Entrepreneurship, College and Credit: The Golden Triangle

Roberto M. Samaniego* Juliana Yu Sun†

April 28, 2016

Abstract

We develop a model to evaluate the impact of college education finance on welfare, inequality and aggregate outcomes. Our model captures the stylized fact that entrepreneurs with college are more common and more profitable. Our calibration to US data suggests this is mainly because higher labor earnings allow college educated agents to ameliorate credit constraints when they become entrepreneurs. The welfare benefits of *subsidizing* education are greater than those of eliminating *financing constraints* on education because subsidies ameliorate the impact of financing constraints on would-be entrepreneurs.

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 entrepreneurs account for a disproportionate share of the wealthiest households. In addition,

*Roberto M. Samaniego, George Washington University, 2115 G St NW Suite 340, Washington, DC 20052. Tel: (202) 994-6150. Fax: (202) 994-6147. Email: roberto@gwu.edu.

†Juliana Y Sun, School of Economics, Singapore Management University, 90 Stamford Road, Singapore 178903. Tel: (65) 6808 5456, Fax: (65) 6828 0833, Email: yusun@smu.edu.sg.

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 – 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

[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) or Cowan (2016) 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.

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).[4] At the same time, Hurst and Lusardi (2004) and Buera (2009) find that wealth is not a significant determinant of whether or not most agents become entrepreneurs. Thus, one might conclude that financing constraints are not key determinants of entrepreneurship rates, a central issue in the economics of entrepreneurship. However, Bates (1990), Parker and van Praag (2006) and Mondragon-Velez (2009) and others find that a disproportionate share of entrepreneurs is college-educated. 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.

[4] Holtz-Eakin et al (1994), and more recently Blanchflower (2009), provide evidence that borrowing constraints indeed limit entrepreneurs' scale of operation.

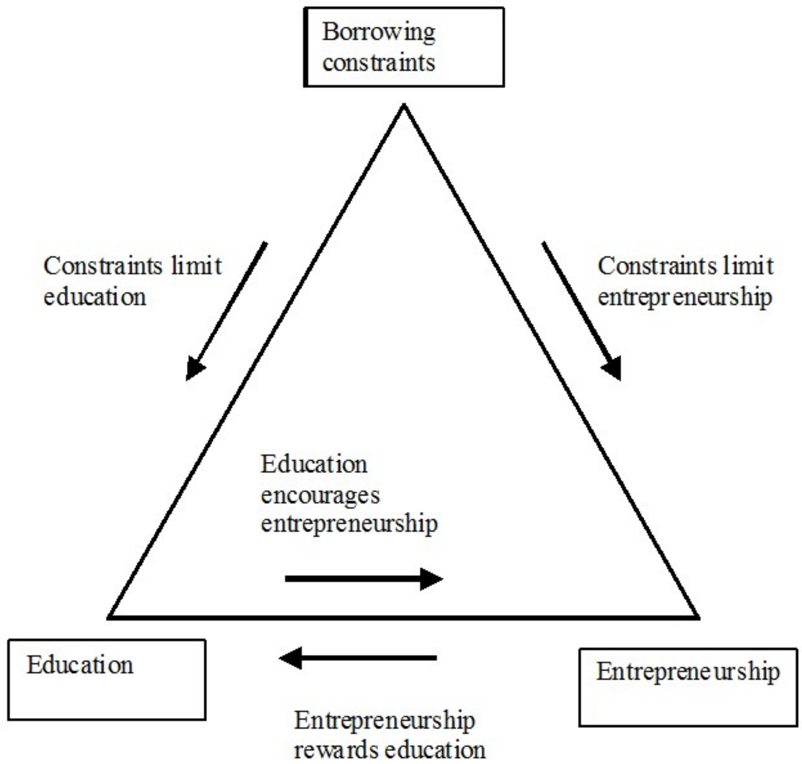

Figure 1 – The Golden Triangle: interrelations between credit constraints on education and on entrepreneurship.

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.[5] 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.

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. We find that this is consistent with responses from the 2005 Factors of Business Success

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

survey conducted by the European Commission, where college educated entrepreneurs are found to rely less on external finance while reporting that expanding the business is a priority as often as the uneducated, indicating no obvious difference in the optimal scale of operations.[6]

This finding has important consequences for our 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 percent, 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 7.55 to 7.20 percent.
- tightening financing constraints on entrepreneurship lowers the number of entrepreneurs from 7.55 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.
- both kinds of constraints have significant aggregate impact. For example, disallowing agents from borrowing for *college* lowers GDP by 14 percent in the steady state equilibrium. Disallowing agents from borrowing for *entrepreneurship* lowers GDP by 36 percent.[7]

Our policy experiments indicate other important interactions between credit constraints on education and entrepreneurship. For example, we find that subsidizing education can increase income and welfare by more than double the impact of removing credit constraints

[6]While we cannot propose a formal inference criterion for our parameters, small changes in the values of the parameters governing entrepreneurial opportunities and productivity cause large changes in the matched statistics (such as the relative income and prevalence of enterprises run by people with or without collage), indicating that the finding is robust. On the use of calibration as an econometric tool see Kydland and Prescott (1996) and Cooley (1997) inter alia.

[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.

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. Subsidizing *entrepreneurs* has a large impact on income but the impact on welfare is an order of magnitude lower because the benefits accrue to a small set of agents who are already disproportionately wealthy (entrepreneurs), whereas the benefits of education support are more equitably distributed. Subsidizing entrepreneurs changes the occupational choice of the marginal entrepreneur, an agent who has barely enough wealth to become an entrepreneur if an opportunity arises. Thus, a subsidy to entrepreneurs (in the form of a subsidy or tax credit on interest) is effectively a transfer to the wealthy. 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. 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, see Evans and Leighton (1989). 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 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. Mondragon-Velez (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 2.35 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.

[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.

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 Belley and Lochner (2007) and 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 obviously operate projects with larger target size**. As

indicated in the literature, the college-educated are generally wealthier. 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. The survey data do not have this 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 again do not obviously require disproportionate quantitites 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.

7. **Support for college finance is correlated with lesss 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 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.

[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.

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

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

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
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

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

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

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. 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

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.

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:

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

Here Y_t^e is output and k_t is capital input. The variable x_t is an idiosyncratic productivity term, as in the model of Lucas (1978).[13] As discussed later, the choice of k_t may be limited by a borrowing constraint.[14]

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

[13] The literature does sometimes find that psychological factors affect entrepreneurs, e.g. Lindquist, Sol and Van Praag (2015): while it is beyond the scope of the paper to address these, we note that the model can accommodate such things as being among the determinants of x_t.

[14] We do not allow entrepreneurs to hire workers for several reasons. First, the survey data indicate that

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: $y_t\tilde{}F^y\left(y_t|y_{t-1}, e\right)$ and $x_t\tilde{}F^x\left(x_t|x_{t-1}, e\right)$. Notice that the Markov process governing the evolution of x_t may depend on the educational level e. Mondragon-Velez (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.

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.

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.

3.2.1 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

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

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 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, $f[x_t k_t^{\nu} + (1 - \delta)k_t]$.

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 $V^e(a_t, x_t, y_t, e)$ 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] 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

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

where w is the wage and y_t is her labor productivity shock and τ is the tax rate, 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

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

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

3.2.2 Old agents

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

$$\begin{aligned} W^r\left(a_t\right) &= \max_{c_t, a_{t+1}} \left\{u\left(c_t\right) + \pi_o \beta W^r\left(a_{t+1}\right) + (1-\pi_o) E V^{new}\left(a_{t+1}, x_{t+1}, y_{t+1}\right)\right\} \\ & \quad s.t. \\ a_{t+1} &\leq a_t\left(1+r\right) - c_t + p \end{aligned} \tag{7}$$

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. In that case they may become old entrepreneurs, whose value W^e is given by:

$$\begin{aligned} W^e\left(a_t, x_t, e\right) &= \max\left\{u\left(c_t\right) + \beta \pi_o E W\left(a_{t+1}, x_{t+1}, e\right)\right. \\ & \quad \left. + \beta(1-\pi_o) E V^{new}\left(a_{t+1}, x_{t+1}, y_{t+1}\right)\right\} \\ & \quad s.t. \\ a_{t+1} &\leq x_t k_t^v + \left(1-\delta\right) k_t - \left(1+r\right)\left(k_t - a_t\right) - c_t \\ k_t &\geq 0, a_t \geq 0 \\ & \quad \text{Borrowing constraint } (4). \end{aligned} \tag{8}$$

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 Lindquist, Sol and Van Praag (2015). Finally,

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

3.2.3 The Newborn

Newborn agents observe their initial values of x_t and y_t, and decide on their educational level. If they 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.[17] 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.[18] Our model contains the typical assumption that agents decide on whether or 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 in that "ability" is 2-dimensional, encompassing the initial values of both x_t and y_t. The initial value of y_t is drawn from the ergodic distribution of F^y for the uneducated.

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:

[17] This is for simplicity. 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.

[18] 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).

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

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

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

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

Notice that if $\kappa\left(e,\epsilon\right)-s\left(e,\epsilon,a_t\right)>a_t$ for any given level of e and ϵ then agents must borrow $\kappa\left(e,\epsilon\right)-s\left(e,\epsilon,a_t\right)-a_t$. In addition, subsidized loans may constitute part of the subsidy scheme s.[19] 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 $D^{educ}\left(a_t,x_t,y_t,e\right)$. While being punished the agent is barred from capital markets and from entrepreneurship, and there is a wage garnishment rate $\theta\left(e\right)$, as well as a probability $\phi\left(e\right)$ that the agent will be forgiven so the punishment regime ends. Thus we have that

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

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.

[19]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, $s\left(e,\epsilon,a_t\right)=s_1\left(e,\epsilon,a_t\right)+\min\left(L,\max\left\{0,\kappa\left(e,\epsilon\right)-s_1\left(e,\epsilon,a_t\right)-a_t\right\}\right)$
$\times s_2\left(e,\epsilon,a_t\right)r$. If the interest rate is lowered by a proportion ς, then we have that $s_2\left(e,\epsilon,a_t\right)=\varsigma$.

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

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

If for given values of e and ϵ this constraint is not satisfied, then the agent cannot attain level of education e.

Finally, define $V^{educ}\left(a_t, x_t, y_t, 0, \epsilon\right) \equiv V^{noneduc}\left(a_t, x_t, y_t\right)$. The value of a newborn is then:[20]

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

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 Mondragon-Velez (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 $g \in \{1, 2, 3, 4\}$ 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 $\Gamma : X \rightarrow X$, so that $\omega_{t+1} = \Gamma\left(\omega_t\right)$. 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.

[20] Notice that since $\kappa\left(0, \epsilon\right) = 0$, $\Xi \neq \varnothing$, 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.

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, υ, 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.[21] Note, however, that it is not necessarily the case that all entrepreneurs 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 Mondragon-Velez (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,

[21] 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.

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 2.35. 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.[22] 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 Mondragon-Velez (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

[22] 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 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 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 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 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 (Spence (1973)) or that higher ability agents might be 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. In fact, given $\xi = 1.4$, 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. 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.

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. We approximate it over a grid of five values of y, so that $\log y = [-1, -0.5,$

0, 0.5, 1].

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 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 Mondragon-Velez (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 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.[23] This threshold turns

[23] The Department of Education reports that 59 percent of college students attended public institutions,

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[24] 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.[25]. Over 4 years that accumulates to 0.59 times the agent's assets. There is also an upper bound on grants of $5645, 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.[26] This is up to a limit of about $5000 for 2013, which is about 15% of the annual private college cost. Similarly, in the model we assume that agents may 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.

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.

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

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

[26] 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	2.35	2.35
share of agents in state college	0.5	0.5

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.

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. 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 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.[27] 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 agents. College educated agents are wealthier, 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

[27] 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.

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.[28]

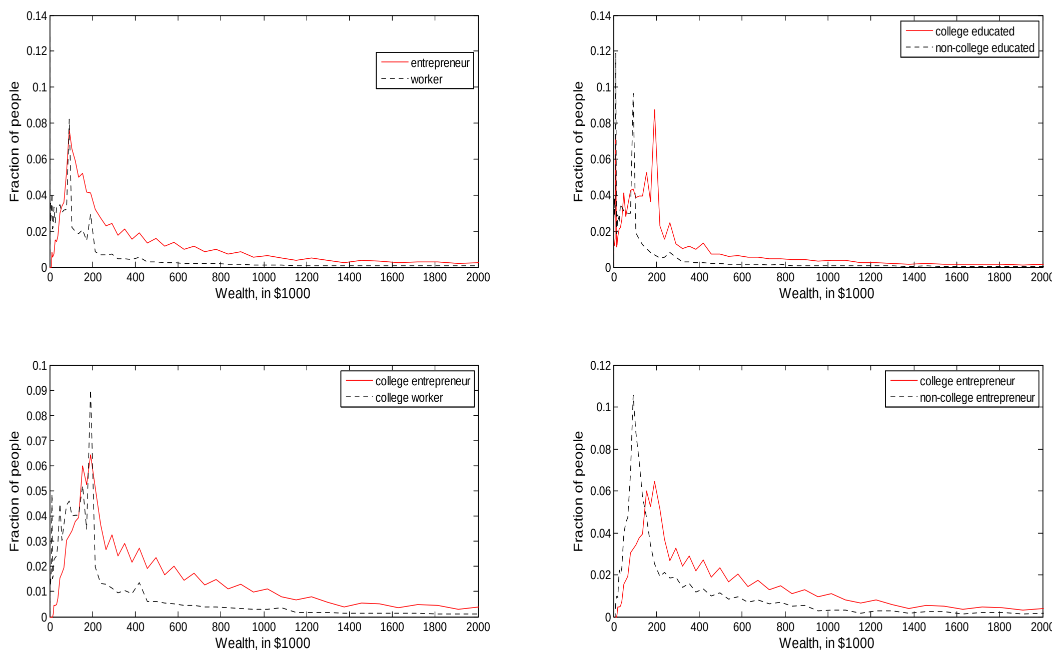

Figure 2 – Wealth distribution by occupation and education.

5.1 Comparing constraints

In the model, college attendance is limited by a credit constraint. 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

[28] 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.

level. This level is decreasing in y and increasing in the cost of college. See Figure 3. Thus, interpreting y as agent ability, the model accounts for the finding in Lochner and Monge-Naranjo (2011) and others that high-ability agents are more likely to go to college.

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 $x = x^{high}$.

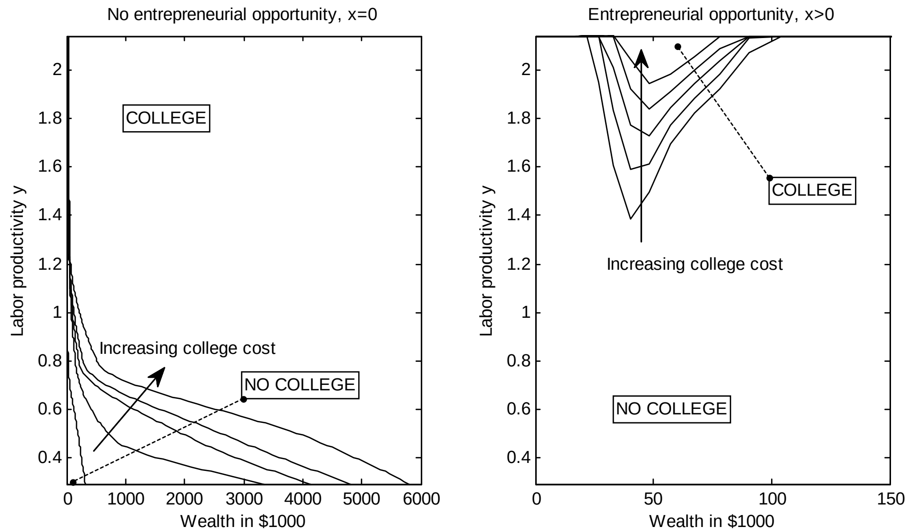

Figure 3 – Decision rule for going to college. Each line corresponds to the income threshold y above which agents attend college in equilibrium, for a given college cost $\kappa(1, \epsilon)$.

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.

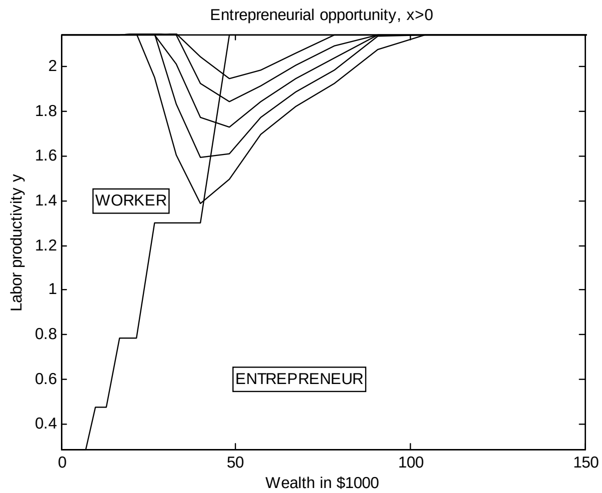

Figure 4 – Decision rules for becoming an entrepreneur for agents with $x > 0$. The increasing step function is the boundary between (a, y) combinations that lead to different optimal occupational choices. The contours represent the educational decision from the previous graph. Above a given contour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

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 not have much impact on entrepreneurship rates. 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% of the population holds 83% of the wealth. The wealthiest 1% of the population holds 40% of the wealth as before. 0 percent 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 the 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 percent), 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.

These results should be taken as benchmarks. Different ways of modeling the labor market could affect the quantitative conclusions. 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 variable v changes a lot in response to policy, very strong offsetting effects would be required to overturn this result in an alternative 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 2.35 to 2.73, 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.[29]

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 output because increased college attendance raises worker productivity and also increases

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

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 point, 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 $\varsigma = 0$. The large impact on income and welfare is due to the much larger stock of human capital, in the form of college-educated agents. 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. The level of entrepreneurship varies between 0.073 and 0.082 depending on the subsidy rate, but the corresponding reduction in the number of agents working is not enough to significantly change the wage rate. Similarly, the interest rate drops between these two scenarios only by 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.

Finally it is useful to know what intensity of subsidies is equivalent to the US financing scheme. A subsidy of 27% generates the same 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.

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.

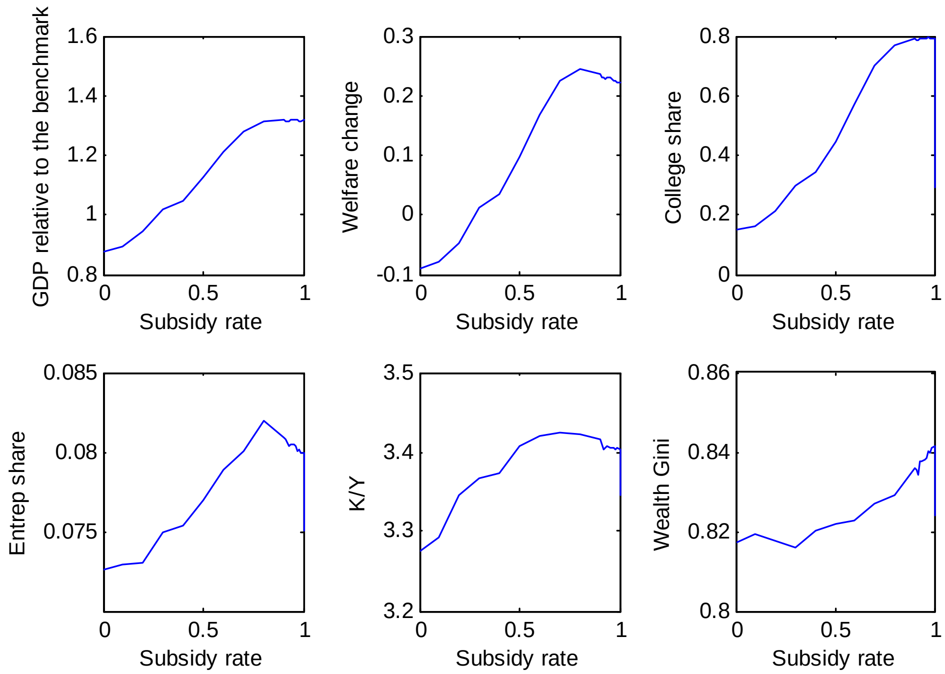

Figure 5 – Subsidies to college and macroeconomic aggregates. Each panel plots the extent to which the cost of college is subsidized against a statistic drawn from the model economy.

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.

Figure 6 indicates that wealth inequality and the college educated population rise with the grant rate. We find that a 100% grant for students who cannot afford college raises welfare by 21.5 percent. Again, the policy generally raises wealth inequality because it enables more entrepreneurship. This time, welfare gains do not deteriorate for high values of ς, as it is more targeted towards financially constrained agents than a broad educational subsidy. Notice that, while grants do not achieve the same maximum level of GDP and welfare as subsidies – because subsidies allow would-be entrepreneurs to have a larger pool of capital – the differences are not large. A 100% grant rate raises GDP by 31% and welfare by 22%. By contrast, a 90% subsidy rate raises GDP by 32% and an 80% subsidy rate raises welfare by 25%.

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.

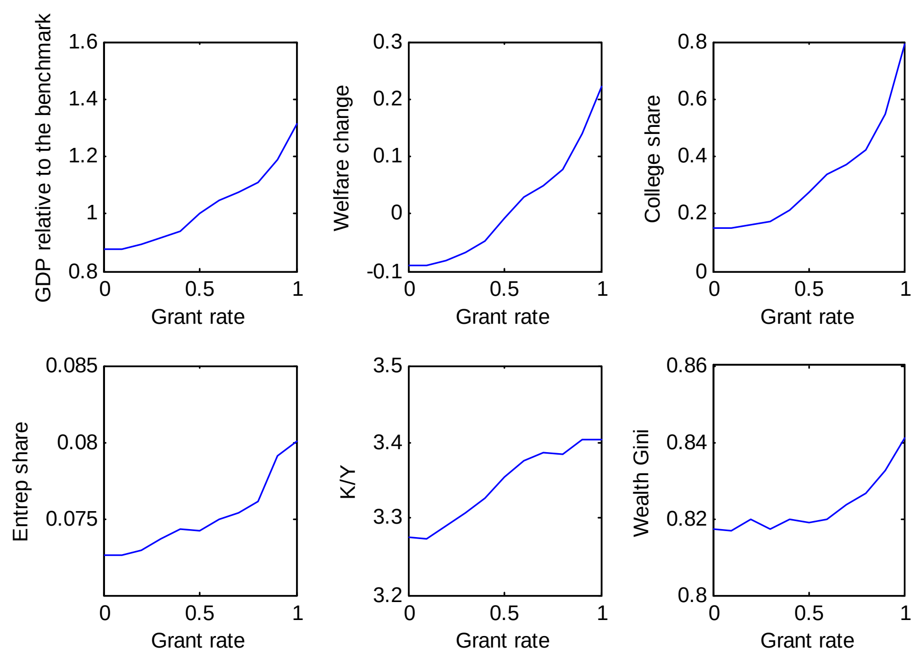

Figure 6 – Education grants for college and macroeconomic aggregates. Each panel plots the extent to which the cost of college above the agent's wealth is subsidized against a statistic drawn from the model economy.

5.5 Other policies

There are two types of financing constraints in the model economy: on education and on entrepreneurship. Our experiments changing the entrepreneurial punishment parameter f suggest that the latter can have a larger impact on aggregates. This begs the question: what would be the impact on capital accumulation and welfare of subsidizing *entrepreneurs*?

We answer this question by studying the impact of a subsidy on the interest paid by entrepreneurs when they borrow capital. Instead of paying interest $r \times \max\{0, k - a\}$ for any capital that exceeds their own wealth, they pay $(1 - \varsigma) \times r \times \max\{0, k - a\}$ where $\varsigma \in [0, 1]$ is the subsidy rate. As before the subsidy is financed out of taxation.

We find that subsidies to borrowing by entrepreneurs can have a substantial impact on aggregate outcomes. GDP increases by up to a factor of 2 – see Figure 7. On the other hand, this does not result in a commensurate increase in welfare: welfare rises by under 20%. This is because the benefits of this policy accrue only to a small set of agents, specifically entrepreneurs, who are already wealthy and have a low marginal utility of consumption. The share of entrepreneurs rises somewhat but by less than a subsidy to education of 100%, because a subsidy to entrepreneurs does not help non-entrepreneurs to accumulate the wealth that would allow them to become entrepreneurs were they to have the opportunity. The capital-output ratio increases dramatically with such a subsidy but so does the Gini coefficient of wealth. Subsidies to education increase welfare for a large set of the agents, as seen in the comparability between the impact of education subsidies on welfare and on output. By contrast, although a subsidy to entrepreneurs dramatically increases output, its impact on welfare is an order of magnitude smaller because most of the benefits accrue to a small number of agents (entrepreneurs, who are under 10% of the agents), who were already disproportionately wealthy (so their marginal utility of consumption is low). Thus, in the class of models where financing constraints on entrepreneurs are important for matching the wealth distribution, subsidies to entrepreneurs seem to generate welfare benefits that are "inequitable", whereas subsidies and grants to education generate welfare benefits that are "equitable."

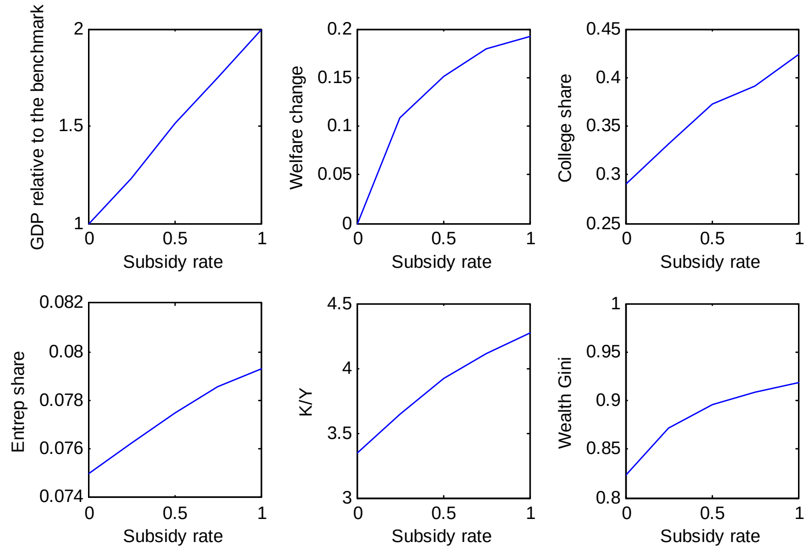

Figure 7 – Subsidies to entrepreneurs in the model economy.

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. 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. Financing education also seems to be more effective in raising welfare for a broad set of agents than subsidizing entrepreneurs. It would be interesting to see whether this conclusion is 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 many models of entrepreneurship, starting from Jovanovic (1982), 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.

References

[1] Acemoglu, Daron. 2002. Directed Technical Change. Review of Economic Studies 69, 781-810.

[2] Attanasio, Orazio P., James Banks, Costas Meghir, and Guglielmo Weber. 1999. "Humps and Bumps in Lifetime Consumption." Journal of Business and Economic Statistics. 17(1): 22-35.

[3] Aiyagari, S Rao, 1994. "Uninsured Idiosyncratic Risk and Aggregate Saving," Quarterly Journal of Economics, 109(3), 659-84.

[4] Bates, Timothy. 1990. "Entrepreneur Human Capital Inputs and Small Business Longevity." The Review of Economics and Statistics, 72(4): 551-559.

[5] Becker, Gary. 1975. "Human Capital," 2nd Ed., New York, NY: Columbia University Press.

[6] Belley, Philippe, and Lance Lonchner. 2007. "The Changing Role of Family Income and Ability in Determining Educational Achievement." Journal of Human Capital, 1(1): 37-89.

[7] Blanchflower, David G. and Andrew J. Oswald. 1998. "What Makes an Entrepreneur?" Journal of Labor Economics 16 (1), 26-60.

[8] Blanchflower, David G. 2009. "Entrepreneurship in the United States." Annals of Finance, 2009, 5 (3-4), 361-396.

[9] Buera, Francisco J. 2009. "A dynamic model of entrepreneurship with borrowing constraints: theory and evidence." Annals of Finance 5(3-4): 443-464.

[10] Buera, Francisco J., Joseph P. Kaboski and Yongseok Shin, 2011. "Finance and Development: A Tale of Two Sectors," American Economic Review 101(5), 1964-2002.

[11] Cagetti, Marco, and Mariacristina De Nardi. 2006. "Entrepreneurship, Frictions and Wealth." Journal of Political Economy, 114(5): 835-70.

[12] Cagetti, Marco, and Mariacristina De Nardi. 2009. "Estate Taxation, Enrepreneurship, an Wealth" American Economic Review, 99(1): 85-111.

[13] Chang, Yongsung Sun-Bin Kim, 2006. "From Individual To Aggregate Labor Supply: A Quantitative Analysis Based On A Heterogeneous Agent Macroeconomy ," International Economic Review, 47(1), 1-27.

[14] Cooley, Thomas F. 1997. "Calibrated Models." Oxford Review of Economic Policy. 13(3), 55-69.

[15] Cowan, Benjamin W. 2016. Testing for Educational Credit Constraints Using Heterogeneity in Individual Time Preferences. Forthcoming, Journal of Labor Economics.

[16] Diaz-Gimenez, Javier, Vincenzo Quadrini, Jose-Victor Rios-Rull. 1997. "Dimensions of inequality: Facts on the U.S. Distributions of earnings, income, and wealth." Federal Reserve Bank of Minneapolis Quartely Review, 21(2): 3-21.

[17] Evans, David S., and Linda S. Leighton. 1989. "Some Empirical Aspects of Entrepreneurship" American Economic Review, 79(3): 519-535.

[18] Evans, David S., and Boyan Jovanovic. 1989. "An Estimated Model of Entrepreneurial Choice under Liquidity Constraints." Journal of Political Economy, 97: 808-27.

[19] Fang, Hanming. 2006. "Disentangling the College Wage Premium: Estimating a Model with Endogenous Education Choices." International Economic Review, 47(4), 1151-1185.

[20] Gollin, Douglas. 2002. "Getting Income Shares Right." Journal of Political Economy, 110(2): 458-74.

[21] Harsanyi, John C. 1975. "Can the Maximin Principle Serve as a Basis for Morality? A Critique of John Rawls's Theory." American Political Science Review 69, No. 2 , pp. 594-606

[22] Hart, Oliver, and John Moore. 1994. "A theory of debt based on the inalienability of human capital." Quarterly Journal of Economics 109(4), 841-879.

[23] Holtz-Eakin, Douglas, David Joulfaian, and Harvey S. Rosen. 1994. "Sticking it out: entrepreneurial survival and liquidity constraints." Journal of Political Economy, 102(1): 53-75.

[24] Hurst, Erik, and Annamaria Lusardi. 2004. "Liquidity constraints, wealth accumulation and entrepreneurship." Journal of Political Economy, 112(2): 319-347.

[25] Ionescu, Felicia. 2008. "Consolidation of Student Loan Repayments and Default Incentives." The B.E. Journal of Macroeconomics, De Gruyter, vol. 8(1), pages 1-37.

[26] Ionescu, Felicia. 2009. "The Federal Student Loan Program: Quantitative implications for college entrollment and default rates." Review of Economic Dynamics, 12: 205-231.

[27] Ionescu, Felicia. 2011. "Risky Human Capital and Alternative Bankruptcy Regimes for Student Loans", Journal of Human Capital, 5(2): 153-206.

[28] Jones, John B. and Fang Yang. 2016. Skill-biased Technical Change and the Cost of Higher Education. Forthcoming, Journal of Labor Economics.

[29] Jovanovic, Boyan, 1982. "Selection and the Evolution of Industry." Econometrica, Econometric Society, vol. 50(3), pages 649-70, May.

[30] Kotlikoff, Laurence J., Kent A. Smetters, and Jan Walliser. 1999. "Privatizing Social Security in the United States—Comparing the Options." Review of Economics Dynamics 2 (July): 532–74.

[31] Kuhn, Peter and Catherine J. Weinberger. 2005. "Leadership Skills and Wages." Journal of Labor Economics, 23(3),395-436.

[32] Kydland, Finn E. and Edward C. Prescott. 1996. "The Computational Experiment: An Econometric Tool." Journal of Economic Perspectives 10(1), 69-85.

[33] Lazear, Edward P. 2005. "Entrepreneurship." Journal of Labor Economics 23(4) 649-680.

[34] Lindquist, Matthew J, Joeri Sol and Mirjam Van Praag. 2015. "Why do Entrepreneurial Parents Have Entrepreneurial Children?" Journal of Labor Economics, 33(2), 269-296.

[35] Lochner, Lance J., and Alexander Monge-Naranjo. 2011. "The Nature of Credit Constraints and Human Capital." American Economic Review, 101(6): 2487-2529.

[36] Lucas, Robert E., Jr. 1978. "On the Size Distribution of Business Firms." Bell Journal of Economics, 9(2): 508-23.

[37] Mondragon-Velez, Camilo. 2009. "The probability of transition to entrepreneurship revisited: wealth, education and age." Annals of Finance, 5:421-441.

[38] Monge-Naranjo, Alexander. 2009. "Entrepreneurship and Firm Heterogeneity with Limited Enforcement." Annals of Finance, 5: 465-494.

[39] Myers, Steward C. and Raghuram G. Rajan. 1998. "The Paradox of Liquidity," Quarterly Journal of Economics 113 (3), 733-771.

[40] Parker, Simon C., Mirjam van Praag. 2006. "Schooling, Capital Constraints, and Entrepreneurial Perormance: The Endogenous Triangle." Journal of Business & Economic Statistics, 24(4):416-431.

[41] Poschke, Markus. 2013. "Who becomes an entrepreneur? Labor market prospects and occupational choice." Journal of Economic Dynamics and Control 37(3), 693-710.

[42] Quadrini, Vincenzo. 2000. "Entrepreneurship, Saving, and Social Mobility." Review of Economic Dynamics, 3(1): 1-40.

[43] John Rawls. 1971. "A Theory of Justice." Cambridge, Mass: Harvard University Press.

[44] Reed, Matthew. 2011. Project on Student Debt Class of 2010. Institute for College Access and Success. http://projectonstudentdebt.org/files/pub/classof2010.pdf. Last checked 12/10/2013.

[45] Spence, Michael. 1973. "Job Market Signaling." Quarterly Journal of Economics 87 (3), 355–374.

[46] Stokey, Nancy L., and Sergio Rebelo. 1995. "Growth Effects of Flat-Rate Taxes." Journal of Political Economy, 103(3): 519-50.

[47] Terajima, Yaz. 2006. "Education and Self-Employment: Changes in Earnings and Wealth Inequality." Bank of Canada working paper 2006-40.

A Simulation Method

The algorithm is the following:

1. Choose a grid A of possible values of wealth.

2. Choose an initial guess for the wage, tax and value functions.[30]

3. Solve c, a', and k to maximize household's problems given interest rate, wage, tax and future values given by the guesses of the value functions and the incentive compatibility constraints.

4. Iterate on step 3 using the new guesses for the value functions until the value functions converge. Blackwell's Theorem indicates this should occur in finite time for any arbitrary degree of desired precision.

5. Compute measures with grid A, setting capital demand in the non-entrepreneurial sector to equal wealth minus capital demand in the entrepreneurial sector. This allows us to compute total labor demand and supply. We use the difference to update the wage guess depending on whether or not labor supply is greater than demand.

6. Go back to step 3 with new wage guess. Iterate until labor market clears.

7. Compute government budget and update tax rate guess depending on whether tax receipts are greater or less than zero. Return to step 2 until government budget is in balance.

B Calibration details

To estimate hazard rates out of entrepreneurship we proceed as follows. First, Cagetti and De Nardi (2006) find an exit rate among entrepreneurs of 0.206 in PSID.[31] Bates (1990) reports a logit regression of the entrepreneurs survival that carries a coefficient of 0.2522 on earning a college degree, a coefficient of 0.1082 on earning a high school degree, and a coefficient of -1.3112 on not having completed high school (the reference group in their sample). The survival odds for a college earner are $e^{-1.3112+0.2522+x}$ where x carries the influence of other factors. For a high school earner, it is $e^{-1.3112+0.1082+x}$. This translates into probability differences of $e^{-1.3112+0.2522+x}/(1+e^{-1.3112+0.2522+x})$ for college and $e^{-1.3112+0.1082+x}/(1+e^{-1.3112+0.1082+x})$ for high school.

[30] The interest rate is determined by the wage, using the optimality conditions for the non-entrepreneurial sector.

[31] This is consistent with our results from the 2005 Factors of Business Success survey, where 81% of entrepreneurs report that their plan for the future is to continue with the enterprise.

The difference between these two obviously depends on x. The average survival rate according to the PSID is $1 - 0.206 = 0.794$. If c is the survival probability for college and n is the survival rate for non-college then to preserve this average we require

$$c \times 0.41 + n \times 0.59 = 0.794$$

Plugging in, we get that

$$e^{-1.3112+0.2522+x}/(1+e^{-1.3112+0.2522+x})\times 0.41+e^{-1.3112+0.1082+x}/(1+e^{-1.3112+0.1082+x})\times 0.59 = 0.794$$

which implies that $x = 2.4945$. Consequently the survival probability for college is 0.8077 and for non-college is 0.7843.

Thus the calibrated tensor F^x is the following: $\begin{bmatrix} 0.954 & 0.2157 \\ 0.046 & 0.7843 \end{bmatrix}$ for non-college educated, and $\begin{bmatrix} 0.954 & 0.1923 \\ 0.046 & 0.8077 \end{bmatrix}$ for college educated. Thus, in terms of the parameters in the text, the flow into potential entrepreneurship for the non-college educated $\eta_{in} = 0.046$, the frequency of entrepreneurial opportunities for the educated relative to the uneducated $\chi_{in} = 1$, the probability of losing an entrepreneurial opportunity for the non-educated is $\eta_{out} = 0.2157$ and the relative exit rate for the educated compared to the uneducated is$\chi_{out} = 0.8915$.