Essays in Macroeconomics and Public Economics

by

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This dissertation contains essays in macroeconomics and public economics. In the first essay, I analyze the interaction between student debt and occupational choice. In recent times, student debt has grown the most among any other types of debt in the US. Student debt can have distortionary behavioral effects and one such effect is in occupational choice. In this paper, I construct a model of occupational choice between being an entrepreneur and a worker and examine how occupational choice is affected by repayment plans available to students. Since entrepreneurship is inherently riskier than becoming a worker, a debt repayment plan that takes into account the income level of the borrower can have an effect on occupational choice. I find that while repayment plans do not change the rate of entrepreneurship in the aggregate, there is substantial change in the composition of entrepreneurs by age.

In the second essay, I study the quantitative effects of the decline in price of investment goods on the process of structural change and economic growth. Using the Korean economy to calibrate a canonical two-sector model of growth, I study labor allocations in agricultural and non-agricultural sectors. The model is able to match several features of the economy and has implications for sectoral value-added and employment shares, GDP per capita and investment. In particular, I find that the decline in the price of investment goods decreases the value-added and employment shares in the agricultural sector and increases the level of GDP per capita and investment.

In the third essay, I provide estimates for the elasticity of taxable income with respect to marginal tax rates using the publicly available Current Population Survey (CPS) dataset. In contrast to studies that use datasets on tax returns that are not publicly available, I use the panel structure of the CPS and exploit tax reforms in the US to employ an instrumental variables approach to study how taxable income responds to changes in tax rates. I find that the elasticity of taxable income is 0.65 for married couples.

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Preface

This dissertation would not have been completed without the encouragement and support from a number of people. Most notably, my wife Sonam Sherpa showed great patience during times of uncertainty and kept faith with me. She deserves a lot more of my attention than I was able to give her during my Ph.D. program. My advisor, Dr. Daniele Coen-Pirani was instrumental in keeping me on track to completing the dissertation. Regular meetings with him greatly motivated me to carry on working. I am also thankful to my committee members Dr. Marla Ripoll, Dr. Sewon Hur and Dr. Najeeb Shafiq for providing insightful comments and suggestions to improve the final draft of the dissertation. Finally, I am eternally grateful to all my family members, with a special mention to my mother Nima Phuti Sherpa.

1.0 Student Debt and Entrepreneurship: The Effect of Repayment Plans on Entrepreneurial Activity

1.1 Introduction

An increase in the demand for higher education in the US has led to a surge in student loans. After home mortgages, aggregate student loan is now the largest among private consumer debts. As figure (1) shows, its size has swollen to over 1.3 trillion dollars. While student loan allows one to pursue and reap the benefits of higher education, it also adds to the financial burden after graduation. The US government has also recognized this as a problem faced by young individuals.[1] This financial burden can have distortionary effects on student's behavior, which can exacerbate the situation for the borrower. In this paper, I consider one such distortionary effect of student loan - occupational choice.

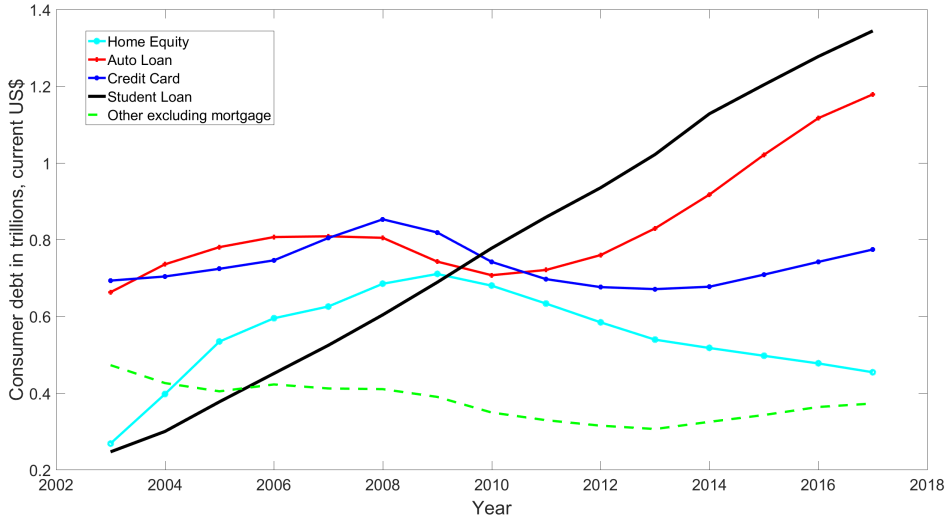


Figure 1: Consumer debt. Source: New York Fed Consumer Credit Panel/Equifax

This paper focuses on two types of occupation - entrepreneurship and workers.[2] A recent paper by Krishnan and Wang (2017) uses data from the Survey of Consumer Finances (SCF)

[1] See "Investing in Higher Education: Benefits, Challenges, and the State of Student Debt", *Executive Office of the President of the United States, July 2016*

[2] I refer to wage earners simply as workers.

to show that having student debt can negatively affect the decision of individuals to start their businesses. They use the Higher Education Amendments of 1992, which made student loan more easily accessible, as an exogenous shock to debt holders to study the causal effect of debt on start up decisions. Using data from the Country Business Patterns (CBP), the Federal Reserve Bank of New York Consumer Credit Panel/Equifax and the decennial census, Ambrose et al. (2015) find a negative correlation between changes in student loan debt and business formation. Outside of academia, the impact of student debt on entrepreneurship is being discussed in the popular media as well.[3]

Student loan can affect occupational choice for a number of reasons. By nature, entrepreneurship is a risky venture and income is uncertain (Hall and Woodward (2010), Iyigun and Owen (1998)). Having student loan that requires repayment of fixed amount can bring net income even lower in the event of a negative income shock. Risk averse agents prefer to avoid such income fluctuations. Starting a business also requires personal funds and in the presence of student loan, asset accumulation can be more difficult.

The objective of the paper is to study occupational choice under different debt repayment plans available to students. In particular, I compare the default standard repayment plan, which requires repayment of a fixed amount until the debt is paid off with an income-based repayment plan, which makes repayment contingent on income. Since entrepreneurship is generally a riskier venture than being a worker, it is natural to think that the repayment structure would affect the decisions of debt holders. In fact, in an effort to boost entrepreneurship in the country, the Small Business Association (SBA) of the US encourages selecting the income-based repayment plan.[4]

I construct a life-cycle model with schooling and occupational choices. Schooling requires external finance, which is provided by student loan. Occupational choice is made between becoming a worker and an entrepreneur. In the model, the two repayment plans are introduced as two different regimes. I find that the aggregate rate of entrepreneurship does not change much in the two different regimes but the composition of entrepreneurs

[3]For instance, "Student-Loan Load Kills Startup Dreams", by Ruth Simon, *Wall Street Journal, Aug 13, 2013*

[4]See "https://www.sba.gov/startupamerica/student-startup-plan". Their catch-phrase is "Defer loans, not entrepreneurship."

are affected. In comparing the repayment plans, the life-cycle of the agents can be divided into three phases: (i) right after graduation and before repayments are over under standard repayment; (ii) between the period when repayment is over under standard repayment and the period when repayment is over under income-based repayments; (iii) period following repayment under income-based repayments. In the first phase, there are more entrepreneurs when repayments are income-based, but in the second phase the situation is the opposite. In the third phase towards the end of the life-cycle the rates of entrepreneurship start to converge under the two repayment plans. I also find that once repayments are over, rates of entrepreneurship converge relatively quickly suggesting the absence of severe scarring effects of debt repayments. Welfare analysis shows that there is a welfare increase of 0.69% under income-based repayment plans compared to the standard repayments.

Related Literature

The paper is motivated by declining entrepreneurial activity in the US, as reported by Decker et al. (2014). Using different measures, Decker and co-authors conclude that there has been a steady decline in business dynamism in the US.[5] The paper is also related to a burgeoning literature on the relationship of entrepreneurship and the macroeconomy. In particular, the model developed in this paper builds off of the model in Cagetti and De Nardi (2006), who study the role of entrepreneurship in explaining the wealth distribution in the US. Similar models, which incorporate incomplete markets in the tradition of Bewley and distinguish entrepreneurs from workers have been used to study TFP losses by Buera et al. (2011) and Moll (2014). Similar to these papers, I also build a model with financial constraint to the entrepreneurs, which will be instrumental in driving some of the results. However, unlike these papers I build a model where entrepreneurship is risky. In that sense, the paper is closer to Angeletos (2007) and Mendoza et al. (2009).

The paper also contributes to the literature on student debt and its effects.[6] Among other recent quantitative papers, Ionescu (2009) looks at the implications of repayments of student loan on college enrollment and default rates. Ji (2018) looks at the job search behavior of

[5] Karahan and Pugsley (2015) and Kopecky (2017) point to the role of demographics in this decline. Kozeniauskas (2017) finds that skill-biased technical change and increase in fixed costs can explain the decline.

[6] Lochner and Monge-Naranjo (2015) provides a survey of the literature.

those with student loans and finds significant effects. Using the National Longitudinal Survey of Youths (NLSY) and the Baccalaureate and Beyond (B & B), Weidner (2016) documents that college graduates tend to have lower wage rate when their debt amount is higher. This, however, is not conclusive. Using the 1987 National Postsecondary Student Aid Survey, Minicozzi (2005) shows that higher educational debt is associated with higher initial wage rate the year after finishing college. Similarly, Field (2009) and Rothstein and Rouse (2011) also find that student loan induces student to choose high paying jobs[7].

1.2 Overview of Student Debt in the US

As costs of attending college have increased in the US, the fraction of people using student loan has increased as well. The federal student loan was first introduced in 1958 under the National Defense Education Act (NDEA) to assist students in select disciplines. Through the Federal Family Education Loan (FFEL) Program initiated in 1965, the government created guaranteed loans that were provided by private lenders. Later, the Higher Education Amendments of 1992 made subsidized and unsubsidized loans more readily available to students. Since 2010 following the passage of the Health Care and Education Reconciliation Act of 2010, the government has stopped providing loan guarantees and instead provides direct loans through the William D. Ford Federal Direct Student Loan (FDSL) Program.

The federal government provides different types of loans. Among them the most popular is the Stafford loans. These loans are either subsidized or unsubsidized and account for around 70 percent of total loans.[8] If subsidized, the government pays the interest on the loans when the student is at school, for six months after graduation (known as grace period) and during approved periods of deferment. Deferments can be made when unemployed, while in military services etc. There is a lifetime limit of $31000 and $57000 for dependent and independent undergraduates respectively. The second most popular type of federal loan,

[7]The results are case studies and hence not nationally representative. While Field attributes her result to debt aversion, Rothstein and Rouse argue that the result is more consistent with credit constraints. Rothstein and Rouse also find evidence that student debt affects academic decisions during college.

[8]Collegeboard (2017)

accounting for around 20 percent of the aggregate loan, is the Federal Direct Plus Loan, which is granted to parents of dependent undergraduates and graduate students. Finally, Perkins loans are provided to students who are in high financial need. It accounts for less than 3 percent of all loans. In this paper, we only consider federal loans provided directly by the government. Private loans exists as well but in recent years, they have accounted for only around 10 percent of total loans.[9] Also, since federal loans are less costly compared to private loans, students likely take out private loans only after they have exhausted their options for federal loan.

As was mentioned earlier, student loan has now grown rapidly in size. In 2015-16, around 60 percent of all college graduates (public and private non-profit universities) borrowed an average of $28,400.[10] Unlike most other debts, student debt is particularly burdensome because it is not dischargeable through bankruptcy. When students miss their payments they enter delinquency and after 270 days of delinquency they default. The consequences of a default are rather severe and can lead to wage garnishment and tax withholding. According to the Department of Education,[11] around 12 percent of those who entered repayment in 2013-14 defaulted on their loans.

Repayment

The government allows multiple federal loans to be consolidated into a single loan. The standard repayment plan requires a fixed amount to be repaid every month for ten years. This is the default repayment plan and in 2017 around 50 percent of the students opted for it. Graduated repayment is also available that allows students to start out by paying a smaller amount and the amount increases gradually. This repayment also goes on for ten years like the standard repayment plan.

Under FFEL and FDSL programs, there are income-driven repayment plans available as well. Through the Student Loan Reform Act of 1993, income-driven repayment plan was first introduced in 1994. Currently, there are four types of income-driven plans: Pay as You Earn (PAYE), Revised Pay as You Earn (REPAYE), Income-Based Repayment (IBR) and

[9] See Collegeboard (2017)

[10] Collegeboard (2017)

[11] See https://www.ed.gov/news/press-releases/us-department-education-releases-national-student-loan-fy-2014-cohort-default-rate

the Income Contingent Repayment (ICR). These repayment plans differ in their eligibility requirements, repayment periods and fraction of income that needs to be paid. Income-driven repayments have progressively become more generous. For example, following a presidential memorandum in 2014, students pay only 10% of their discretionary income under IBR, compared to 15% in prior years. Table (1) shows the different structures of repayment plans available to students.

Income-driven repayments can relieve students who are financially burdened and yet many chose not to use it, while default rate was relatively high. However, enrollment rate was low for a long time. Dynarski and Kreisman (2012) suggest this could be due to the high time cost and effort required in switching from the default standard repayment plan to income-based plans. In 2012, only around 5 percent of the borrowers chose income-driven repayments. However, this rate is increasing now, partly due to governmental initiatives.[12] Close to 28 percent now choose income driven payments.[13][14]

Payment	Amount	Period	Eligibility	Forgiveness
Standard	Fixed	10 years	All	No
REPAYE	10% of discretionary income	20 years	Direct Stafford Loans	20 years
PAYE	10% of discretionay income	20 years	Direct Stafford loans after Oct. 1, 2007	20 years
IBR	10/15% of discretionary income	20/25 years	FFEL/Direct Stafford loans	20/25 years
ICR	20% of discretionary income	25 years	Stafford/PLUS loans	25 years

Table 1: Repayment plans. Source: U.S. Department of Education

[12] See "Investing in Higher Education: Benefits, Challenges, and the State of Student Debt", *Executive Office of the President of the United States, July 2016*

[13] Collegeboard (2017)

[14] Check figure (24) in the appendix for an example of payment under standard repayment and income-based repayment.

1.3 Entrepreneurs

The literature on entrepreneurship characterizes an entrepreneur in several ways. The Schumpeterian view is that an entrepreneur is someone who brings new ideas, innovates and disrupts the economy. Congruent to this view of entrepreneurship, Levine and Rubinstein (2017) define entrepreneurs as those who run incorporated companies. They find that those having incorporated businesses also tend to have cognitive and non-cognitive abilities that exceed those who own unincorporated businesses.

A second way of studying entrepreneurs is simply by looking at the self-employed. For example, Hamilton (2000) and Evans and Leighton (1989) analyze the self-employed. In many publicly available datasets like the Current Population Survey (CPS), Panel Study of Income Dynamics (PSID) and the National Longitudinal Survey of Youths (NLSY), the self-employed and their demographic information are readily available, which makes it easier to analyze them.

In this paper, I consider an individual who is described as self-employed in the CPS to be an entrepreneur. Fig (2) shows the rate of self-employment by age. Most people become self-employed when they are older but there is still a significant fraction of self-employed who are younger, the group most likely to be burdened by student loan.

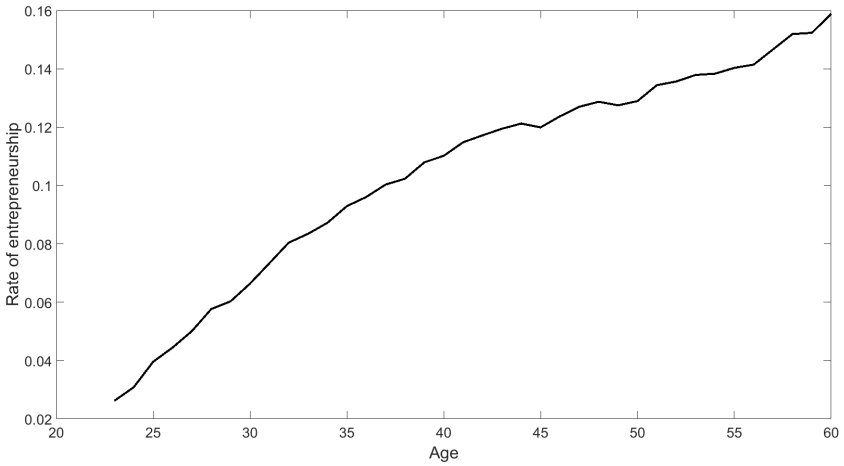


Figure 2: Rate of entrepreneurship by age. Source: Current Population Survey (CPS)

I focus on the self-employed for a few reasons. First of all, the entrepreneur in the paper is not confined to those who disrupt markets and innovate. Instead, we are concerned

with those who choose not to become wage earners. The self-employed captures this group. Secondly, even if we were to concern with just the talented entrepreneurs by considering just the incorporated, for example, it could omit many of the entrepreneurs who start out small, owning unincorporated firms, but later grow their businesses and incorporate. Figure (3) is consistent with this narrative. Younger entrepreneurs tend to be unincorporated. Since the earlier periods of an entrepreneur's life-cycle is most likely going to be affected by student debt, it is important that we consider the unincorporated self-employed as well. It is also true that student loan may not affect every type of entrepreneur. For example, someone who inherits a well established business from his/her parents may not be affected by having to pay their student debt. However, it is difficult to isolate the types of entrepreneurs who might be affected by student debt. Since the self-employed encompasses all types of entrepreneurs, it is a safe definition in the sense that it does not miss those potential entrepreneurs who might be affected by debt. Of course, it comes with the caveat that those who might be unaffected by debt are also included. Tables (20) and (21) lists the fraction of entrepreneurs by occupation and industry.

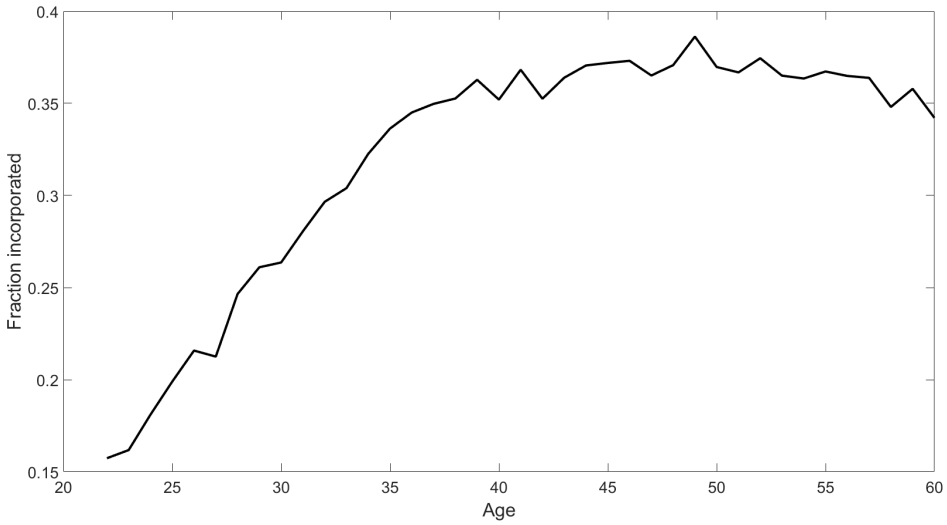


Figure 3: Fraction of incorporated entrepreneurs. Source: CPS

Entrepreneurs generally earn less on average. As seen in figure (4), it is clear that there is a higher proportion of individuals with very low or negative income. [15] The low average income for entrepreneurs is consistent with findings in Hurst and Pugsley (2011)

[15]For entrepreneur's income I use the variable 'INCBUS', which "indicates each respondent's net pre-

and Hamilton (2000) that non-pecuniary reasons are just as important in becoming an entrepreneurs. However, entrepreneurs could be earning less for other reasons as well.[16] E.g. young firms might have to go through a period of low levels of revenue before they start making profits. Exploring why average income levels are lower for entrepreneurs is beyond the scope of the paper.

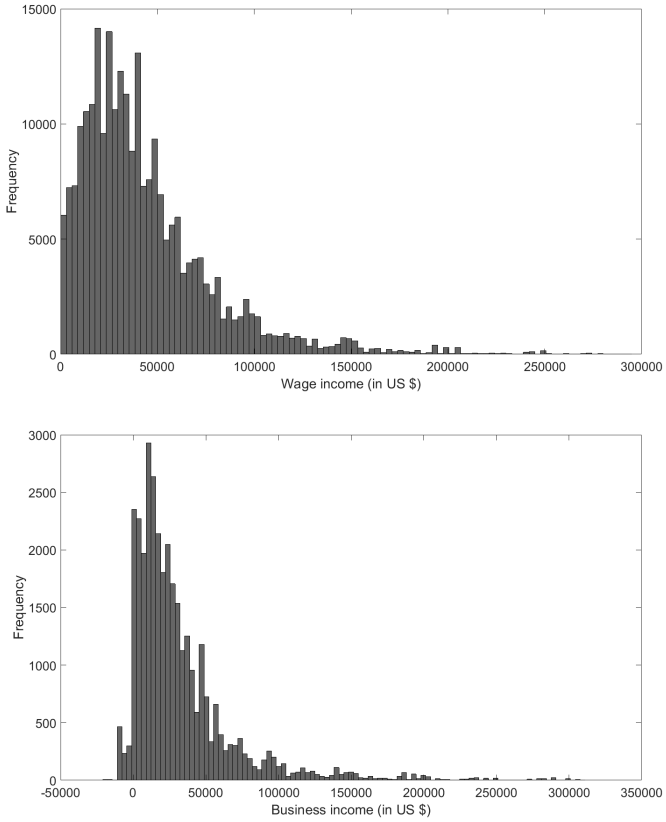


Figure 4: Income distribution for entrepreneurs and workers. Source: CPS

Entrepreneurship by College Education

Below, figure (5) shows the rates of entrepreneurship by college education. Between 2000 and 2017, the rate of entrepreneurship for those without college degree has fallen by 5.5%, whereas for those with college degree the rate has fallen by 22%. While not conclusive,

income-tax non-farm business and/or professional practice income for the previous calendar year". For the wage earner's income, I use 'INCWAGE', which "indicates each respondent's total pre-tax wage and salary income–that is, money received as an employee–for the previous calendar year".

[16]The income is self-reported. It is also possible that the self-employed under-report their earnings. But even with mis-reporting it is hard to dismiss that entrepreneurs earn less than workers because the fraction of people who earn less than $10,000 is significantly higher for entrepreneurs.

the rapid rise in student loan might have played a part in the relatively higher decline in entrepreneurship for college graduates.

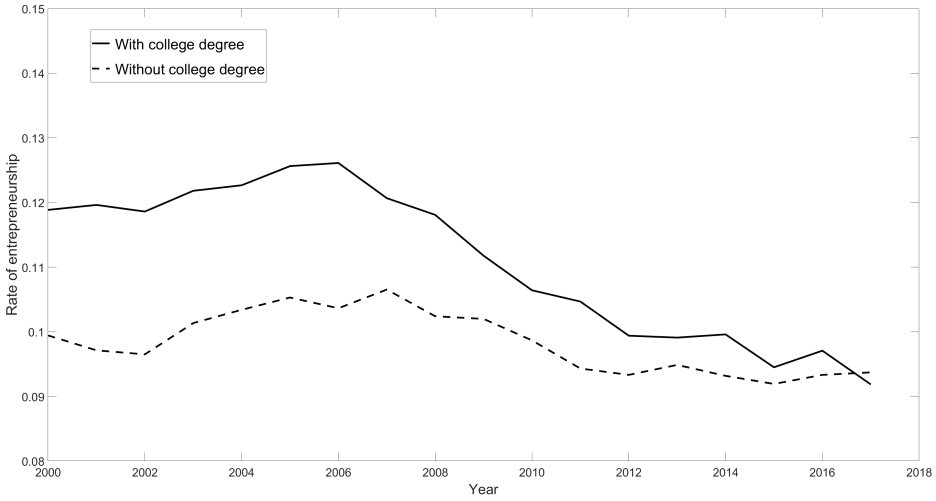


Figure 5: Rates of entrepreneurship. Source: CPS

1.4 Model

The key ingredients of the model are occupational and schooling choices. I build the model from the frameworks in Cagetti and De Nardi (2006) and Buera et al. (2011). I construct an overlapping generations model by adding life-cycle to their model. Although Cagetti and De Nardi (2006) also has life-cycle, they model it in a perpetual youth framework. Time is discrete and agents live for J periods. There is a measure one of agents in the economy. Measure $\frac{1}{J}$ of agents are born each period and the same measure of agents die. There is no retirement period in the model. At age 1, the agents make schooling choice and at each age subsequently choose to become a worker or an entrepreneur.

Agents receive flow utility from consumption $u(c_j)$ at each age j. The utility function $u(.)$ satisfies the standard conditions $u' > 0$, $u'' < 0$, $\lim_{c\to 0} u'(c) = \infty$ and $\lim_{c\to\infty} u'(c) = 0$. In period J, agents receive utility from bequest b. In addition to utility from consumption and bequest, each agent suffers a psychic cost κ by attending college. Using such psychic

costs to capture college enrollment is common in the literature[17]. Agents aim to maximize their expected lifetime utility

$$E\sum_{j=1}^{J}\beta^j u(c_j) + \beta^J v(b) - \kappa I_{\{college=1\}}$$

$\beta \in (0,1)$ is the discount factor and $I_{\{college=1\}}$ is an indicator function which equals 1 if the agent attends college and 0 otherwise. The subscripts and superscripts are avoided wherever it is possible to do so without confusion.

College Choice

Agents are born with wealth level y_0, schooling cost f and disutility from attending college κ. These are drawn from a joint distribution $F(y_0, f, \kappa)$. Agents are also characterized by their entrepreneurial ability $z \in Z = [\underline{z}, \infty)$. In the first period all agents start out with $z = \underline{z}$.

There are many ways in which schooling cost is covered in reality. There are grants, scholarships, parental contributions and so on. For ease of modeling, I assume that the schooling cost f is any pecuniary cost left after other sources, besides student loan and personal wealth, are used. Thus, student loan d is determined using

$$d = \max\{f - y_0, 0\}$$

Let $U_c(y_0, \kappa, f)$ be the expected utility of going to college and $U_{nc}(y_0)$ be the expected utility of not going to college. The agent chooses to go to college if

$$U_c(y_0, \kappa, f) \geq U_{nc}(y_0).$$

Debt Repayment

Student debt holders face an exogenously determined interest rate, r_d[18]. The debt is repaid at the end of every period using the standard repayment plan. Under this plan, a fixed amount is paid every period for the first ten periods. The standard repayment amount

[17] See Heckman et al. (1998)

[18] Unlike Ionescu (2009), I abstract from shocks to the interest rate. Prior to 2006, interest rates on student loan could change over time. However, in recent years, interest rates are fixed at the level that was determined during the time of borrowing.

is calculated using the simple interest formula and is given by

$$pay_j = \frac{r_d}{(1+r_d)\left[1 - \frac{1}{(1+r_d)^{10-(j-1)}}\right]} d_j \ , \quad 1 \leq j \leq 10 \tag{1.1}$$

The debt level evolves according to

$$d' = (1+r_d)(d - pay). \tag{1.2}$$

Once the repayment periods are over, $d = 0$.

Timeline and Choices

For ease of exposition, I begin by explaining the sequence of events starting from the second period. The agent starts out with the vector of state variables (y, z, d, j, s) where y is wealth, z is entrepreneurial ability, d is outstanding student debt, j is age and s is education level. The state variable s takes the following values

$$s = \begin{cases} 1 & \text{if agent has college education} \\ 0 & \text{if agent does not have college education} \end{cases}$$

Figure (6) explains the sequence of events for an educated agent within a period.

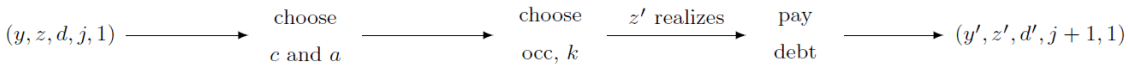


Figure 6: Sequence of events after first period

The first choice that the agent makes is on the division of wealth into consumption c and risk-free asset a,

$$c + a = y$$

Following the consumption-savings decision, the agent makes his decision on occupation. He can either become a worker or an entrepreneur. Workers earn a wage that is determined by his education level. If the agent has college education, he becomes a skilled worker and can earn wage w_s, whereas if the agent didn't go to college, he becomes an unskilled worker who earns w_u. We let

$$w_s = \bar{h} w_u,$$

where $\bar{h}$ denotes the skill premium. In the data, there is an age profile for wages that initially grows and declines towards the end of the life-cycle. This is usually explained through on the job training as in Ben-Porath (1967) or learning by doing as in Imai and Keane (2004). However, since in the present model agents switch between occupations over time, these forces are hard to incorporate. As a simplifying assumption, I let wages to remain constant over time but differ across educational groups. Bhattacharya et al. (2013) make a similar assumption in their life-cycle model of occupational choice.

If the agent chooses to become an entrepreneur, he invests capital k into the following technology

$$z'k^{\nu} + (1-\delta)k$$

where $\nu \in (0,1)$ is the parameter dictating the marginal return on investment. z' is a random entrepreneurial ability, which realizes after the capital investment is made. As can be seen in figure (6) ability is realized within the period. Entrepreneurial ability is persistent and the z at the beginning of the period works as a signal for what level of ability will be realized. In particular, following Buera et al. (2011), I assume that with probability γ, z remains unchanged and with probability $1-\gamma$ a new ability is drawn from the distribution $\eta_i(z)$, where $i \in \{c, nc\}$.

Income uncertainty is a crucial element in the model. The time-line for occupational choice introduces uncertainty in becoming an entrepreneur, which is different from Cagetti and De Nardi (2006) and Buera et al. (2011), where capital is chosen after entrepreneurial ability is realized. This simplifies the problem by making the entrepreneur's capital choice a static problem - producing analytical solutions. Introducing income uncertainty makes the problem dynamic and much more complicated[19].

The agent pays a tax on the wage/profits at the rate τ and makes debt repayments. Using $\pi' = z'k^{\nu} - (r+\delta)k$, wealth next period is given by

$$y' = \begin{cases} (1-\tau)\pi'(z',k) + (1+r)a - pay & \text{for entrepreneur} \\ (1-\tau)w_i + (1+r)a - pay & \text{for worker} \end{cases}$$

[19] A similar structure to this paper is found in Glover and Short (2015).

An entrepreneur can borrow for capital but he cannot choose infinite levels of capital. In particular, the entrepreneur is restricted by the constraint

$$(1-\tau)(\underline{z}k^{\nu}-(r+\delta)k)+(1+r)a-pay>0.$$

The constraint implies that entrepreneurs cannot borrow at a level which will leave him with negative wealth next period. Borrowing is done within a period. There is no inter-temporal borrowing, i.e. $a \geq 0$.

In the first period, agents do not consume and start out with $z = \underline{z}$. The rest of the decisions are the same as after the first period. The following tree figure demonstrates the decisions made.

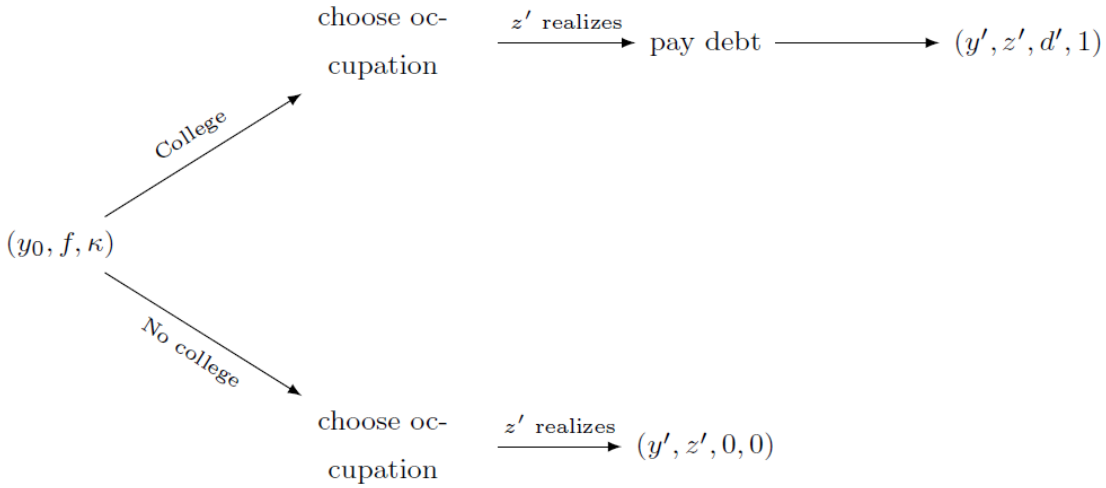


Figure 7: Sequence of events in the first period

Corporate Sector

The model also features a representative corporate sector that operates the following production function

$$Y_c = Z_c K^{\alpha} H^{1-\alpha}$$

where Z_c, K and H are productivity, physical capital and human capital respectively. The corporate sector maximizes profit by solving

$$\max_{K,H} \; Z_c K^{\alpha} H^{1-\alpha} - RK - w_u H$$

Capital Rental Market

The rental price R satisfies

$$R = r + \delta.$$

Government

The government in this economy lends to the students and spends an amount G, which doesn't bring any utility to the agents. It finances these expenditures by collecting payments on the loans and taxes. The budget constraint is given by

$$\begin{aligned}\int d \times I_{\{college=1\}} \; \partial y \; \partial f \; \partial \kappa + G = &\sum_{j=1}^{10} \int_Y \int_Z \int_D (p(y,z,d,j,1)) \; \partial y \; \partial z \; \partial d \\ &+ \sum_{j=1}^{J} \sum_{c=0}^{1} \int_Y \int_Z \int_D \tau w + \tau \pi(y,z,d,j,c) \; \partial y \; \partial z \end{aligned} \tag{1.3}$$

Value Functions

The value function of an agent with college degree is given by

$$V(y,z,d,j,1) = \max \left\{ V^E(y,z,d,j,1), V^W(y,z,d,j,1) \right\} \tag{1.4}$$

where V^E and V^W are value functions of the entrepreneur and the worker respectively.

The value function and the problem of the entrepreneur is given by

$$V^E(y,z,d,j,1) = \max_{c,a,k} u(c) + \beta E V(y',z',d',j+1,1) \tag{1.5}$$

$$\begin{aligned} s.t. \qquad & c + a = y \\ & (1-\tau)\underline{z}k^\nu - (r+\delta)k + (1+r)a - pay > 0 \\ & y' = (1-\tau)z'k^\nu - (r+\delta)k + (1+r)a - pay \\ & d' = (1+r_d)(d - pay) \\ & c > 0, \; y > 0 \end{aligned}$$

Similarly, the worker's problem is given by

$$V^W(y,z,d,j,1) = \max_{c,a} u(c) + \beta EV(y',z',d',j+1,1) \tag{1.6}$$

$$\begin{aligned} s.t. \quad & c + a = y \\ & y' = (1-\tau)w_s + (1+r)a - pay \\ & d' = (1+r_d)(d - pay) \\ & c > 0,\ y > 0 \end{aligned}$$

pay is determined by equation (1.1).

Similarly, the value functions and the problems for the agents with no college are given by

$$V(y,z,0,j,0) = \max\{V^W(y,z,0,j,0), V^W(y,z,0,j,0)\}. \tag{1.7}$$

The value function and the problem of the entrepreneur is given by

$$V^E(y,z,0,j,0) = \max_{c,a,k} u(c) + \beta EV(y',z',0,j+1,0) \tag{1.8}$$

$$\begin{aligned} s.t. \quad & c + a = y \\ & (1-\tau)\underline{z}k^\nu - (r+\delta)k + (1+r)a > 0 \\ & y' = (1-\tau)z'k^\nu - (r+\delta)k + (1+r)a \\ & c > 0,\ y > 0 \end{aligned}$$

Similarly, the worker's problem is given by

$$V^W(y,z,0,j,0) = \max_{c,a} u(c) + \beta EV(y',z',0,j+1,0) \tag{1.9}$$

$$\begin{aligned} s.t. \quad & c + a = y \\ & y' = (1-\tau)w_u + (1+r)a \\ & c > 0,\ y > 0 \end{aligned}$$

The utility of choosing to go to college in the beginning of the first period is given by

$$U_c(y_0, \kappa, f) = V(y, \underline{z}, d, 1, 1) - \kappa$$

where

$$d = \max\{f - y_0, 0\}$$

and

$$y = \max\{y_0 - f, 0\}.$$

Similarly, the utility of choosing to not go to college is given by

$$U_{nc}(y_0) = V(y_0, \underline{z}, 0, 1, 0)$$

At the beginning of period 1, the agent solves

$$U(y_0, f, \kappa) = \max\{U_c(y_0, \kappa, f), U_{nc}(y_0)\} \tag{1.10}$$

1.5 Stationary Competitive Equilibrium

Below I define the policy functions.

$$\begin{aligned}
&o : Y \times Z \times D \times J \times S \to R_+ && \text{(occupational choice)}\\
&c : Y \times Z \times D \times J \times S \to R_+ && \text{(consumption choice)}\\
&a : Y \times Z \times D \times J \times S \to R_+ && \text{(asset level)}\\
&k : Y \times Z \times D \times J \times S \to R_+ && \text{(capital level)}\\
&s : Y \times F \times K \to (0, 1) && \text{(schooling choice)}
\end{aligned}$$

Let Ω be the stationary distribution over the state variables.

$$\Omega : Y \times Z \times D \times J \times S \to [0, 1]$$

A stationary competitive equilibrium is given by a set of policy functions $o(y, z, d, j, s)$, $c(y, z, d, j, s)$, $a(y, z, d, j, s)$, $k(y, z, d, j, s)$, $s(y_0, f, \kappa)$ K, L_s, L_u, invariant distribution over the state variables, $\Omega(y, z, d, j, s)$, tax rate τ and prices w_s, w_u, r such that:

1. Given the prices, the policy function $o(y, z, d, j, s)$ solves (1.4) and (1.7), policy functions $c(y, z, d, j, s)$, $a(y, z, d, j, s)$, $k(y, z, d, j, s)$ solve (1.5), (1.6), (1.8) and (1.9), and policy function $s(y_0, f, \kappa)$ solves (1.10).
2. Given the prices, the corporate sector maximizes its profit. The optimal choices K and H satisfy

$$R = \alpha Z_c K^{\alpha-1} H^{1-\alpha}$$
$$w_u = (1-\alpha) Z_c K^{\alpha} H^{-\alpha}$$

3. Rental price is given by

$$R = r + \delta$$

4. The government balances its budget, given by (1.3).
5. The invariant distribution is consistent with the policy functions.
6. Markets clear. I.e.

$$K + \int k(y, z, d, j, s) \partial\Omega(y, z, d, j, s) = \int a(y, z, d, j, s) \partial\Omega(y, z, d, j, s)$$
$$H = \int \left[I_{\{c=0, o(y,z,d,j,s)=w\}} + \bar{h} I_{\{c=1, o(y,z,d,j,s)=w\}} \right] \partial\Omega(y, z, d, j, s)$$

1.6 Quantitative Exercise

Calibration

Some of the parameters are borrowed from the literature, while others are calibrated to match statistics in the data. A period in the model is one year in the data. I use $T = 38$ to study the population between the ages 23 and 60. There is no retirement in the model.

Preferences

The economic agents derive flow utility from consumption and bequest at the end of the

period. I use CRRA utility function for both.

$$u(c) = \frac{c^{1-\sigma}}{1-\sigma}$$
$$v(b) = \zeta \frac{b^{1-\sigma}}{1-\sigma}$$

The parameter for relative risk aversion σ is a common parameter in DSGE models. I assign a value of 3 to σ, which is within the range of commonly used values. Lifetime preference is also affected by the discount factor β. Following Buera et al. (2011), I assign it a value of 0.92. ζ captures altruistic motive. To pin down the value of ζ, I follow Guren et al. (2018) and compare the ratio of net worth for the median agent between the ages of 60 and 50.[20] The values for net worth is taken from the 2016 summary variables available in the public dataset from the Survey of Consumer Finances.

The psychic cost of college is given by κ, which is drawn from an exponential distribution.

$$\omega(\kappa) = \psi e^{-\psi\kappa}$$

The parameter ψ is used to match the fraction of population with a college degree. This number averages around 33% between 2010 and 2017 in the Current Population Survey.

Technology

From Gollin (2002), the capital share α in the production function of the corporate sector is given the value 0.33. The depreciation rate δ is assigned the value 0.06, following Buera et al. (2011). The productivity parameter for the production function is normalized to equal 1.

Following Cagetti and De Nardi (2006), the parameter ν is assigned the value 0.88. The stochastic process for entrepreneurial ability follows Buera et al. (2011). The ability variable z persists with probability γ and with probability $(1-\gamma)$ an individual draws a new ability level from an exponential distribution, with pdf η over ability levels. The exponential distribution has scale and given by θ_c if he has college education and θ_{nc} if he doesn't.

$$\eta_i(z) = 1 - e^{-\frac{(z)}{\theta_i}}$$

[20] Guren et al. (2018) compare net worth between ages 60 and 45.

where $i \in \{c, nc\}$.

In order to identify these parameters $(\gamma, \theta_c, \theta_{nc})$, I target the fraction of skilled and unskilled individuals who are entrepreneurs, the fraction of individuals who respond having negative business income in the Current Population Survey and the fraction of individuals who transition out of entrepreneurship in a period. These statistics are 0.09, 0.09, 0.03 and 0.1 respectively.

The wage premium $\bar{h}$ is set by comparing per capita wages of those with college education and those without. This gives $\bar{h} = 1.6$.

The interest rate on debt, r_d, faced by the student is set by federal law and is fixed. The rate has varied over time in the data and the interest rate faced by a particular borrower is set at the time of borrowing. Although the rate was lower in recent years to I set a value of $r_d = 0.068$ to be consistent with the interest rate that prevailed for the lengthiest period in recent years. Ionescu (2009) uses the same interest rate in her analysis.

Agents draw the cost of going to college, κ, from a uniform distribution over $[0, \mu]$. I assume that the distribution is independent of initial wealth and pyschic cost of attending college. μ is chosen to match the average amount of student debt at the time of graduation. The value for average debt is taken from Hershbein and Hollenbeck (2015), who compute the statistic using the National Postsecondary Student Aid data. They provide average debt amount for various years but I restrict the observations to 2000 and onwards and take the average of the available data points. The average student debt for those years is $\$17,705$. This gives us a value of 9.2 for μ.

Table (2) summarizes the pre-determined parameter values.

Parameter	Value	Source/Target
σ	3.0	Standard value
β	0.92	BKS (2011)
α	0.33	Gollin (2002)
δ	0.06	Standard value
r_d	0.068	Ionescu (2009)
ν	0.88	Cagetti and Denardi (2006)
Z_c	1.0	Normalization
T	38	38 years of working age

Table 2: Parameter values

The following table summarizes the parameter values that are obtained through calibration. Except for the ratio of net worth at ages 60 and 50, the model performs satisfactorily in other dimensions.

Parameter	Value	Target	Data	Model
ζ	3.0	Networth ratio at ages 60 and 50	2.92	2.15
ψ	1.42	Fraction of college graduates	0.33	0.34
μ	9.2	Mean Student debt	$\$17,705$	$\$17,220$
θ_c	0.71	Fraction of skilled entrepreneur	0.09	0.08
θ_{nc}	0.81	Fraction of unskilled entrepreneur	0.09	0.08
γ	0.94	Occupational switching rate	0.10	0.05
$\bar{h}$	1.6	Ratio of wages for skilled and unskilled	1.60	1.60

Table 3: Calibrated parameters

In evaluating the model, the rate of entrepreneurship over age is crucial because the younger agents tend to hold more of the debt. The age profile wasn't targeted in the

calibration process, but the model does well in producing the rate of entrepreneurship by age. Below, the graphs showing these rates are presented for the skilled and unskilled populations.

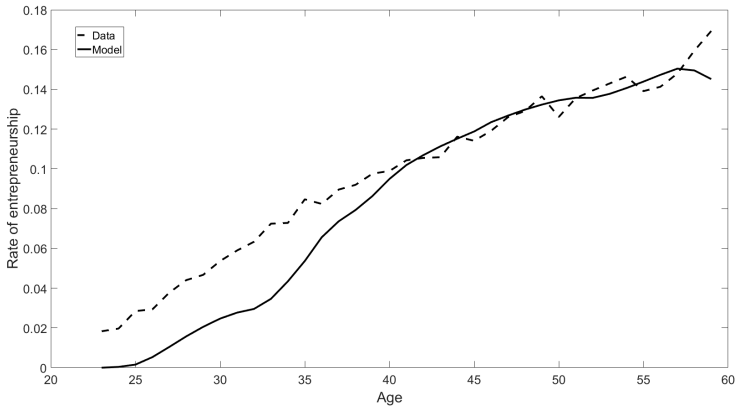


Figure 8: Rate of entrepreneurship for college graduates

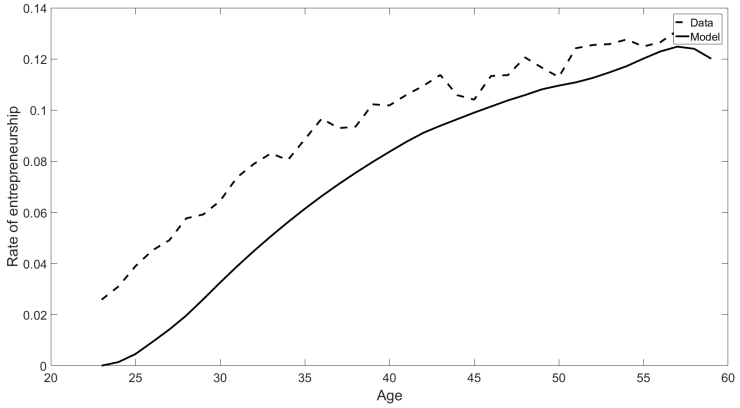


Figure 9: Rate of entrepreneurship for those without college degree

The model under-predicts the rates of entrepreneurship for both skilled and unskilled agents. This is particularly the case during early periods of their lifetime. This points to the importance of initial conditions with regards to entrepreneurship. In the model agents start out with the lowest level of entrepreneurial ability and a wealth distribution in which most agents have low levels of wealth. In reality, there are other factors that might contribute to entrepreneurial choice early in one's life. Entrepreneurial ability might be transferable from parents to kids, which would make some young agents more able as entrepreneurs. Likewise, some agents might inherit firms from their parents and start out as entrepreneurs

in the very beginning of their lives. These are important dimensions that can help explain the age profile of entrepreneurship better. In the exercise here, I am more interested in finding the difference in the rate of entrepreneurship under different debt repayment plans, but incorporating other dimensions that can help explain the levels of entrepreneurship will be something to explore in the future.

Income-based Repayment

We now solve the model under income-based repayment. Under income-based repayment plan the payment amount is given by the following formula

$$pay_j = \min\{0.10 \times \max(inc_j - pov, 0)\} \quad 1 \leq j \leq 20 \tag{1.11}$$

where pov is 150% of the poverty level. Under income-based repayment, any unpaid amount after period 20 is forgiven. In reality, students are free to choose any repayment plan at any time. In particular, they can switch between either of the repayment plans. In the exercise here, I conduct the experiment as if the two plans were two different regimes. Until recently, almost all of the students were enrolled in the standard repayment plan. The number of students enrolled in the income-based plan is now increasing, and with the plans to expand it further,[21] the assumption is a first step in analyzing its effects. More importantly, this makes the problem significantly easier to solve.[22]

When repayments are income-based, agents are less worried about having to repay a hefty amount when their income is low. In the model, the borrowing constraint faced by the entrepreneurs ensures that consumption cannot be negative, but for the same income level, agents get to consume more when repayments are income-based compared to the standard repayment plan. Additionally, since the borrowing constraint depends on asset level and the lowest realization of entrepreneurial ability, the constraint is more relaxed when repayments are income-based. Figure (10) shows how occupational choice varies under different repayment plans by looking at the policy functions of the agents with respect to wealth and ability levels. I fix the debt amount to $\$21,000$ and age to 28 years old. The

[21] See "Investing in Higher Education: Benefits, Challenges, and the State of Student Debt", *Executive Office of the President of the United States, July 2016*

[22] To make the problem computationally tractable, other papers like Ionescu (2009) and Ji (2018) allow agents to switch once between the repayment plans.

agents choose to become entrepreneurs to the right of the curve and choose to become workers to the left of the curve. Generally, agents choose to become entrepreneurs when their wealth and ability levels are high. As expected, the curve for income-based repayments is to the left of the curve for standard repayments. The threshold levels of ability and wealth is lower for agents with income-based repayments than those with standard repayments. The threshold starts to merge when wealth levels are higher. This is when debt repayments as a fraction of wealth is less significant.

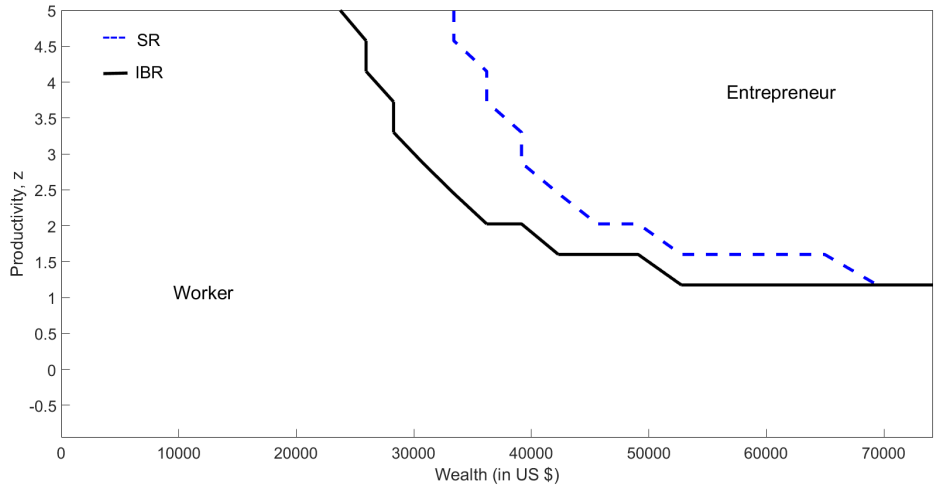


Figure 10: Occupation choice (SR - standard repayment, IBR - income-based repayment)

Now we examine the general equilibrium effects of considering the repayment plans.

	Standard Repayment	Income-Based Repayment
College enrollment	34%	41%
Average loan	\$15,435	\$18,323
Tax Rate	0	1.5%
Income for skilled	\$65,361	\$60,527
Income for unskilled	\$38,488	\$35,604

Table 4: Statistics under repayment plans

College enrollment is affected by the fact that repayments when entrepreneurial income is low are also low. This lenient repayment plan attracts more college-goers. However,

insurance against entrepreneurial risk is not the only motive for going to college. With the standard repayment plan, the marginal students who decide not to go to college are those who draw high pecuniary costs of going to college. When repayments are income-based, their repayment amounts are only a fraction of their income, which could be lower than under standard repayment amount during the initial years of life. When agents are impatient and inter-temporal borrowing is not allowed like in this model, this also leads to higher college enrollment. And since those facing higher costs are entering college, the average loan goes up as well. Since there is an upsurge in human capital following an increase in college enrollment, wages go down for both skilled and unskilled workers. The equilibrium interest rate is lower than the interest rate on student loan. Therefore, under the standard repayment plan the government does not levy any tax on the agents.

Figure (11) shows the rates of entrepreneurship for the two different repayment plans. Entrepreneurship for those without college degree is unaffected in this experiment, so I only focus on those who have a college degree. Under income-based repayments there is a higher rate of entrepreneurship in the beginning. Those enrolled in standard repayments catch up and the rates coincide towards the later part of the life-cycle.

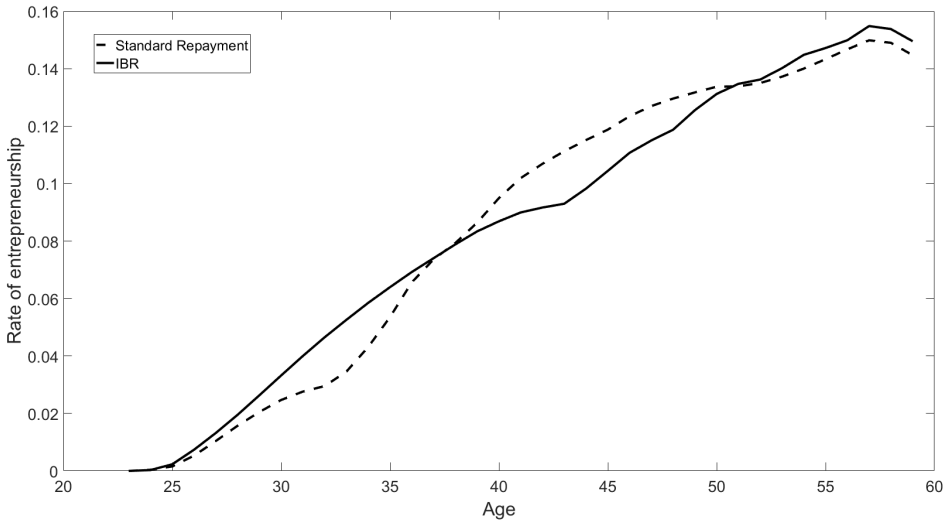


Figure 11: Rates of entrepreneurship by repayment plans

First, we observe that under income-based repayment, there is a higher fraction of agents choosing to become entrepreneurs when they are young. This is expected because when repayments have insurance built into it, agents are less reluctant to choose a riskier occupation.

Also, when repayments are income-based the borrowing constraint for entrepreneurs are relaxed, which allows high ability entrepreneurs to invest more capital and therefore increase their revenue. Also, in the above figure, observe that for standard repayments, entrepreneurship starts to accelerate around the age 33. This is the age when repayments are over and agents do not have debt anymore. On the other hand, in the case of income-based repayments, agents still have repayments to make. Given that debts accumulate interest every period, agents who hold debts prefer less risky occupation. Even though there is relief in repayment burden, choosing to become an entrepreneur is likely to increase debt in the next period. This is not the case in the standard repayment plan because agents will have run down their debt. Once repayments are over in the income-based case, entrepreneurship under both repayment plans coincide.

The fact that entrepreneurship rates catch up, initially for the standard repayments and later for the income-based repayment suggests that tightened borrowing constraint due to lower levels of asset may be quickly overcome. During young age under standard repayment, for example, with lower levels of income savings are also lower, which decreases wealth levels and constrains the entrepreneurs. However, the acceleration of entrepreneurship post repayments suggest this effect does not last long.

In the table below, I show how entrepreneurship is affected during different phases of the life-cycle. The different age groups reflect the points of intersection in figure (11).

Age group	Standard Repayment	Income-Based Repayment	Percent Change
23-36	2.37%	3.09%	30.19 %
37-47	10.11%	9.11%	-9.94 %

Table 5: Rates of entrepreneurship by repayment plans and ages

Notice that in the aggregate, there is little change in the rates of entrepreneurship under the two repayment plans. However, the percent changes are substantial if we focus on just the young entrepreneurs. This also suggests that while student debt can affect younger entrepreneurs scarring effects are not that significant.

No College Choice

College choice and therefore debt amounts are endogenous in the model. As such, in

comparing the repayment plans, the effects on entrepreneurship can be due to different levels of debt carried by the agents. It then becomes unclear as to how much of the effect is due to insurance motive or a relaxed borrowing constraint under income-based repayments. To ensure comparability I abstract away from college choice and study the case where agents have the same amount of debt. The only thing that changes is the repayment plans.[23] Table (6) shows how the rates of entrepreneurship look like for different ages under the two repayment plans.

Age group	Standard Repayment	Income-Based Repayment	Percent Change
23-36	2.44%	3.19%	31.04 %
37-47	9.43%	8.94%	-5.24 %

Table 6: Rates of entrepreneurship by repayment plans and ages

The percent change for different age groups and the aggregate are similar to the case with college choice. However, the magnitude of percent change during the age group 37-47 is smaller. This is not surprising given that the agents enter college with a higher amount of loan when we allow college choice. Under income-based repayment, this higher amount of debt weighs more heavily on the agents during the second phase of their lives.

Welfare

In computing the welfare, I calculate the percent increase in lifetime consumption that will make an agent indifferent between the two repayment regimes. I find that there is a 0.69% increase in welfare under the income-based repayment compared to the standard repayment.

In the model, agents have similar outcomes during the latter periods of their lives. However, their occupational choices are highly affected during the early years when loans are being repaid. During the middle phase of the agent's life, under the standard repayment agents are debt free and can consume relatively more. Given that the discount factor is somewhat small, the higher level of consumption feasible with the income-based repayment during early years increases overall welfare.

[23] The parameters are kept the same as in calibration.

Discussion

Policies related to repayment of loans are important as far as entrepreneurship is concerned. Steps in that direction have been taken in the past. For instance, interest rate on the loan changed from being time-varying to fixed in 2006.[24] This paper analyzes the newly introduced income-based repayments. The model in this paper suggests that while there are compositional effects of changing repayment schemes, the rates of entrepreneurship are similar in the aggregate. This may not necessarily be true, especially when the model does not consider the role of experience among other things. I conjecture that adding gains in entrepreneurial experience, which is an important aspect of any occupation, can produce longer term dynamic benefits of income-based repayments and an overall higher levels of entrepreneurship. In the paper there are lower rates of entrepreneurship for those in the middle of their lifecycles. The young benefit more by having their repayments income-based. They are the ones who generally have lower levels of wealth and are affected more by income shocks and financing constraints. Had experience been valuable, there would be a higher retention of entrepreneurs. The dynamic benefit could also result from entrepreneurs quickening their accumulation of assets, relaxing their financing constraints and operating at more optimal levels.

The issue of student loan is under further scrutiny given the ever-increasing costs of attending a college. Figure (12) shows that this cost is has been increasing steadily over the years. Unless there is an increase in other forms of financing, this increase will push towards higher loan amount and a change in the composition of debt with high interest private loans being more ubiquitous. A higher amount of government loan will be an even more challenging under the standard repayment plan since the repayment amount will go up as well. The income-based repayments can become even more important to encourage entrepreneurship. But because the income-based repayments incur societal costs through taxation, optimal policies might have to be revised.

[24] See "https://studentaid.ed.gov/sa/types/loans/interest-rates"

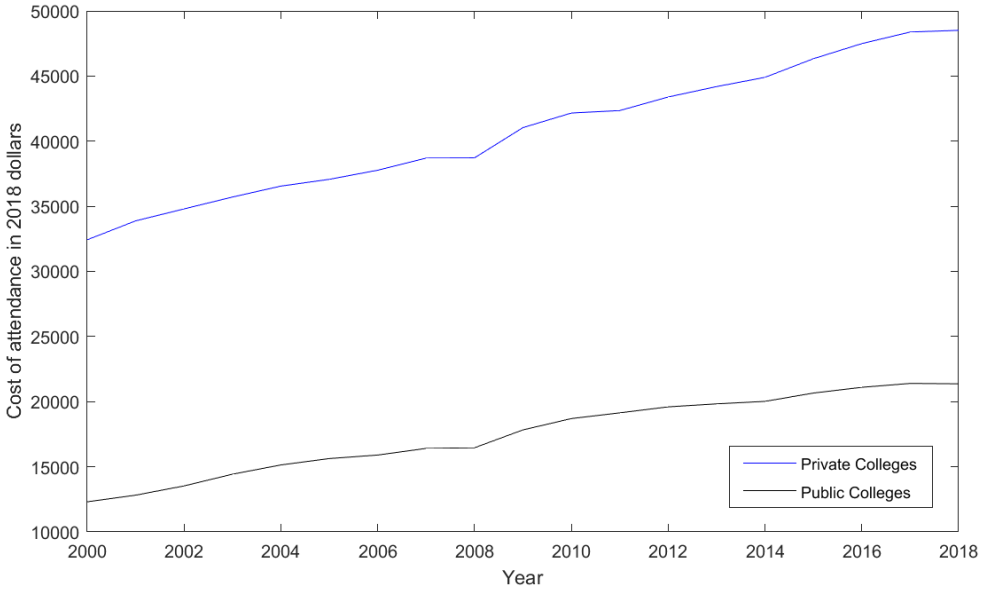


Figure 12: Cost of college attendance. Source: Collegeboard

The decline of entrepreneurship is a concerning issue. The social costs of this phenomenon needs to be better understood in order to design better loan-related policies. I consider a few occupational features to study occupational choice. However, there are other possible implications of the effects of student loan on entrepreneurship. For example, entry into entrepreneurship might be important in economic growth through innovation. Entrepreneurship, with the flexibility it allows, can be liberating to those with time constraints. As a result economic decisions like whether to have children or whether to enjoy leisure are also affected. These are aspects related to entrepreneurship that might be affected by student debt but are outside of the scope of the paper. Exploring these can be meaningful.

1.7 Conclusion

In this paper, I build a model of occupational choice over the life-cycle - individuals can choose to become wage earners or entrepreneurs. I study the impact of student loan on occupational choice and how different repayment plans affect the rate of entrepreneurship. I find that in aggregate the two types of repayment have little effect, but there is substantial

compositional effects. In particular, under the standard repayment plan agents choose the safer occupation, wage earner, when they are young but once the repayment period is over, more of them choose entrepreneurship. Once the repayment periods are over for both types of repayment, rates of entrepreneurship converge, suggesting a lack of persistent effect. Overall, there is a small increase in welfare under the income-based repayment.

2.0 Price of Investment Goods and Structural Change: Analysis of the Korean Economy

2.1 Introduction

Structural change, where labor is reallocated from the agricultural to non-agricultural sectors, is a salient feature of any growing economy. This fact was documented in their early work by Rothbarth (1941), Chenery (1960) and Kuznets (1957), among others. More recently, Herrendorf et al. (2014) document this phenomenon for a larger group of countries, including those that grew rapidly in recent times like Japan and Korea. In this paper, I examine the contribution of the decline in the price of investment in structural change as well as economic growth. In particular, the decline in the price of investment catalyzes the formation of capital necessary to boost the economy and the capital-intensive non-agricultural sector. It also has implications for output per capita and in particular output per capita increases when the price of investment declines.

To quantify the effect of the decline in the price of investment I use the Korean economy as a laboratory. Figures (13) and (14) show the employment and value added shares in the agricultural sector over the time period 1970-2005.[1] The data for employment share was taken from the World Bank and the data for the value added shares was taken from the Bank of Korea, Economic Statistics System. Both measures show a drastic shift in the economy away from agriculture. This is in contrast to many of the advanced economies that went through the process over a much longer period of time. Just before this transition in the 1960s, the Korean economy underwent major reforms that contributed to the decline in the price of investment. Among other reforms, the tariff on the import of capital goods was substantially reduced (Jung-ho (1993)). The years following the introduction of these reforms on tariff saw a gradual decline in the price of investment good. Figure (15) shows the relative price of investment good. The Chinn-Ito index, which measures the restriction

[1] I restrict data to this period because the value-added share didn't start to decline until mid-1960s. Investment price also started declining around the same time and flattened around 2005 before the global financial crisis.

in cross-border financial transactions, also shows an increase in financial openness of the Korean economy (Chinn and Ito (2006)). The normalized index, between 0 and 1, shows the Korean economy's index increase from 0.16 in 1970 to 0.41 in 2005 and as high as 1 in recent years.

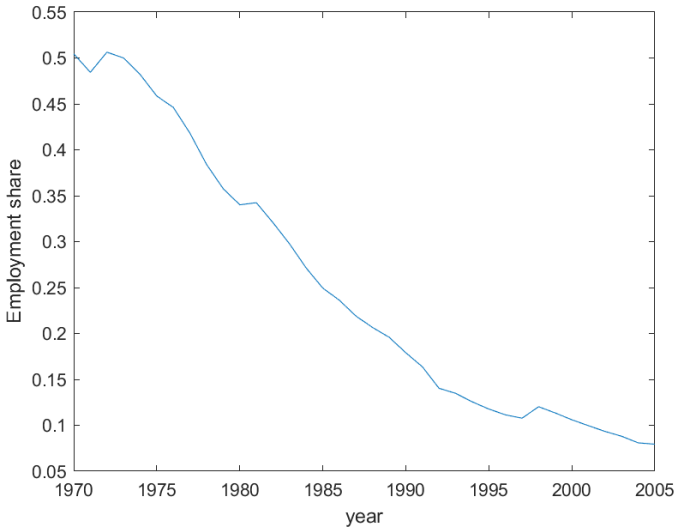


Figure 13: Employment share in agriculture in Korea. Source: World Bank

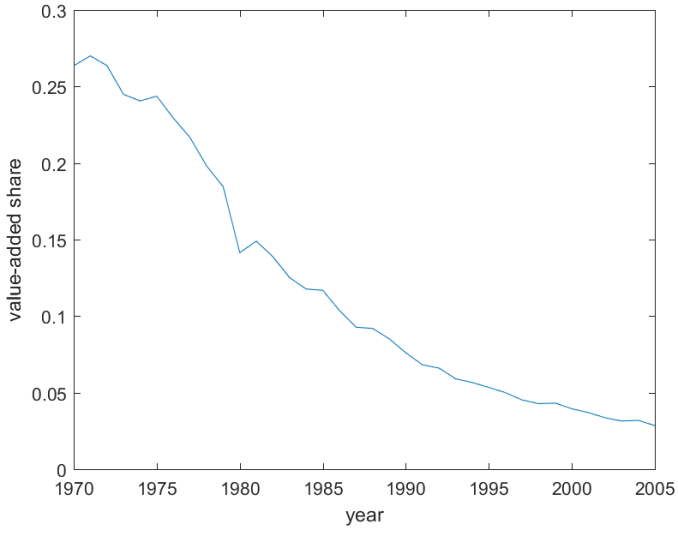


Figure 14: Value added share in agriculture in Korea. Source: Bank of Korea

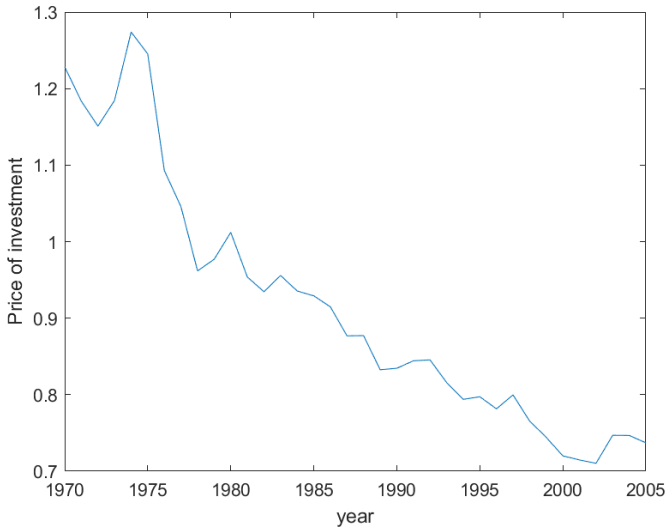


Figure 15: Relative price of investment. Source: Penn World Table 7.1

The model in the paper comprises of two sectors: an agricultural sector and a non-agricultural sector.[2] An important feature of the economy is that the agricultural sector requires just labor,[3] while the industrial non-agricultural sector employs both capital and labor, combined through a constant returns to scale production function. As is common in the literature, the agricultural good is purely for consumption, whereas the non-agricultural good is used for consumption as well as investment. However, there is a distortion that doesn't allow a one-to-one conversion of consumption of the non-agricultural good to investment. Higher levels of distortion imply that capital is more expensive. As the economy undergoes reforms, this distortion is gradually removed, which expedites the process of capital accumulation and structural change. The model also features non-homotheticity in the preferences as in Kongsamut et al. (2001).[4] There is a subsistence level of consumption of

[2]It is common in the literature to study three sectors, namely agricultural, manufacturing and services. Different measures of structural change show that as a function of income, there is a downward trend in the shares of agricultural sector, a hump shape in the manufacturing sector and an increase in the services sector. Since this paper is concerned with the effect of the price of investment goods and the services and manufacturing sectors tend to have the same factor shares in general, I distinguish the economy into just the agriculture and non-agricultural sectors. Also, the commonly used Stone-Geary utility function, also used in this paper, is less effective in capturing the hump-shape of the manufacturing share. See for example, Buera and Kaboski (2009) and Uy et al. (2013)

[3]Valentinyi and Herrendorf (2008) show that this is not the case for an advanced country like the US. They find that factor shares are almost equal to across sectors. However, in poorer countries, the technology used in the agricultural sector is usually more primitive. Other papers like Gollin et al. (2007) also model the agricultural sector as running a labor-only technology.

[4]With non-homothetic preferences, agricultural goods are viewed as necessities, while non-agricultural

agricultural good, which must be produced before there is production of non-agricultural goods. This non-homotheticity in preference is responsible for generating structural change in the model alongside the decline in investment price.

The model is calibrated to match several features of the economy including the level of output, investment rates, sectoral employment shares and sectoral value added shares. In the calibration process, the level of distortion on investment is computed to match the price of investment in the data. I then study a counterfactual experiment, where the distortion is kept at the 1970 level, which shows that in the presence of the distortion there is a decrease in output per capita of up to 22%, and an increase in agricultural employment shares of up to 12%. The removal of distortion also facilitates a higher level of investment and capital deepening.

2.1.1 Related Literature

This paper is mostly related to the literature on structural change.[5] Two popular theories that explain this empirical fact rely on non-homotheticity of preferences and differential productivity growth between sectors as in Kongsamut et al. (2001) and Ngai and Pissarides (2007)[6] respectively. The model used in this paper incorporates non-homothetic preferences, which is especially important for economies transitioning from very low levels of income. The differential rates of productivity growth is less important in the case of Korea since a faster productivity growth does not precede structural change. Among other theoretical work, Acemoglu and Guerrieri (2008) construct a model of non-balanced growth where sectors differ in their factor shares. Their model predicts an increase in output, accompanied by a decrease in the capital and employment in the capital-intensive sector. Buera and Kaboski (2012) build a model in which high-skilled and specialized labor contributes to the increase in the service sector. They are able to explain the rapid rise in the service sector observed in the data. Matsuyama (2009) studies structural change in the context of an open economy and argues

goods are luxury goods. The relative demand for agricultural goods decline as income level rises generating a structural change away from the agriculture sector.

[5] See Herrendorf et al. (2014) for a survey of the literature.

[6] Ngai and Pissarides (2007) formalize the idea first proposed by Baumol (1967). When different types of goods are complements, an increase in the productivity in the agriculture sector causes a decline in the price of agricultural goods and moves the economy towards non-agriculture sector.

for a global view to understand the patterns of structural change in the world economy. He argues that the global decline in the manufacturing sector can be attributed to productivity gains in the manufacturing sector but in a cross-section of countries higher productivity in the manufacturing sector may not be associated with decline in manufacturing.

The paper adds to the expanding literature on quantifying the role of different mechanisms in structural change. Buera and Kaboski (2009) asks whether the traditional theories of non-homothetic preferences and differential productivity growth can explain the structural change observed in the US. They first show that a model that incorporates both these forces cannot generate a balanced growth path and when combined, the two forces are incapable of explaining the structural change entirely. Specifically, the model fails to capture the rapid rise in the service sector from 1950 onward. Buera et al. (2011) quantifies the role of financial friction in the allocation of factors of production between the manufacturing and service sectors. A number of papers have looked at the role of trade in addition to the traditional mechanisms. Uy et al. (2013), Sposi (2019), Betts et al. (2017), Teignier (2018) all study the Korean economy and highlight the importance of openness in the structural change. Other examples of quantitative studies of the open economy include Coleman (2007), Reyes-Heroles et al. (2018), Galor and Mountford (2008), Stefanski (2014) and Ungor et al. (2012).

This paper is also related to the literature on the role of capital accumulation during the growth process. For example, Young (1994) and Young (1995) highlight the role of increasing investment rates in explaining growth miracles in East Asian countries. The model in this paper also features a high price of capital during early years of development, which is consistent with the findings of Caselli and Feyrer (2007). The model in this paper is able to generate the path of investment rates qualitatively as well as quantitatively.

The paper is organized as follows. I first lay out the model in section 2, define the competitive equilibrium and discuss the features of the model. In section 3, I calibrate the model to the Korean economy and in sub-section 3.1, I run counterfactual experiments to quantify the effects of openness and discuss possible channels to explain the discrepancy between the open and closed economy. Section 4 concludes.

2.2 Model

The model is a canonical version of models used to study structural change. There are two sectors in the model: agriculture and non-agriculture. Agricultural goods are only used for consumption while the non-agricultural good can be used for consumption and investment. There is a representative household in the economy that is infinitely lived and consumes these two goods. The consumption of agricultural good is represented as C_t^1 and the consumption of non-agricultural good is represented as C_t^2. The objective of the agent is to maximize his lifetime utility given by

$$\sum_{t=0}^{\infty} \beta^t u(C(C_t^1, C_t^2)). \tag{2.1}$$

where $0 < \beta < 1$ is the discount factor. The per-period utility function satisfies $u' > 0$, $u'' < 0$, $\lim_{c\to 0} u'(C) = \infty$ and $\lim_{C\to\infty} u'(C) = 0$. $C(C_t^1, C_t^2)$ is a constant elasticity of substitution function that aggregates the consumption goods - i.e.

$$C(C_t^1, C_t^2) = \left[\theta(C_t^1 - \bar{c})^{\frac{\epsilon-1}{\epsilon}} + (1-\theta)(C_t^2)^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon}{\epsilon-1}}$$

$0 < \theta < 1$ is the share of agricultural good and $\epsilon \geq 0$ is the elasticity of substitution between the two consumption goods. Note also that there is a subsistence requirement of the agricultural good represented by the parameter $\bar{c} \geq 0$. The preference is therefore non-homothetic and exhibits a non-linear Engel curve. In particular, the relative demand for the non-agricultural good increase as income increases.

The size of the household is given by L_t, which grows at a constant gross rate g_n. The agent maximizes his lifetime utility subject to the per-period budget constraint,

$$p_t C_t^1 + C_t^2 + \tau_t I_t = R_t K_t + w_t L_t \tag{2.2}$$

The left hand side of the constraint is the expenditure and the right hand side is the income of the agent. Aggregate capital accumulates according to the law of motion given by:

$$K_{t+1} = I_t + (1-\delta)K_t. \tag{2.3}$$

The price of non-agricultural good is normalized to one. τ_t is a distortion to capital accumulation.

There are two representative firms producing the two goods in the economy. The production functions differ in terms of the factors of production they use. The agricultural good is produced using labor only.

$$Y_t^1 = z_t L_t^1$$

The representative agricultural firm solves

$$\max_{L_t^1} p_t z_t L_t^1 - w_t L_t^1 \tag{2.4}$$

On the other hand, the non-agricultural good is produced using a constant returns to scale Cobb-Douglas production function. Unlike the agricultural sector, the non-agricultural sector uses both capital and labor.

$$Y_t^2 = K_t^\alpha (z_t L_t^2)^{1-\alpha}$$

The firm solves

$$\max_{K_t, L_t^2} K_t^\alpha (z_t L_t^2)^{1-\alpha} - R_t K_t - w_t L_t^2. \tag{2.5}$$

Note that the labor productivity in both sectors, z_t, is the same. I assume that z_t grows at a constant rate g_z over time.

The resource constraint for labor is given by

$$L_t^1 + L_t^2 = L_t, \tag{2.6}$$

where L_t is the total labor supplied by the household.

The resource constraints for the two goods are given by:

$$C_t^1 = Y_t^1 \tag{2.7}$$

$$C_t^2 + \tau_t I_t = Y_t^2 \tag{2.8}$$

Competitive Equilibrium

The competitive equilibrium is allocations $\{C_t^1, C_t^2, I_t, K_t, L_t^1, L_t^2\}_{t=0}^\infty$, *prices* $\{p_t, w_t, R_t\}_{t=0}^\infty$ *and the distortions* $\{\tau_t\}_{t=0}^\infty$, *such that*

1. *Taking prices as given, the household maximizes its lifetime utility (2.1) subject to the budget constraint (23).*
2. *Taking prices as given, the both the firms maximize their profits. I.e. they solve problems (2.4) and (2.5).*
3. *Markets clear for labor, capital and outputs. I.e. equations (2.6) - (2.8) hold and capital supplied by the household equals capital demanded by the firm in the non-agricultural sector.*

2.2.1 Discussion

In generating structural change, the two major forces discussed in the literature are declining income elasticity of agricultural goods and differential sectoral productivity growths, known as the Engel effect and Baumol effect respectively. These are primarily incorporated in growth models by introducing a subsistence parameter for the agricultural good and differing productivity growth rates across sectors. But as discussed in Buera and Kaboski (2009), including both these channels in a growth model is inconsistent with a balanced growth path at any time. If sectoral productivities grow at the same rate and relative prices are constant, balanced growth requires $\bar{c} = 0$. And if $\bar{c} = 0$ but sectoral productivities grow at different rates, a balanced growth path requires elasticity of substitution between sectoral goods to be less than one and the inter-temporal elasticity of substitution equal to one, specifically, $u(c) = \log(c)$ and $\epsilon < 1$. Since $\bar{c} > 0$ is a crucial assumption, there is no hope of getting a balanced growth path in the current model. Instead, I resort to a model that converges to a balanced growth path asysmptotically. Since intertemporal elasticity of substitution can play an important role, I use a general CRRA function. But this precludes letting prices change over time in the long-run.

With a CRRA utility function of the form

$$u(C) = \frac{C^{1-\sigma}}{1-\sigma},$$

the first order conditions that characterize the solution of the model is given by:

$$C_t^2 = \left(C_t^1 - \bar{c}\right)\left(\frac{1-\theta}{\theta}p_t\right)^{\epsilon}$$

$$\left(\frac{C_{t+1}^2}{C_t^2}\right)^{\sigma} = \beta\frac{g(p_t)}{g(p_{t+1})}\left[\frac{\alpha}{\tau_t}K_{t+1}^{\alpha-1}(z_{t+1}L_{t+1}^2)^{1-\alpha} + \frac{\tau_{t+1}}{\tau_t}(1-\delta)\right]$$

$$p_t = (1-\alpha)K_t^{\alpha}(z_t L_t^2)^{-\alpha}$$

$$C_t^2 + \tau_t K_{t+1} = K_t^{\alpha}(z_t L_t^2)^{1-\alpha} + \tau_t(1-\delta)K_t$$

$$C_t^1 = z_t L_t^1$$

$$L_t^1 + L_t^2 = L_t$$

where

$$g(p_t) = \left[\theta\left(\frac{\theta}{1-\theta}\frac{1}{p_t}\right)^{\epsilon-1} + 1 - \theta\right]^{\frac{\epsilon\sigma-1}{\epsilon-1}} \tag{2.9}$$

From equating the marginal product of labor across sectors, we find the labor allocated to the non-agricultural sector:

$$L_t^2 = (1-\alpha)^{1-\alpha}\frac{K_t}{z_t p_t^{\frac{1}{\alpha}}} \tag{2.10}$$

The labor share in the non-agricultural share goes up when capital goes up. This is intuitive because an increase in the level of capital increases the marginal product of labor in the non-agricultural sector, so there is a movement of labor into this sector. On the other hand, when agricultural price goes up, there is a higher demand for labor by the firm in the agricultural sector and labor moves out of the non-agricultural sector.

The value-added share of the agricultural sector, VA, is given by:[7]

$$VA = \frac{1-\alpha}{1-\alpha+\frac{L_t^2}{L_t^1}} \tag{2.11}$$

The value-added share has a one-to-one relation with the ratio of the labor shares. Specifically, the value added shares decreases when the employment shares in the non-agricultural

[7] Check Appendix B for derivation.

sector relative to the agricultural sector increases. Therefore, the distortion in the price of investment affects the value added shares in the agricultural (and therefore the non-agricultural) sector to the extent it affects the reallocation of labor from the agricultural to the non-agricultural sector and vice-versa.

2.3 Quantitative Analysis

Calibration

The model is solved numerically. There are several preference and technology parameters along with the sequence for distortions $\{\tau_t\}$ that need to be calibrated.

We take data from the Korean economy focusing particularly between the period 1970-2005. A period in the model corresponds to a year in the data. Table (7) lists the parameters and their values taken directly from the literature.

β	0.97
σ	2.0
α	0.33
δ	0.06
g_n	1.01

Table 7: Pre-determined parameters

The values for $\{\beta, \sigma, \alpha, \delta\}$ are all standard. The value for g_n is the growth rate of population, which equals 1.011 and the initial population is normalized to one. The data is available in the Penn-World Table 7.1.[8]

The remaining parameters are $\{\bar{c}, \theta, \epsilon, z_0, g_z, k_0\}$. These parameters are jointly calibrated to minimize the sum of the square of the difference between the output per capita, employment shares in the agricultural sector and relative price of agricultural goods in the model and the data. The data come from a few different sources. Output per capita is available

[8]Check http://pwt.econ.upenn.edu/php_site/pwt_index.php.

from the World Bank Indicators. The employment shares are taken from the World Bank. The relative price of agricultural goods is constructed using the data from OECD.[9] The parameter values are presented in table (8).

$\bar{c}$	0.49
θ	0.15
ϵ	1.55
z_0	1.09
g_z	1.05
k_0	0.97

Table 8: Calibrated parameters

The parameter ϵ is an important parameter in the literature. In a Ngai and Pissarides (2007) environment $\epsilon < 1$ is required to generate a balanced growth path. This restriction is crucial when the relative price of sectoral goods are growing as well. In our model, the relative price changes in the short-run but asymptotically remains unchanged, and hence the restriction is not important for the asymptotic balanced growth path.

It remains to find the sequence $\{\tau_t\}$. These distortions are inferred from the data on relative price of investment good. Figure (16) shows the price of the investment good and a second degree polynomial that approximates the price. This second-degree polynomial approximation is fed into the model for the period 1970-2005. For the remaining periods the price is fixed at the level of 2005.

[9] Check https://stats.oecd.org/.

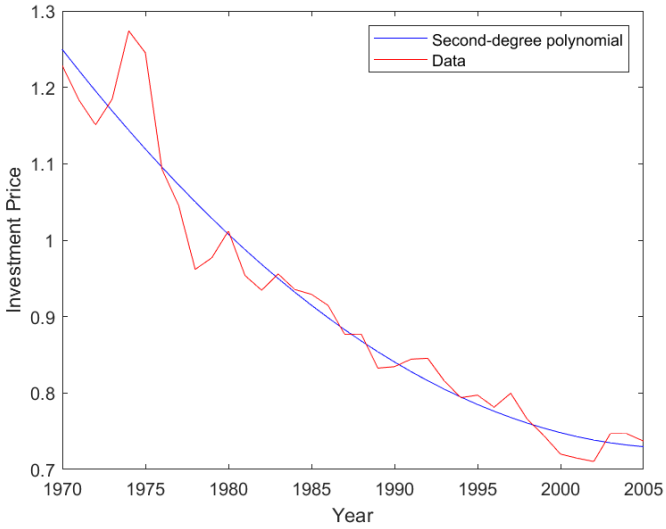


Figure 16: Relative price of investment

To infer the sequence of distortions, we equate the relative price of investment in the model to the data. I.e.

$$\frac{\tau_t}{P_t} = \chi_t \tag{2.12}$$

where χ_t is the relative price of investment in the data and P_t is the composite price of consumption good given by

$$P_t = \left[\theta^{\epsilon}(p_t)^{1-\epsilon} + (1-\theta)^{\epsilon}\right]^{\frac{1}{1-\epsilon}}$$

The values of $\{\tau_t\}$ is given in figure (17).

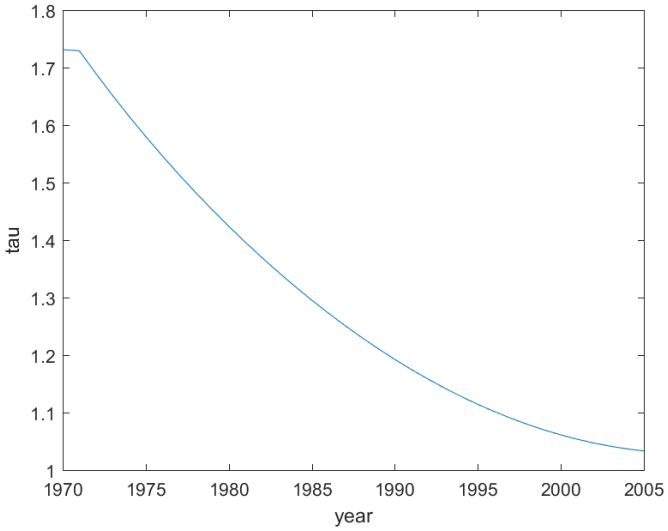


Figure 17: Values of τ_t

To see how the model performs, we begin by comparing output per capita from the model and the data. As can be seen in figure (18) the model is able to mimic output per capita well. Similarly, figure (20) compares employment shares in the agricultural sector from the model and the data.

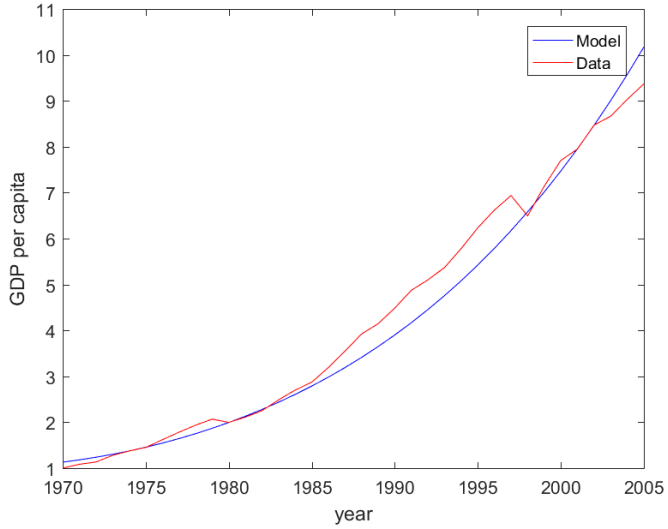


Figure 18: Output per capita

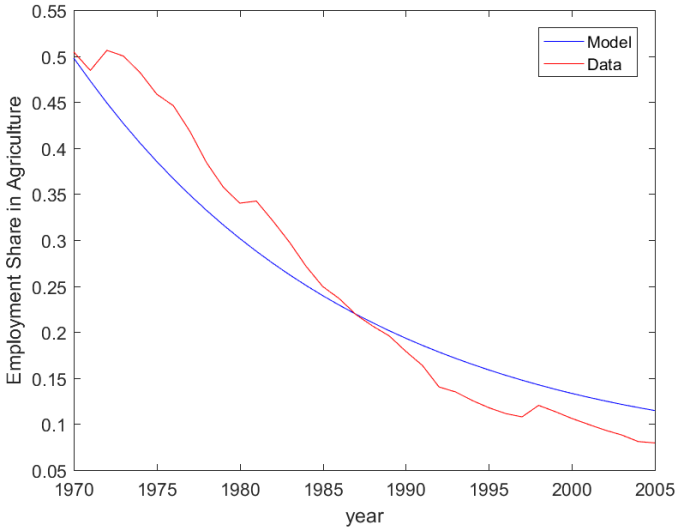


Figure 19: Employment shares of agriculture

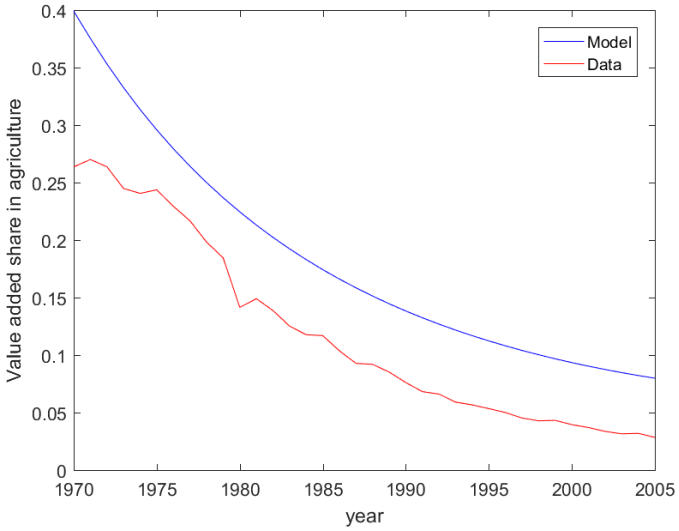


Figure 20: Value-added shares of agriculture

While untargeted, there is a close relationship between the employment share and the value-added share. Figure (20) shows how the model does in capturing the value-added shares. The value-added shares are taken from the Bank of Korea's Economic Statistics System (ECOS).[10] Like the employment shares, the model is able to predict the decrease in value-added shares in the agricultural sector. However, the model over-predicts the value-added shares quantitatively.

[10]Check https://ecos.bok.or.kr/EIndex_en.jsp. The ECOS provides data on GDP by kind of economic activity in current prices as well as base year prices in Korean Won.

The increasing and high investment rate in the Korean economy during the second half of the twentieth century are well-documented facts. (e.g. Young (1994), Young (1995)) The model is able to produce this pattern for investment rate quite well. As noted by Cai et al. (2015) a one-sector model produces a U-shaped pattern for investment rate, which is inconsistent with what is observed in the data.

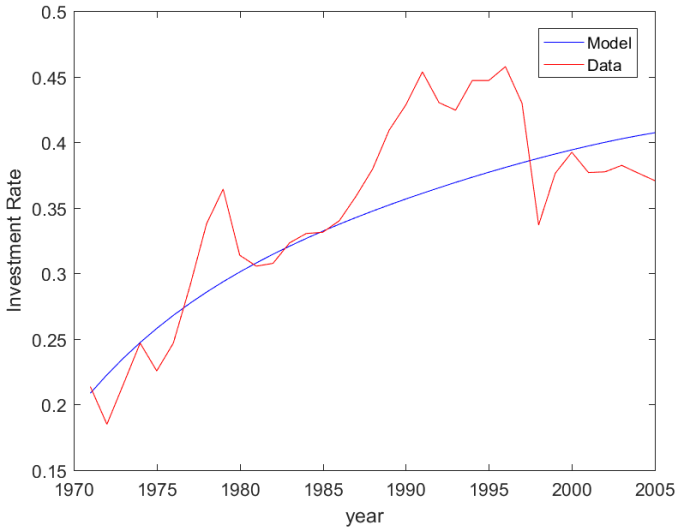


Figure 21: Investment rate

2.3.1 Counterfactuals

To understand how the reforms affected the economy, I now consider a counterfactual experiment in which the values of distortion τ is kept at the 1970 level. This is the pre-reform version of the economy. The initial conditions in the models are the same as in the previous economy.

Value-added and Employment Shares of Agriculture

In order to compare the value-added and employment shares of agriculture, I compute the ratios of these variables in the pre-reform economy relative to that in the post-reform economy. Table (9) lists these ratios by decade. The first thing to notice is that there is hardly any difference in the shares in the first decade. However, the ratios start to increase in the longer horizon. In 2005, the value-added share in the pre-reform economy is 7% higher than

that in the post-reform economy. Similarly, the employment share in agriculture is also 7% higher in the pre-reform economy relative to the post-reform economy. To put it in context, the employment share in the post-reform economy is 11.4% in 2005, so when employment share is 7% higher in the pre-reform economy, around 300,000 more are employed in the agricultural sector.[11] Both employment and value-added shares in the pre-reform economy stabilizes around 10% higher than those in the post-reform economy in the long-run.

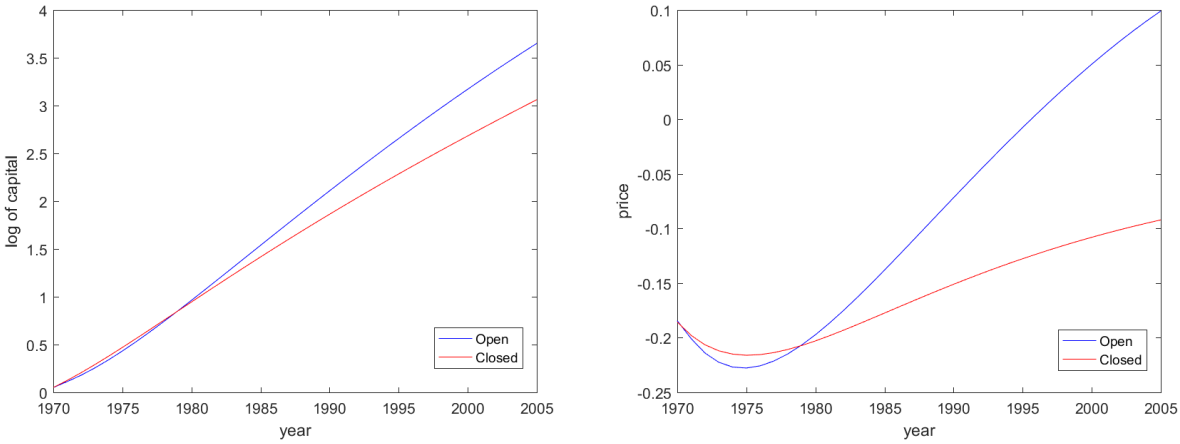
Year	Employment shares (Pre/Post)	Value-added shares (Pre/Post)
1970	1.00	1.00
1980	1.01	1.01
1990	1.02	1.02
2000	1.05	1.06
2005	1.07	1.08
2020	1.10	1.11

Table 9: Value-added shares and employment shares in agriculture

To understand why the employment shares in the pre-reform economy is higher than in the post-reform economy, consider the expression for employment shares given by equation (2.10). The difference in employment shares depend on how the relative price of agriculture and the level of capital behave under the two regimes. These are shown in figure (22). In both cases, there is a rise in the level of capital and agricultural price after the first decade. The post-reform economy exhibits higher levels for both these variables. A higher level of capital draws higher levels of labor as well. At the same time, while higher agricultural prices puts downward pressure on the non-agricultural labor, because $\epsilon > 1$ and the two goods are substitutes, there is a substitution away from the agricultural to the non-agricultural sector causing a reallocation of labor into the non-agricultural sector.[12]

[11] This number is computed by multiplying 0.07 by the working age population in the economy employed in the agricultural sector.

[12] I consider values of $\epsilon < 1$, in which case the results are the opposite. Value-added and employment shares in the agricultural shares are higher in the post-reform economy relative to the pre-reform economy.



(a) Capital *(b)* Price of agricultural good.

Figure 22: Capital and price of agricultural goods in open and closed economies

Output

A similar exercise comparing two regimes shows that output per capita is lower under the pre-reform economy compared to the post-reform economy. Increased investment in capital and increase in employment in the agricultural sector both cause output to increase. As seen in table 10, output per capita under the pre-reform economy is 17% lower in the pre-reform economy relative to the post-reform economy in 2005. In the long-run, output per capita is 20% lower in the pre-reform economy.

Year	GDP per capita (Pre/Post)
1970	0.99
1980	0.99
1990	0.92
2000	0.85
2005	0.82
2020	0.79

Table 10: GDP per capita

Investment Rate

Table (11) compares investment rates in the two economies. Investment rate is generally higher in the pre-reform economy, especially in the early years. Firstly, this is due to the

higher price of investment in the pre-reform economy. Secondly, when investment price decreases in the post-reform economy, households temporarily increase their consumption of the non-agricultural good, and decrease their savings. However, over time, investment rates catch up with the pre-reform economy once households start to increase their savings.

Year	Investment Rate (Pre/Post)
1970	1.11
1980	1.06
1990	1.04
2000	1.00
2005	0.99
2020	0.99

Table 11: Investment rates

2.4 Concluding Remarks

This paper studies the effects of decline in investment prices, brought about by economic reforms, on the process of structural change and economic growth. Economic reforms are represented by the level of distortion present in investment of capital. Using the Korean economy to calibrate a two sector model, the paper compares an economy in which reforms take place with one where they don't. I find that the reforms have implications for sectoral value-added and employment shares, output levels and investment rates in the economy. In particular, the post-reform economy generates a higher level of output and higher employment and value-added shares in the non-agricultural sector. The investment levels decrease in the short-run in the post-reform economy but accelerate quickly thereafter.

This research can be extended by incorporating difference in productivity across sectors. For example, the change in sectoral productivity can have implications for the structural change in the economy. A balanced growth path would cease to exist if this channel was

incorporated in the current model. But comparing the outcomes of this model to one where there is productivity growth differentials can potentially provide further insights.

3.0 Estimating the Tax Elasticity of Taxable Income Using the CPS

3.1 Introduction

Understanding behavioral responses to changes in tax policies is one of the central goals in economics. Since tax change is an important policy tool for policymakers, the interest in understanding such responses extends beyond academics. Much of the previous work in this area, summarized in a survey study by Blundell and MaCurdy (1999), focused on the responses of labor supply and savings behavior. The general consensus is that the elasticity of male labor supply is very low and labor force participation for married women is significant. On the other hand, there isn't a strong consensus on the response of savings. Starting from Lindsey (1987), in an effort to capture the effect of taxation on a wide range of behavioral responses, the focus has shifted from the elasticity of labor supply to elasticity of taxable income. In principle, taxable income captures a variety of responses including labor hours, tax evasion, effort and so on and is perhaps a better measure of response to tax changes. The fact that previous work have found sizable effects of taxation on taxable income also suggests that more studies need to be done to check the robustness and reliability of the estimates.

In this paper, I use the Economic Growth and Tax Relief Reconciliation Act of 2001 (EGTRRA), Jobs and Growth Tax Relief Reconciliation Act of 2003 (JGTRRA) and the American Tax Relief Act of 2012 (ATRA) to determine the elasticity of taxable income (ETI). Endogeneity is a major concern in estimating the elasticity of taxable income. We are interested in the change in taxable income but with graduated tax structure, an increase in income also implies a higher tax rate. Using the tax reform helps in this regard as we can use an instrumental variables approach. The tax reforms considered here applied to individuals across the board. Therefore, it is feasible to study household behavior for those with lower income as well. The data is taken from the Current Population Survey (IPUMS-CPS). Although the CPS is generally used as a source for cross-sectional observations of individuals, I use its panel structure in the analysis. Unlike the tax return data commonly

used in estimating the elasticity parameter, the CPS has several demographic information one can control for.[1]

I find an ETI of 0.65 for married couples, which is within the range of estimates found in the literature. For singles, I find an ETI of 0.2 but the estimate is not statistically significant.

Related Literature

As mentioned previously, measuring elasticity to policy variables is important in economics. These estimates are helpful in prescribing policy changes as well as building economic models to derive predictions in a variety of contexts. It is therefore unsurprising that a number of studies have tried to estimate the elasticity of income. However, getting a robust estimate is far from simple. We encounter various issues related to endogeneity. Different methodologies have been suggested in the literature to address these issues, and several values for the elasticity have been proposed ranging from -1.3 to as high as 3.05 (Goolsbee et al. (1999), Feldstein (1995)). I discuss some of the previous work done and caveats below.

In studying the effects of tax rate on income, Feenberg and Poterba (1993) analyze aggregated data. They study how income share of the top 0.5 percent evolved before 1990 and argue that the time-series demonstrates behavioral response to the declining marginal tax rate for that group. Saez et al. (2012) does a simple calculation where they compute the change in the share of income of the top 1 percent when there was a change in the net-of-tax rate. The estimate varied from -0.39 to 1.36 depending on which tax reform they were looking at. They also estimate the elasticity by regressing income share on net-of-tax rate across different reforms, which yields a value of 1.71. This is done without accounting for factors contributing to the changing inequality. Adding a time trend and other controls brings the elasticity to a much smaller number.

Some studies have also used repeated-cross-section data. For example, Lindsey (1987), which was the first paper to study the response of income to tax reform, uses repeated cross-section tax return data. He exploits the Economic Reform Tax Act of 1981 (ERTA), which reduced tax rates significantly for the high income earners. He computed the distribution of

[1] e.g. Feldstein (1995), Saez (2003) use the NBER tax panel, Auten and Carroll (1999), Sammartino and Weiner (1997), Auten and Carroll (1993) use treasury tax panel, Goolsbee et al. (1999) uses tax statistics tables

income that would be expected in the absence of tax changes and attributed the difference in actual tax return data to the response of taxpayers. He restricts the data to those with adjusted gross income (AGI) of more than $5,000 and estimates the elasticity of taxable income in the range of 1.053 to 2.750. Like Lindsey, Goolsbee et al. (1999) uses repeated cross-sectional data to estimate the ETI from tax changes between 1920 and 1966. In their paper, they find ETI ranging from -1.3 to 2. They consider those with income higher than $30,000. Studies that use repeated-cross-section data usually employ a difference-in-differences approach, where they divide the data into groups of income. E.g. the top 1 percent and the next 9 percent in the distribution. The fact that the trends for these two income groups are not parallel implies that an unbiased estimate is not guaranteed.

Feldstein (1995) was the first paper to use panel data to investigate the ETI. He used panel data from the Treasury department for around 4000 taxpayers to estimate the ETI based on the Tax Reform Act of 1986 (TRA), which saw a large decline in the tax rates for high-income earners. Restricting the sample to married individual with income higher than $30,000, he divides the sample into groups based on the 1985 marginal tax rates and compares them to one another in a difference-in-differences approach to obtain large values for ETI ranging from 1.1 to 3.05. This seminal paper was instrumental in popularizing the use of panel data. Following Feldstein (1995) several studies exploiting different reforms and panel data have been carried out. For example, Auten and Carroll (1999) use the Treasury Tax Panel to study the TRA and produce an elasticity of taxable income of 0.75 for those with income level higher than $\$15,000$. They also address issues like mean reversion, endogeneity and income trends in their instrumental variables approach. Moffitt and Wilhelm (1998) use the Survey of Consumer Finances (SCF) and the TRA as well and provide an estimate ranging from 0 to 2. In addition to estimating the elasticity of income with respect to marginal tax rates, they also study labor supply, which they find does not change alongside income. Both Auten and Carroll (1999) and Moffitt and Wilhelm (1998) provide estimates by estimating the elasticity over two years of data. Gruber and Saez (2002) use the NBER panel of tax returns over the period 1979-1990 and use a framework to decompose the effect of taxation into income and substitution effects. Their long panel allows them to control for time trends more effectively. They provide an estimate of 0.4 for those with income higher

than $\$10,000$.

Other studies have looked at the income response of tax changes in countries other than the US. For example, Blow and Preston (2002) focus on the UK, Kleven and Schultz (2014) estimates the ETI using the Danish data, Sillamaa and Veall (2001) computes the ETI for Canada and so on.

3.2 Reforms

The data from CPS makes it possible to study any tax reform after 1992. As such, I consider the three major policy changes related to taxation: Economic Growth and Tax Relief Reconciliation Act of 2001 (EGTRRA), Jobs and Growth Tax Relief Reconciliation Act of 2003 (JGTRRA) and the American Taxpayer Relief Act of 2012 (ATRA).

The Economic Growth and Tax Relief Reconciliation Act of 2001 (EGTRRA), Jobs and Growth Tax Relief Reconciliation Act of 2003 (JGTRRA), collectively known as the "Bush tax cuts", were signed into law in June 2001 and May 2003 respectively. JGTRRA was implemented retroactively and the tax relief was applied to all income from the beginning of 2003. The two reforms were introduced with the aim of promoting growth by creating incentives to work and invest. Among other things, the main feature of the tax reform was a decrease in the marginal tax rates on income across the board. EGTRRA was initially conceived as a tax reform to be phased in over a period of multiple years and scheduled to expire in 2010. However, due to a sluggish economy, the tax reform was accelerated by the JGTRRA and many of the tax cuts were implemented ahead of the plan. The tax reform saw the marginal tax rates go from (15%,28%,31%,36%,39.6%) to (10%,15%,25%,28%,33%,35%). Tables 4-9 show how the marginal income tax rates and tax brackets changed over the reform period. On the corporate side, the JGTRRA also reduced taxation on dividends and capital gains.[2]

The American Taxpayer Relief Act of 2012 (ATRA) was signed into law in January 2013

[2]The aim of JGTRRA was to bring investment and spur growth but as Chetty and Saez (2005) argue, it ended up increasing dividend payments to shareholders instead. Yagan (2015) also argues that the tax cuts did not increase investment as was intended.

amidst a recovering economy and call for more redistribution to address the inequality in the nation. Among other features of the reform, this reform also included changes to the marginal income tax rate. But unlike the previous two reforms, only those in the top income bracket saw their tax rate increase from 35% to the pre-EGTRRA tax rate of 39.6%.

3.3 Data

I use the Current Population Survey (CPS) data from 1992 to 2013. CPS is a monthly survey that collects extensive data on labor market characteristics. Unlike other data sources that study tax policies, it also has rich information on demographics including age, sex, education, marital status, race and so on. In particular, I use the Annual Social and Economic Supplement of the CPS. This supplementary survey, which is conducted in March of every year collects information on income (from multiple sources) among other things. Based on the information provided by the interviewee, CPS-IPUMS also provides information on taxes for the individual.

The survey is conducted in a 4-8-4 system, where an individual is interviewed for four consecutive months and discontinued for the next eight months. After the eight months, the same individual is interviewed for the next four months before he/she exits the survey. This survey design allows us a way to link an individual across time and create a panel structure.[3] For our purposes, the panel structure is necessary as we compare tax and income across years.

CPS-IPUMS only allows us to link an individual across a maximum of two years. The strategy is to look at the difference in incomes as a function of change in marginal tax rates. Mean reversion is identified as a problem in the literature. While I use income in the first year as a control to alleviate this problem, following Gruber and Saez (2002) I also restrict the data to exclude individuals (or households for married) with income less than $\$10,000$ to avoid extreme mean reversion.

The income measure used in the study is taxable income. CPS has data on taxable income

[3]See Rivera Drew et al. (2014) for details on linking individuals.

only for those with taxable income less than $100,000 for years prior to 2011. However, data is available for those with income more than $100,000 after 2011, which allows us to exploit ATRA because only those with the highest marginal tax rate were affected. Also, for those who were married and filed their taxes jointly, only one value for taxable income is available. So I carry out the study for individuals and married separately. For the married, any change in income should be seen as change in cumulative income. The intrahousehold allocation of work hours or income is not considered here, although this would be an interesting topic to look at. Tables (12) and (13) provide some summary statistics on the data.

Mean age (men)	45
Mean age (women)	43
Fraction of men in labor force	0.89
Fraction of women in labor force	0.73
Fraction both (huband and wife) in labor force	0.67
Fraction with children	0.64
Mean number of children (# of child > 0)	2
Fraction self-employed (men)	0.14
Fraction self-employed (women)	0.07
Fraction both self-employed	0.03
Fraction of men with college degree	0.31
Fraction of women with college degree	0.32
Fraction both with college degree	0.20
Mean taxable income	$59,870
S.D. of taxable income	$68,294
Mean net of tax rate	0.81
N	15,200

Table 12: Summary statistics for married couples. Source: Current Population Survey

Mean age	43
Fraction men	0.50
Fraction in labor force	0.83
Fraction self-employed	0.06
Fraction with college degree	0.29
Mean taxable income	$25,522
S.D. of taxable income	$37,699
Mean net of tax rate	0.84
N	15,709

Table 13: Summary statistics for singles. Source: Current Population Survey

3.4 Empirical Strategy

3.4.1 Conceptual Framework

In order to derive the regression equation, I use a model following Gruber and Saez (2002). A household derives utility from consumption, c and income z. Here, income is used to broadly capture labor hours, unobserved effort etc. that determine income. Since it's natural to think that activities that increase income are costly, higher levels of income decreases the agent's utility. The agent faces the budget constraint

$$c = z - T(z) \equiv (1 - \tau)z + y,$$

where y is "virtual" income. Virtual income is the amount of non-labor income when $z = 0$. As figure (23) shows, in an economy with progressive taxation, where marginal rates are non-decreasing, the budget line is non-linear.[4] It can also be seen in the figure that if there is a tax reform that changes the marginal tax rate for income above z^*, this changes both the slope of the after tax income as well as the virtual income.

[4]See Hausman (1985) for this concept.

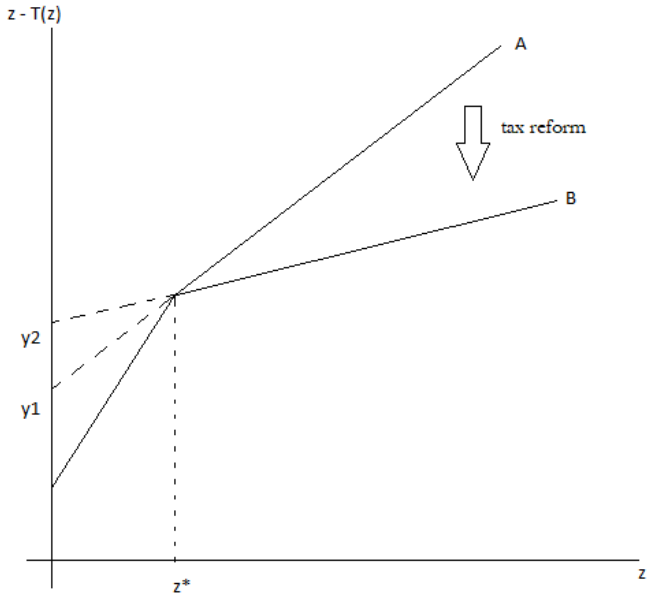


Figure 23: Tax reforms and budget constraints

The agent therefore solves

$$\max_{c,z} u(c,z) \quad \text{subject to} \quad c = (1-\tau)z + y$$

This maximization yields an income z, as a function of the net of tax rate $1-\tau$ and income y, $z = z(1-\tau, y)$. A change in the tax rate $d\tau$ and income dy produces the following change in income,

$$dz = -\frac{\partial z}{\partial(1-\tau)}d\tau + \frac{\partial z}{\partial y}dy \tag{3.1}$$

Let $\mu^u = (\frac{1-\tau}{z})(\frac{\partial z}{\partial(1-\tau)})$ be the uncompensated elasticity of income with respect to $1-\tau$ and let $\xi = (1-\tau)\frac{\partial z}{\partial y}$ be the income effect. After some algebra, we can write (3.1) as

$$dz = -\mu^u z\frac{d\tau}{1-\tau} + \xi\frac{dR}{1-\tau}. \tag{3.2}$$

If μ^c is the compensated elasticity of income with respect to $1-\tau$, we have $\mu^c = \mu^u - \xi$. Using this relationship in (3.2), we get

$$\frac{dz}{z} = -\mu^c\frac{d\tau}{1-\tau} + \xi\frac{dR - zd\tau}{z(1-\tau)}. \tag{3.3}$$

Now we write equation (3.3) as regression model. The data is a two year panel and we

call the two years year 1 and year 2.[5] We assign the value of year 1 income to z. dz is the change in income and equals $z_2 - z_1$. $d\tau$ is the change in marginal tax rate, $\tau_2 - \tau_1$. $dR - zd\tau$ is the change in after tax income and can be written as $(z_2 - T_2(z_2)) - (z_1 - T_1(z_1))$.

As is common in the literature, using a log-log specification, from (3) we get to the regression equation,

$$\log(z_2) - \log(z_1) = \mu[\log(1-\tau_2) - \log(1-\tau_1)] + \xi[\log(z_2 - T_2(z_2)) - \log(z_1 - T_1(z_1))] + \epsilon \quad (3.4)$$

3.4.2 Discussion

Equation (3.4) in its current form cannot be used to estimate the elasticity parameter. Notice that while taxable income depends on the marginal tax rates, the tax rates itself depend on the level of income. In particular, if there is a rise in the level of income for an individual for any reason other than the tax rate, this will cause the net-of-tax rate to go down. Similarly, if there is a decline in income, this will cause the net-of-tax rate to increase. Due to this endogeneity, OLS estimates will be biased downwards. To fix this, we can use an instrumental variables approach. A natural way to construct an instrument is to compute the predicted marginal tax rate, $\tau_2(z_1)$, by using the income in year 1, i.e., given a household's income in the first year, what is their marginal tax rate after the reform? We can then use $\log(1 - \tau_2(z_1)) - \log(1 - \tau_1(z_1))$ as an instrument for the first regressor and $\log(z_1 - T_2(z_1)) - \log(z_1 - T_1(z_1))$ as an instrument for the second regressor.

Mean reversion is another issue that can bias the elasticity estimate. Households that report low levels of income in the first year due to an income shock or misreporting typically have higher levels of income the next year. One way to mitigate this problem is to control for the log of income from the first year. Then, any bias due to mean reversion is reduced by adding this term. Log of income is also a way to control for the effects of changing income inequality. If income distribution is changing over time for some reason, there is a positive correlation between the shocks ϵ and income. So controlling for income in the first period

[5] In many of the other papers that look at the elasticity of income, they look at a difference of three years. Since it is possible that behavioral changes as a response to policy changes can take a longer time period, it would be desirable to have a panel covering several years. This is perhaps a drawback of using the CPS, which covers a maximum of two years.

could also help resolve this issue. However, this is more of a problem when studying income changes over longer periods of time. It is less severe here because we only have a one year window to consider.

As described above, the CPS provides joint income for married couples and individual income for singles. I study these two groups separately below.

3.5 Results

3.5.1 Singles

I first present the results for singles. I present the OLS and IV estimates in table (14). In the IV regression, I use just the instrument on the net-of-tax rate because the F-statistics for the instrument on income effect is less than 5. On the other hand, the F-statistic for the coefficient of net-of-tax rate instrument is higher than 20. As discussed above, the OLS estimate is biased downward.

Dependent variable: $\log\left(\frac{z_2}{z_1}\right)$

Variable	OLS	IV		
$\log\left(\frac{1-\tau_2}{1-\tau_1}\right)$	-0.148^{***} (0.003)	0.240 (0.530)	0.075 (0.519)	0.054 (0.516)
$\log(z_1)$	0.001^{***} (0.000)	-0.047^{***} (0.016)	-0.514^{***} (0.016)	-0.512^{***} (0.016)
College			0.325^{***} (0.019)	0.326^{***} (0.019)
Self-employed				-0.118^{***} (0.037)
constant	-0.009^{***} (0.002)	4.65^{***} (0.14)	4.933^{***} (0.143)	4.923^{***} (0.142)
Year fixed effects	Yes	Yes	Yes	Yes
N	11,706	10,665	10,665	10,665
R^2			0.24	0.24

*** significant at the 1 % level ** significant at the 5 % level * significant at the 10 % level

Table 14: Results for singles

The regression for singles result in a coefficient of 0.24, which is within the range of estimates found in the literature. However, the estimate is not statistically significant. This could be because majority of the individuals are those with income less than $\$100,000$, for whom previous studies have found a smaller and less significant coefficient as well.

3.5.2 Married Households

Like in the case of the singles, the regression in the first stage has an F-statistic larger than 20 for the coefficient of the instrument on the tax rate, but the F-statistic for the coefficient of the instrument on the income effect is much smaller around 3. As such, I run the analysis with just the change in net-of-tax rate as the regressor. Gruber and Saez (2002) also find a small F-statistic for the coefficient on the instrument of income effect and run their baseline analysis without the income effect. They also argue that while income effect may be present it is usually small in magnitude.[6]

The main result of the regression is shown in table (15). The baseline regression controlling for just the year effects and initial income yields an estimate of 0.65. When more controls are added to the regression, the estimate rises to 0.69. The dependent variable in the regression is the total taxable income of a married couple. The result suggests that there is behavioral response to tax changes. One possible channel is through changes in the labor supply. However, the regression of labor supply on net-of-tax rate results in statistically insignificant estimates.

[6]Other studies like Auten and Carroll (1999) start with a model without the income effect.

Dependent variable: $\log\left(\frac{z_2}{z_1}\right)$

Variable	OLS	IV			
$\log\left(\frac{1-\tau_2}{1-\tau_1}\right)$	-0.260^{***} (0.002)	0.650^{**} (0.32)	0.650^{**} (0.32)	0.690^{**} (0.32)	0.690^{**} (0.32)
$\log(z_1)$	-0.002^{***} (0.0002)	-0.450^{***} (0.013)	-0.450^{***} (0.013)	-0.510^{***} (0.014)	-0.510^{***} (0.014)
Self-employed husband			0.320 (0.21)	0.016 (0.02)	0.015 (0.02)
Self-employed wife			0.009 (0.020)	0.005 (0.020)	0.005 (0.020)
College educated husband				0.196^{***} (0.017)	0.019^{***} (0.017)
College educated wife				0.169^{***} (0.017)	0.170^{***} (0.017)
Child					-0.030^{**} (0.014)
constant	-0.220^{***} (0.002)	4.60^{***} (0.135)	4.590 (0.13)	5.120^{***} (0.140)	0.140 (5.160)
Year fixed effects	Yes	Yes	Yes	Yes	Yes
N	13,003	13,003	13,003	13,003	13,003
R^2		0.15	0.15	0.17	0.17

*** significant at the 1 % level ** significant at the 5 % level * significant at the 10 % level

Table 15: Results for married couples

In order to understand why there is a change in taxable income when tax rates change, one variable we could look at is hours worked. In table (16) I regress the change in log of hours between year one and two on the change in log of net of tax rates. Once again, the OLS estimate is biased but unlike with income, we cannot construct instruments to get unbiased estimates. Similar to the OLS estimate with income, the estimates for the correlation between the two variables are negative.

Dependent variable: $\log\left(\frac{h_2}{h_1}\right)$		
Variable		
$\log\left(\frac{1-\tau_2}{1-\tau_1}\right)$	-0.059^{**} (0.023)	-0.030 (0.025)
$\log(z_1)$		-0.008^{***} (0.002)
constant	-0.005^{***} (0.001)	0.088^{***} (0.030)
Year fixed effects	No	Yes
N	5,711	5,711

*** significant at the 1 % level ** significant at the 5 % level * significant at the 10 % level

Table 16: Correlation between change in hours worked and change in net of tax rates

By College Education

I now divide the sample into three types of married couples based on both their education levels:

(i) Neither have a college degree

Dependent variable: $\log\left(\frac{z_2}{z_1}\right)$	
Variable	IV
$\log\left(\frac{1-\tau_2}{1-\tau_1}\right)$	1.040^{***} (0.420)
$\log(z_1)$	-0.520^{***} (0.017)
constant	5.240 (0.180)
Year fixed effects	Yes
N	6,952
R^2	0.16

*** significant at the 1 % level ** significant at the 5 % level * significant at the 10 % level

Table 17: Results when neither spouse has a college degree

(ii) Exactly one spouse has a college degree

Dependent variable: $\log\left(\frac{z_2}{z_1}\right)$	
Variable	IV
$\log\left(\frac{1-\tau_2}{1-\tau_1}\right)$	0.900
	(0.680)
$\log(z_1)$	-0.550^{***}
	(0.035)
constant	5.690
	(0.360)
Year fixed effects	Yes
N	3,093
R^2	0.15

*** significant at the 1 % level ** significant at the 5 % level * significant at the 10 % level

Table 18: Results when exactly one spouse has a college degree

(iii) Both spouses have college degrees

Dependent variable: $\log\left(\frac{z_2}{z_1}\right)$	
Variable	IV
$\log\left(\frac{1-\tau_2}{1-\tau_1}\right)$	0.480
	(0.750)
$\log(z_1)$	-0.520^{***}
	(0.037)
constant	5.460
	(0.390)
Year fixed effects	Yes
N	2,958
R^2	0.18

*** significant at the 1 % level ** significant at the 5 % level * significant at the 10 % level

Table 19: Results when exactly one spouse has a college degree

The results suggest that those who do not have college degrees responded more to the tax changes most strongly. The next interesting step will be figure out the exact behavioral responses that brings about the change in income.

Discussion

A few caveats are in order. Like in other studies, the analysis here is limited by data availability. When using the CPS, data is only available for two consecutive years but the

effect of taxation could take place over multiple years. Without a longer panel, we cannot guarantee that the behavioral change in the two years completely capture the effects of tax change. In their baseline analysis, Gruber and Saez (2002) conduct the same analysis with a three year window but also consider two and three year windows. They find the results to be similar in all cases. Another caveat in the analysis here is that people of every income level is assumed to have the same elasticity, but this may not be the case. In particular, those with higher incomes are generally found to be more sensitive to tax changes.

Saez et al. (2012) also allude to a few issues in using panel data. While income in the base year is used to control for mean reversion it is not clear whether it controls for mean reversion or changes in income inequality. This is even more concerning given that controlling for income can absorb variation in the tax rates, which tend to be correlated with income. As a result, some information can be lost. Also, using panel data is informative when income levels are persistent over years but it is found that there is a non-negligible fraction of people whose income changes dramatically. This is worsened when income changes across multiple years are considered. These concerns and the fact that results using the panel data are found to be very sensitive to specifications, Saez et al. (2012) argue that in some cases using repeated cross-sectional data is more appropriate.

3.6 Concluding Remarks

Estimating the elasticity of income is of central importance in economics. In this paper I use the panel structure of the CPS to estimate this elasticity parameter. The Economic Growth and Tax Relief Reconciliation Act of 2001 (EGTRRA), Jobs and Growth Tax Relief Reconciliation Act of 2003 (JGTRRA) and the American Tax Relief Act of 2012 (ATRA) provide an opportunity to employ an instrumental variables approach to estimate the elasticity of taxable income with respect to taxation. I find that the elasticity of taxable income is around 0.65 for married couples. Much of this comes from couples who do not have college degrees.

Appendix A

Chapter 1

(i) **Repayment under different repayment plans - an example**

Suppose an individual earns $\$30,000$ a year and has loaned out \$30,000. The following diagram shows the fraction of the principal remaining over time.

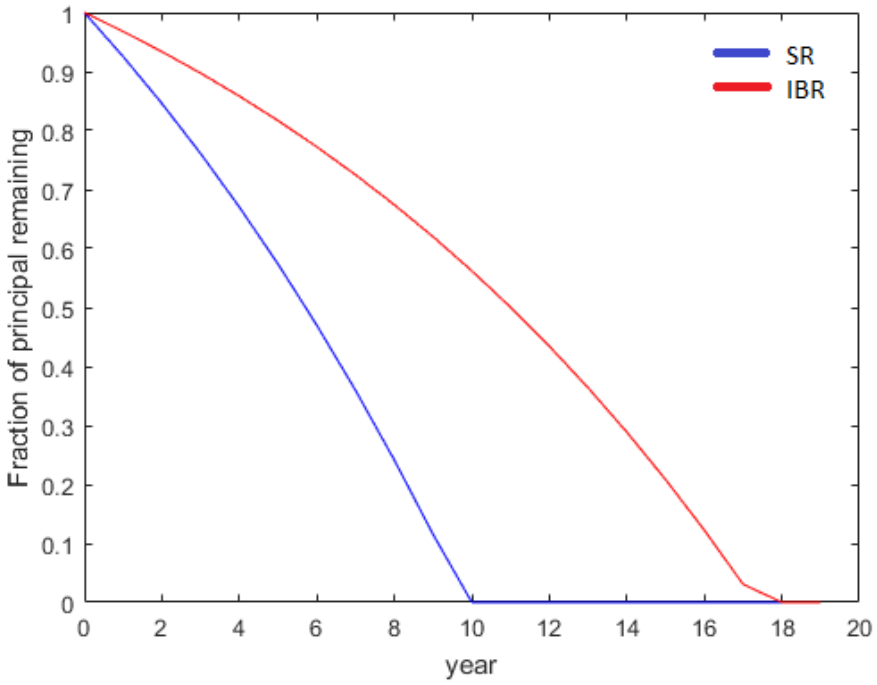


Figure 24: Fraction of principal

(ii) **Entrepreneurs by occupation and industry**

The tables below show the fraction of entrepreneurs by industry and occupation.

Occupation	College	No college
Managerial and Professional Specialty	66.11%	16.4%
Technical, Sales and Administration	22.06%	27.5%
Service Occupation	6.09%	21.1%
Precision Production, Craft and Repair	2.4%	13.9%
Operators, Fabricators and Laborers	2.3%	17.2%
Farming, Forestry and Fishing	0.09%	3.7%

Table 20: Entrepreneurs by occupation. Source: Current Population Survey

Industry	College	No college
Professional and Related Services	44.8%	20.0%
Finance, Insurance and Real Estate	9.2%	5.1%
Retail Trade	8.2%	19.2%
Manufacturing	8.1%	11.9%
Business and Repair Services	7.9%	7.5%
Public Administration	6.9%	4.1%
Transportation, Communications and Other Public Utilities	4.7%	8.3%
Construction	2.6%	10.2%
Wholesale Trade	2.1%	2.6%
Professional Services	2.0%	4.3%
Entertainment and Recreation Services	1.4%	1.8%
Agriculture, Forestry and Fisheries	1.3%	3.6%
Mining	0.05%	1.1%

Table 21: Entrepreneurs by industry. Source: Current Population Survey

(iii) **Computational algorithm:**

a. Guess a value for tax rate τ^{guess}.

b. Guess a value for interest rate r^{guess}. Using the corporate production function, compute wage rates.

$$w_u = (1-\alpha)\left(\frac{\alpha}{r+\delta}\right)^{\frac{\alpha}{1-\alpha}}$$

c. Use backward induction to solve for agents' value functions and policy functions.

d. Using the policy functions, compute the distribution over the state variables.

e. Using the distribution and policy functions, compute the total asset saved by the agents. Also, compute the capital used by the entrepreneurs. Using the market clearing condition for capital, we get the capital used by the corporate sector, K.

f. Using the occupational choices of agents and the distribution over the state variables compute total human capital supplied, H.

g. Using K and H from the previous two steps, find the value of r using

$$r^{updated} = \alpha K^{\alpha-1} H^{1-\alpha} - \delta$$

h. If $|r^{updated} - r^{guess}| < \epsilon$, where ϵ is a small number, proceed to step 10.

i. If $r^{updated} > r^{guess}$ increase the value of r^{guess} and repeat steps 2 - 8. If $r^{updated} < r^{guess}$ decrease the value of r^{guess} and repeat steps 2 - 8.

j. If government expenditure is close to government revenue, the model is solved. Otherwise, if government expenditure is bigger than revenue increase τ^{guess} and repeat steps 1 - 10 and if government expenditure is lower than revenue decrease τ^{guess} and repeat steps 1 - 10.

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Appendix B

Chapter 2

(i) **Deriving the value added share of agriculture given by (2.11):**

One of the first order conditions equates the marginal product of labor across sectors. I.e.

$$p_t = (1-\alpha)K_t^{\alpha}(z_t L_t^2)^{-\alpha}$$

Now,

$$\begin{aligned} VA &= \frac{pz_t L_t^1}{pz_t L_t^1 + K_t^{\alpha}(z_t L_t^2)^{1-\alpha}} \\ &= \frac{1}{1 + \dfrac{K_t^{\alpha}(z_t L_t^2)^{1-\alpha}}{pz_t L_t^1}} \end{aligned} \tag{B.1}$$

Plug in the term for p_t and focus just on the right term in the denominator. The right term is given by:

$$\begin{aligned} \frac{K_t^{\alpha}(z_t L_t^2)^{1-\alpha}}{p_t z_t L_t^1} &= \frac{K_t^{\alpha}(z_t L_t^2)^{1-\alpha}}{(1-\alpha)K_t^{\alpha}(z_t L_t^2)^{-\alpha} z_t L_t^1} \\ &= \frac{L_t^2}{(1-\alpha)L_t^1} \end{aligned}$$

Plug this expression in (B.1) and we get equation (2.11)

(ii) **Algorithm for solving the transition dynamics:**

Begin by normalizing and re-defining the variables in the following way:

$$\hat{c}_t^2 = \frac{c_t^2}{z_t L_t}, \quad \hat{k}_t = \frac{K_t}{z_t L_t}, \quad \hat{c}_t^1 = \frac{c_t^1}{z_t L_t}, \quad n_t^1 = \frac{L_t^1}{L_t}$$

The first order conditions can be rewritten in terms of normalized variables:

$$\left(\frac{\hat{c}_{t+1}^2}{\hat{c}_t^2}\right)^{\sigma} = \beta \frac{g(p_t)}{g(p_{t+1})} \left(\frac{\alpha}{\tau_t} \hat{k}_{t+1}^{\alpha-1} (1 - n_{t+1}^1)^{1-\alpha} + \frac{\tau_{t+1}}{\tau_t}(1-\delta)\right) \tag{B.2}$$

$$\hat{c}_t^2 + \tau_t \hat{k}_{t+1} = \hat{k}_t^{\alpha} (1 - n_t^1)^{1-\alpha} + \tau_t (1-\delta)\hat{k}_t \tag{B.3}$$

$$\hat{c}_t^2 = \left(n_t^1 - \frac{\bar{c}}{z_t L_t}\right)\left(\frac{1-\theta}{\theta} p_t\right)^{\epsilon} \tag{B.4}$$

$$p_t = (1-\alpha)\hat{k}_t^{\alpha}(1 - n_t^1)^{-\alpha} \tag{B.5}$$

Again, $g(p_t)$ is given by (2.9).

I employ a shooting algorithm targeting the steady state value of $\hat{k}_t$ to solve for the time series of the endogenous variables. The algorithm is as follows:

(1) For given $\hat{k}_0$, guess a value for $\hat{c}_0$.

(2) Using (B.4) and (B.5), we can find the values for n_0^1 and p_0.

(3) With $\{\hat{k}_0, \hat{c}_0, n_0^1, p_0\}$, solve the system of four equations - (B.2), (B.3). and period 1 versions of (B.4) and (B.5). This step yields $\{\hat{k}_1, \hat{c}_1, n_1^1, p_1\}$.[1]

(4) With values for $\{\hat{k}_t, \hat{c}_t, n_t^1, p_t\}$, repeat step 3 to obtain $\{\hat{k}_{t+1}, \hat{c}_{t+1}, n_{t+1}^1, p_{t+1}\}$.

(5) Repeat step 4 until $t = T$, where T is a large number.

(6) Compare $\hat{k}_T$ to the steady state value of $\hat{k}_t = \hat{k}_{ss}$. Note that for a large enough value of T, the fraction $\dfrac{\bar{c}}{z_T L_T} \to 0$.

(7) If $|k_T - \hat{k}_{ss}| < 0.0001$, stop. Otherwise, if $k_T > \hat{k}_{ss}$, increase the value of the guess $\hat{c}_0$ or if $|k_T < \hat{k}_{ss}|$, decrease the value of $\hat{c}_0$ and repeat steps (2) - (7).

[1] A non-linear solver is required. I use fsolve in MATLAB.

(iii) **Constructing the series for the price of agricultural goods:**

Following the procedure in Uy et al. (2013), I collect data on final consumption expenditures for two broad group of sectors from the OECD national accounts data. Agricultural sector is defined as the food and non-alcoholic beverages and alcoholic beverages, tobacco and narcotics. Non-agricultural goods is the sum of durable goods, non-durable goods, semi-durable goods and services. Data is available for both current and 2010 prices in local currency. Let C_t^i be the consumption expenditure in current prices, and let c_t^i be the consumption expenditure in 2010 prices for sector i in time t. The price of each sector p_t^k is given by

$$p_t^k = \frac{C_t^i}{c_t^i} \frac{ppp_t}{ppp_{2010}}$$

ppp_t is the purchasing power parity at time t to convert the sectoral prices in US dollars.

Appendix C

Chapter 3

Married			Single		
MTR	Greater than	Less than	MTR	Greater than	Less than
15.0%	0	43,850	15.0%	0	26,250
28.0%	43,850	105,950	28.0%	26,250	63,550
31.0%	105,950	161,450	31.0%	63,550	132,600
36.0%	161,450	288,350	36.0%	132,600	288,350
39.6%	288,350	-	39.6%	288,350	-

Table 22: Marginal tax rates, 2000

Married			Single		
MTR	Greater than	Less than	MTR	Greater than	Less than
15.0%	0	45,200	15.0%	0	27,050
27.5%	45,200	109,250	27.5%	27,050	65,550
30.5%	109,250	166,500	30.5%	65,550	136,750
35.5%	166,500	297,350	35.5%	136,750	297,350
39.1%	297,350	-	39.1%	297,350	-

Table 23: Marginal tax rates, 2001

Married			Single		
MTR	Greater than	Less than	MTR	Greater than	Less than
10.0%	0	12,000	10.0%	0	6,000
15.0%	12,000	46,700	15.0%	6,000	27,950
27.0%	46,700	112,850	27.0%	27,950	67,700
30.0%	112,850	171,950	30.0%	67,700	141,250
35.0%	171,950	307,050	35.0%	141,250	307,050
38.6%	307,050	-	38.6%	307,050	-

Table 24: Marginal tax rates, 2002

Married			Single		
MTR	Greater than	Less than	MTR	Greater than	Less than
10.0%	0	14,000	10.0%	0	7,000
15.0%	14,000	56,800	15.0%	7,000	28,400
25.0%	56,800	114,650	25.0%	28,400	68,800
28.0%	114,650	174,700	28.0%	68,800	143,500
33.0%	174,700	311,950	33.0%	143,500	311,950
35.0%	311,950	-	35.0%	311,950	-

Table 25: Marginal tax rates, 2003

Married			Single		
MTR	Greater than	Less than	MTR	Greater than	Less than
10.0%	0	17,400	10.0%	0	8,700
15.0%	17,400	70,700	15.0%	8,700	35,350
25.0%	70,700	142,700	25.0%	35,350	85,650
28.0%	142,700	217,450	28.0%	85,650	178,650
33.0%	217,450	388,350	33.0%	178,650	388,350
35.0%	388,350	-	35.0%	388,350	-

Table 26: Marginal tax rates, 2012

Married			Single		
MTR	Greater than	Less than	MTR	Greater than	Less than
10.0%	0	17,850	10.0%	0	8,925
15.0%	17,850	72,500	15.0%	8,925	36,250
25.0%	72,500	146,400	25.0%	36,250	87,850
28.0%	146,400	223,050	28.0%	87,850	183,250
33.0%	223,050	398,350	33.0%	183,250	398,350
35.0%	398,350	450,000	35.0%	398,350	400,000
39.6%	450,000	-	39.6%	400,000	-

Table 27: Marginal tax rates, 2013

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