschke (2013), self employment in those environments is generally different from our notion of entrepreneurship in the sense that many agents are self-employed "out of necessity", especially in developing countries. The notion of entrepreneurship in this paper is that of an agent who has a highly-productive, capital-intensive idea, the implementation of which may be limited by financing constraints.

The paper is organized as follows. Section 2 provides some background to the exercise, motivating the model in Section 3 using a combination of background literature and a recent, large survey of entrepreneurs. Section 4 explains the calibration process and Section 5 reports the results of our quantitative experiments.

2 Motivation

We now provide a brief survey of the related literature that motivates our study. In addition, we provide a snapshot of entrepreneurship based on a large survey of entrepreneurs across Europe, which provides further insight into the impact of financing constraints on entrepreneurship and education.

2.1 Background Literature

The determinants of entrepreneurship have been subject to extensive research. In particular, it is well known that entrepreneurs tend to be wealthy. According to Cagetti and De Nardi (2006), under 8 percent of the workforce is made up of entrepreneurs – defined as business owners who manage their firms[8] – yet 54 percent of the households in the top percentile of

[8] This is our definition too. In our model, it is key that the human capital of the owner be a central determinant of the profits of the firm: thus, for example, someone who manages a business but does not own it, or who owns a business but outsources its management, is not an entrepreneur in terms of our model.

the wealth distribution are entrepreneurs.

An extensive literature finds that entrepreneurs tend to be wealthy, including Evans and Jovanovic (1989), Blanchflower and Oswald (1998), Hurst and Lusardi (2004) and Cagetti and De Nardi (2006, 2009). Independently, the empirical literature regularly finds that *educational* is linked to entrepreneurship – however, this link has received much less attention. Mondragón-Vélez (2009) documents that among entrepreneurs, 41% have college education or higher, while only 29% among the general population have attended college. Bates (1990) finds that the probability of firm survival is higher if the entrepreneur has completed college. Terajima (2006) finds that the *earnings* of college educated entrepreneurs between 1983 and 2001 was 2.3 times higher than the earnings of non-college educated entrepreneurs.

This raises two questions. First, are educated entrepreneurs more successful than the uneducated because education increases their productivity, or simply because they are *more wealthy*? Since the labor market rewards education, educated entrepreneurs might be more successful simply because they accumulate wealth more rapidly, not because they are better entrepreneurs. Notably, Diaz-Jimenez et al (1997) find that the college-educated are 2.6 times as wealthy as the high-school educated.

Second, it is well known that for some the ability to attend college is limited by wealth – see Becker (1975), as well as more recent work such as Lochner and Monge-Naranjo (2011). Human capital acquired through education is inalienable: as a result, default on an educational loan tends to trigger a harsh punishment regime, including temporary exclusion from capital markets and wage garnishment (Ionescu (2009, 2011)), but the human capital itself cannot be retrieved.

If the educated are more likely to be entrepreneurs, but education can be limited by financing constraints, then financing constraints could in fact limit the number of entrepreneurs in the economy *because many agents do not attain the college education that would* *have increased their likelihood of becoming entrepreneurs in the first place.* Conversely, it could be that the college educated are more likely to be entrepreneurs simply because only the wealthy can become college educated in the first place – something which will depend on the extent of government aid to students with financial need. Resolving these questions is important for understanding the incentives to go to college, the determinants of entrepreneurship, and the implications of policy in support of education or entrepreneurship. Related quantitative work such as Cagetti and De Nardi (2006) that studies the role of finance and entrepreneurship in inequality is unable to address these questions, because those models do not include an education decision. Terajima (2006) does include an education decision, but educational choice in his model is not subject to financing constraints.

2.2 A snapshot of entrepreneurship

In addition to the data provided in the literature, we draw upon the 2005 Factors of Business Success survey conducted by the European Commission. Covering about 338,000 entrepreneurs across Europe, this survey provides a unique opportunity to establish certain stylized facts about the link between entrepreneurship, college education and finance. While we use data to calibrate our model from the US, Europe has a broadly similar level of development as the US. Moreover, while countries in Europe are very open to cross-border financial flows, they have very different regimes for financial support for college education, which allows us to further exploit cross-country variation in education finance regimes to learn more about these links. We measure it using the World Bank 1998-2012 share of GDP of government support per student in tertiary education.

1. **Entrepreneurship is a state, not a type.** Across the EU, only about 16% of new entrepreneurs surveyed mentioned managing another enterprise as their previous activity (as opposed to being an employee, student, or unemployed). See Table 1.

This rises to 19% for people with some form of tertiary education – either because entrepreneurial opportunities come along more often, or because they are better able to take advantage of them. See Table 2. On the other hand 81% of entrepreneurs report that their plan for the future is to continue with the enterprise: entrepreneurship is a persistent state. Finally, 73% of respondents report the prospect of a higher income as a primary reason for becoming an entrepreneur: agents pursue entrepreneurship if and when it is profitable.

2. **Entrepreneurship is largely an individual activity**. the vast majority of entrepreneurs (82%) report that they are the sole manager. Thus, the *human capital of the entrepreneur* will be a critical input into the success or failure of the business. Also 68% of respondents report that they have no other current gainful activity: entrepreneurship is a full time job. See Table 1.

3. **Self-finance is critical for entrepreneurs**. Fully 85% of entrepreneurs reported self-financing as a key source of funds for their enterprise – 85% of the uneducated and 88% of the educated. Interestingly, bank loans are less important for more educated entrepreneurs, suggesting that their ability to self-finance is more likely to be sufficient. This is consistent with the educated being wealthier: indeed the difficulty of financing as an obstacle to entrepreneurship is decreasing in education also. See Tables 1 and 2.

4. **Financing constraints are a common problem constraining entrepreneurs.** Many entrepreneurs, at least 41%, report some kind of financing constraint as being a serious impediment to their business activity, and more than half report that the highest priority if profits increase is to invest in the business. In Table 1 only about a quarter indicate that paying off loans is the highest priority (and in Table 2 the college-educated report this less often).

5. **Scale is constrained in terms of capital, not employment.** Only 24% of respondents say that expanding employment is a priority if earnings increase. Also, only

15% report expansion of employment as the "expected development of the business activity."

6. **The educated do not operate projects with larger target size, or are better able to overcome financing constraints, or both**. If the educated were disproportionately productive, we would expect educated entrepreneurs to report either that they are more constrained by their personal wealth or more dependent on external finance due to larger target size – unless they are disproportionately wealthy, which would only matter in an environment where financing constraints are important. The survey data do not have property. The college educated report that paying off loans is a high priority less often than the uneducated, indicating that they are better able to self-finance and/or do not obviously require disproportionate quantities of external funds to realize their projects. Also, the rate at which entrepreneurs report that business expansion is their priority if earnings increase does not vary by education. This is something our calibration will explore later, but the data do not obviously indicate that the educated typically have projects of average larger size. Of course, as mentioned it could be that the college-educated do have larger target sizes, but their wealth is greater so they do not experience any particular difficulty in attaining it. However, then we might expect the college educated to be more likely to report higher income as the motivation behind their pursuit of entrepreneurship: the reverse is true.

7. **Support for college finance is correlated with looser financing constraints on entrepreneurs, and higher profitability.** Table 3 reports that in countries where college is subsidized entrepreneurs report fewer difficulties raising funds from external sources.[9] They also clearly report higher profitability. Interestingly these responses are related to greater access to bank loans by *all* entrepreneurs, not just the educated. This suggests that there is some spillover from subsidized college to all potential entepreneurs

[9] Although we do not have many countries in the survey (14 or 15 depending on the question), we can still extract suggestive evidence from cross-country variation in the survey responses.

Table 1: Selected responses to the 2005 Factors of Business Success survey. Values correspond to the share of respondents who answered "yes".

Survey question	% respondents
Start-up financing - own funds or savings	0.85
Start-up financing - bank loan without collateral	0.07
Start-up financing - bank loan with collateral	0.11
Start-up difficulties - to get financing	0.55
Previous occupation - employee	0.56
Other current gainful activity - no	0.68
Current management - alone	0.82
Impediments to developing the business activity - availability of bank loans	0.41
Impediments to developing the business activity - availability of risk capital	0.31
Impediments to developing the business activity - availability of short term credit	0.36
Highest priority if earnings increase - invest in the activity of the enterprise	0.54
Highest priority if earnings increase - pay off loans or credits	0.26
Highest priority if earnings increase - hire more employees	0.24
Expected development of the business activity - hire more employees	0.15
Start-up motivation - prospect of making more money	0.73
Strategic plans - continuing the enterprise	0.81
Expected development of business activity - increase of number of employees	0.15

in the economy, for example through the creation of a greater pool of wealth from which any entrepreneur might draw. On the other hand, the overall share of GDP spent on education is *not* significantly related to these responses – unlike the extent of support for college. Most interestingly, nor is the market capitalization of domestic firms as a share of GDP, nor the ratio of private credit to GDP, both standard indicators of financial development (see Rajan and Zingales (1998) for example).[10] Thus, support for college is not a proxy for local financial development.

In what follows we develop a model of college and entrepreneurship that captures the features underlined above, and we explore the impact of education policy in the model.

[10] All these country variables are measured using data from the World Bank WDI database.

Table 2: Selected responses to the 2005 Factors of Business Success survey - college vs. non-college respondents. Values correspond to the share of respondents who answered "yes".

Survey question	No college	College
Start-up financing - own funds or savings	0.849	0.877
Start-up financing - bank loan without collateral	0.072	0.053
Start-up financing - bank loan with collateral	0.122	0.081
Start-up difficulties - to get financing	0.576	0.460
Start-up motivation - prospect of making more money	0.738	0.685
Impediments to developing the business activity - availability of bank loans	0.439	0.304
Impediments to developing the business activity - availability of risk capital	0.333	0.240
Impediments to developing the business activity - availability of short term credit	0.377	0.277
Highest priority if earnings increase - invest in the activity of the enterprise	0.537	0.546
Highest priority if earnings increase - pay off loans or credits	0.285	0.180
Start-up motivation - prospect of making more money	0.738	0.685
Strategic plans - continuing the enterprise	0.817	0.805

Table 3: Selected responses to the 2005 Factors of Business Success survey. Values correspond to the cross-country correlation between the share of respondents who answered "yes" and country level measures. Coll. sup. is government support for each college student as a share of GDP. Ed. sup. is the share of GDP devoted to government support for education. CAP is the market capitalization of publicly traded firms as a share of GDP. CRED is private credit as a share of GDP. One and two asterisks represent statistical significance at the five and one percent levels respectively. Source: Eurostat or WDI.

Sample	College sample	Full sample			
Survey question	Coll. sup.	Coll. sup.	Ed. sup.	CAP	CRED
Start-up financing - bank loan without coll.	0.790**	0.809**	0.305	0.168	0.240
Start-up financing - bank loan with coll.	0.560*	0.685*	0.305	0.614*	0.554*
Start-up difficulties - to get financing	-0.766**	-0.766**	-0.462	-0.437	-0.253
Judgement of profitability - very good	0.906**	0.899**	0.287	0.375	0.333
Judgement of profitability - good	0.679*	0.793**	0.208	0.418	0.465
Judgement of profitability - barely suf.	-0.636*	-0.676**	0.135	-0.200	-0.258
Judgement of profitability - poor	-0.578*	-0.692**	-0.493	-0.447	-0.395
Highest priority - invest in the enterprise	-0.452	-0.384	0.433	-0.029	-0.345
Highest priority - pay off loans or credits	0.102	0.255	-0.154	0.377	0.484
Expected development - increase profits	-0.331	-0.233	0.531*	-0.163	-0.448

3 Model Economy

We present a general equilibrium model where households choose whether to work or to become entrepreneurs, based on their expected earnings in either activity. These earnings are a function of idiosyncratic productivity shocks and of their capital (wealth). There is incomplete insurance, in that the only way agents may insure against idiosyncratic shocks is by holding capital, as in Aiyagari (1994). Entrepreneurs may use their capital to produce themselves, rather than renting it to other agents. Entrepreneurs may also produce using borrowed capital: however, the extent to which they are able to borrow capital is limited by an imperfect enforcement problem. If entrepreneurs refuse to repay their loans, then only a fraction f of their profits and remaining capital may be garnished.[11] Thus, in equilibrium agents may only borrow capital up to the point that they are indifferent between repaying and reneging. This inability to obtain the first-best level of capital from external sources is what provides entrepreneurs with an incentive to amass wealth. The model builds on a standard approach to modeling entrepreneurs under financing constraints, extended to allow for college entrepreneurs in a way consistent with the above empirical observations.

When born, agents choose an education level $e \geq 0$, at a cost. Agents may borrow to become educated: however, like entrepreneurs, they may renege on repayment. Human capital is inalienable, so there is no way to reduce the agent's chosen value of e if they default. Instead, they are excluded from credit markets for a period of time, during which a share θ of their wages may be garnished. This follows the treatment of defaulted college loans documented in Ionescu (2008, 2009 and 2011). If for a given value of e the agent cannot afford education on her own but would default if she were to borrow, then that level of e is ruled out of the agent's choice set. As a result, agents have an incentive to accumulate savings so that their offspring may be less limited in their educational choices.

[11] See Quadrini (2000), Cooley et al. (2004), Cagetti and De Nardi (2006, 2009) and Buera et al (2011) for similar constraints.

An important element of the model will be state support of education. This is because we calibrate the economy to data for the United States, where there is extensive state support for college education.

3.1 Technology

There are two sectors in the economy: entrepreneurial and non-entrepreneurial. The non-entrepreneurial sector represents large publicly traded firms.[12] It operates the standard constant-returns technology:

$$Y_t = AK_t^{\alpha} L_t^{1-\alpha} \tag{1}$$

where Y_t is output, K_t is capital, L_t is labor and A is a productivity term.

Entrepreneurial firms are run by a single entrepreneur who operates the technology:

$$Y_t^n = x_t k_t^v,\ 0 < \nu < 1. \tag{2}$$

Here Y_t^n is output and k_t is capital input. The variable x_t is an idiosyncratic productivity term, and it summarizes all economic or psychological factors that might determine the availability or productivity of entrepreneurial opportunities. As discussed later, the choice of k_t may be limited by a borrowing constraint.[13]

[12] See Quadrini (2000) and Cagetti and De Nardi (2006, 2009) for similar models.

[13] We do not allow entrepreneurs to hire workers for several reasons. First, the survey data indicate that expansion of employment is neither a priority nor an expected outcome of the business.the firm is larger for the educated, one would expect them to report expansion of the business as being a priority more often. Second, this maintains the focus of our work on the accumulation of physical/financial capital, which both the literature and the survey data indicate is the main priority of entrepreneurs.

3.2 Households

There is a continuum of agents in discrete time. Each period a mass of agents called "Newborns" enters the model. Newborns start life with a wealth inheritance, choosing their level of education $e \geq 0$. The following period they become "Young." The young face a constant probability of remaining young, π_y, whereas with probability $1 - \pi_y$ they become "Old." in turn, old agents face a probability π_o of remaining old, whereas with probability $1 - \pi_o$ they leave the model. When old agents exit the model, they are each replaced by a newborn, who inherits the old agent's assets. We normalize the population to equal one.

Regardless of age, agents maximize expected discounted utility. Their instantaneous utility function is $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$, $\sigma > 1$, and their discount factor is β. Each period agents are endowed with one unit of labor, which they supply inelastically if they are workers. Agents who choose to be entrepreneurs use up their labor managing the firm.

At each point in time, agents have two state variables, x_t and y_t. The variable x_t is the agent's entrepreneurial ability and y_t is their labor market earnings ability, net of any education premia. These two states follow independent Markov processes: $y_t \tilde{} F^y (y_t|y_{t-1}, e)$ and $x_t \tilde{} F^x (x_t|x_{t-1}, e)$. Notice that the Markov process governing the evolution of x_t may depend on the educational level e. Mondragón-Vélez (2009) report that the college-educated form a disproportionate share of entrepreneurs, and Terajima (2006) reports that college educated entrepreneurs are more profitable. On the other hand, our survey data did not obviously suggest that entrepreneurs are significantly more productive if they also have college. We wish to establish whether this is because the college-educated are more likely to have higher values of x_t, or because the college-educated tend to be wealthier and thus less financially-constrained. In addition, the process for y_t may also depend on education, capturing the well-known finding that more educated agents tend to have higher labor market earnings.[14] If x is too low, the enterprise is closed and the agent returns to the labor market.

There are incomplete markets: agents may self-insure against different forms of idiosyncratic risk via holdings a_t of financial assets, which are claims on physical capital. Capital pays net interest rate r and depreciates at rate δ.

3.2.1 Young agents

Each period, young agents choose whether to be entrepreneurs or workers. Young entrepreneurs use the technology (2) to generate income, using their own capital or borrowing capital from other agents. They also earn income from capital they lend to other agents. With their income they purchase consumption c_t, and assets a_{t+1} for next period.

A young entrepreneur has the value function

$$\begin{aligned} V^n\left(a_t, x_t, y_t, e\right) &= \max_{c_t, a_{t+1}, k_t} \left\{u\left(c_t\right) + \pi_y \beta EV\left(a_{t+1}, x_{t+1}, y_{t+1}, e\right)\right. \\ &\quad \left. + \left(1-\pi_y\right)\beta EW\left(a_{t+1}, x_{t+1}, e\right)\right\} \\ &\quad s.t. \\ c_t + a_{t+1} &\leq x_t k_t^{\nu} + \left(1-\delta\right)k_t - \left(1+r\right)\left(k_t - a_t\right) \\ k_t &\geq 0, a_t \geq 0 \\ &\quad \text{Borrowing constraint } (4)\text{, see below} \end{aligned} \tag{3}$$

where V is the young agent's expected value in the future if they remain young, to be explained below, and W is their expected value in the future if they become old, to be discussed below. The expectation E is taken with respect to x_{t+1} and y_{t+1}, the idiosyncratic

[14] As in Cagetti and De Nardi (2006) we allow the processes for x and y to evolve independently. We show in the Appendix that the key features of the calibration are not sensitive to this assumption.

entrepreneurial and labor market productivity shocks respectively. Note that the distribution of x_{t+1} and y_{t+1} depends on e: for example, the well-known presence of a college wage premium would imply that the distribution for F^x among the more educated first-order stochastically dominates the distribution of F^x among the less-educated. Thus, although we use the notation E to denote expectations for x_{t+1} and y_{t+1} with simple notation, the reader should remember that the expectation is conditional on current values of x_t and y_t as well as e.

Entrepreneurs are also subject to a borrowing constraint. If $k_t - a_t > 0$ then the agent is borrowing and must pay $(1+r)(k_t - a_t)$ to other agents. If the agent refuses to make this repayment, they are punished by the garnishment of a fraction f of their profits and their holdings of undepreciated capital, $f\left[x_t k_t^{\nu} + (1-\delta)k_t\right]$.

Along the equilibrium path agents will not default. However, the fact that they *could* default introduces an incentive compatibility constraint that can limit the extent to which firms can borrow.[15] This constraint compares the value of repaying $V^n(a_t, x_t, y_t, e)$ with the value of default, including the possibility that agents might choose different values of a_{t+1} off the equilibrium path. However, Buera et al (2011) show that the incentive compatibility constraint takes the simple form

$$x_t k_t^{\nu} + (1-\delta)k_t - (1+r)(k_t - a_t) \geq (1-f)\left[x_t k_t^{\nu} + (1-\delta)k_t\right] \tag{4}$$

In other words, what matters is whether or not the profits from default are higher now.[16]

[15] In some models e.g. Evans and Jovanovic (1989), the financing constraint takes the form of a simple factor of wealth. However, Parker and van Praag (2006) find that the extent to which firms are financially constrained appears to depend not just on wealth but also on education, indicating that such a constraint is not appropriate in this context. This suggests a model such as Cagetti and De Nardi (2006, 2009) or Buera et al (2011) where financing constraints are due to a limited enforcement problem, whereby agents may default on their debts. In this case, agents' financing constraints will depend endogenously on their wealth but also on their level of education, since it affects both the profitability of entrepreneurship and the foregone income if they default and are punished. A model like this is also less subject to the Lucas Critique.

[16] The value function $V(\cdot)$ is strictly increasing in a_t, and with higher income agents can attain both higher consumption and higher savings a_{t+1}. Thus, the value of default is higher than that of repayment if and

If the unconstrained optimal capital usage violates this constraint, then the agent will only be able to use the level of capital k_t such that equation (4) holds with equality, or such that $k_t = a_t$, whichever is larger.

If the young agent chooses to be a worker, her value is

$$
\begin{aligned}
V^w\left(a_t, x_t, y_t, e\right) &= \max_{c_t, a_{t+1}} \left\{u\left(c_t\right) + \pi_y \beta E V\left(a_{t+1}, x_{t+1}, y_{t+1}, e\right)\right. \\
&\quad \left. + \left(1-\pi_y\right) \beta E W^r\left(a_{t+1}, x_{t+1}, e\right)\right\} \\
&\quad s.t. \\
a_{t+1} &\leq (1-\tau) w y_t + a_t (1+r) - c_t
\end{aligned} \tag{5}
$$

where w is the wage and y_t is her labor productivity shock and τ is the labor income tax rate,[17] and where the expectation is conditional on x_{t+1}, y_{t+1} and e. If the worker ages she retires, earning value W^r to be described below.

Finally, the agent chooses her occupation optimally. As a result, her value function V is

$$
V\left(a_t, x_t, y_t, e\right) = \max\left\{V^n\left(a_t, x_t, y_t, e\right), V^w\left(a_t, x_t, y_t, e\right)\right\}. \tag{6}
$$

3.2.2 Old agents

Most old agents simply retire. The value for a retiree is W^r, where

only if the current profits from default exceed those from repayment.

[17] As in Cagetti and De Nardi (2006), we do not tax entrepreneurs, consistent with the generally lower capital than labor taxes in the US. See Section 5 for a discussion.

$$
\begin{aligned}
W^{r}\left(a_{t}\right) &= \max_{c_{t},a_{t+1}} \left\{u\left(c_{t}\right)+\pi_{o}\beta W^{r}\left(a_{t+1}\right)+(1-\pi_{o})EV^{new}\left(a_{t+1},x_{t+1},y_{t+1}\right)\right\} \qquad (7)\\
& s.t.\\
a_{t+1} &\leq a_{t}\left(1+r\right)-c_{t}+p
\end{aligned}
$$

Here, p is a social security payment. Recall that with probability π_o the agent exits the model and is replaced by a newborn. The function V^{new} is the value function for the newborn.

Young entrepreneurs who become old may choose to continue running their firms, if they prefer not to retire, capturing the fact that entrepreneurs do sometimes continue operating their firms well into old age. In that case they may become old entrepreneurs, whose value W^e is given by:

$$
\begin{aligned}
W^{e}\left(a_{t},x_{t},e\right) &= \max\left\{u\left(c_{t}\right)+\beta\pi_{o}EW\left(a_{t+1},x_{t+1},e\right)\right. \qquad (8)\\
&\quad \left.+\beta(1-\pi_{o})EV^{new}\left(a_{t+1},x_{t+1},y_{t+1}\right)\right\}\\
&\quad s.t.\\
a_{t+1} &\leq x_{t}k_{t}^{v}+\left(1-\delta\right)k_{t}-\left(1+r\right)\left(k_{t}-a_{t}\right)-c_{t}\\
k_{t} &\geq 0, a_{t}\geq 0\\
&\quad \text{Borrowing constraint } (4)\,.
\end{aligned}
$$

where $\pi_o \in (0,1)$ is the probability of remaining old. As in Cagetti and De Nardi (2006), the expected value of the newborn's value function is taken with respect to the invariant distribution of y_t, and their value of x_t follows the usual Markov process based on the newborn's parent's value of x_{t-1} and e. This allows agents to potentially inherit their parents' firms – a feature we introduce into the model due to the well known tendency of entrepreneurship to run in families, see Blanchflower (2009).

Newborn agents observe their initial values of x_t and y_t, and decide on their educational level. The initial value of y_t is drawn from the ergodic distribution of F^y for the uneducated, so agents do not inherit labor market conditions.

Finally, the old chose whether to retire or (if they have a firm) to continue it:

$$W(a_t, x_t, e) = \max\left\{W^e(a_t, x_t, e), W^r(a_t)\right\}. \tag{9}$$

3.2.3 The Newborn

If newborns choose not to become educated, they are identical to young agents for whom $e = 0$, choosing whether to be workers or entrepreneurs. If they choose $e > 0$, they may work but they may not become entrepreneurs. This is for theoretical reasons[18], but is also not restrictive in that entrepreneurship rates are close to zero for people of college age and a few years beyond, see Stangler and Spulber (2013). In this case, they must also pay an education cost $\kappa(e, \epsilon)$, where $\kappa(0, \cdot) = 0$, $\kappa_e(e, \epsilon) > 0$ and $\kappa_\epsilon(e, \epsilon) > 0$. ϵ is a random variable that affects the cost of education for a given agent, drawn from a distribution F^ϵ. We introduce ϵ because later, in our calibration, we will have few values of e, so allowing for some noise in the cost of education will ensure that educational decisions are not too "lumpy" in our simulations.[19] Our model contains the typical assumption that agents decide on whether or

[18] If we allow the newly-educated to be entrepreneurs then there will be two financing constraints facing certain entrepreneurs, one related to firm size and one related to education, and it would be difficult to specify what occurs if the agent defaults on one type of loan but not the other. Since the very young are unlikely to be entrepreneurs (in the calibrated economy entrepreneurs are under 8 percent of the population and current college students are about 1 percent), we simply assume the newborns may not be entrepreneurs.

[19] For example, if we let $e \in \{0, 1\}$ where $e = 1$ represents going to college, then ϵ can be thought as representing the fact that the college application process is uncertain and that there is variation in the cost across universities (due to different tuition costs, cost of living differences, etc).

not to go to college based on their ability and the relative payoff from doing so, as in for example Jones and Yang (2016). Our model differs from the prior literature on education in that "ability" is 2-dimensional, encompassing the initial values of both x_t and y_t. In addition, we differ from most of the prior literature in allowing education to affect the productivity of work and the productivity of entrepreneurship to different degrees.[20]

To attain level of education e, agents may receive governmental support $s(e, \epsilon, a)$. The function s depends on the level of education e, its cost draw ϵ and the agent's wealth a. Allowing for support $s(\cdot)$ will be important because it affects the education-wealth link.

The value of an uneducated newborn $V^{noneduc}(a_t, x_t, y_t)$ is:

$$\begin{aligned} V^{noneduc}(a_t, x_t, y_t) &= \max\{V^n(a_t, x_t, y_t, 0), V^w(a_t, x_t, y_t, 0)\} \\ &= V(a_t, x_t, y_t, 0) \end{aligned}$$

where $V^n$and V^w are the value functions for entrepreneurs and workers respectively, as defined earlier.

For educated newborn agents, the value $V^{educ}(a_t, x_t, y_t, e, \epsilon)$ is:

$$\begin{aligned} V^{educ}(a_t, x_t, y_t, e, \epsilon) &= \max_{c, a'} \{u(c_t) + E\beta V(a_{t+1}, x_{t+1}, y_{t+1}, e)\} \\ & s.t. \\ a_{t+1} &\leq (1-\tau) w_t y_t + (a_t - \kappa(e, \epsilon) + s(e, \epsilon, a_t))(1+r) - c_t \end{aligned}$$

[20] An exception is the model of Xiang and Yeaple (2016) where there are two types of human capital, as here (analytical and "leadership", the latter being linked to entrepreneurship), each of which may be enhanced by education to a different degree.

Notice that if $\kappa(e,\epsilon) - s(e,\epsilon,a_t) > a_t$ for any given level of e and ϵ then agents must borrow $\kappa(e,\epsilon) - s(e,\epsilon,a_t) - a_t$. In addition, subsidized loans may constitute part of the subsidy scheme s.[21] In order to borrow, agents must satisfy an incentive compatibility constraint, otherwise they would default. If an agent defaults on an education loan then she enters a "punishment regime" where she earns value $D^{educ}(a_t, x_t, y_t, e)$. While being punished the agent is barred from capital markets and from entrepreneurship, and there is a wage garnishment rate $\theta(e)$, as well as a probability $\phi(e)$ that the agent will be forgiven so the punishment regime ends. Thus we have that

$$
\begin{aligned}
D^{educ}(a_t, x_t, y_t, e) &= \max_{c_t, a_{t+1}} \left\{ \begin{array}{l} u(c_t) + \pi_y[(1-\phi(e))\beta E D^{educ}(a_{t+1}, x_{t+1}, y_{t+1}, e) + \\ \beta\phi(e)\, EV(a_{t+1}, x_{t+1}, y_{t+1}, e)] + (1-\pi_y)\beta W^r(a_{t+1}) \end{array} \right\} \\
& \quad s.t. \\
a_{t+1} &\leq (1+r)\, a_t + (1-\theta(e))(1-\tau)\, w_t y_t - c_t
\end{aligned}
$$

If the agent is forgiven, from then on she can choose occupations and borrow as a normal young agent. If the agent is still unforgiven when she becomes old, she retires.

Since at the moment of default the agent would have no assets (having spent them on education), the incentive compatibility constraint is

$$V^{educ}(a_t, x_t, y_t, e, \epsilon) \geq D^{educ}(0, x_t, y_t, e).$$

If for given values of e and ϵ this constraint is not satisfied, then the agent cannot attain level of education e. Agents choose optimally their education e among the feasible set that

[21] For example, suppose that s_1 is a system of grants and subsidies, whereas s_2 is a rate of loan subsidization up to a threshold L (like subsidized Stafford loans in the US). Then, $s(e,\epsilon,a_t) = s_1(e,\epsilon,a_t) + \min(L, \max\{0, \kappa(e,\epsilon) - s_1(e,\epsilon,a_t) - a_t\})$
$\times s_2(e,\epsilon,a_t)\, r$. If the interest rate is lowered by a proportion ς, then we have that $s_2(e,\epsilon,a_t) = \varsigma$.

is not ruled out by credit constraints, conditional on x and y. In the calibrated economy we will find that y and e are positively related, consistent with the finding that agents with higher earnings potential (e.g. IQ) are more likely to be educated, as found by Lochner and Monge-Naranjo (2011) among others.

Finally, define $V^{educ}(a_t, x_t, y_t, 0, \epsilon) \equiv V^{noneduc}(a_t, x_t, y_t)$. The value of a newborn is then:[22]

$$
\begin{aligned}
V^{new}(a_t, x_t, y_t) &= \int \max_{e \in \Xi} V^{educ}(a_t, x_t, y_t, e, \epsilon)\} dF^{\epsilon}(\epsilon) \\
\Xi &= \left\{ e : V^{educ}(a_t, x_t, y_t, e, \epsilon) \geq D^{educ}(0, x_t, y_t, e) \right\}
\end{aligned}
$$

where Ξ is the set of educational levels that is not ruled out by the incentive compatibility constraint.

There is no childhood in the model: as in the related literature, we focus on the part of the lifecycle during which agents are economically active. We also collapse college into one period. Having 4 periods would allow students to drop out of college before completion: however, this is not central to our topic of interest as the entrepreneurial returns to college jump up for agents who *completed* college, see Mondragón-Vélez (2009).

3.3 Equilibrium

Let ω_t be the aggregate state variable, the measure over different types of agents. The measure ω_t is defined over the quintuple (a, x, y, e, g): the agent's asset holdings, a, entrepreneurial productivity x, labor market productivity y, education level e, and a variable

[22] Notice that since $\kappa(0, \epsilon) = 0$, $\Xi \neq \varnothing$, so as long as there are finite values of e or the choice of e is compact the problem of educational choice will have a solution.

$g \in \{1, 2, 3, 4\}$ which indicates the agent's life cycle stage: agents are classified as newborn, young, old entrepreneurs or retirees. The measure $\omega_t \in X$ is an element of the set X, where $X = \mathbb{R}_+^4 \times \{1, 2, 3, 4\}$. There is a transition mapping $\Gamma : X \to X$, so that $\omega_{t+1} = \Gamma(\omega_t)$. The mapping Γ is a function of agent's optimal decision rules regarding savings, education and occupational choice, as well as the stochastic processes for x, y, ϵ and ageing.

Definition 1 *A stationary equilibrium is a wage w, an interest rate r, a tax rate τ and a measure ω such that:*

- *Young agent's consumption, investment, capital use and occupational choices are optimal, solving problems* (3), (5) *and* (6), *subject to the incentive compatibility constraint on entrepreneurs.*
- *Old agent's consumption, investment, capital use and occupational choices are optimal, solving problems* (7) *and* (8), *subject to the incentive compatibility constraint on entrepreneurs.*
- *Labor markets clear: total labor supply from workers equals the labor demand from the nonentrepreneurial sector.*
- *Capital markets clear: total capital supply from all agent's savings equals capital demand from both entrepreneurial and nonentrepreneurial sectors.*
- *The government budget is in balance: total tax receipts equal total social security transfers to retirees as well as total education support to newborns.*
- *The distribution of agents is invariant: $\omega = \Gamma(\omega)$.*

4 Calibration

We need to calibrate the parameters α, ϕ, σ, δ, π_y, π_o, β, p, v, f, θ, τ as well as the functions s, κ, F^y and F^x. We choose one year as our period length.

We try to fix as many parameters as possible and calibrate the remaining parameters to match various statistics regarding education, entrepreneurship and inequality in the US. The depreciation rate of capital δ is 6% as in Stokey and Rebelo (1995). The coefficient of relative risk aversion σ is 1.5, from Attanasio et al. (1999). Productivity in the non-entrepreneurial sector is normalized to 1. The share of capital in the aggregate production function α is 0.33, as in Gollin (2002). The probabilities of being young and old are chosen to yield an average working life of 45 years and an average retirement period of 11 years. The discount factor β is calibrated to match capital to output ratio of 3.3 as in Cooley and Prescott (1995). See Tables 4 and 5.

We use a parsimonious specification for entrepreneurship, setting x to equal either zero or a positive value that depends on the level of education: $x \in \{0, \zeta(e) \times x_{high}\}$, $x_{high} > 0$. Parameter x_{high} is the productivity of an uneducated entrepreneur, and $\zeta(e)$ is a premium that an educated entrepreneur might have over that. Thus $\zeta(0) = 1$. $\zeta(e) > 1$ means that a potential entrepreneur with education level e has more productive ideas than an uneducated agent. $\zeta(e) < 1$ means that the opposite is the case.

This way, as in much of the related literature, agents either do or do not have an entrepreneurial opportunity.[23] Note, however, that it is not necessarily the case that all entrepreneurs

[23] Poschke (2013) observes that about 12 percent of the self-employed in the US do so "out of necessity." We could introduce such agents into our model by having more values of $x < x_{high}$. However this would significantly increase the computational cost. In addition, those agents would have small scale and any financing constraints on their operations would be of little consequence for aggregate savings behavior. Thus we follow the approach of Cagetti and De Nardi (2006) and focus on the high-ability entrepreneurs who do not start enterprises "out of necessity." The Poschke (2013) definition of an entrepreneur is broader and the number is larger do we do not view an adjustment to the Cagetti an De Nardi(2006) targets as being necessary.

have the same target level of capital in equilibrium, since entrepreneurial productivity may depend on education e. The calibration process will establish the empirically reasonable values of the entrepreneurial education premium $\zeta(\cdot)$.

We set the set of education values $e \in \{0, 1\}$, interpreting $e = 1$ as a college education. We do this because Mondragón-Vélez (2009) finds that the probability of being an entrepreneur rises significantly with college attendance, whereas Bates (1990) finds that the probability of firm exit drops significantly if the entrepreneur has a college degree. Thus it does not seem useful to allow e to be defined more finely, while this would significantly increase the computational cost.

To select x_{high}, we must establish the empirical counterpart of our notion of an entrepreneur. In our model, the entrepreneur owns and manages her own business, such that her human capital – in the form of her entrepreneurial productivity x and her education e – is key to the profitability of the enterprise. As a result, we consider an entrepreneur to be someone who is both self employed and actively involved in the running of the enterprise. The Survey of Consumer Finance contains an employee category of "self employed" and also "business owner with an active management role." As in Cagetti and De Nardi (2006), we consider people who satisfy both criteria to constitute the empirical counterpart of an entrepreneur in our model. We calibrate x_{high} to match a share of entrepreneurs of 0.0755, as in Cagetti and De Nardi (2006). The college premium for entrepreneurs $\zeta(1)$ is calibrated to target average earnings of college educated entrepreneurs over the non-college educated, as reported in Terajima (2006), which is 2.3. We use Terajima (2006) as it is the only source, to our knowledge, which reports this and related statistics about college-educated entrepreneurs over a prolonged time frame (1983-2001).

The transition matrix F^x is a $2 \times 2 \times 2$ tensor, since we allow the Markov process governing the evolution of x_t to depend on e. This requires in principle four parameters:

one each for the probability into and out of entrepreneurship for each level of e.[24] Thus, $\begin{bmatrix} 1-\eta_{in} & \eta_{out} \\ \eta_{in} & 1-\eta_{out} \end{bmatrix} \otimes [1,0]$ for non-college educated, and $\begin{bmatrix} 1-\eta_{in}\chi_{in} & \eta_{out}\chi_{out} \\ \eta_{in}\chi_{in} & 1-\eta_{out}\chi_{out} \end{bmatrix} \otimes$ $[0,1]$ for college educated.

We proceed as follows. First, Cagetti and De Nardi (2006) find an exit rate among entrepreneurs of 0.206 in PSID. Bates (1990) reports a logit regression that indicates how the probability of survival varies when an agent earns a college degree. We choose the probabilities of firm survival to match the mean from Cagetti and De Nardi (2006) and the differences from Bates (1990) (see Appendix for details). This pins down values for η_{out} and χ_{out}, leaving us to calibrate η_{in} and χ_{in}.

The parameter η_{in} is the probability that an uneducated worker with $x = 0$ has an entrepreneurial draw of $x = x_{high}$ and the parameter χ_{in} is the extent to which the educated are more likely to have a draw of $x = x_{high}$. $\chi_{in} = 1$ implies that the probability of a draw of $x = x_{high}$ is equal for workers regardless of education. To match hazard rates into entrepreneurship for college and non-college groups we match two statistics. One is the flow rate of workers into entrepreneurship, which Cagetti and De Nardi (2006) report to be 2.3 percent. The other is the share of entrepreneurs with a college education, which is 41 percent in Mondragón-Vélez (2009).

We define $F^y(y'|y,0) \equiv F^y(y'|y)$ as the baseline distribution of shocks to labor income. Then we set $F^y(\xi \times y'|y,1) = F^y(y'|y)$, $\xi \geq 1$. In words, there exists a college wage premium ξ such that the distribution of labor income shocks for the college-educated first-order stochastically dominates that for the uneducated. This specification is useful because the function $\xi(\cdot)$ can be calibrated to match the well-known college earnings premium. At the same time, there will be significant variation in labor market outcomes across agents with

[24] The probability of remaining an entrepreneur for each education group is one minus the probability of going out of entrepreneurship, and the probability of remaining a worker is one minus the probability of going into entrepreneurship. Thus, with these 4 parameters, the entire tensor is determined.

Table 4: Parameters of The Model

A. Fixed Parameters	
Parameter	Value
σ	1.5 Attanasio et al. (1999)
δ	6% Stokey and Rebelo (1995)
α	0.33 Gollin (2002)
A	1 Normalization
π_y	0.978 see text
π_o	0.911 see text
ϕ	1/7
$\theta(1)$	0.15
ξ	1.4 Fang (2006)

B. Calibrated Parameters	
Parameter	Calibrated value
p	40% of GDP Kotlikoff, et al (1999)
v	0.926
x	$[0 \quad 0.448]$
F^x	see text
β	0.8706
F^y	see text
f	0.4083
$\kappa(1,\cdot)$	[3.29 3.47 3.65 3.84 4.02]
$\zeta(e)$	$[1 \quad 1]$
y	[0.29 0.48 0.79 1.30 2.14]
$s(\cdot)$	see text

Table 5: Parameters of The Model

Parameter	Matched moments
p	Transfer size as share of GDP
v	Gini coefficient of wealth
x	% of entrepreneurs in the whole work force
F^x	flow of workers into entrepreneurship (%), share of college educated entrepreneurs
β	capital to GDP ratio
F^y	Gini coefficient of earnings
f	median net worth of entrepreneurs vs whole population
$\kappa(1,\cdot)$	percentage of college educated population
$\zeta(e)$	average earnings of college vs. non-college educated entreps
$s(\cdot)$	share of agents in state college (see text)

the same value of e, due to the realizations of y. We set the college premium for workers ξ to equal the estimate of 1.4 in Fang (2006). Fang (2006) considers that the observed college premium combines the fact that worker productivity may rise as a result of earning a college education, but that it could also be that college simply provides a signal to employers about worker ability, or that higher ability agents are more likely to attend college. The estimate of 1.4 refers to the productivity increase from going to college, net of any signalling and selection effects, which is exactly our parameter ξ. In our context, this corresponds to the idea that newborns choose whether or not to go to college based on their values of x and y, so the unconditional average college premium in the model may also not accurately reflect the productivity increase that comes from going to college. Because of these selection effects, assuming that $\xi = 1.4$, we find that the average wage of a college graduate in our model is 1.9 times higher than that of the average worker without college, underlining the importance of the endogeneity of the college attendance decision. Indeed, over 1983-2001, Terajima (2006) reports that in the Survey of Consumer Finances (SCF) the ratio of average earnings of college educated vs. non-college educated workers is precisely 1.9. Thus our model is able to account for the observed unconditional educational premium based on self-selection amd credit constraints.

To match the earnings process $F^y(y'|y)$, we set $\log y_t = \log y_{t-1} + \varepsilon_t$ where the error is normally distributed, and set the variance of ε_t to match the Gini of earnings to be 0.4 as in the PSID data.[25] We approximate it over a grid of five values of y, so that $\log y = [-1, -0.5, 0, 0.5, 1]$.

[25] We write the process F^y as a random walk – as opposed to a mean-reverting process – for several reasons. First, the persistence of the income process is known to be very high. Second, in practice, since labor productivity y_t is drawn from a finite number of values, the actual calibrated process will be mean-reverting. Adding a persistence parameter is not going to change the F^y matrix much and the fact that the matrix is bounded means it already satisfies that feature: the fact of having a finite number of values of y itself introduces some persistence. In fact, if we generate a long series of values for y and estimate an AR1 process for y the persistence value that emerges is 86 percent. The literature differs on the value of this parameter but a typical range of estimates is between 0.82 (Guvenenen 2009) and 0.95 (Storesletten, Telmer and Yaron 2004) depending on the details of the specification so we fall well in that range in practice.

We set the social security transfer p to match a ratio of social security transfers to GDP of 40%, as in Kotlikoff et al (1999). The degree of decreasing returns to scale in the entrepreneurial production v is set to match a Gini coefficient of wealth[26] of 0.8. The entrepreneurial punishment parameter f is calibrated to match the ratio of the median net worth of entrepreneurs compared to the whole population, which Cagetti and De Nardi (2006) report to equal 0.3.

Finally we discuss the structure of the education costs $\kappa(\cdot)$, the education financing scheme $s(\cdot)$, and the punishment strategy for default on educational loans.

The education cost $\kappa(e, \epsilon)$ is uniformly distributed over five values. We set the mean cost to match the share of educated agents in the population. This is 0.29 in the PSID according to Mondragón-Vélez (2009). The other values are set to cover uniformly the range plus or minus 10% of the mean value. This provides some smoothing of the decision rules regarding education.

The education financing scheme $s(e, \epsilon, a_t)$ is set to reproduce basic features of the United States education financing system. This is built on the following pillars:

1. The existence of state colleges, which are subsidized relative to private colleges
2. grants, such as Pell grants, up to a certain limit and contingent on household assets.
3. subsidized loans, also up to a certain limit and contingent on household assets.

First we capture the existence of state colleges by assuming that some agents receive a subsidy that covers a certain proportion of the education cost $\kappa(1, \epsilon)$. This proportion is set equal to 0.57. We arrive at this value by noting that the US Department of Education "Fast

[26] We find a value of $v = 0.926$. This implies that in the calibrated economy 3.9 percent of income accrues to entrepreneurs. Atkeson and Kehoe (2005) find that the corresponding value in US data is 3.3 percent, very close.

Facts 2013" reports that the ratio of the cost of public vs private college is 0.43. We assume furthermore that the purpose of state support $s(\cdot)$ is to reduce the link between wealth and the ability to go to college. As such, we assume that only agents below a certain wealth threshold are allowed to go to state colleges. We choose this threshold to match the share of agents who go to state college and pay state tuition, which is 0.5.[27] This threshold turns out to be about five times GDP per capita. This is a reasonable value. Consider that in the United States the mean age of first birth for a woman is in the mid 20s, and for men is slightly higher. This means that households who are sending their children to college tend to be in their mid-40s at the earliest. The Census Bureau[28] reports that in 2007 the median wealth of households with a head of household in the age range 45-54 in this group was 3.5 times GDP, and the mean wealth was 12 times GDP.

Next, we calibrate grants. First, the need-based grant system in the United States implies an expected contribution of at least 20% of assets each year.[29]. Over 4 years that accumulates to 0.59 times the agent's assets. There is also an upper bound on grants of $\$5,645$, which turns out to be 17% of the cost of attending a private college in 2013 (US Department of Education "Fast Facts 2013"). Thus, all agents (regardless of whether or not they attend a public institution) are allowed a grant of up to the smallest of 17 percent of the mean value of the college cost $\kappa(1,\cdot)$ or $1-0.59$ of their assets.

Last, we calibrate subsidized loans by assuming that interest on loans is subsidized so that the interest rate is half the market rate. This is based on the treatment of subsidized vs. unsubsidized Stafford loans.[30] This is up to a limit of about $\$5,000$ for 2013, which is about 15% of the annual private college cost. Similarly, in the model we assume that agents may

[27] The Department of Education reports that 59 percent of college students attended public institutions, whereas according to Wintergreen Orchard House (an educational database compiler) the median share of out of state students at public universities is 14 percent, see http://www.collegexpress.com/lists/list/percentage-of-out-of-state-students-at-public-universities/360/, last checked 8/28/14.

[28] See http://www.census.gov/compendia/statab/2011/tables/11s0720.xls, last checked 8/28/14.

[29] See the detailed formula for computing the Expected Family Contribution at http://ifap.ed.gov/efcformulaguide/attachments/091913EFCFormulaGuide1415.pdf, last checked 8/28/14.

[30] See https://studentaid.ed.gov. Last checked 09/04/14.

Table 6: Calibration Statistics

	Target	Baseline Model
Transfer size as share of GDP	0.4	0.4
capital to GDP ratio	3.3	3.3
Gini coefficient of wealth	0.80	0.82
% of entrepreneurs in the whole work force	7.6	7.5
median net worth of entrepreneurs vs whole population	0.3	0.3
percentage of college educated population	0.29	0.29
share of college educated entrepreneurs	0.41	0.41
flow of workers into entrepreneurship (%)	2.3	2.3
Gini coefficient of earnings	0.38	0.34
average earnings of college vs. non-college educated entreps	2.3	2.3
share of agents in state college	0.5	0.5

borrow up to 15% of the college cost, assuming this does not exceed their funding through subsidies and/or grants. Thus, in all three forms, government support for education depends on the cost of college and on the agent's wealth.

We calibrate the punishment parameters for defaulting on educational loans as follows. The probability of being forgiven in the education loan market $\phi = 1/7$ so that defaulters are forgiven after 7 years of punishment on average. This is the period of time for which a default notice remains on the credit report of someone who defaults on a student loan. The wage garnishment rate for education loan defaulters, $\theta = 0.15$, which is the limit in the US for default on a subsidized loan. We do not distinguish in the benchmark economy between subsidized loans and unsubsidized loans as far as the garnishment rate is concerned.

Finally, a comment on our definition of GDP in the model. We do not consider spending on college as a component of GDP. The reason for this is that it is small (only 1 percent of agents are newborn college attendees in any period), and because we do not want the impact of policy on GDP to be simply due to the fact that spending on college is itself counted as part of GDP.

We match the parameters to the desired target statistics by minimizing a loss function (sum of squared differences) using a simulated annealing algorithm – see Bertsimas and

Tsitsiklis (1993).

5 Results

The calibration procedure matches broad statistics such as the Gini coefficient of the wealth distribution. However, the model also matches reasonably well other features of the wealth distribution. For example, in the model, the wealthiest 20% of the population holds 83.6% of the wealth. In the US data, according to Chang and Kim (2006), this statistic is about 80% in the SCF. Furthermore, in the model the wealthiest 1% of the population holds 40% of the wealth. According to Wolff (2010), this figure has varied between 34% and 39% for overall wealth between 1983 and 2007, and between 42% and 47% for non-home wealth. At the other end of the wealth distribution, 10 percent of the agents in our model have zero wealth: this is the range of $7-13\%$ found in the SCF by Cagetti and de Nardi (2009). Thus, our model does a good job replicating the shape of the wealth distribution, even though the calibration process did not attempt to match anything but the Gini coefficient.

There are certain other results from the calibration that are worthy of mention. In particular, we find that college educated entrepreneurs are *no more likely* than the non-college educated to earn an entrepreneurial opportunity: $\chi_{in} = 1$. Nor are college educated entrepreneurs more productive: $\zeta(0) = \zeta(1) = 1$. This is consistent with the "snapshot of entrepreneurship" in Section 2. This is an important finding because it implies that, while the educated are more likely to be entrepreneurs, and even though they tend to be more successful, this is not because entrepreneurial opportunities or productivity are different for them – except for the hazard rate out of entrepreneurship, which is about 0.22 for agents without college and 0.19 for the college educated (quite close). Entrepreneurship is more profitable for the educated primarily because the educated are also wealthier.

Why might this be? Lazear (2005) finds that entrepreneurs tend to be generalists, who have knowledge about many different aspects of management, rather than specialists. It could be that higher education is more likely to create specialists, who may have brilliant ideas but who may not necessarily have developed the ancillary skills to make it happen. For example, Kuhn and Weinberger (2005) find that leadership skills, something that could be important for entrepreneurs, are developed in high school rather than in college, indicating that the process that creates entrepreneurial skills and opportunities is likely independent from whether or not agents have gone to college.

Given the importance of this finding, its robustness is important. In a calibration exercise of this kind it is generally difficult to perform statistical inference (e.g. formulating confidence intervals), since we are directly comparing the steady state of the model to moments from the data. However, we checked for robustness in the following ways. First, we started off our calibration with several different initial conditions: it eventually always converged to these values. Second, we varied each of these parameters, individually, by ± 10 percent. The parameters we varied were $\zeta(1)$ (the productivity of educated entrepreneurs relative to uneducated entrepreneurs and χ_{in} (the extent to which a worker is more likely to have an entrepreneurial opportunity if she is educated). We then examined whether this significantly changed the match between model-generated statistics and the data.

For example, varying the productivity of educated entrepreneurs relative to the uneducated $\zeta(1)$ by ± 10 percent changes the income of the educated entrepreneurs relative to the uneducated over a range of 1.1 to 4.9, compared to the calibrated value of 2.3. These are substantial changes in the statistic most directly affected by this parameter.[31] In addition, other statistics change significantly. The share of college educated agents in the economy varies from 0.23 to 0.41 (compared to a calibrated value of 0.29), and the share of educated

[31] This is because our calibrated value of v is high, around 0.9, so small differences in k can lead to large discrepancies in returns for groups with different access to capital. If we interpret $1-v$ as returns to entrepreneurship and management, Atkeson and Kehoe (2005) argue that $1-v \in [0.2, 0.1]$. If we interpret $1-v$ to equal the returns purely to entrepreneurial activity then $1-v \in [0.04, 0.02]$.

entrepreneurs varies from 0.29 to 0.60 (compared to a calibrated value of 0.41). Thus, we view the result that $\zeta(1) \approx 1$ as being robust. This result also shows the sensitivity of educational decisions to entrepreneurial returns.

Varying the probability of an entrepreneurial opportunity for the educated worker relatively to the uneducated χ_{in} by ± 10 percent changes the share of educated entrepreneurs from 0.34 to 0.45 (compared to a calibrated value of 0.41). The overall share of college educated agents in the economy varies from 0.26 to 0.30 (compared to a calibrated value of 0.29), and the earnings of educated entrepreneurs relative to the uneducated vary from 2.0 to 2.7. Thus, we view the result that $\chi_{in} \approx 1$ as being robust too.[32] This result also shows the sensitivity of educational choice to entrepreneurial opportunity.

Finally, based on the related literature, in our calibration the probability of survival of an entrepreneurial opportunity is set to be higher for an educated entrepreneur – i.e. $\chi_{out} \neq 1$. It is worth asking whether this result is robust too: in other words, if we impose that $\chi_{out} = 1$, so that the entrepreneurial opportunity process is identical for all agents regardless of education, does anything change? It turns out that, if we set $\chi_{out} = 1$ and preserve the average exit rate among entrepreneurs, the statistics matched change negligibly. We conclude that assuming $\chi_{out} \neq 1$, as indicated by the related empirical literature, is not critical for the calibration. In other words, F^x is *not* significantly different for different levels of education in terms of the outcomes it generates for the statistics we used to calibrate the model economy. Nonetheless we maintain the assumption that $\chi_{out} \neq 1$ in what follows, as this is what the empirical literature indicates.

Now we compare the wealth of agents with different occupations and education levels, see Figure 2. In the upper-left panel, entrepreneurs are in generally wealthier than workers. The upper-right graph shows the wealth distribution of college and non-college educated

[32] In an earlier draft we calibrated the model to match all the relevant statistics assuming that there was no support for education, also finding that neither the production function for entrepreneurs nor the probability of becoming an entrepreneur were significantly different for agents with or without college education.

agents. College educated agents are wealthier as found by Mondragón-Vélez (2009), while the population with zero assets are mainly the non-college educated. When comparing the wealth levels between college educated entrepreneurs and workers (the lower-left graph in Figure 2), entrepreneurs are disproportionately wealthy. All these findings are consistent with the data. We further compare the wealth of college educated and non-college educated entrepreneurs (the lower-right graph in Figure 2). College educated entrepreneurs are wealthier, because of their higher labor productivity and also because creditors require a higher wealth threshold to lend to college educated entrepreneurs, since the value of working (related to the earnings from default) is higher for them.[33] The ratio of wealth among those with and without college is 3.9 in the model, and 3.5 in the data of Diaz-Jimenez et al (1997).[34]

FIGURE 2 ABOUT HERE

5.1 Comparing constraints

In the model, college attendance is limited by a credit constraint, and also affected by the productivity terms x and y. What is the impact of this constraint on equilibrium behavior? It turns out that if the newborn has no entrepreneurial opportunity ($x = 0$) then agents only go to college if they have wealth above a certain level – see Figure 3. This level is decreasing in y and increasing in the cost of college. Thus, the model accounts for the finding in Lochner and Monge-Naranjo (2011) and others that high-ability workers are more likely to have gone to college, as well as agents with higher initial wealth.

[33] In a model of this kind, the probability of entrepreneurship is increasing in wealth. Empirically, Hurst and Lusardi (2004) find that the probability of entrepreneurship is fairly flat over much of the wealth distribution. As in Cagetti and de Nardi (2006), we find that repeating the Hurst and Lusardi (2004) estimation using samples of agents drawn from the model yields confidence intervals that cover their estimated wealth-entrepreneurship profile. Results are available upon request.

[34] Diaz-Jimenez et al (1997) report income for agents with and without high school: we weight them using the shares in Mondragón-Vélez (2009).

FIGURE 3 ABOUT HERE

If the newborn *does* have an entrepreneurial opportunity ($x > 0$), the decision rule has a different structure which underlines the interaction between education, entrepreneurship and credit constraints. For low values of y, no agent goes to college: college is unaffordable for low-wealth agents, and entrepreneurship preferable for high-wealth agents. For high values of y, things are more complicated. Again, if agents have low wealth they do not go to college as they cannot afford it – nor do they become entrepreneurs, see Figures 3 and 4. Above a certain level of wealth agents can afford college and they do attend, and this is preferable to entrepreneurship because of their low wealth, which would lead their firms to be unprofitably small. Finally there is another higher wealth threshold above which again agents to do not go to college. In this case their wealth is sufficient for the returns from entrepreneurship to outweigh the higher wages from going to college. Thus, even though the specification of education and entrepreneurship in the model economy is very parsimonious, there will be a few young high-ability agents who become entrepreneurs instead of completing college, some "Bill Gates." As before, high-y agents are more likely than low-y agents to go to college even when $x = x^{high}$.

FIGURE 4 ABOUT HERE

What is the macroeconomic impact of constraints on education? We compared the behavior of the benchmark economy with 2 other economies. In one, there is no punishment for borrowing, so borrowers default for sure. Thus, credit constraints are at their tightest: no borrowing will occur for college. In the other economy, the punishment for default is infinity, so any agent may borrow for college if the benefits of college exceed those from not becoming educated for their type. In both experiments the education support function s is held constant.

We find that, relative to the benchmark economy, when borrowing for college is not allowed then GDP drops to 86% of the benchmark value. Thus, the ability to borrow for college has a significant aggregate impact – even though there is significant public aid to college students. The share of educated agents is 12%, down from 29%. The share of entrepreneurs with college drops from 41% to 18%. Nonetheless, college educated entrepreneurs are now 2.9 times more profitable than their uneducated counterparts. This is because college-goers are now only those that can attend without borrowing, so any college educated entrepreneurs will be disproportionately wealthy.

We find that, when credit constraints on education are removed altogether (i.e. there is infinite punishment for reneging on college loans), the aggregate impact is also significant. GDP rises by 12%. The number of college educated agents rises to 44% and the share of entrepreneurs with college rises to 58%. Thus the model suggests that tightening punishment on college default also has significant aggregate impact.

Interestingly, varying between no constraints on education borrowing and full constraints on education borrowing, entrepreneurship rates vary from 7.20 percent to 7.64 percent, with the benchmark value in between at 7.50 percent. Thus, education borrowing constraints do affect entrepreneurship rates, but the effect is small. Their aggregate impact is through the stock of human capital and the greater physical capital accumulated by more educated agents, which can then be used by entrepreneurs to expand. Interest rates change negligibly (by 0.5 percent across scenarios) so the key channel here is self-financing.

In the introduction we asked whether constraints on the financing of education could be important for causing the "fat tail": in the US wealth distribution. In the calibrated model, the wealthiest 20% of the population holds 84% of the wealth. Furthermore, the wealthiest 1% of the population holds 40% of the wealth. 10 percent of the agents in our model have zero wealth. When there is no borrowing for education (i.e. punishment for default is zero), the wealthiest 20% of the population holds 82% of the wealth. The wealthiest 1% of the population holds 40% of the wealth as before. 10 percent of the agents in our model have zero wealth. On the other hand, when there are no constraints on borrowing for education (i.e. punishment for default is infinite), the wealthiest 20 percent of the population holds 83% of the wealth. The wealthiest 1% of the population holds 40% of the wealth as before. 0% of the agents in our model have zero wealth. Thus, constraints on the financing of education are not in fact the principal cause of the fat tail in the income distribution, but being able to borrow for education without constraints turns out to make a big difference to the *poorest* agents – i.e., the *left* tail.

We also find that the aggregate impact of constraints on entrepreneurs is even larger than the impact of education constraints. For example, recall that when we vary the punishment for reneging on an education loan between zero and infinity, GDP ranges from 86% to 112% of the benchmark value. This range of GDP values relative to the benchmark is obtained by varying the value of the entrepreneurial punishment parameter f from 0.37 to 0.43 (recall that the benchmark value is $f = 0.4083$). We find that, relative to the benchmark economy, when borrowing for entrepreneurship is not allowed at all ($f = 0$, no punishment) then GDP drops to 64% of the benchmark value. This is a large value, and it is due to the fact that the ability to borrow in the calibrated economy is critical for entrepreneurs with relatively low wealth to be able to achieve a reasonable scale of operation. The number of entrepreneurs drops to 4.5% of the workforce. The share of educated agents is 26%, down from 29%. The share of entrepreneurs with college rises from 41% to 42%. Interestingly college educated entrepreneurs are now only 1.9 times more profitable than their uneducated counterparts. This is because the wealth distribution is flatter, the Gini coefficient of wealth drops to 0.71. The capital-output ratio drops to 2.9. Since capital is hard to borrow it becomes expensive (the interest rate rises by 1.7 percentage points), limiting the returns to entrepreneurship – and hence also to college, relative to the calibrated economy. Thus, credit constraints on entrepreneurs have a substantial impact on the incentive to go to college.

5.2 Policy Experiments

We now conduct some policy experiments to evaluate the impact of the financing of education on the aggregate economy. We perform several experiments, mainly by changing the support function $s(\cdot)$. First, we examine environments in which the cost of college is subsidized. This allows us to assess the extent to which support for college education in general affects aggregate outcomes. Second, we examine environments in which the cost of college is subsidized only for agents who cannot afford it – i.e. there are educational grants. This allows us to assess the extent to which support for college education *taking account of wealth* affects aggregate outcomes. Finally, we compare educational subsidies to other policy measures in our economic environment.

5.3 Welfare

An important part of our analysis will be the impact of policy on welfare. In a representative agent context, welfare is commonly measured using the per-period increase in consumption in the steady state equilibrium that would make the agent indifferent between the environments with and without policy – the compensating variation. We require a welfare criterion that is applicable to a *heterogeneous* agent environment. A type-by-type comparison of agent welfare is not appropriate since the number of agents of each type is endogenous and since agent identities are unrelated to their types. Thus we propose the following welfare criterion. Define environment O to be the steady state equilibrium of the benchmark economy, and let environment P be the equilibrium of an economy with some policy. Now consider an agent who is not in the model, but has preferences the same as the agents in the model. This agent will be randomly dropped into environment O. The agent does not, however, know what type (a, x, y, e, g) she will be. The probability that the agent has a given type is determined by the equilibrium measure of agent types ω. The welfare criterion is the percentage of consumption that should be added to each agent in environment O such that the agent would be indifferent between being dropped into environment O or environment P. This criterion is based on the "original position" concept in Rawls (1971), but assumes that agents maximize expected utility as argued in Harsanyi (1975), since all agents have the same utility function in our environment. We name this an OP compensating variation.

Of course there are changes in the economic environment that benefit many agents, and other changes that benefit few agents. A change that benefits all agents by a certain amount, and a different change that benefits a few agents by a huge amount, may have a similar OP compensating variation. As a result, from a welfare perspective, we are interested in distinguishing between these two scenarios, since they have very different *distributional* implications. In one case agents are generally better off, whereas in another they are better off on average because some of them have a small shot at a very high payoff. We identify these two scenarios by seeing whether a particular change in the environment generates changes in both GDP and in welfare that are of the same order of magnitude. If they are, we call it an "equitable" change. If they are not, we call it an "inequitable" change.

5.4 The impact of US college finance

First, to evaluate the impact of the current US financing scheme as calibrated, we remove all support by setting $s(e, \epsilon, a) = 0$. We find that welfare and output decrease significantly once educational subsidies are removed. Welfare by the OP criterion drops by 9 percent, and GDP drops by 12 percent. The number of agents who attend college decreases sharply from 29 to 15 percent. Interestingly the number of entrepreneurs changes only from 7.5 percent to 7.2 percent, suggesting that the current level of education support in the US is not enough to significantly change the wealth of young would-be entrepreneurs who graduate from college. This indicates that the current scheme providing financial support for education is effective at resolving to some extent the limited enforcement problems in the market for education. The ratio of the earnings of college educated to those of non-college educated entrepreneurs rises from 2.3 to 2.7, yet the share of entrepreneurs with college drops from 0.41 to 0.22. Thus, fewer agents can afford college, and those that can are wealthy, so that when they become entrepreneurs they are disproportionately able to generate income.

5.4.1 Subsidized education

A broad way to get a sense of how important government support for education can be is to consider a simple subsidy towards the costs of college. This is useful because it tells us how general support for the education sector matters for aggregate outcomes, and also because comparing subsidy outcomes to the US regime gives us a sense of the equivalent subsidy scheme, a sense of the intensity of actual support for the education sector.

The government finances the education cost for newborn agents at rate $\varsigma \in [0,1]$. Agents face an education cost of $\kappa(1,\epsilon) \times (1-\varsigma)$, and for each college student the government provides a subsidy of $\kappa(1,\epsilon) \times \varsigma$, if the agent chooses to attend college given this financing arrangement. The subsidy is financed from taxation in the same way as pension payments, and the budget constraint must hold with equality each period.[35]

FIGURE 5 ABOUT HERE

Figure 5 shows that GDP, the Gini coefficient of wealth, the college share of population and the share of entrepreneurs generally rise with the subsidy rate ς. The subsidies increase

[35] Tax rates in our policy experiments vary little, ranging between 21 and 23 percent.

output because increased college attendance raises worker productivity and also increases the number of entrepreneurs, who are also less credit constrained. On the other hand the subsidies also lead to greater wealth inequality because wealth is more concentrated among the educated entrepreneurs. A 100% subsidy to education ($\varsigma = 1$) leads to a rise in welfare of 38.3 percent – a significant amount. The Gini coefficient of wealth increases indicating that there is increasing inequality, because more college educated agents means more entrepreneurs. Notably, however, a 100% subsidy is not the most efficient level in terms of GDP or welfare, because past a certain point taxation becomes burdensome. Above about 70% ($\varsigma = 0.7$) the policy does little to encourage college attendance and entrepreneurship, so the policy becomes mainly redistributive. Above this rpoint, GDP is flat and welfare actually decreases as the subsidy rate rises.

It is notable that the wage hardly changes: even when $\varsigma = 1$ the efficiency wage w is only 2 percent higher than when $\varsigma = 0$. Similarly, the interest rate only varies from 9.55 percent when there are no subsidies to 9.32 percent when college is fully subsidized. The large impact on income and welfare is due to the much larger stock of human capital encouraged by the subsidies, in the form of college-educated agents, rather than general equilibrium effects related to prices. With more college educated agents, there are also more entrepreneurs, because agents are wealthier and thus less likely to be constrained in their scale of operation.

FIGURE 6 ABOUT HERE

The level of entrepreneurship varies between 0.073 and 0.082 depending on the subsidy rate, a fairly small change. The reason it is small is because the probability of getting an entrepreneurial opportunity is the same for all agents, regardless of education (note that this is a result from the calibration process, not a modeling assumption). This means that the number of educated people has no impact on the number of agents who have an entrepreneurial opportunity at a given point in time. Instead, the number of entrepreneurs will only change to the extent that people who previously had an entrepreneurial opportunity but turned it down due to insufficient wealth, now have enough wealth for it to be worth pursuing the opportunity. This is the "marginal potential entrepreneur": a person who has an entrepreneurial opportunity and has just enough wealth to make them indifferent between pursuing it and not pursing it. Since the wealth distribution is very spread out, a change in this wealth threshold affects only a small share of the population.

FIGURE 7 ABOUT HERE

Since this represents only a small reduction in the number of agents working, it is not enough to significantly change the wage rate – see Figure 6. Similarly, the interest rate varies between these two scenarios only by about 4 percent of its benchmark value. The increase in capital generated by having more educated agents is offset by the increase in the scale of entrepreneurial operations and thus the demand for capital.

Notice that the increase in welfare from subsidies can be larger than the increase in welfare from eliminating credit constraints on education finance. The reason is that educational financing constraints are not the only market failures in this economy: constraints on entrepreneurs exist also. Subsidies imply that students who go to college will have more wealth when they graduate, leading them to be able to finance any entrepreneurial opportunities that might come along at a more efficient level – as well as having more wealth they could lend to *other* agents who might have entrepreneurial opportunities. This policy not only relaxes the college credit constraint but also the entrepreneurial credit constraint. This is consistent with our survey results, where countries with greater support for college education tend to have more profitable entrepreneurs who are less likely to report financing constraints as a limitation.

Figure 6 displays some additional statistics regarding the impact of subsidies on the model economy. Notice that tax rates, and transfers as a share of GDP, do not rise monotonically with increased subsidization of education. This is because support for education is a small share of GDP, and because increased income from having a more productive workforce implies that the government's funding committments can be met without necessarily raising taxes.

FIGURE 8 ABOUT HERE

Figure 7 displays the wealth distribution by occupation and education groups. It is interesting that, aside from uneducated entrepreneurs, no group displays a significant increase in wealth as subsidies increase. In part, this is because the composition of these groups by (x, y) type is different: as more agents become educated, agents with lower y are more likely to be educated, so that the wealth of the educated workers tends to decline with sunsidies. Rather, it is changes in the educational composition of the economy (i.e. changes in the number of agents represented in each panel in Figure 7) rather than changes in the wealth and earnings of agents in each panel that causes the overall wealth of the economy to increase.

FIGURE 9 ABOUT HERE

Finally, Figure 8 displays welfare by occupation and education. Again, it is difficult to interpret each panel because, aside from income determinants such as the interest rate and wage rate changing over time, the composition of each group varies with the subsidy rate, both in terms of wealth a and in terms of agent types (x, y). However, it is notable that the overall impact on welfare as subsidies rise in Figure 5 is much larger than what we see for particular groups in any of these panels. In other words, once again, it is the shift in agents between educational and wealth types that accounts for the welfare results in Figure

5, rather than what happens to any particular education-occupation combination.

Finally it is useful to know what intensity of subsidies is equivalent to the US financing scheme. A subsidy of 27% generates the same [36]level of GDP as the US scheme in the calibrated economy. A 28% subsidy generates the same level of welfare as the US scheme. Thus, the US scheme lies about a third of the way in terms of the broad spectrum of possible financial support of college education.

So far we have assumed that the cost of college is not sensitive to changes in the college financing regime. What if the increased availability of college support leads the cost of college to rise? To do this, suppose that the cost of college is a function of the subsidy rate, so $\kappa(1,\epsilon) = \bar{\kappa}(1,\epsilon) \div (1 - \varphi\varsigma)$. Here φ is the pass-through rate: $\varphi = 0$ means the cost of college is unaffected by support, whereas $\varphi = 1$ implies that a subsidy increases the cost of college proportionately. We then set $\bar{\kappa}$ so that, in the case where $\varsigma = 0.27$, the cost of college is the same as in the benchmark economy – recall that, in terms of the impact of welfare and on GDP, the US financing scheme is similar to a subsidy of 27 percent.[37] Thus, if we assume a pass-through rate of about 50 percent, as found in Lucca, Nadauld and Shen (2015) we find that the range of outcomes achievable through subsidies is not noticeably affected. See Figure 9. Thus, our findings are in fact robust to a significant amount of pass-through from the financing scheme to the cost of college.

[36] This is not to say that general equilibrium effects are not important at all. We repeated our subsidy experiments while forcing the occupational decision rules to be the same as in the benchmark economy and found that subsidies tended to have slightly stronger impact on aggregates. Since wages rise with subsidies in equilibrium, this increases the opportunity cost of entrepreneurship and makes a given type of agent less likely to pursue entrepreneurship. The impact of educational subsidies on wealth swamps the impact of prices on decision rules.

[37] It also turns out that, in the benchmark economy, a total of 30.3 percent of all college costs are covered by grants subsidies or other state support.

5.4.2 Grants

Now we examine education cost grants for those agents who need to borrow to attend college. Thus if an agent has assets a where $a < \kappa(1, \epsilon)$, then the government subsidizes the cost of college above their assets at rate $\varsigma \in [0, 1]$, providing $\varsigma \times (\kappa(1, \epsilon) - a)$, if the agent is willing and able to attend college. Again, these subsidies are financed out of general taxation and the government budget constraint must be satisfied each period. We assume there is no pass-through in this experiment.

In Figure 10, wealth inequality and the college educated population rise with the grant rate. A 100% grant for students who cannot afford college raises welfare by about as much as a similar subsidy. Again, the policy generally raises wealth inequality because it enables more entrepreneurship, up to a point beyond which it becomes a pure transfer that does not create any benefits (e.g., as with subsidies, the college share flattens out).

FIGURE 10 ABOUT HERE

Again, it is useful to know what intensity of subsidies is equivalent to the US financing scheme. A grant rate of 50% generates the same level of GDP as the US scheme in the calibrated economy. A 52% grant rate generates the same level of welfare as the US scheme. Thus, in the model economy, need–based grants can have a large impact on welfare and on income, although not as large as subsidies. The US scheme is about half way in terms of the possible scope of need–based support for education.

Figure 11 shows that, as with subsidies, tax rates are not monotonic in the extent of subsidization. Since educational grants boost GDP, they do not necessarily require an increase in tax rates. Figure 12 displays the wealth distribution by occupation and education groups and shows results that mirror those of educational subsidies: aside from uneducated entrepreneurs, no group displays a significant increase in wealth as subsidies increase. It is changes in the educational composition of the economy (i.e. changes in the number of agents represented in each panel in Figure 7) rather than changes in the wealth and earnings of agents in each panel that causes the overall wealth of the economy to increase. Finally, Figure 13 show that the subsidies do not necessarily have a positive effect on agents of any particular educational level or occupation. Rather, it is the large shifts in people among groups that lead to the large welfare and GDP increases seen in Figure 11.

FIGURES 11, 12 AND 13 ABOUT HERE

With grants, as with subsidies, the wealth of any particular type of worker does not necessarily rise with support – see Figure 12, which is similar to Figure 7. Instead, it is changes in the educational composition of the economy that causes the overall wealth of the economy to increase, rather than what happens within any particular category. The same applies to welfare in Figure 13.

5.5 Discussion

The impact of educational finance policy on aggregates in the model is found to be potentially substantial. These results should be taken as benchmarks, but they are likely to be robust to changing key assumptions of the model assumptions of the model, as we now discuss.

Different ways of modeling the labor market could affect the quantitative conclusions For example, in general an increase in the supply of an input (e.g. college-educated labor) might be expected to lower its relative price. However, Acemoglu (2002) shows that an increase in skilled labor may under certain conditions lead to an *increase* in its relative price in an environment with induced technical change. Thus it is not a priori clear how a change in the supply of college-educated agents will affect the college wage premium. This is the sense in which our policy results are a benchmark: they are agnostic as to the manner in which the supply of college labor might affect the skill premium. At the same time, the *qualitative* features of the policy analysis should be robust, as should the orders of magnitude. For example, if some variable X changes a lot in response to policy, very strong offsetting effects would be required to overturn this result in an alternative environment. A related caveat is that this exercise assumes that the price of college itself is not affected by changes in the college financing regime. There is some work that suggests that (at least in the short run) such pass-through from college support to college prices may exist – see for example Lucca, Nadauld and Shen (2015). We showed that our results are not significantly affected by the possibility of pass-through in Section 5.4.1 above.

An assumption of our model is that college increases worker remuneration because it increases its productivity. An alternative approach would be for college-educated workers and others to be imperfect substitutes in the production function. Following Acemoglu (2002), suppose that the aggregate production function were of the form:

$$Y = AK^{\alpha}\left[(\xi_L N_L)^{\frac{\varepsilon-1}{\varepsilon}} + (\xi_H N_H)^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}(1-\alpha)}$$

where ξ_i is the productivity of labor of type i, N_i is the quantity of labor of type i and $i \in \{L, H\}$ indicating low skill or high skill. Suppose that $\xi_L = 1$ without loss of generality, and set $\xi_H = 1.4$ as in the text. The production function in the model is equivalent to this as $\varepsilon \to \infty$. One might ask: how might the results change if ε were finite?

We suspect that with finite ε the impact of educational support on aggregates and welfare will share the same pattern as in the basline model – increasing up to a certain point, and decreasing once the college-educated share of the workforce is large. To see why, consider the following back-of-the-envelope exercise. First, note that the share of the workforce that is college-educated is about 0.33 when there are no subsidies at all. With 100 percent subsidies this increases to about 0.95 in the model. The observed increase in GDP between the two extremes is a factor of 1.477. On the other hand, consider how output might increase as N_H increases from zero to one, and $N_L = 1 - N_H$ in the aggregate production function (i.e. ignoring the small share of workers who are entrepreneurs, since it changes little). As $\varepsilon \to \infty$, output will increase by a factor of 1.1535 if we vary N_H between 0.33 and 0.95 and hold K constant. In other words, the remaining two thirds of the impact of subsidies on GDP acts through increases in the capital stock and improvements in the allocation of capital, not through the direct impact of expanding the skilled labor force. The peak is around 80% subsidies.

If we have a finite elasticity (estimates in the literature are positive, tending to range between 2 and 4 – see the findings and surveys in Blankenau and Cassou (2011) and Mollick (2011) inter alia) it might be that GDP does not increase monotonically with the share of college-educated agents as before, but that the turning point is at a lower subsidy rate. If we repeat the above experiment with $\varepsilon = 2$ and holding the capital stock constant, the maximum GDP is obtained when $N_H = 0.55$. When $\varepsilon = 3$, the maximum GDP is obtained when $N_H = 0.63$. When $\varepsilon = 4$, the maximum GDP is obtained when $N_H = 0.70$. The maximum impact of subsidies would then be somewhere around these numbers depending on what the relevant elasticity of substitution is thought to be. On the other hand, it is important to remember that educated labor is generally viewed as being complementary to capital – see for example Krusell et al (2000). This means that, as more people become educated, capital accumulates, which further raises the return to capital. Since there are contradictory effects, this would require a separate study to compare against our benchmark framework the importance of these elasticities.

Another assumption of our model is that the total labor supply is exogenous, aside from the occupational choice decision. One might wonder whether allowing labor supply to be endogenous would shrink overall labor supply with the tax increase, possibly affecting the welfare computations. This is unlikely to happen for several reasons. First, given that most agents' earnings are substantially higher after the policy, if labor supply were endogenous it would likely *increase*, rather than decreasing. Second, even if it were decreasing, in any reasonable calibration the labor supply elasticity should be such that its equilibrium value does not vary much, certainly not beyond the range of values observed for developing countries. Rogerson (2001) finds that this range is small, an order of magnitude less than the impact on GDP. Third, across the subsidy experiments the tax rates only vary from 20.6 to 23.5 percent, too small to make much difference in any reasonably calibrated model with endogenous labor supply.

We assumed that entrepreneurs are not taxed in the model: all taxes come out of wage income. We make this assumption because in practice entrepreneurs pay lower taxes than laborers – see Cullen and Gordon (2002). First, entrepreneurs have incentives to under-report their income to avoid taxes, and this is easier for business-owners than for wage earners. Second, the existence of carryforwards and carrybacks allows entrepreneurs to avoid taxes by using losses in any particular year to offset taxable income in other years. Third, it is easy to incorporate, where the effective tax rate is 15 percent or lower – substantially lower than for wage earners. If we were to tax entrepreneurs our results would not change much, however, because when we increase support for education the tax rates in the economy rise by very little. Taxing entrepreneurs makes work relatively more attractive and thus increases the incentives to defaut, tightening credit constraints and increasing the impact of any policy that might loosen them. Indeed for robustness we conducted experiments with educational subsidies allowing entrepreneurial earnings to be taxed at half the rate of workers, and the impact of subsidies on aggregates was a little stronger in that framework, but the overall picture is similar.

Our model of entrepreneurship is fairly simple: there are no entry costs and there are only two values of entrepreneurial productivity x_t. We do this for several reasons. As mentioned earlier, this is a complex model with many dimensions and the run-time of a model with more values of x_t (particularly the run-time of the calibration process) would be prohibitive. In addition, we are building on the model of Cagetti and De Nardi (2006), which also has only two values of x_t yet is able to match the wealth distribution (ignoring education) very well. Maintaining this assumption ensures that our findings – particularly at the calibration stage – can easily be compared and contrasted with theirs. It would be interesting in future work to see how the model behavior might be sensitive to having more values of x_t – not just in our context, but for this class of model in general. This would likely make agents' decision problems and occupational choices smoother so that the impact of policy changes on aggregates would be smoother accordingly.

In our model, the only risk faced by entrepreneurs is that the business opportunity disappears – which happens with probability η_{out} or $\eta_{out}\chi_{out}$ depending on the level of education. If there were a new kind of shock that materializes before he/she has paid the loan back that means that they cannot do so, then we speculate that there could be a risk premium in the model depending on the likelihood of this risk. That would likely make credit constraints on borrowers even tighter, increasing the impact of educational subsidies. Allowing for this kind of default risk would be interesting to introduce in future work as it might be useful for understanding changes over time in the rates of college loan default.

One might also wonder what could happen if there were an entry cost. We did not consider that because the formal cost of starting a firm in the US is very small – see Djankov et al (2002). In contrast, startup costs would have to be very large compared to the potential earnings of the entrepreneurs to make any difference to the results. As an empirical matter, Hurst and Lusardi (2004) find that higher initial capital requirements do not appear to be an important determinant of entrepreneurs' ability to borrow. In any case introducing startup costs would just raise the amount of capital needed to start a firm, exacerbating financing constraints and amplifying the effects in the paper.

We allow agents to work while in college. We make this assumption because typically students in college do work.[38] Most of them do not work full time, of course. Still, recall that the model compresses college into one period. This means that students only earn one year's wages against the cost of 4 years of college, equivalent to having them work only part time (as most do). We could allow college in the model to take 4 periods, of course, which would be an interesting extension which, given uncertainty about x_t and y_t, would allow us to study student drop-out rates (and perform counterfactual experiments to study the determinants of those rates). That would be a very interesting extension of our framework. In that case we would calibrate the model so that college students may only work part time.

6 Conclusion

We study the interaction of credit constraints on education and on entrepreneurship. Entrepreneurs are disproportionately college-educated, and college-educated entrepreneurs are more profitable. We find in our model that, even though education and entrepreneurship rates are highly sensitive to the differential returns to entrepreneurship across educational groups, these findings are because the college educated are wealthier, not because they are intrinsically better entrepreneurs, consistent with the European survey data. Thus, education benefits entrepreneurship indirectly, by raising the earnings and wealth available for would-be entrepreneurs. This is an important finding that is worthy of corroboration using disaggregated data in the future.

Interestingly, the aggregate impact of education policy that subsidizes education through redistribution is larger than the impact of removing the financing constraints on education.

[38] Recently up to 70 percent of college students worked, with about 25 percent working full time. See https://www.cnbc.com/2015/10/29/more-college-students-are-working-while-studying.html, last checked 3/11/2018.

The reason is that, by generating more high-earning college graduates, education policy has a powerful effect on physical capital accumulation in the economy, making capital cheaper and more available and loosening the credit constraints experienced by entrepreneurs, as well as ensuring this capital is accumulated by a large number of agents. This is consistent with our survey results, where in European countries with more support for tertiary education entrepreneurs report lighter credit constraints and higher profitability. Thus, taking the constraints on entrepreneurs as given, subsidizing education turns out to be a way to substantially raise welfare and GDP in the long-run. It would be interesting to see whether these conclusions are robust to different approaches to modeling education and self employment, but this paper sets a benchmark in the context of a modeling framework that is known to deliver a strong match to the wealth distribution.

In what is already a complicated economic environment, we abstract from some important factors that might affect both entrepreneurship and education, such as learning. In some models of entrepreneurship, entrepreneurs learn about their types. Such an environment would require new dimensions of heterogeneity but would allow for richer and more complex dynamics, and could endogenize exit. Similarly, it may be that agents do not know their suitability for college, differing in some sort of ability distinct from labor productivity y, and they learn this in college. Finally a model in which agents overlap with their parents so that there is inter-vivo giving would be interesting too. Such a model would likely require both parents and children to care about each other, again significantly raising the level of complexity in the model. We also abstract from the field of study of the educated: while our presentations of this work suggested that there is a common belief that entrepreneurship is more common in certain fields or professions, Lazear (2005) finds that entrepreneurs tend to be generalists, suggesting that a student's college major may not be a first order determinant of their future entrepreneurial decisions. This remains an open question.

Also our model of college is simple. There exists a technology whereby agents may increase their human capital at a cost. An extension that includes a more detailed model of the market for college would be interesting to the extent that the cost of college might in turn respond to the policy considerations raised in this paper. Such a model would be suitable for studying the causes of the recent rise in the cost of college in the US, and is left for future work.

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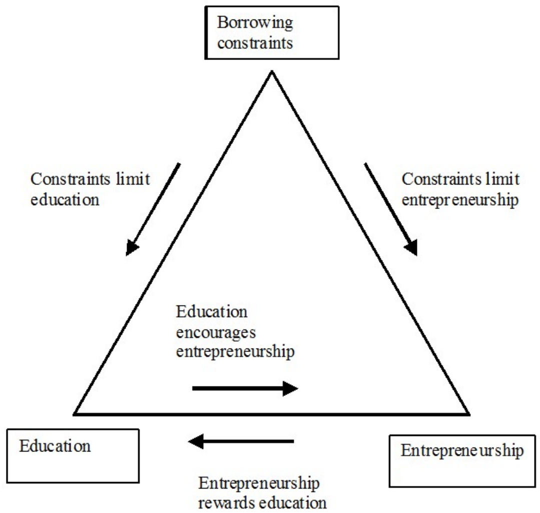

Figure 1 – The Golden Triangle: interrelations between credit constraints on education and on entrepreneurship.

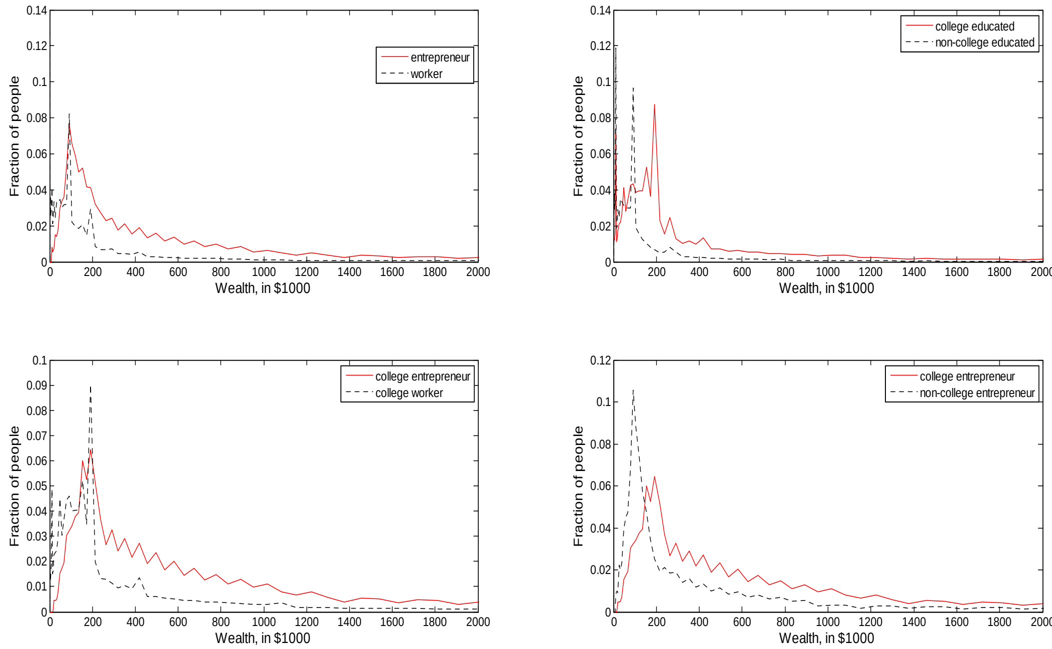

Figure 2 – Wealth distribution by occupation and education.

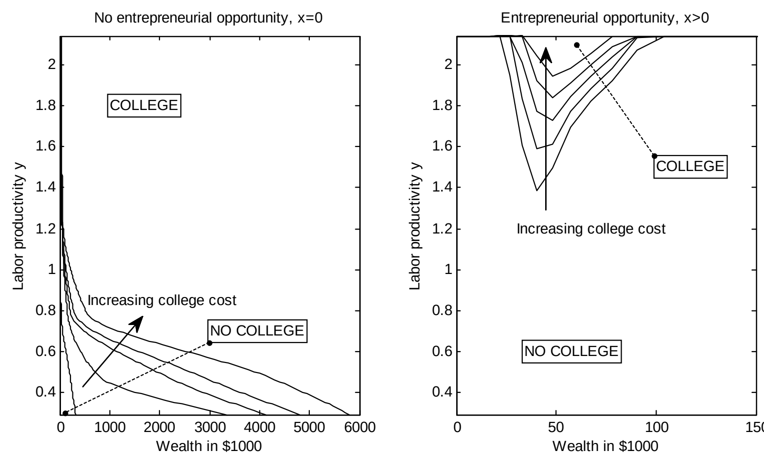

Figure 3 – Decision rule for going to college. Each line corresponds to the income threshold y above which agents attend college in equilibrium, for a given college cost $\kappa(1, \epsilon)$. Conditional on wealth, higher labor productivity is associated with a greater likelihood of college attendance among workers.

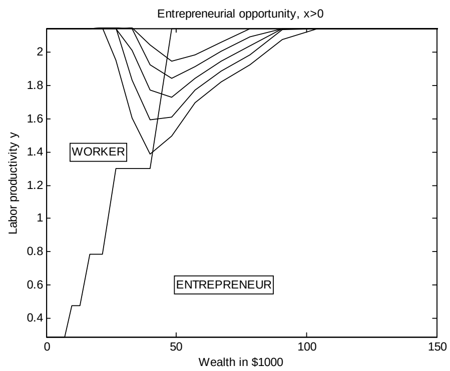

Figure 4 – Decision rules for becoming an entrepreneur for agents with $x > 0$. The increasing step function is the boundary between (a, y) combinations that lead to different optimal occupational choices. The contours represent the educational decision from the previous graph. Above a given contour line, agents optimally go to college. Higher contour lines represent higher college costs $\kappa(1, \epsilon)$.

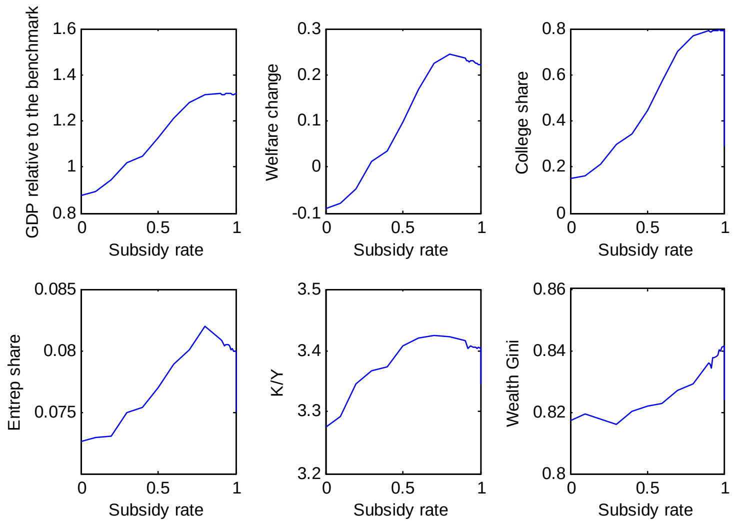

Figure 5 – Subsidies to college and macroeconomic aggregates. Each panel plots the extent to which the cost of college is subsidized against a statistic drawn from the model economy.

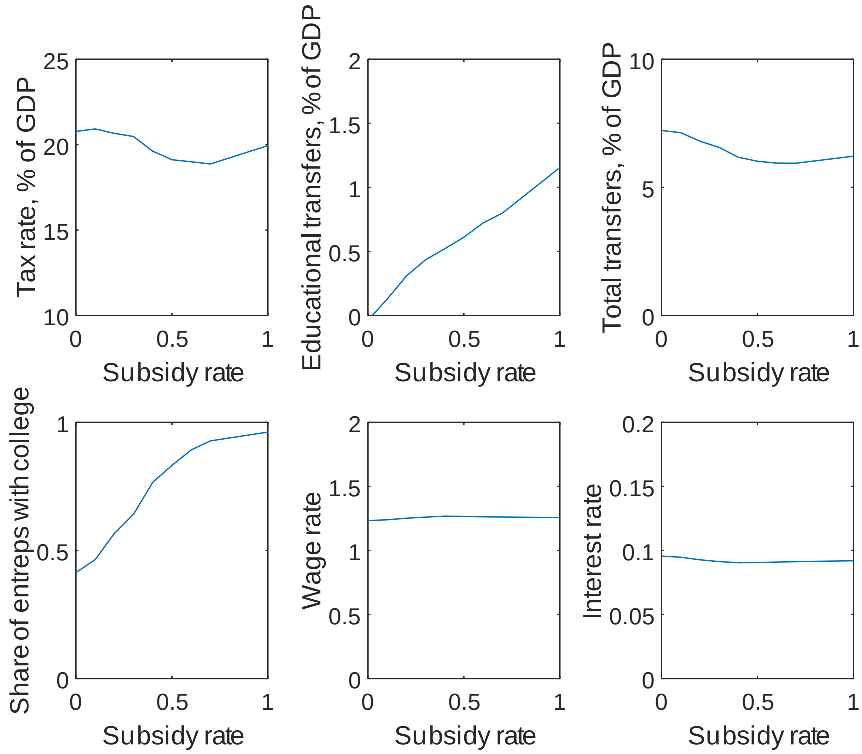

Figure 6 – Subsidies to college and additional macroeconomic variables.

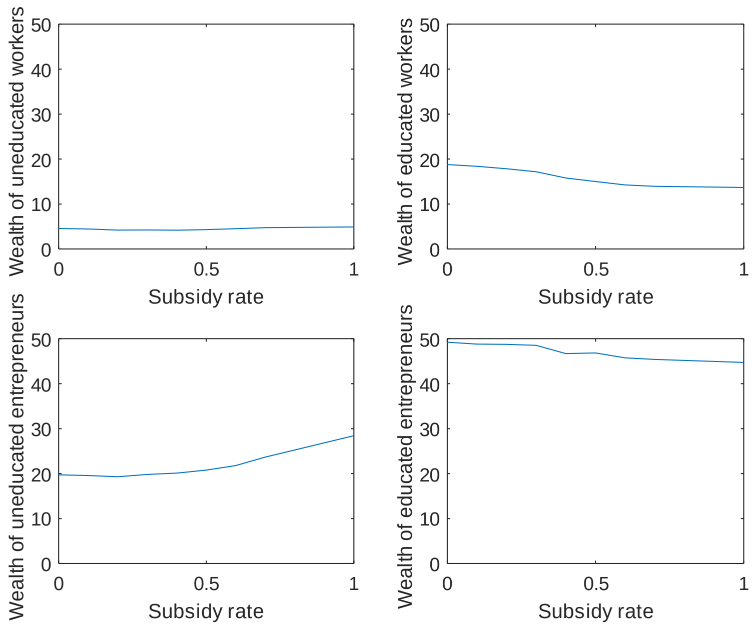

Figure 7 – Wealth by group and educational subsidies.

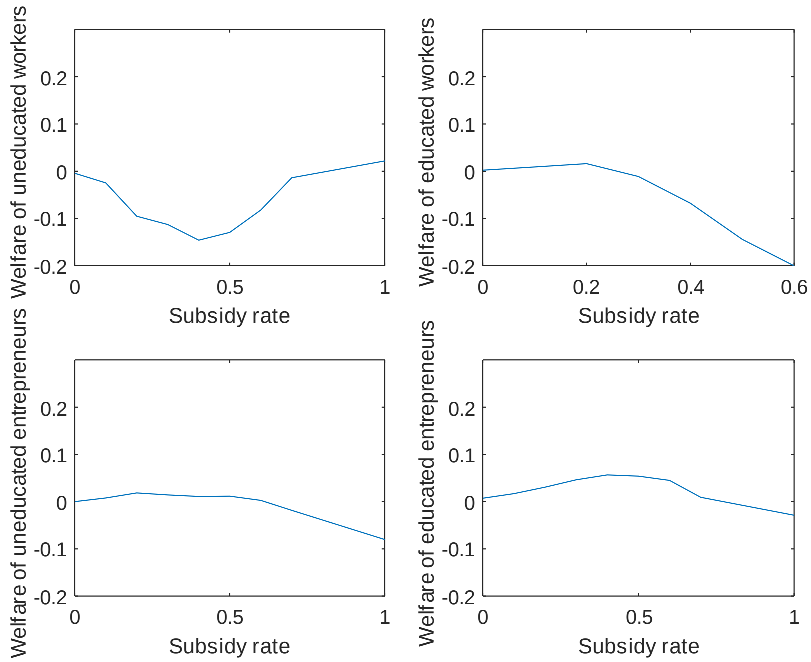

Figure 8 – Welfare by group and educational subsidies. The welfare is the proportional compensating variation relative to the benchmark economy.

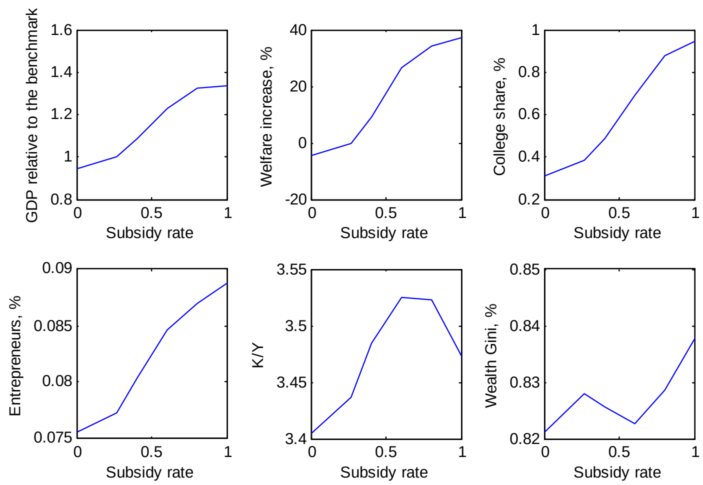

Figure 9 – Subsidies to college and macroeconomic aggregates. Each panel plots the extent to which the cost of college is subsidized against a statistic drawn from the model economy. Assumes 50 percent pass-through from subsidies to the cost of college.

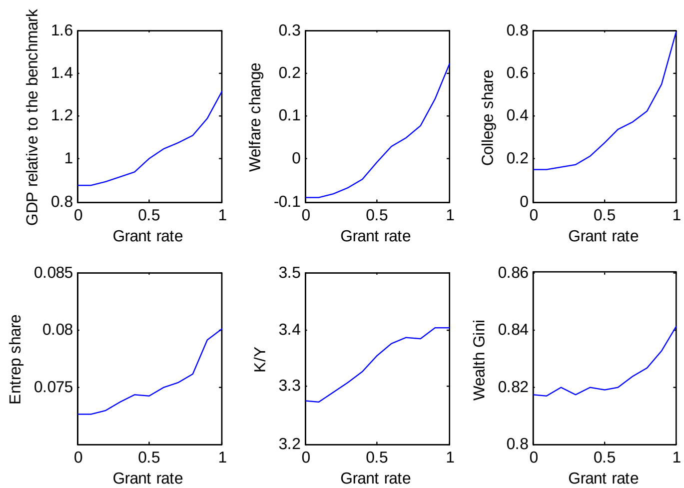

Figure 10 – Education grants for college and macroeconomic aggregates. Each panel plots the extent to which the cost of college above the agent's wealth is subsidized against a statistic drawn from the model economy.

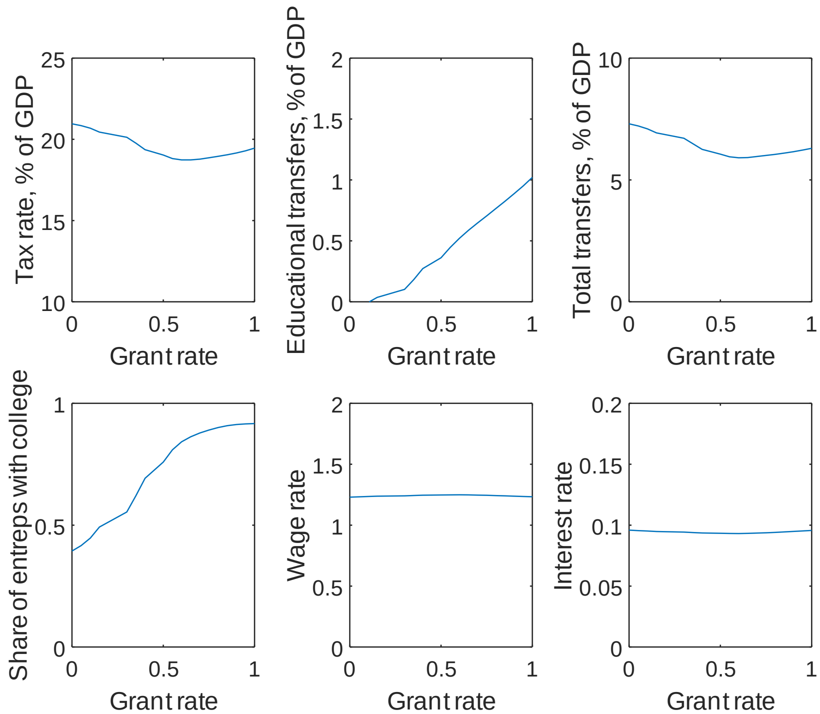

Figure 11 – Additional aggregate statistics regarding educational grants.

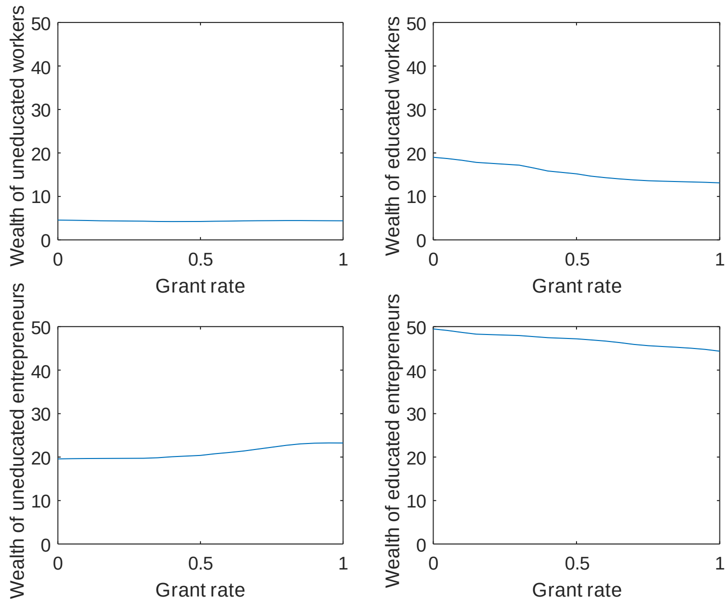

Figure 12 – Wealth by group and educational grants.

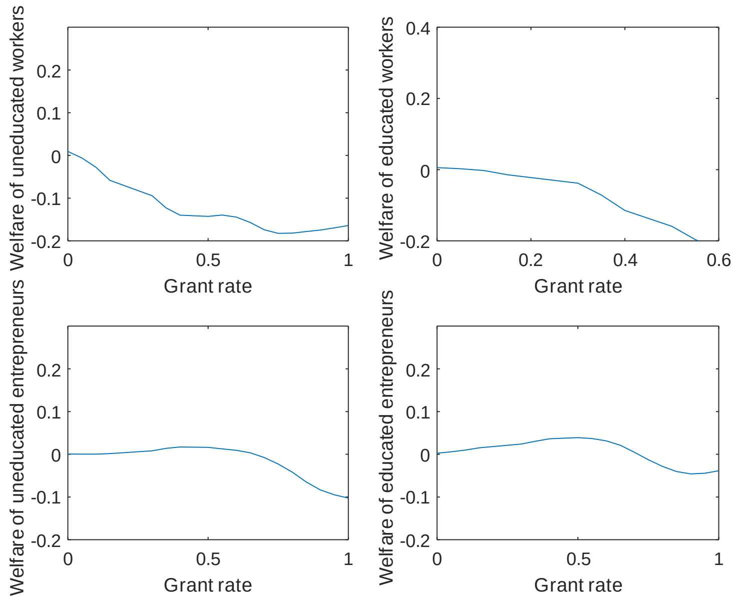

Figure 13 – Welfare by group and educational grants.