Essays on Cooperation and Social Insurance

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Abstract

I used information collected in field experiments in the Greater Accra region in Ghana to assess the effects of religion identity, using priming techniques, on altruism and trust. We use standard versions of the dictator and trust game, and primed participants for religion using pictures. We find that priming for religion decreases the average amount sent by dictators and investors, and that it makes the religious affiliation of the other player a key determinant of behavior, with inter-group biased behavior as a result. We also analyze the insurance provided by the U.S. social security and income tax system within a model where agents receive idiosyncratic, wage-rate shocks that are privately observed. We consider two reforms: a piecemeal reform that optimally chooses the social security benefit function and a radical reform which eliminates the entire social insurance system and replaces it with an optimal tax on lifetime earnings. The radical reform outperforms the piecemeal reform and achieves nearly all of the maximum possible welfare gain when wages differ permanently over the lifetime. When wage shocks match properties in U.S. data, the piecemeal reform outperforms the radical reform.

This dissertation is dedicated to my family,

for being the light, fuel, and greatest source of joy in my life.

With all my love,

Juan Carlos Parra

Contents

1 Introduction

This research deals with two main topics: social cooperation and social insurance. Regarding social cooperation, there exists substantial evidence that religious or ethnic diversity within a community, region, or country, can significantly limit cooperative outcomes. On the other hand, the fast expanding literature on the role of social capital in economic development highlights the role of social cohesion in facilitating the flow of information, reducing adverse selection and moral hazard, and advancing norms of accountability and cooperation. However, much remains unknown on the emergence functioning, and enforcement of norms of fairness, reciprocity, and cooperation in homogenous communities. A better understanding of these mechanisms in turn can provide practical guidelines that can promote cooperation in heterogeneous societies and extend our current state of knowledge on how to structure intergroup interaction so as to promote benign attitudes. This research proposes field based experimental methods to delineate the effects of religious affiliation on social cooperation through a variety of controlled treatments.

The fast expanding literature on social capital has highlighted the positive effects of social homogeneity on economic development. Also, a considerable literature that has built up over the past two decades has presented substantial evidence that religious or ethnic diversity within a community, region, or country, can significantly limit cooperative outcomes leading to under provision of public goods. Social capital manifested through social networks plays a major role in facilitating the flow of information, reducing adverse selection and moral hazard, and advancing norms of accountability and cooperation in long period relationships. At the social level, there is much evidence that trust between people reduces transaction costs, fosters cooperation, and is hence important for economic and social development. In less developed economies where the cost of legality is high, and where financial markets are thin or missing, relations based on trust or informal enforcement mechanisms may provide the only avenue of access to credit and insurance. It has been suggested that trust in existing institutions may therefore affect trust in other people. Religious or ethnic affiliations or caste status are generally considered as important institutions that promote social cohesion. Barro and McCleary (2004) point out that religiosity affects individual characteristics, such as work ethic, honesty and thrift, and thereby influences economic performance. Berman (2000) presents a model in which religious groups provide mutual insurance and charity, and rituals serve to signal members' commitment to the group. Ruffle and Sosis (2007) using experimental and individual data on religious rituals from Israeli Kibbutz show that costly and observable rituals allow religious individuals to identify and cooperate with one another.

Camerer and Fehr (2004) advocate the use of economic experiments to measure the relative importance of social norms, while Carpenter (2002) proposes the use of economic experiments to measure social capital and norms of trust and reciprocity. Developments in game theory have shown that prototypical games like the dictator game and the trust game can be used to come up with hypotheses about how individuals care for their material payoffs relative to others.

In Chapter 2 we use information collected during artefactual field experiments in the Greater Accra region in Ghana to assess the effects of religion on social cooperation. In particular, we quantified the effects of religious priming on altruism and trust. We consistently find that priming for religion decreases altruism and trustworthiness to people with different religious affiliations, and overrules reciprocity and most other variables that help explain behavior under no priming. These results indicate that if religion identity is made more salient, through the use of religious discourse during electoral campaigns, for example, there would be less social cooperation, in the form of altruism and trustworthiness, in a religious- and ethnically diverse context in Ghana. We find that religion decreases the levels of altruism and trust, and that it makes the religious affiliation of the other player a key determinant of behavior, with inter-group biased behavior as a result.

On the topic of social insurance, Chapter 3, which is based on joint work with Mark

Huggett, we assess the inefficiency of the social insurance system in the US. Social insurance systems are one of the key sources of insurance for different transitions throughout life, and are characterized by different degrees of moral hazard (Mirrlees 1995). Since the amount of insurance is a function of (observed and unobserved) behavior, a problem of incentives arises.

It is often the case in policy discussions that different reform options are analyzed without an even approximate assessment of how far these options are from the maximum attainable efficiency gains. Chapter 3 is a first effort to assess those gains in a stylized model of the US social insurance system, defined as the retirement component of the US social security system together with the income tax, where agents face idiosyncratic wage risk.

Two sets of literature are closely related to the analysis in chapter 3. The literature on dynamic contract theory that analyzes optimal planning problems in which some key information is only privately observed. This literature builds upon the pioneering work by Mirrlees (1971), who studied the optimal design of income tax systems. A good survey of the recent literature can be found in Golosov, Tsyvinski, and Werning (2006).

Another set of literature that is related to our work in chapter 3 deals with social security systems with idiosyncratic risk. Nishiyama and Smetters (2007) is one interesting paper from this literature. They consider various ways of partially privatizing the U.S. social security system. They find important efficiency gains when they abstract from idiosyncratic wage risk. When idiosyncratic risk is added, they find either no efficiency gains or very small gains for the reforms they analyze.

In Chapter 3 we explore two main reforms. First, we conduct an optimal piecemeal reform by allowing the social security benefit function to be chosen optimally without changing the social security tax rate or the income tax system. This reform leads to almost no welfare gain in the permanent-shock model but a welfare gain equivalent to a 1.15 percent consumption increase each period in the full model.

The second reform is more radical. We eliminate the model social insurance system and replace it with an optimal tax on the present value of earnings. An optimal present-value tax achieves a welfare gain of 3.95 percent of consumption in the permanent-shock model - nearly all of the maximum possible welfare gain. The present-value tax performs so well because it approximates the wedges between marginal rates of substitution and transformation arising in a solution to the planning problem while allowing for a flexible relationship between lifetime earnings and lifetime consumption. In the full model this optimal reform leads to no welfare gain. Thus, while a present-value tax is well designed for models with only permanent labor productivity differences that remain over the entire lifetime it does not lead to a welfare gain in models with permanent, persistent and temporary sources of labor productivity variation that mimic properties in U.S. wage data.

2 The Effects of Religious Priming on Social Cooperation: Results from a Field Experiment in Ghana[1]

2.1 Motivation and literature review

Identity politics is not an uncommon practice in the developing world. Even though several studies investigate the ways in which political rhetoric prime social identity (Mendelsohn 1996), its effects on voting behavior and social cooperation are relatively unexplored.[2] Are politicians, on the way to increasing their odds of being elected, affecting (at least temporarily) the norms of social interaction? In Ghana, for example, Dovlo (2005) reports a pervasive use of religion during political elections despite the Constitutional prohibition of organizations using ethnic or religious propaganda to increase the odds of election of persons on account of their ethnic or religious affiliation. We also have anecdotal evidence that religious arguments are often used during local council sessions and other decision making bodies in Ghana. The ethnic card is also often played in African politics (McCauley 2009). Despite its pervasiveness, very little is known about the effects of religious identity politics on social cooperation and other economic outcomes.

We investigate the impact of identity politics, religious identity in particular, and other potential sources of cues for religious identity on social cooperation in Ghana. Ghana is a good country for our investigation for at least two reasons: i) Ghana has experienced relatively low levels of conflict (ethnic or religious) since 1980 despite its diverse population, according to Jönsson (2009). The Pito War (1981) and the Guinea Fowl War (1994-1995),

[1]The data used in this chapter was collected by George Joseph at The World Bank as part of a bigger research project.

[2]See McCauley (2009) for a study of the differential effects of religious and ethnic politics. See Chapp (2008) for a study of the effects of religious campaign rhetoric on candidate evaluations.

both inter-ethnic and in the northern regions are the only localized episodes of violence; ii) Religion is important for identity in Ghana. Langer and Ukiwo (2009) conducted a street survey and found that 70% of respondents in 3 cities in Ghana reported religion among the 3 most important identities, the highest percentage, and more important than ethnicity (around 40%).

We used information collected during field experiments in the Greater Accra region in Ghana to assess the effects of religion identity, using priming techniques, on altruism and trust. Standard versions of the dictator and trust game were used, and participants were primed for religion using pictures. We find that priming for religion decreases the average amount sent by dictators and investors, and that it makes the religious affiliation of the other player a key determinant of behavior, with inter-group biased behavior as a result.

There is a large literature on the effect of religion on social behavior including trust (Johansson-Stenman et al. 1999), cooperation (Ruffle and Sosis 2007), and altruism (Batson et al. 1993). Johansson-Stenman et al. (1999) used a survey and a field experiment among Muslims and Hindus in rural Bangladesh to study the relationship between religious affiliation and trust. The surveys show less trust to other religions, but this is not confirmed by the experiment. Ruffle and Sosis (2007) found more cooperation from members of religious kibbutzim in Israel, and the frequency of rituals for these individuals is a good predictor of the degree of cooperation. Batson et al. (1993) review lab evidence that religion is related to self-reported behavior, but its relationship to actual behavior is much weaker. These studies have limitations: they either stop at measuring correlations, are based on self-reported information, or unobservables might be causing both a higher/lower religious affiliation and the observed behavior. In this study we use priming to generate exogenous variation in religious identity that allows us to make causal inferences.

Some experiments have used priming to assess the effects of religion on economic outcomes. Shariff and Norenzayan (2007) conducted a lab experiment and used a scrambled sentence task as a priming mechanism. They found that after being primed for religion, dictators left more for recipients in a dictator game. Ahmed and Salas (2008) using a scrambled sentence task found increased prosocial behavior in dictator and prisoner's dilemma after priming for religion. Benjamin, Choi, and Fischer (2010) found no effect on dictator giving using the exact same priming mechanism as Shariff and Norenzayan above. The paper that is closest to what we do is McCauley (2009), who conducted a field experiment in Côte d'Ivoire and Ghana using a pre-recorded radio message as a priming mechanism for both ethnicity and religion. He found higher average contributions in a dictator game but lower contributions to people from a different religion after subjects are primed for religion.

This chapter is organized as follows. Section 2.2. presents the experimental design. Section 2.3. describes the results for the two games. Section 2.4. presents conclusions.

2.2 Experimental design

2.2.1 Sampling

As part of a larger study, a team of 10 assistants randomly sampled 776 individuals who agreed to participate from 36 areas in the Greater Accra region. We use for this study the information for 393 individuals that were either primed for religion or not primed (referred to as *the sample*) during one of the 18 sessions that were held.[3] Using local knowledge, the 36 areas were a posteriori identified as i) Christian dominated, where 95 percent of the participants is Christian; and ii) other areas, where 51 percent of the participants is Christian.[4] Basic personal information (name, age, gender, ethnicity, religious affiliation, level of education, and employment status) for those who agreed to participate was collected during sampling and was used for the group assignments described below. Each individual

[3] I was provided with de-identified data collected during the experiments.
[4] Only 6 participants reported practicing a religion different from Christianism and Islam.

in the sample was randomly assigned to one of the two primings (treatments). As shown in Table **??**, the distribution of characteristic is very similar across treatments, with a higher share of low-education participants in the primed subsample being the only statistically significant difference.[5]

Table 2.1: Sample characteristics (shares of observations in each column)

Characteristic	**No priming**	**Priming for religion**
Total number of participants	213	180
Males	0.68	0.64
Christians	0.64	0.64
From Christian-dominated areas	0.29	0.29
Married	0.33	0.35
At most incomplete primary	0.14	0.23**
Complete primary to incomplete secondary	0.52	0.50
Complete secondary and above	0.34	0.27
Akan	0.29	0.26
Ga	0.23	0.26
North	0.29	0.29
Ewe	0.13	0.13

** Different from no priming at 5%

Since religion and ethnicity are correlated in Ghana, in order to isolate their potentially confounding effects, participants were randomly assigned to one of three different groups corresponding to the comparison of religion and ethnicity between the two players for each of the two games that were played: 1) same religion same ethnicity -SRSE-; 2) different religion same ethnicity -DRSE-; and 3) same religion different ethnicity -SRDE-. For example, if participant i was assigned to the group DRSE (different religion same ethnicity), both of her partners (one per game) were randomly drawn from the pool of participants that had a different religion from i and the same ethnicity.[6]

[5] We included interaction terms in our estimations and the difference in education levels does not explain the differences in behavior before and after priming.

[6] If participant i resides in area a, then her partners were drawn for areas outside a to minimize the

2.2.2 Priming

The objective of priming is to make a certain personality trait or category more salient. According to self-categorization theory, individuals belong to different categories (gender, occupation, nationality, ethnicity, religious affiliation, etc.), each with its own set of norms. Behavior in a given moment is more affected by the norms of categories that are salient than the norms of categories that are not. We use priming to make religion more salient and to generate exogenous variation of religion which makes causal inference of religion on behavior possible.

Pictures were used to prime participants for religion and a neutral category, which we refer to as no priming. The fact that many of the participants do not read ruled out any priming activity involving reading. Depending on the priming they were assigned to, participants would go to a separate room where a total of 6 pictures related to the priming (see examples in Figures 2.A.1.1 and 2.A.1.2; pictures of fruits were used for the neutral category) were shown before each game, as an assistant would prompt them to say out loud what they thought the picture was about.[7] An active method of priming was used following Simmons and Prentice (2006) who find that priming has an effect only if participants are paying active attention to the priming. No picture was repeated during the two priming sessions.

2.2.3 Games

The participants played standard versions of both dictator and trust games. In a dictator game a Proposer divides a sum S between herself and another player, the Recipient (Kahneman et al. 1990, Forsythe et al. 1994). In equilibrium, self-interested proposers should allocate nothing to the recipient and any positive allocation is treated as a reflection of

possibility of players knowing each other.

[7]The same treatment (type of priming) was applied before each game to avoid diminishing effects of priming over time. The assistant prompted participants to make sure they were thinking about religion-related concepts, or in other words, to make sure the priming "took".

pure altruism. However, laboratory and field experiments have shown that: (1) against the equilibrium prediction, Proposers on average allocate 10 to 25 percent of S to the receiver (Weber et al. 2004); (2) real participants in the field typically allocate more than the student population in the lab, suggesting that real life interactions increase norms of fairness towards others (Carpenter and Matthews 2006); and (3) culture and the level of market integration affects the amount sent (Henrich et al. 2001, in fifteen small societies around the world). In our case, the "dictator" was given GH¢ 6, of which she could send any amount[8] between GH¢ 0 and GH¢ 6 to the recipient; the game ends after the transfer is made. The payoff for the dictator is what she kept for herself, and the recipient gets what was sent by the dictator. Let x_a denote the share of the endowment that player a decides to keep for herself, and π_a her payoff, where $a \in \{d, r\}$, d denotes the dictator and r denotes the recipient.

$$\pi_d = 6x_d \qquad\qquad \pi_r = 6(1 - x_d)$$

A Trust game is essentially a modification of the dictator game where the receiver (Trustee) dictates the allocation, but the amount to be allocated is decided by the proposer (Investor). In the game, designed by Berg, Dickhaut, and McCabe (1995), one of the players is labeled Investor and the other is labeled Trustee. The investor was given GH¢ 6 that she could split any way she wanted with the trustee. Let x_i denote the share kept by the investor. The amount sent by the investor $6(1 - x_i)$, was then multiplied by 3 and was given to the trustee, who in turn could send back any amount up to what she received, $18(1 - x_i)$, to the investor.[9] Let x_t denote the share kept by the trustee. The payoff for the investor equals the amount she kept for herself plus whatever is sent back by the trustee, while the trustee receives the amount she decided to keep for herself. Let π_a denote player $a's$ payoff, where

[8]The players were given five GH¢ 1 bills and two 50 pesewas coins (GH¢ 0.50 each). GH¢ 6 corresponds roughly to one week's wage for people in the first quartile of the income distribution.

[9]Both splits are constrained by the denomination of the currency that was given to the players, which was equal to the total amount minus one in GH¢ 1 bills and GH¢ 1 in two 50 pesewas coins.

$a \in \{i, r\}$, i denotes the investor and t denotes the trustee. Algebraic expressions for the payoffs are given below.

$$\pi_i = 6x_i + 18(1 - x_i)(1 - x_t) \qquad \pi_t = 18(1 - x_i)x_t$$

The subgame perfect equilibrium for both self-interested players is to transfer zero. Independent of the transfer made by the investor, a self-interested trustee would send zero back, and anticipating this, the investor would transfer zero to the trustee. Deviation from zero transfers are interpreted as trust for the investor, and trustworthiness for the trustee. Typically, trust games are used to understand reciprocal behavior and informal enforcement of agreements and incomplete contracts. But in trust games, trust may be confounded with altruism, since altruistic individuals playing a trust game will send money without expecting anything back. Information from the dictator game is then used as a control to analyze trust in the absence of altruism (Cox 2004, Carter and Castillo 2002). Laboratory and field experiments have shown that: (1) individuals depart from the self-interested behavior with both the Investor and Trustee sending positive amounts (Berg et al. 1995 in Zimbabwe, Carter and Castillo 2009 in South Africa); (2) cultural factors like ethnicity (Habyarimana et al. 2007 in urban Uganda, Bernhard et al. 2006 in Papua New Guinea, and Fershtman and Gneezy 2001 in Israel), economic organization (Karlan 2005 in Peru on members in a micro finance organization), and government policies on resettlement (Barr 2003 in rural villages with traditional and settled populations) affect trust and reciprocity.

All participants faced real profiles drawn from the sample but there was no personal contact nor images of the participants were showed.[10] This made possible to have every participant playing the dictator game as a dictator, and only one of the roles in the trust

[10]Note that this is not very different from experiments where participants were told that their partners are humans, when in fact they were computers. Some examples include Weimann (1994), Blount (1995), and Winter and Zamir (2005).

game without having to bring them sequentially to the experiment site.[11]

2.2.4 Protocol

At arrival to the experiment site (in what we call *the big room*), participants were informed about the conditions for participation (a show-up fee of GH¢ 5 was announced) and those who agreed to participate (all of them) signed consent forms. No communication among participants was allowed during the session. After general instructions and instructions for the first game were provided in Twi, and in Pidgin (broken English) or Hausa as needed, the group was divided in two subgroups according to the priming each individual was assigned to. Each subgroup went to a separate room where the priming would take place. After the 6 pictures were shown, the subgroups went back to *the big room* and started making decisions in individual closed cubicles where assistants read the profile (name, gender, age, religion, marital status, ethnicity, education, and area of residence, in that order) for the person they would interact with, and repeated instructions for the game being played using two envelopes: a green envelope where they should put the money they wanted to keep for themselves and a pink envelope for the money they wanted to send to the other party[12]. Participants had complete privacy while making their decisions. After all participants had made their first decision, instructions for the second game were provided in *the big room*, after which priming was conducted in the same 2 rooms as before, but using a different set of pictures for the same topic. Decision making for the second game would take place, this time facing a different partner but keeping the relationship between religion and ethnicity constant. Finally payments were made after both games were played and participants were

[11] 167 participants played the role of investors and 190 played the role of trustees. Since the assignment was random before participation, the difference in the number of participants is explained by different rates of non-participation across roles. The sum of these two numbers does not match the number of participants in the sample -390- since 36 observations for the trust game had to be dropped due to inconsistencies in the payment information. The information for the dictator game is correct for all participants.

[12] The participants were not allowed to keep money during the session trying to minimize wealth effects.

dismissed[13].

2.3 Results

Priming can have three different potential effects on altruism and trust. It can have a *warm glow/cold prickle* effect that makes people more/less altruistic to people from all groups (religious affiliations in our case); it can have a *targeted* effect, where altruism or trust increases when facing people from your own group; and it can have an *antagonist* effect, where altruism or trust decreases when facing people from the other group. These effects are not mutually exclusive.

There are plausible reasons to explain a potential *warm glow* effect. Shariff and Norenzayan (2007) found that after being primed for God-related concepts, subjects allocated more money to strangers in the anonymous dictator game, partially attributing this fact to the activation of the perception of being watched by God. In the other two cases, one possible explanation of why priming for religion might change the allocations differently is that it increases the awareness of the differences among religions, or what might be equivalent in terms of outcomes, it makes a potentially differentiating variable more salient. McCauley (2009), for example, finds that priming for religion increases average contributions in a dictator game, but decreases contributions to other religious groups.

Table **??** presents the average shares kept by participants in the two games.[14] Average shares kept increased for the three roles after priming, but the increase for the trustees is not statistically significant. Further analysis will allow us to identify what kind of effect (among the three mentioned above) is driving this increase.

[13]Transportation to and from the experiment site was provided to all participants.

[14]Note that every participant played as a dictator in the dictator game and roughly half of the sample played as investors and the rest played as trustees.

Table 2.2: Average share kept by participants

	Dictator	Investor	Trustee
No priming	0.631	0.628	0.650
Priming	0.670**	0.678*	0.688
p-value	0.047	0.065	0.115

* Different from no priming at 10%
** Different from no priming at 5%

2.3.1 Dictator game

On average, we find that priming for religion increases the share kept by dictators as shown in Table ??. Priming for religion reduces the allocations to subjects with a different religious affiliation (Table ??). Both Christians give less to Muslims after priming as well as Muslims give less to Christians. The average allocations for recipients with the same religion are not affected (statistically) by priming.

Table 2.3: Share kept by dictators by priming and religion

			Dictator			
			No priming		Religion priming	
			Christian	Muslim	Christian	Muslim
Recipient	Christian	Mean	0.639	0.561	0.655	0.656*
		St. dev.	0.239	0.195	0.235	0.169
		Nobs	105	15	88	16
	Muslim	Mean	0.646	0.633	0.753*	0.653
		St. dev.	0.278	0.218	0.173	0.182
		Nobs	24	54	24	44

* significantly different from no priming at 10%

Trying to better understand the mechanism through which priming affects behavior, we estimate a regression model with the share kept by the dictator as the dependent variable[15]

[15] We use a fractional logit with robust errors with the share kept being treated as a continuous variable.

and all the individual characteristics for both the dictator and the recipients as explanatory variables. We estimate separate regressions for the participants that were primed and those who were not, under the hypothesis -that we cannot reject- that priming changes behavior.[16] Table **??**, that includes only significant variables and the dummies DRSE (dictator faces a recipient with different religion but same ethnicity) and SRDE (dictator faces a recipient with same religion but different ethnicity), presents coefficients and marginal effects from the estimation. Under no priming, Christian dictators keep more for themselves than Muslims, dictators keep more when facing older recipients, and dictators from the Ewe and Akan ethnic groups keep less. After being primed for religion, all explanatory variables become insignificant except the dummy DRSE that takes the value of one when the dictator faces a recipient with a different religious affiliation and same ethnicity. Its positive sign indicates that the share kept by dictators is higher when facing someone from a different religion. The fact that religious differences overrule all other explanatory variables after priming suggests a mechanism through which priming affects behavior. The positive sign of the coefficient is consistent with the second case presented above, where priming has an *antagonist* effect.

2.3.2 Trust game

In both the investor and the trustee's decisions altruism might play a role. The investor might transfer money to the trustee just because she cares about the trustee's payoff, independent of the decision the trustee will make regarding how much to send back. The same might be true about the trustee's decision. In the case of the trustee, he also might reciprocate the investor's decision, by transferring a low amount if the investor sends too little, and rewarding a generous investor with a higher transfer.

Table **??** presents the average kept by investors by religion and priming. The only statis-

[16]We estimated models jointly with priming and no priming including interaction effects and the results do not change qualitatively.

Table 2.4: Regression for share kept by dictator

	No priming		Religion	
VARIABLES	Coefficient	Marginal	Coefficient	Marginal
Christian dictator	0.435*	0.102*	-0.167	-0.036
	(0.249)	(0.059)	(0.286)	(0.061)
Recipient's age	0.402*	0.093*	-0.223	-0.049
	(0.200)	(0.046)	(0.185)	(0.040)
Married dictator	0.259*	0.059*	-0.157	-0.035
	(0.157)	(0.035)	(0.167)	(0.037)
Dictator is working	-0.245*	-0.056*	0.213	0.047
	(0.142)	(0.032)	(0.146)	(0.033)
Ewe dictator	-0.621***	-0.150***	-0.259	-0.058
	(0.234)	(0.058)	(0.273)	(0.063)
Akan dictator	-0.510**	-0.121**	0.105	0.023
	(0.205)	(0.049)	(0.211)	(0.045)
DRSE	-0.325*	-0.077*	0.310*	0.066*
	(0.189)	(0.046)	(0.171)	(0.035)
SRDE	-0.273*	-0.064*	0.006	0.001
	(0.166)	(0.040)	(0.177)	(0.039)
Constant	0.510		1.028***	
	(0.393)		(0.375)	
Observations	213	213	180	180

Robust standard errors in parentheses.
* Statistically significant at 10%.
** Statistically significant at 5%.

tically significant difference due to priming is the higher share kept when Muslim investors face a Muslim trustee. A regression of non primed participants[17] shows that altruistic motives (the share kept when the investor played as a dictator) play a role in the investor's decision, with the degree of altruism being positively associated to the size of the transfer to the trustee. Older trustees are given more by investors and more educated investors give more. After priming for religion, the only variable that is significant in the regression is the

[17] Again using fractional logit with robust errors, and only variables that are significant under no priming or priming, and the dummies DRSE and SRDE are shown in Table **??**.

share kept by the investor when he played as dictator (altruistic motives). Even though non significant, the different-ethnicity (SRDE) and different-religion (DRSE) dummies are both positive after priming for religion, as was the case for the dictator game.

Table 2.5: Share kept by investors by religion and priming

			Investor			
			No priming		Religion priming	
			Christian	Muslim	Christian	Muslim
Trustee	Christian	Mean	0.660	0.571	0.694	0.500
		St. dev.	0.202	0.089	0.227	0.272
		Nobs	47	7	36	4
	Muslim	Mean	0.667	0.583	0.692	0.671*
		St. dev.	0.192	0.244	0.208	0.172
		Nobs	13	25	10	19

* significantly different from no priming at 10%

Table 2.6: Regression for share kept by investor

	No priming		Religion	
VARIABLES	Coefficient	Marginal	Coefficient	Marginal
Share kept as dictator	3.063***	0.705***	3.269***	0.688***
	(0.639)	(0.149)	(0.572)	(0.119)
Trustee's age	-0.325*	-0.075*	0.006	0.001
	(0.184)	(0.042)	(0.205)	(0.043)
Investor with complete primary but less than complete secondary	-0.382**	-0.087**	-0.305	-0.064
	(0.191)	(0.044)	(0.249)	(0.052)
Investor with complete secondary or more	-0.507**	-0.119**	0.205	0.042
	(0.216)	(0.051)	(0.366)	(0.074)
Investor from "Other ethnic groups"	-0.962**	-0.235**	0.090	0.019
	(0.487)	(0.118)	(0.292)	(0.060)
DRSE	-0.061	-0.014	0.147	0.031
	(0.190)	(0.044)	(0.239)	(0.049)
SRDE	-0.131	-0.031	0.362	0.073
	(0.230)	(0.054)	(0.244)	(0.048)
Constant	-0.650		-1.612***	
	(0.762)		(0.578)	
Observations	96	96	71	71

Robust standard errors in parentheses.
* Statistically significant at 10%
** Statistically significant at 5%
*** Statistically significant at 1%

The average shares kept by the trustees by religion and priming are presented in Table **??**. Even though there are no statistically significant differences due to priming, the share kept increases when the trustee faces an investor with a different religion. The low number of observations in the cells where religious affiliations of trustee and investor are different is behind the non significance of relatively large differences.

Table 2.7: Share kept by trustee by religion and priming

			Trustee			
			No priming		Religion priming	
			Christian	Muslim	Christian	Muslim
Investor	Christian	Mean	0.629	0.743	0.653	0.794
		St. dev.	0.228	0.164	0.240	0.138
		Nobs	54	5	48	12
	Muslim	Mean	0.688	0.658	0.795	0.652
		St. dev.	0.301	0.188	0.198	0.187
		Nobs	10	27	11	20

To check whether the amount initially sent by the investor has any effect on the share that is kept by the trustee, we estimate the latter share as a function of individual characteristics of both players, the amount sent by the investor to capture reciprocal motives[18], and the decision made by the trustee when playing as a dictator (share kept) to capture altruistic motives. We estimated separate regressions for participants who were not primed and for those primed for religion. The results are shown in Table **??** below.[19] Once again, the altruistic motives are significant and positive, indicating that more altruistic individuals, measured by a lower share kept when playing as dictator, tend to give more as trustess. The coefficient of the amount sent by the investor is negative and significant for the non primed players, which could be interpreted as indicating the presence of reciprocity -the more is sent by the investor, the less the trustee keeps for herself-. Priming for religion (two rightmost columns in Table **??**) vanishes the influence of the amount sent by the investor and of all individual characteristics, leaving only the degree of altruism, trustee's age, and the dummy for different religious affiliations -DRSE- as the only significant variables. As was the case for the dictator, priming makes religion one of the primary determinants of behavior.

[18]We specify a third degree polynomial in the amount sent by the investor to capture nonlinearities. Note that this is not a completely valid test for reciprocity since simple altruistic preferences could predict the relationship between investor and trustee's decision.

[19]Only variables that are statistically significant in at least one of the regressions and the dummies DRSE and SRDE are shown in the Table.

Table 2.8: Regression for share kept by trustee

	No priming		Religion	
VARIABLES	Coefficient	Marginal	Coefficient	Marginal
Share kept as dictator	2.209***	0.494***	3.151***	0.655***
	(0.533)	(0.122)	(0.766)	(0.162)
Amount sent by investor	-1.414**	-0.317**	-0.208	-0.043
	(0.564)	(0.126)	(0.468)	(0.097)
(Amount sent by investor)^2	0.165**	0.037**	0.023	0.005
	(0.069)	(0.015)	(0.056)	(0.012)
(Amount sent by investor)^3	-0.006**	-0.001**	-0.001	-0.000
	(0.003)	(0.001)	(0.002)	(0.000)
Christian trustee	-0.736***	-0.157***	-0.094	-0.019
	(0.262)	(0.053)	(0.410)	(0.084)
Trustee married	0.516**	0.111***	0.298	0.061
	(0.207)	(0.043)	(0.253)	(0.050)
North trustee	-0.661**	-0.153**	0.091	0.019
	(0.260)	(0.061)	(0.410)	(0.084)
DRSE	-0.348	-0.080	0.500*	0.098**
	(0.235)	(0.056)	(0.265)	(0.049)
SRDE	-0.358	-0.082	0.205	0.041
	(0.236)	(0.055)	(0.263)	(0.052)
Constant	3.140**		-0.959	
	(1.652)		(1.370)	
Observations	98	98	92	92

Robust standard errors in parentheses.
* Statistically significant at 10%
** Statistically significant at 5%
*** Statistically significant at 1%

2.4 Conclusion

Using data from a field experiment with 393 participants in the Greater Accra region in Ghana, we tested whether religion (using priming techniques) has an effect on altruism and trust. We consistently find that priming for religion decreases altruism and trustworthiness to people with different religious affiliations, and overrules reciprocity and most other variables that help explain behavior under no priming. These results indicate that if religion identity is made more salient, through the use of religious discourse during electoral campaigns, for example, there would be less social cooperation, in the form of altruism and trustworthiness, in a religious- and ethnically diverse context in Ghana.

Fairly *positive* pictures about religion were used for priming and still observed inter-group bias based on religious affiliation. We can only guess that the results would be stronger (more bias towards other groups) in the presence of a more negative type of priming.[20] We conjecture that our pictures might be increasing awareness of different groups along the religious dimension, instead of generating a God-is-watching-you feeling conjectured in other studies.

For future work, the different types of results obtained after priming for religion highlight the need to have a better understanding of the mechanisms through which different types of priming affect behavior and how. In the case of religion, this is related to the question, What does it mean to prime for religion? Does it refer to the fact that I belong to a specific religious group, or is it closer to following the word of God?

[20]By *positive* we mean pictures that do not highlight undesirable aspects of the other group or potentially tense situations and differences across them.

2.A Appendix

The Appendix contains four sections. The first section provides examples of pictures used for priming. Section two contains the list of variables used in the regression models. Section three presents the consent form that was signed by participants. The last section provides an example of the instructions sheet that was used by assistants at each of the cubicles where decision making took place.

2.A.1 Pictures used for priming

Figure 2.A.1.1. Examples of pictures used for religion priming

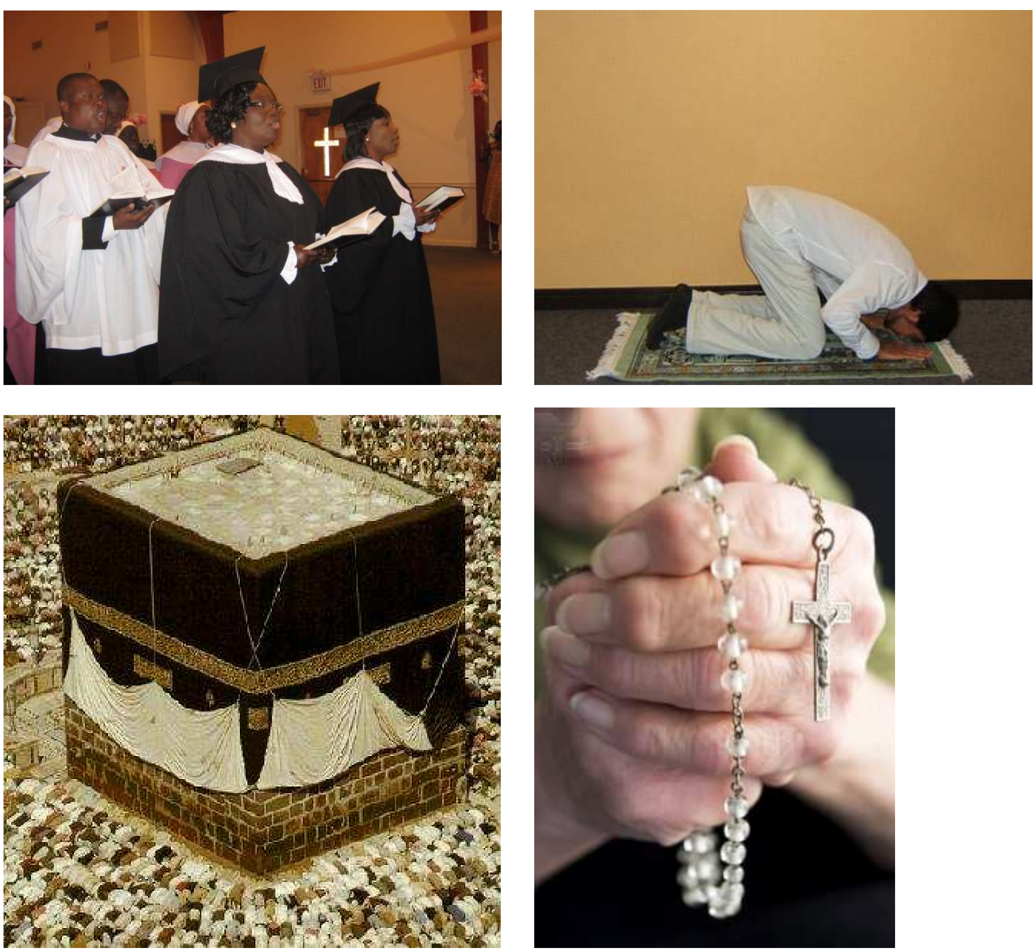


Figure 2.A.1.2. Examples of pictures used for "no priming" (fruits)

2.A.2 List of variables used in the regression models

Variable	Notes
Dummies	
Christian	
Male	
Different gender	Partner has different gender = 1
Christian dominated	Resides in Christian dominated area = 1
Married	
Is working	
Partner is working	
Incomplete primary but less than secondary	One dummy for role being explained and one dummy for partner
Complete secondary or more	One dummy for role being explained and one dummy for partner
Ewe	From Ewe ethnic group = 1
North	From Northern ethnic groups = 1
Akan	From Akan ethnic group = 1
Other ethnic group	From other ethnic groups = 1
DRSE	Partner has different religion and same ethnicity
SRDE	Partner has same religion and different ethnicity
Non dummies	
Age	In years
Partner's age	In years

2.A.3 Consent form

THE WORLD BANK AND ABIBIMMAN FOUNDATION INVITATION FOR RESEARCH

You are invited to participate in a research study on social norms.

This information sheet describes the research and its purpose. Being in the study is voluntary. You do not have to be in the study.

PROJECT TITLE: Experiments on social norms in Ghana.

PRINCIPAL INVESTIGATORS: George Joseph, The World Bank.

WHY IS THIS RESEARCH STUDY BEING DONE?

This study is being done to better understand how people interact with each other in different situations. We expect to learn how community relations can be improved.

WHAT WILL I BE ASKED?

We are interested in the ways in which people interact with each other in different situations. We are going to ask you to make decisions. Some decisions will involve only you. Some other decisions will involve you and other people. You will be expected to participate in the research project for approximately three hours.

INFORMATION PRIVACY

Your private information and your responses will remain confidential and security measures including password protection will be used to protect it further. The information will not be made available to anyone other than the researchers involved in this study.

PAYMENT

You will be paid for being in this study. You will receive a show-up fee of GH¢ 5, and in addition, you will be able to earn extra money depending on the decisions you make as part of the research project. In similar research projects, people have earned an average of GH¢

18 in addition to the show-up fee during participation. All the money will be given out to you at the end of the study today.

RIGHTS

Being in this study is voluntary. You do not have to be in it. You do not have to answer every question. You can quit whenever you want to. You will not be penalized in any way.

WHAT IF I HAVE QUESTIONS OR PROBLEMS?

Call George Joseph at (xxx)xxx-xxx if:

- You have questions about the study.
- You have any problems related to the study.

2.A.4 Example of instructions sheet

ID code: 2B-719 (of the person making the decision)

Activity 1

(Profile for the recipient in the dictator game)

Name: Name1

Gender: Man

Age: 27

Religion: Christian

Marital status: Single

Ethnicity: Akan

Education level: JSS / Middle school

Area: Tulaku

You have GH¢ 6. You now need to decide how much to send to Name1. You can decide to KEEP ALL the money for yourself, you can decide to SEND SOME money to Name1, or you can decide to SEND ALL the money. IT IS YOUR DECISION.

Please put the money you want to keep for yourself in the green envelope, and put the money you want to send to Name1 in the pink envelope. Both of you will be paid the amount in the envelopes.

Activity 2

(Profile for the trustee/investor in the trust game)

Name: Name2

Gender: Woman

Age: 38

Religion: Christian

Marital status: Single

Ethnicity: Akan

Education level: Secondary school / Technical / Vocational / Teacher training college

Area: Community 4

Trustee

Name2 was given GH¢ 6 at one of our offices together with your personal information. Then out of the GH¢ 6, Name2 decided to send GH¢ 1 for you. We tripled that money, and that is why you are now receiving GH¢ 3. You now need to decide how much to send back to Name2. You can decide to KEEP ALL the money for yourself, you can decide to SEND SOME money to Name2, or you can decide to SEND ALL the money. IT IS YOUR DECISION.

Please put the money you want to keep for yourself in the green envelope, and put the money you want to send back to Name2 in the pink envelope.

Investor

You have GH¢ 6. You now need to decide how much to send to Name2. You can decide to KEEP ALL the money for yourself, you can decide to SEND SOME money to Name2, or you can decide to SEND ALL the money. IT IS YOUR DECISION.

The amount you send to Name2 (PINK ENVELOPE) is going to be tripled and given to him/her. Name2 will then decide how much to send back to you. Name2 can decide to KEEP ALL the money for him/her self, (s)he can decide to SEND SOME money to you, or (s)he can decide to SEND ALL the money to you.

You will be paid what you decide to keep for yourself now, plus any amount that is returned to you by Name2.

Please put the money you want to keep for yourself in the green envelope, and put the money you want to send to Name2 in the pink envelope.

3 How Well Does the US Social Insurance System Provide Social Insurance?

(with Mark Huggett)[21]

"From the point of view of insurance, there seem to me to be two compelling theoretical arguments for having the State rather than the market provide a wide range of insurance, for old-age pensions, disability and sickness, unemployment and low income: the first is that the market handles adverse selection badly. The second is that, even if adverse selection were not important, people should take out insurance at an age when they are incapable of doing so rationally, namely zero." - Mirrlees (1995, p. 384)

3.1 Motivation and literature review

One rationale for a government-provided, insurance system is the provision of insurance for risks that are not easily insured in private markets. One can find this rationale in textbooks, in public policy documents and in the work of prominent economists.[22]

An important risk that is often discussed in the context of social insurance is labor income risk. Individual workers experience substantial variation in wage rates which are not related to systematic life-cycle variation or to aggregate fluctuations.[23] A common view is that labor income is not easily insured because it is partly under an individual's control by the choice of unobserved effort or unobserved labor hours and because a component of labor income risk is realized at a young age. It is often claimed that a progressive income tax system together with a progressive social security system may provide valuable insurance. The Economic Report of the President (2004, Ch. 6) claims that the progressive relationship

[21] This chapter was published in the *Journal of Political Economy* 118: 76-112, 2010.

[22] See Rosen (2002, Ch. 9), The Economic Report of the President (2004, Ch. 6) and Mirrlees (1995).

[23] See Heathcote, Storesletten, and Violante (2010) or Kaplan (2010).

between monthly social security benefit payments in the U.S. and a measure of lifetime labor income may be an important source of insurance.

We provide a benchmark analysis of how well a stylized version of the U.S. social insurance system provides social insurance. We do so by determining the maximum possible gain to superior insurance. We analyze only the retirement component of the social security system, treat social security together with income taxation as the entire social insurance system and focus only on a single but very important source of risk. The risk that is examined here is idiosyncratic, wage-rate risk.

Our methodology involves the analysis of two decision problems. One decision problem is that of a cohort of ex-ante identical agents. Each agent maximizes expected utility in the presence of the model social insurance system. It is assumed that asset markets transfer resources over time and that the social insurance system (i.e. social security and income taxation) is the only way to transfer resources across different histories of wage shocks. We then contrast the ex-ante expected utility in the model insurance system with the maximum ex-ante expected utility that a planner could deliver to this cohort. The planner uses no more resources in present-value terms than are used by a cohort in a solution to the model insurance system. The planner is also restricted to choose allocations that are incentive compatible. The incentive problem arises from the fact that the planner observes each agent's earnings but not an agent's hours of work or an agent's wage.

The model we analyze is closely related to the work of Kaplan (2010). He first estimates a process for male wages that accounts for the variation in mean wages and the idiosyncratic component of wages over the life cycle. He then estimates preference parameters to best match moments characterizing the distribution of consumption, hours and wages over the life cycle. The main deviation from Kaplan's model is that we replace the proportional tax rates on labor and capital income in his model with the structure of the U.S. social security system and the U.S. federal income tax system.

We analyze two versions of this model. The full model captures the pattern of permanent, persistent and purely temporary idiosyncratic wage variation estimated from U.S. data, whereas the permanent-shock model shuts down the variance in the persistent and temporary shock components. The analysis of the permanent-shock model is motivated in part because we can solve the planner's problem for this model but not for the full model. Thus, we calculate maximum welfare gains to superior insurance only for the permanent-shock model. However, we calculate optimal parametric policy reforms in both models.

We find that the maximum welfare gain to improved insurance in the permanent-shock model is large. The maximum welfare gain is equivalent to a 4.09 percent increase in consumption each model period. Important differences in time spent working are behind this welfare gain. Specifically, high productivity agents work too little and low productivity agents work too much under the U.S. system as compared to the solution to the planning problem.

One reason for these differences in work time is that the pattern of intratemporal wedges in the planning problem differs markedly from the wedges under the U.S. system. In the planning problem, the wedge between the intratemporal marginal rate of substitution and the wage rate is zero for the highest wage agents at each age and increases as an agent's wage rate falls. Thus, the greatest wedge at each age is for the lowest productivity agent. In the U.S. system, the pattern of wedges is exactly the opposite because marginal income tax rates are progressive and because the social security benefit function is concave in a measure of lifetime earnings.[24]

We explore two main reforms. First, we conduct an optimal piecemeal reform by allowing the social security benefit function to be chosen optimally without changing the social security tax rate or the income tax system. This reform leads to almost no welfare gain

[24] Average tax rates on lifetime earnings are substantially more progressive in a solution to the planning problem than in the model of the U.S. system. Thus, the large welfare gain originates both from too *little* progression in lifetime taxation and from the wrong pattern of marginal tax rates at each age.

in the permanent-shock model but a welfare gain equivalent to a 1.15 percent consumption increase each period in the full model.

The second reform is more radical. We eliminate the model social insurance system and replace it with an optimal tax on the present value of earnings. An optimal present-value tax achieves a welfare gain of 3.95 percent of consumption in the permanent-shock model - nearly all of the maximum possible welfare gain. The present-value tax performs so well because it approximates the wedges between marginal rates of substitution and transformation arising in a solution to the planning problem while allowing for a flexible relationship between lifetime earnings and lifetime consumption. In the full model this optimal reform leads to no welfare gain. Thus, while a present-value tax is well designed for models with only permanent labor productivity differences that remain over the entire lifetime it does not lead to a welfare gain in models with permanent, persistent and temporary sources of labor productivity variation that mimic properties in U.S. wage data.

Two literatures are most closely related to the analysis in this chapter. First, there is the dynamic contract theory literature which analyzes optimal planning problems in which some key information is only privately observed.[25] Our work is similar in spirit to Hopenhayn and Nicolini (1997), Wang and Williamson (2002) and Golosov and Tsyvinski (2006). These papers analyze optimal planning problems and stylized social insurance systems.

Second, there is the literature on social security systems with idiosyncratic risk (e.g. Imrohoroglu, Imrohoroglu, and Joines (1995), Huggett and Ventura (1999) and Storesletten, Telmer, and Yaron (1999)). Nishiyama and Smetters (2007) is one interesting paper from this literature. They consider various ways of partially privatizing the U.S. social security system. They find important efficiency gains when they abstract from idiosyncratic wage risk. When idiosyncratic risk is added, they find either no efficiency gains or very small gains

[25] This work builds upon Mirrlees (1971). Golosov, Tsyvinski, and Werning (2006) review the recent theoretical literature.

for the reforms they analyze.

Our findings paint a different picture. We find that the maximum welfare gain to improved insurance substantially increases as the magnitude of idiosyncratic wage risk increases. Our work differs from Nishiyama and Smetters (2007) in at least two main ways. First, we focus on ex-ante welfare as is common in the contract theory literature rather than the ex-interim notion they use. This allows us to assess insurance provision over shocks realized early in life. Second, the methodology differs as we solve for allocations maximizing ex-ante welfare rather than trying particular reforms. This methodology allows one to determine if the maximum possible welfare gain is large or small and to determine which reforms are well focused. It also allows one to take steps towards designing superior insurance systems simply because properties of solutions to the planning problem are known in advance.

The chapter is organized as follows. Section 3.2 presents the framework. Section 3.3 sets model parameters. Section 3.4 and 3.5 present the main results. Section 3.6 concludes.

3.2 Framework

3.2.1 Preferences

An agent's preferences over consumption and labor allocations over the life cycle are given by a calculation of ex-ante, expected utility.

$$E\left[\sum_{j=1}^{J}\beta^{j-1}u(c_j,l_j)\right]=\sum_{j=1}^{J}\sum_{s^j\in S^j}\beta^{j-1}u(c_j(s^j),l_j(s^j))P(s^j)$$

Consumption and labor allocations are denoted $(c,l)=(c_1,...,c_J,l_1,...,l_J)$. Consumption and labor at age $j=1,...,J$ are functions $c_j:S^j\rightarrow R_+$ and $l_j:S^j\rightarrow[0,1]$ mapping j-period shock histories $s^j\in S^j$ into consumption and labor decisions. The set of possible j-period histories is denoted $S^j=\{s^j=(s_1,...,s_j):s_i\in S, i=1,...,j\}$, where S is a finite set of shocks. $P(s^j)$ is the probability of history s^j. An agent's labor productivity in period j, or equivalently at age j, is given by a function $\omega(s_j,j)$ mapping the period shock s_j and the agent's age j into labor productivity - effective units of labor input per unit of time worked.

3.2.2 Incentive Compatibility

Labor productivity is observed only by the agent. The principal observes the earnings of the agent which equals the product of a wage rate, labor productivity and work time. In this context, the Revelation Principle implies that the allocations (c,l) that can be achieved between a principal and an agent are precisely those that are incentive compatible.[26]

We now define incentive compatible allocations. For this purpose, consider the report function $\sigma\equiv(\sigma_1,...,\sigma_J)$, where σ_j maps shock histories $s^j\in S^j$ into S. The truthful report function σ^* has the property that $\sigma_j^*(s^j)=s_j$ in any period for any j-period history. An allocation (c,l) is *incentive compatible* (IC) provided that the truthful report function always

[26]See Mas-Colell, Whinston, and Green (1995, Prop. 23.C.1).

gives at least as much expected utility to the agent as any other feasible report function.[27] The expected utility of an allocation (c, l) under a report function σ is denoted $W(c, l; \sigma, s_1)$.[28] Using this notation, (c, l) is IC provided $W(c, l; \sigma^*, s_1) \geq W(c, l; \sigma, s_1), \forall s_1, \forall \sigma$.

$$W(c, l; \sigma, s_1) \equiv \sum_{j=1}^{J} \sum_{s^j \in S^j} \beta^{j-1} u \left(c_j(\hat{s}^j), \frac{l_j(\hat{s}^j)\omega(\sigma_j(s^j), j)}{\omega(s_j, j)} \right) P(s^j | s_1)$$

$$\hat{s}^j \equiv (\sigma_1(s^1), ..., \sigma_j(s^j))$$

3.2.3 Decision Problems

This chapter focuses on two decision problems: the U.S. social insurance problem and the planning problem. These problems have the same objective but different constraint sets. V^{us} and V^{pp} denote the maximum ex-ante, expected utility achieved.

$$V^{us} \equiv \max_{(c,l) \in \Gamma^{us}} E\left[\sum_{j=1}^{J} \beta^{j-1} u(c_j, l_j)\right]$$

$$\Gamma^{us} = \{(c, l) : \sum_{j=1}^{J} \frac{c_j}{(1+r)^{j-1}} \leq \sum_{j=1}^{J} \frac{(w\omega(s_j, j)l_j - T_j(x_j, w\omega(s_j, j)l_j))}{(1+r)^{j-1}}$$

$$\text{and } x_{j+1} = F_j(x_j, w\omega(s_j, j)l_j, c_j), x_1 \equiv 0\}$$

$$V^{pp} \equiv \max_{(c,l) \in \Gamma^{pp}} E\left[\sum_{j=1}^{J} \beta^{j-1} u(c_j, l_j)\right]$$

$$\Gamma^{pp} = \{(c, l) : E\left[\sum_{j=1}^{J} \frac{(c_j - w\omega(s_j, j)l_j)}{(1+r)^{j-1}}\right] \leq Cost \text{ and } (c, l) \text{ is IC } \}$$

The constraint set Γ^{us} is specified by a tax function T_j and a law of motion F_j for a vector of state variables x_j. The tax function states the agent's tax payment at age j as a function of period earnings $w\omega(s_j, j)l_j$ and the state variables x_j. Earnings equal the product of a wage

[27] A report function σ is feasible for (c, l) provided (1) $\omega(s_j, j)$ is always large enough to produce the output required by a report (i.e. $0 \leq l_j(\hat{s}^j)\omega(\sigma_j(s^j), j) \leq \omega(s_j, j), \forall j, \forall s^j$, where $\hat{s}^j \equiv (\sigma_1(s^1), ..., \sigma_j(s^j)))$ and (2) σ maps true histories into reported histories that can occur with positive probability.

[28] $W(c, l; \sigma, s_1)$ is defined only for $\omega(s_j, j) > 0$. Later in the chapter, we will set labor productivity to zero beyond a retirement age. It is then understood that labor supply is set to zero at those ages.

rate w per efficiency unit of labor, labor productivity $\omega(s_j, j)$ and work time l_j. Allocations in Γ^{us} have the property that the present value of consumption is no more than the present value of labor earnings less net taxes for any history of labor-productivity shocks.[29] The next section demonstrates that this abstract formulation can capture important features of the U.S. social security and income tax system.

The constraint set Γ^{pp} for the planning problem has two restrictions. First, the expected present value of consumption less labor income cannot exceed some specified value, denoted $Cost$. We set $Cost$ to the present value of resources extracted from a cohort in a solution to the U.S. social insurance problem: $Cost \equiv E[\sum_{j=1}^{J} -\frac{T_j(x_j, w\omega(s_j,j)l_j^{us})}{(1+r)^{j-1}}]$. As all shocks are idiosyncratic, a known fraction of agents $P(s^j)$ in a cohort receives any shock history $s^j \in S^j$. Thus, while the resources extracted from a single agent over the lifetime is potentially random, the resources extracted from a large cohort is not random. Second, allocations (c, l) must be incentive compatible (IC).

Ex-ante expected utility can be ordered in these problems so that $V^{pp} \geq V^{us}$. The argument is based on showing that if the allocation (c^{us}, l^{us}) achieves the maximum, then (c^{us}, l^{us}) is also in Γ^{pp}. Since (c^{us}, l^{us}) satisfies the present value condition in Γ^{us}, then it also satisfies the expected present value condition in Γ^{pp} by the choice of $Cost$. It remains to argue that (c^{us}, l^{us}) is incentive compatible. However, the fact that (c^{us}, l^{us}) is an optimal choice implies that it is incentive compatible.

3.2.4 Model Tax-Transfer System

The tax function and law of motion (T_j, F_j) are now specified to capture features of U.S. social security and federal income taxation. The tax function T_j is the sum of social security taxes T_j^{ss} and income taxes T_j^{inc}. The state variable $x_j = (x_j^1, x_j^2)$ in T_j has two components:

[29]The constraint set can equivalently be formulated as a sequence of budget restrictions where the agent has access to a risk-free asset, starts life with zero units of this asset and must end life with non-negative asset holding.

x_j^1 is an agent's average earnings up to period j and x_j^2 is an agent's asset holdings.

$$T_j(x_j, w\omega(s_j, j)l_j) = T_j^{ss}(x_j^1, w\omega(s_j, j)l_j) + T_j^{inc}(x_j^1, x_j^2, w\omega(s_j, j)l_j)$$

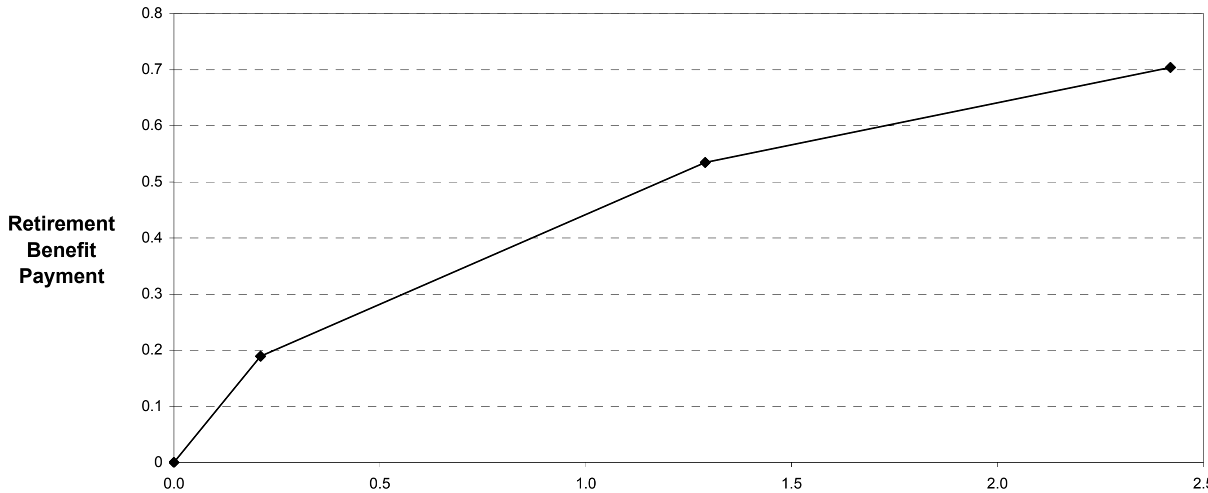
Social Security

The model social security system taxes an agent's labor income before a retirement age R and pays a social security transfer at and after the retirement age. Specifically, taxes are proportional to labor earnings $(w\omega(s_j, j)l_j)$ for earnings up to a maximum taxable level e_{max}. The social security tax rate is denoted by τ. Earnings beyond the maximum taxable level are not taxed. At and after the retirement age, a transfer $b(x^1)$ is given that is a fixed function of an accounting variable x^1. The accounting variable is an equally-weighted average of earnings before the retirement age R (i.e. $x_{j+1}^1 = [\min\{w\omega(s_j, j)l_j, e_{max}\} + (j-1)x_j^1]/j$). The earnings that enter into the calculation of x_j^1 are capped at a maximum level e_{max}. After retirement, the accounting variable remains constant at its value at retirement.

$$T_j^{ss}(x_j^1, w\omega(s_j, j)l_j) = \begin{cases} \tau \min\{w\omega(s_j, j)l_j, e_{max}\} & : \quad j < R \\ -b(x_j^1) & : \quad j \geq R \end{cases}$$

The relationship between average past earnings x^1 and social security benefits $b(x^1)$ in the model is shown in Figure **??**. Benefits are a piecewise-linear function of average past earnings. Both average past earnings and benefits are normalized in Figure **??** so that they are measured as multiples of average earnings in the economy. The first segment of the benefit function in Figure **??** has a slope of .90, whereas the second and third segments have slopes equal to .32 and .15. The bend points in Figure **??** occur at 0.21 and 1.29 times average earnings in the economy. The variable e_{max} is set equal to 2.42 times average earnings.

Figure 3.1: US Social Security Benefit Formula



Source: Social Security Handbook (2003).
Average earnings and benefit payments are both expressed as a multiple of average economy wide earnings.

We set the bend points and the maximum earnings e_{max} equal to the actual multiples of mean earnings used in the U.S. social security system. We also set the slopes of the benefit function equal to actual values.[30] Figure **??** says that the social security retirement benefit payment is about 45 percent of mean earnings in the economy for a person whose average earnings over the lifetime equals mean earnings in the economy.

Two differences between the model system and the old-age component of the U.S. system are the following:[31]

[30]In the U.S. social security system, a person's monthly retirement benefit is based on a person's averaged indexed monthly earnings (AIME). For a person retiring in 2002, this benefit equals 90% of the first \$592 of AIME, plus 32% of AIME between \$592 and \$3567, plus 15% of AIME over \$3567. Dividing these "bend points" by average earnings in 2002 and multiplying by 12 gives the bend points in Figure **??**. Bend points change each year based on changes in average earnings. The maximum taxable earnings from 1998-2002 averaged 2.42 times average earnings. All these facts, as well as average earnings data, come from the Social Security Handbook (2003). The retirement benefit above is for a single-person household. We abstract from spousal benefits.

[31]We do not try to capture the degree to which the progressivity of the old-age component of social security is mitigated by a positive correlation between survival rates and earnings.

(i) The accounting variable in the U.S. system is an average of the 35 highest earnings years, where the yearly earnings measure which is used to calculate the average is capped at a maximum earnings level.[32] In the model, earnings are capped at a maximum level just as in the actual system, but earnings in all pre-retirement years are used to calculate average earnings.

(ii) In the U.S. system the age at which benefits begin can be selected within some limits with corresponding actuarial adjustments to benefits. In the model the age R at which retirement benefits are first received is fixed.

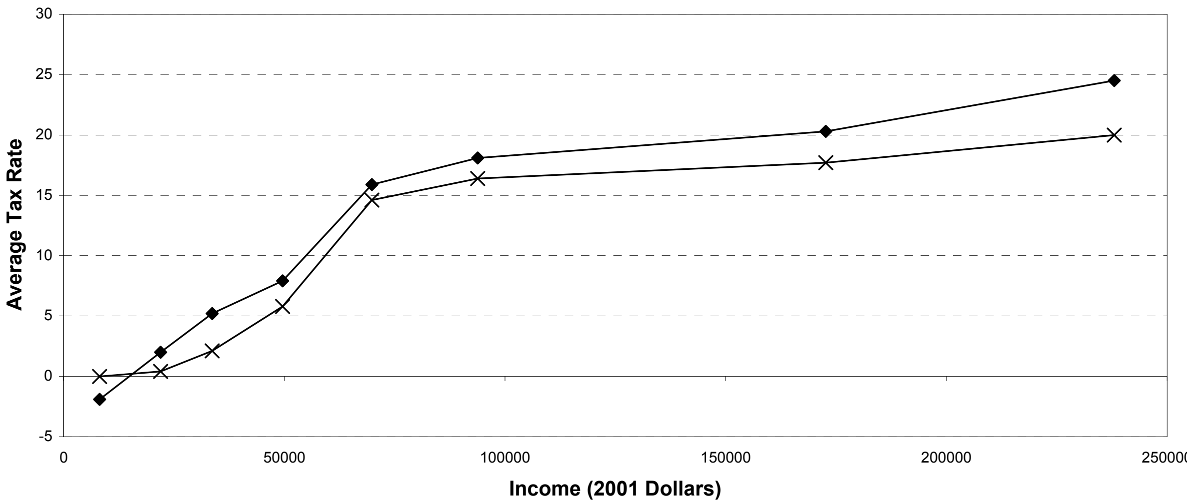
Income Taxation

Income taxes in the model economy are determined by applying an income tax function to a measure of an agent's income. The empirical tax literature has calculated effective tax functions (i.e. the empirical relationship between taxes actually paid and income).[33] We use tabulations from the Congressional Budget Office (2004, Table 3A and Table 4A) for the 2001 tax year to specify the relation between average effective federal income tax rates and income. Figure **??** plots average effective tax rates for two types of households: head of household is 65 or older and head of household is younger than 65. The horizontal axis in Figure **??** measures income in 2001 dollars. Figure **??** shows that average federal income tax rates increase strongly in income.

[32]The 35 highest years are calculated on an indexed basis in that indexed earnings in a given year equal actual nominal earnings multiplied by an index. The index equals the ratio of mean earnings in the economy when the individual turns 60 to mean earnings in the economy in the given year. In effect, this adjusts nominal earnings for inflation and real earnings growth.

[33]See, for example, Gouveia and Strauss (1994).

Figure 3.2: Average Federal Income Tax Rates



Source: Congressional Budget Office (2004).

In the model economy, we choose income taxes $T_j^{inc}(x_j^1, x_j^2, w\omega(s_j, j)l_j)$ before and after the retirement age R to approximate the average tax rates in Figure **??**. We proceed in three steps. First, we approximate the data in 2001 dollars with a continuous function. Specifically, we use the quadratic function passing through the origin that minimizes the squared deviations of the tax function from data. This gives average tax functions before and after the retirement age. Second, we express model income in 2001 dollars.[34] Third, the average tax rates on model income are given by the function estimated in the first step after expressing model income in 2001 dollars. Model income equals the sum of labor income $w\omega(s_j, j)l_j$, asset income $x_j^2 r$ and social security transfer income $b_j(x_j^1)$, where initial assets are zero (i.e. $x_1^2 = 0$).

[34]This is done using the ratio between the average U.S. earnings and average model earnings. The figure for average U.S. earnings is $\$32,921$. This comes from the benefit calculation section of the Social Security Handbook (2003).

3.3 Parameter Values

The results of the chapter are based upon the parameter values in Table ??. Model parameters are principally set equal to the values estimated by Kaplan (2010). The goal of Kaplan's work is to understand many dimensions of cross-sectional inequality from the perspective of a standard, incomplete-markets model with endogenous labor supply. Model parameters are estimated to account for the cross-sectional, variance-covariance patterns of hours, consumption and wages at different ages over the life cycle.[35]

One key departure from Kaplan's model is that our tax-transfer system differs. We consider a tax-transfer system that captures features of social security and federal income taxation. Thus, net marginal tax rates will vary with an agent's age and state. Capital and labor taxes in Kaplan's work are proportional taxes that are age and state invariant.[36]

There are $J = 56$ model periods in an agent's life. Retirement occurs at model period $R = 41$. At the retirement age labor productivity is zero and an agent starts collecting social security benefits. One model period corresponds to one year. Thus, we view the agent as starting the working life at a real-life age of 25, retiring at age 65 and dying after age 80.

An agent's labor productivity is $\omega(s_j, j) = \mu_j \, exp(s_j^1 + s_j^2 + s_j^3)$. The wage at age j is determined by a fixed wage rate w per efficiency unit of labor and by labor productivity $\omega(s_j, j)$. Labor productivity is given by a deterministic component μ_j and by an idiosyncratic shock component $s_j = (s_j^1, s_j^2, s_j^3)$ which captures permanent, persistent and temporary sources of productivity differences. The permanent component s^1 stays fixed for an agent over the life cycle and is distributed $N(-\sigma_1^2/2, \sigma_1^2)$. The persistent component follows an autoregressive process $s_j^2 = \rho s_{j-1}^2 + \eta_j$, $\eta_j \sim N(0, \sigma_2^2)$. The temporary component s_j^3 is independent across

[35] Heathcote et al. (2010) analyze a related model with time-varying variances of different components of wages to account for the change in cross-sectional hours, wage, earnings and consumption inequality in the U.S. over time.

[36] There are two other departures. First, we do not allow for heterogeneity in the preference parameters. Second, the working lifetime is 40 years rather than the 38 years in Kaplan (2010). We thank Greg Kaplan for providing his estimates of the mean productivity profile based upon 40 working years.

periods and is distributed $N(-\sigma_3^2/2, \sigma_3^2)$.

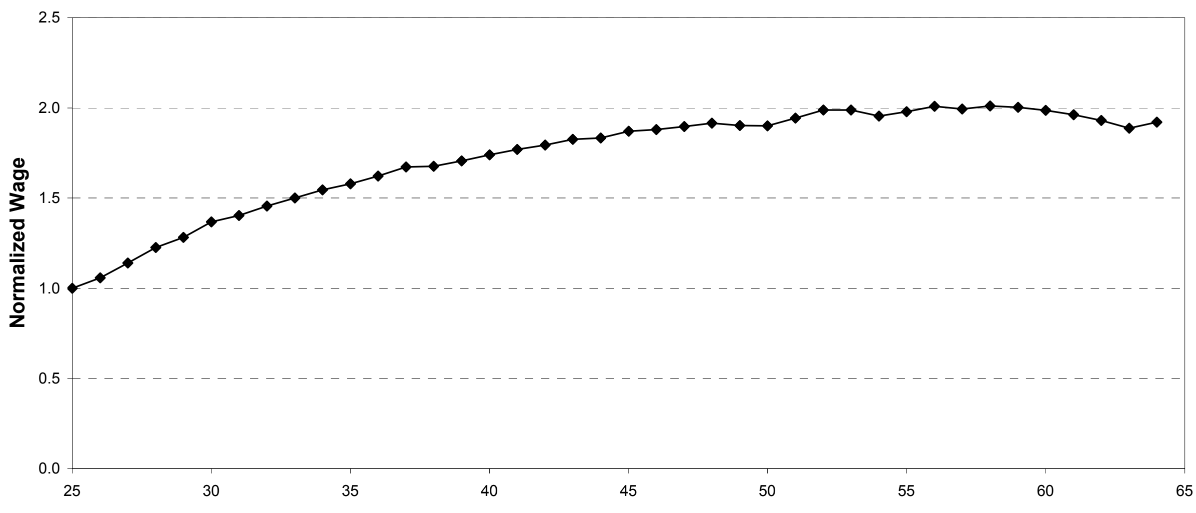
Table 3.9: Parameter values

Definition	Symbol	Value	Source
Model Periods	J	$J = 56$	Age 25 - 80
Retirement Period	R	$R = 41$	Kaplan (2010)
Labor Productivity	$\omega(s_j, j)$	$\omega(s_j, j) = \mu_j \; exp(s_j^1 + s_j^2 + s_j^3)$ $s_j^1 \sim N(-\sigma_1^2/2, \sigma_1^2)$ $s_j^2 = \rho s_{j-1}^2 + \eta_j, \eta_j \sim N(0, \sigma_2^2)$ $s_j^3 \sim N(-\sigma_3^2/2, \sigma_3^2)$ Permanent-Shock Model $(\sigma_1^2, \sigma_2^2, \sigma_3^2, \rho) = (.056, 0, 0, 0)$ Full Model $(\sigma_1^2, \sigma_2^2, \sigma_3^2, \rho) = (.056, .019, .072, .946)$	Kaplan (2010)
Mean Productivity	μ_j	Figure **??**	Kaplan (2010)
Preferences	$u(c, l)$	$u(c, l) = \frac{c^{(1-\nu)}}{(1-\nu)} + \phi \frac{(1-l)}{(1-\gamma)}^{(1-\gamma)}$ $(\nu, \gamma, \phi) = (1.66, 5.55, 0.13)$	Kaplan (2010)
Social Security Tax	τ	$\tau = .106$	OASI tax rate
Benefit Function	$b(x)$	Figure **??**	SS Handbook (2003)
Income Tax	T^{inc}	Figure **??**	CBO (2004)
Interest Rate	r	$r = 0.042$	Siegel (2002)
Discount Factor	β	$\beta = .98803$	See Text

We consider a benchmark model with only permanent shocks as well as a full model with all three stochastic components. The parameters are set to estimates from Kaplan (2010). A one standard deviation permanent shock leads to about a 24 percent permanent change in wages, whereas a one standard deviation innovation to the persistent component changes wages by about 14 percent. The persistent shock is set to zero for each agent at the beginning of the working life cycle.

The deterministic wage component μ_j is given in Figure **??**. This component implies that wages approximately double over the life cycle. We approximate each productivity process with a discrete number of shocks.[37]

Figure 3.3: US Wage Profile



Source: Kaplan (2010).

The period utility function in the model is additively separable $u(c,l) = \frac{c^{(1-\nu)}}{(1-\nu)} + \phi\frac{(1-l)^{(1-\gamma)}}{(1-\gamma)}$. Utility function parameters are set equal to Kaplan's estimates. The coefficient of relative risk aversion is $\nu = 1.66$. The coefficient $\gamma = 5.55$ governs the Frisch elasticity of labor (i.e. $\epsilon_{labor} = \frac{1}{\gamma}\frac{(1-l)}{l}$ so that the Frisch elasticity is 0.27 evaluated at $l = .4$). These values lie well

[37]We approximate the permanent component with 5 equally-spaced points in logs on the interval $[-\sigma_1^2/2 - 3\sigma_1, -\sigma_1^2/2 + 3\sigma_1]$. Following Tauchen (1986), probabilities are set to the area under the normal distribution, where midpoints between the approximating points define the limits of integration. The persistent component is approximated with 3 equally-spaced points on the interval $[-4\sigma_2, 4\sigma_2]$. Transition probabilities are calculated following Tauchen (1986). The temporary component is approximated with 2 values.

within a range of values estimated in the literature based upon micro-level consumption and labor data - see Browning, Hansen, and Heckman (1999). The value $\phi = 0.13$ is the mean value estimated by Kaplan.

One important restriction on the utility function $u(c, l)$ is the assumption of additive separability. Much of the literature on dynamic contract theory with a labor decision employs this assumption. We make use of this assumption when we design a procedure to compute solutions to the planning problem.[38]

The parameters of the model tax-transfer system are set to capture features of social security and federal income taxation in the U.S. Thus, the social security tax rate τ is set to equal 10.6 percent of earnings. This is the combined employee-employer tax for the old-age and survivor's insurance component of social security. The social security benefit function $b(x)$ and the income tax function T_j^{inc} are given by Figure **??** and Figure **??**, which were discussed in the previous section.

The model is explicitly a partial equilibrium model in that wage w per efficiency unit of labor and the real interest rate r are exogenous. They do not vary as we consider alternative social insurance arrangements. Nevertheless, we choose the value of the agent's discount factor β so that a steady state of a general equilibrium version of the full model produces the interest rate $r = .042$ in Table **??**. This interest rate is the average of the real return to stock and to long-term bonds over the period 1946-2001 (see Siegel (2002, Tables 1-1 and 1-2)). The value of the wage w in the model is then set to the value consistent with the factor inputs that produce this real return as explained in the Appendix.[39]

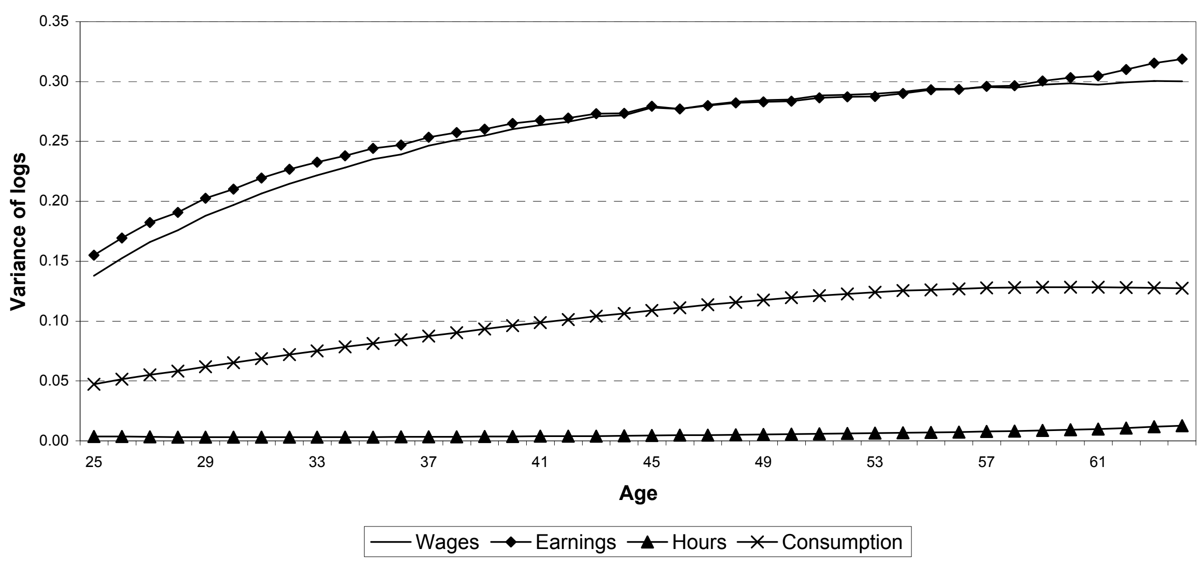
Figure **??** displays the evolution of the variance of (log) wages, earnings, work hours and consumption within the full model. The dispersion in wages early in life reflects the sum of

[38]It is used in Theorem A1 in the Appendix to establish which incentive constraints bind and to reduce dimensionality when we compute solutions to the permanent-shock problem.

[39]The notion of a steady state and how to compute it is standard and follows Huggett (1996). This involves choosing an aggregate production function and setting factor prices to marginal products. The Appendix describes in detail how this is carried out.

the permanent and temporary components of productivity. The rise in wage dispersion with age reflects the role of persistent shocks. The dispersion in earnings over the life cycle closely mimics the pattern for wages. One reason for this is that, absent preference heterogeneity, the model produces little dispersion in work hours. The rise in consumption dispersion over the life cycle reflects mainly the role of persistent shocks. The levels of consumption, earnings and wage dispersion are lower at all ages within the full model compared to the U.S. facts documented in Heathcote, Storesletten, and Violante (2005). This is because Kaplan (2010) analyzes residual dispersion - dispersion after controlling for observable sources of variation such as those related to differences in education - rather than total dispersion. Although the estimate of the permanent wage shock variance is reduced compared to the estimates in Heathcote et al. (2010), the parameters related to persistent and temporary shocks are not greatly affected.

Figure 3.4: Inequality Over the Life Cycle - Full Model



3.4 Analyzing Welfare Gains

This section analyzes welfare gains within the permanent-shock model.

3.4.1 Maximum Welfare Gains

The maximum welfare gain to improved insurance is measured by the percentage increase α in consumption in the allocation (c^{us}, l^{us}) solving the U.S. social insurance problem so that ex-ante expected utility is the same as in an allocation (c^{pp}, l^{pp}) solving the planning problem.[40] These allocations use the same expected present value of resources. This calculation is shown below. The results of this section are based on computing solutions to each problem. Computational methods are described in the Appendix.

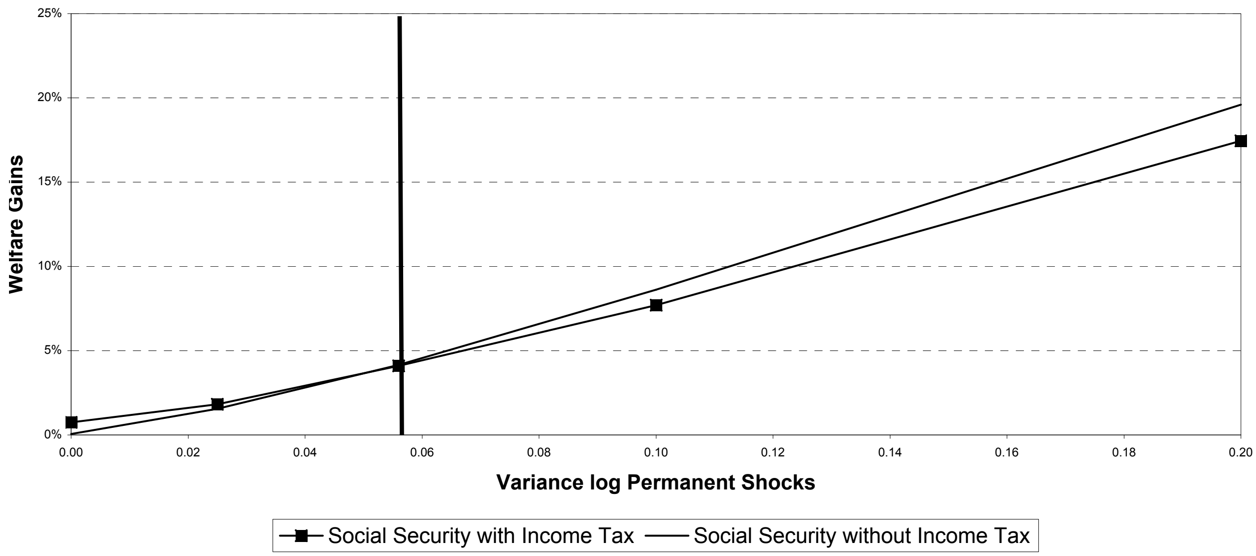
$$E\left[\sum_{j=1}^{J} \beta^{j-1} u(c_j^{us}(1+\alpha), l_j^{us})\right] = E\left[\sum_{j=1}^{J} \beta^{j-1} u(c_j^{pp}, l_j^{pp})\right] \equiv V^{pp}$$

Figure **??** highlights the maximum welfare gains attainable for a range of values of the variance of the permanent component of wage shocks. Figure **??** shows that the welfare gain is increasing in this variance. This is true both when the model social insurance system only includes social security and when the model social insurance system includes both social security and income taxation.

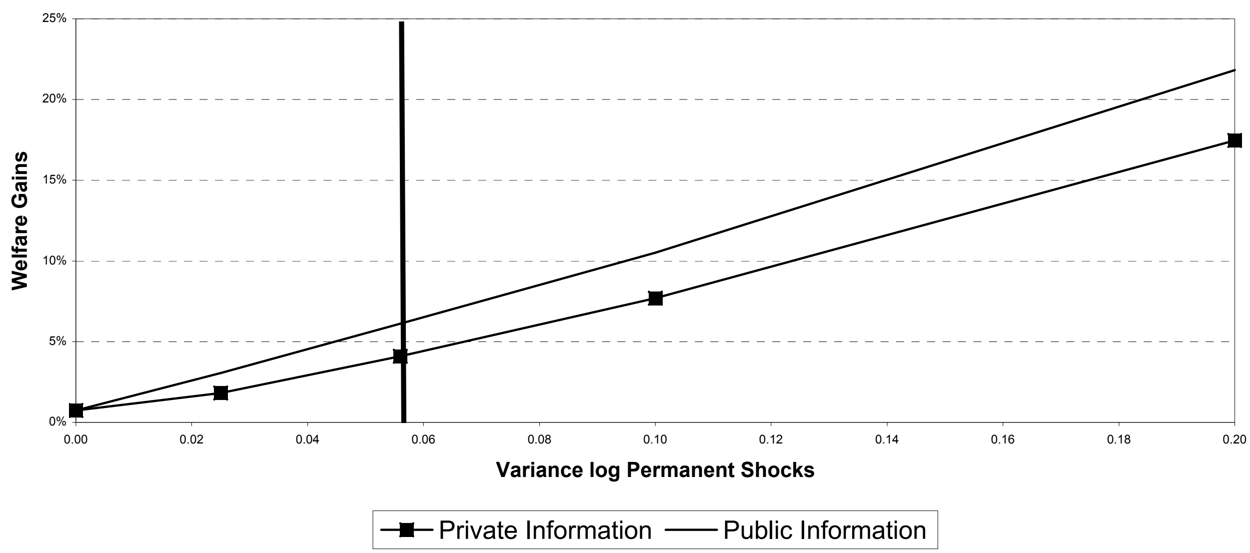
[40] When the range of the period utility function of consumption is not bounded from above, then there is always a value α solving this equation. The utility to consumption is bounded above by zero for the period utility function in Table **??**. Nevertheless, as Figure **??** highlights, α is well defined for all the examples analyzed.

Figure 3.5: Maximum Welfare Gains - Private Information

(a) Private information



(b) Public information



The bold vertical line in Figure **??** highlights the location of the point estimate of the variance described in the text.

To quantify the size of the maximum welfare gain, we need an estimate of this variance. Kaplan (2010) estimates that $\sigma_1^2 = .056$ for permanent shocks. Thus, a one standard deviation shock increases wages permanently over the lifetime by about 24 percent. Heathcote et al. (2010) estimate a wage process with a similar structure to Kaplan (2010) but find that $\sigma_1^2 = .109$. One reason for this difference is that in a first stage regression Kaplan controls for permanent differences in wages related to education whereas Heathcote et al. do not. It is valuable to keep both estimates in mind in viewing Figure **??**a. Using Kaplan's estimate, Figure **??**a shows that the maximum welfare gain in the model of the combined social security and income tax system is equivalent to a 4.1 percent increase in consumption each period.

The analysis in Figure **??**a is based upon the idea that while earnings are publicly observed both individual hours of work and individual wage rates are only privately observed. This implies that any mechanism determining consumption and labor over the lifetime must respect the incentive compatibility constraints. Figure **??**b describes how important private information is for limiting the size of the gains to superior insurance. Figure **??**b plots the maximum welfare gain in the economy with social security and income taxation when wage rates are private information and when they are public information. At the value $\sigma_1^2 = .056$, the maximum welfare gain under public information is equivalent to a 6.1 percent change in consumption at each age. This gain is achieved by having all agents of a given age consume the same amount despite large differences in earnings across agents with different productivities.

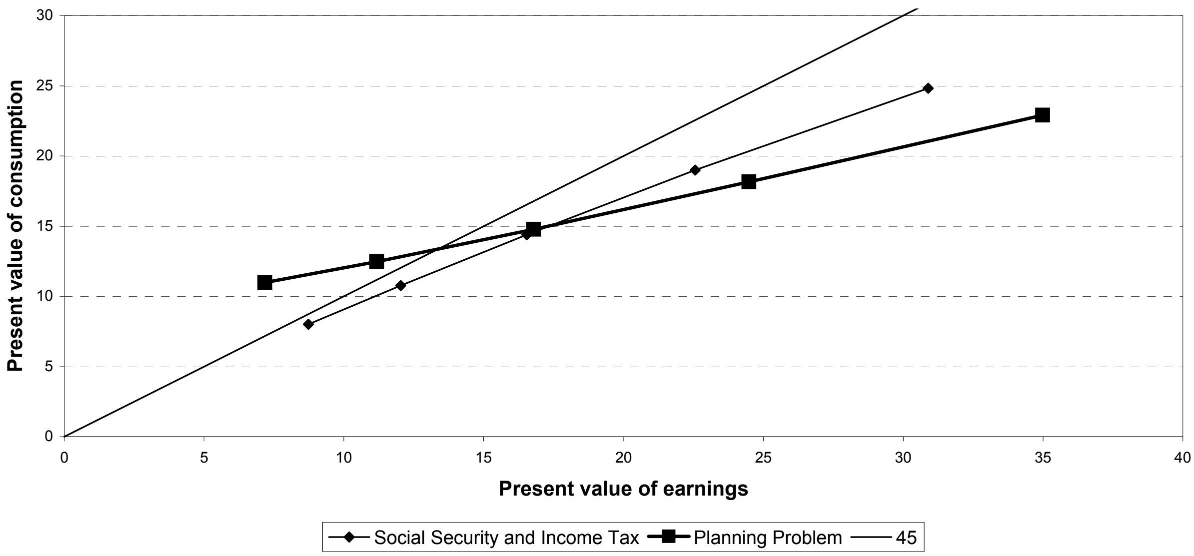
The remainder of section 3.4 develops an understanding of what lies behind the patterns in Figure **??**. In doing so, the following questions are addressed: (1) How do patterns of lifetime taxation differ in the two problems?, (2) To what degree can welfare be improved by reallocating consumption, fixing the labor allocation?,(3) How do marginal rates of substitution in the model insurance system differ from those in the planning problem? and (4) Why does the welfare gain increase as the shock variance increases?

3.4.2 Patterns of Lifetime Taxation

To get a preliminary idea of the economics behind the maximum welfare gains, it is useful to examine patterns of lifetime taxation. Figure **??** graphs the present value of earnings and consumption for agents at each of the five values of the permanent shock. This is done both in the model social insurance system and in the planning problem for the benchmark variance of $\sigma_1^2 = .056$. Figure **??** shows that lifetime taxation is progressive in both allocations in that the ratio of the present value of consumption to the present value of earnings falls as lifetime earnings increase. Furthermore, there is much more progression in lifetime average tax rates in the planning allocation than in the allocation under the model social insurance system. One additional feature of Figure **??** is that both allocations involve extracting resources in present-value terms from a cohort. This last point is clear as the lifetime tax patterns under the model social insurance system is below the 45 degree line for agents at all permanent shock levels.[41]

[41] Intuitively, a pay-as-you-go social security system alone should extract resources from current and future birth cohorts to pay for "free" benefits to previous cohorts. Fullerton and Rogers (1993, Table 4-14) calculate that lifetime average tax rates in the U.S. are roughly progressive in lifetime income and that resources are extracted in present-value terms from the cohorts they analyze.

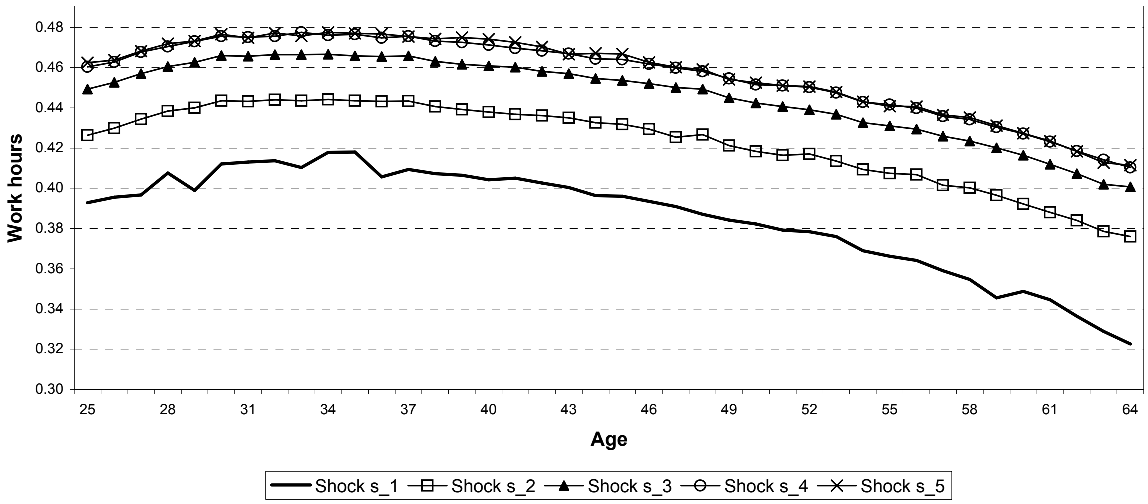
Figure 3.6: Lifetime Taxation



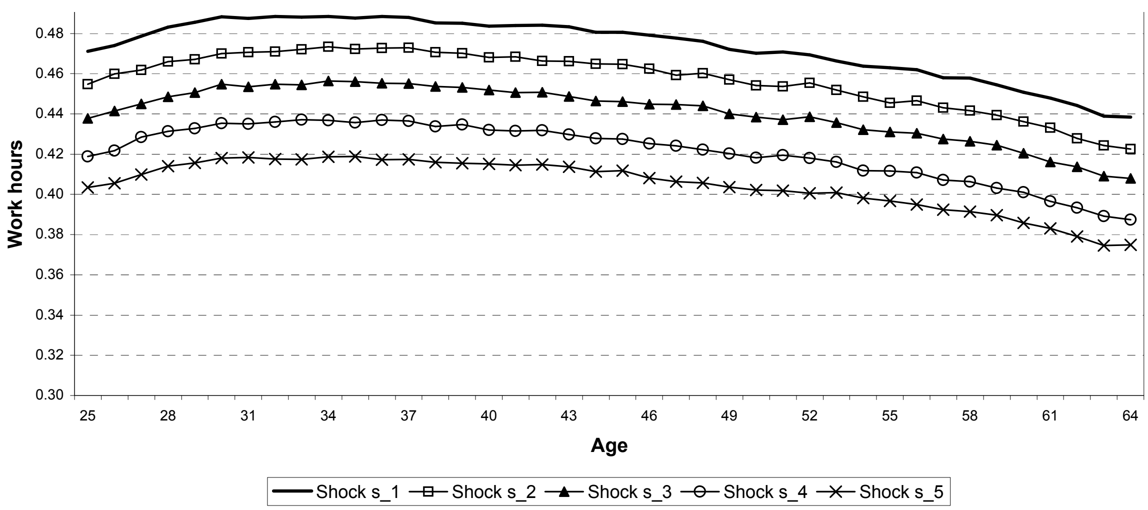
A quick look at Figure ?? reveals that the labor allocation must be quite different across these two allocations as the present value of earnings differs sharply. To highlight this, we plot work time over the life cycle. Figure ?? shows that in the planning problem the highest productivity shock agents work the greatest fraction of time and the lowest productivity shock agents work the least. In the model social insurance system this pattern of work time is exactly reversed.

Figure 3.7: Work Hours Profiles - Permanent Shocks

(a) Planning Problem



(b) Social Security with Income Tax



Labor productivity $w(s, j)$ increases in the shock s. There are five possible shock values $s_1 < s_2 < s_3 < s_4 < s_5$.

One issue raised by Figures ?? and ?? is the extent to which the maximum welfare gains arise from simply reallocating consumption across agents with different permanent shocks, holding the labor allocation fixed. The remaining gains are related to changing work time. Thus, if it were possible to raise the consumption of low shock agents and lower that of high shock agents, how far would such a reallocation go to improving welfare? While such a reallocation would improve ex-ante utility because the utility function is concave in consumption, this reallocation can only be pushed up to the point where the incentive constraints bind.

To answer this question, we calculate the new allocation (c^{*}, l^{us}) which maximizes ex-ante utility, holding labor fixed at l^{us}, while imposing incentive compatibility and the present value resource constraint. We find that at the benchmark value $\sigma^2 = .056$ the new allocation (c^{*}, l^{us}) increases welfare over (c^{us}, l^{us}) by 2.9 percent, compared to a maximum 4.09 percent achieved in the planning problem. Thus, important parts of the maximum welfare gain are due both to reallocating consumption and changing the labor allocation.

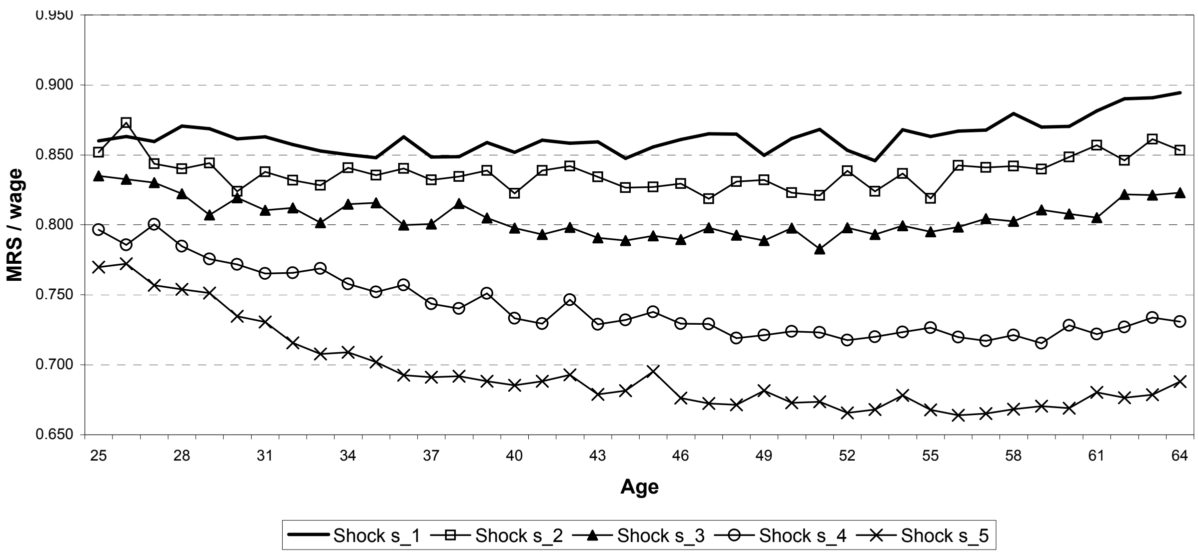
3.4.3 Analyzing Wedges

We now try to better understand the sources of the welfare gains documented in Figure **??**. To do so, we focus on the wedges between marginal rates of substitution and transformation. One wedge is the intratemporal wedge between the consumption-leisure marginal rate of substitution and the agent's wage. The other wedge is the intertemporal wedge between the marginal rate of substitution of consumption intertemporally and the gross interest rate. We will see shortly that the differences in work hours across the two problems turn out to be related to the differences in the intratemporal wedge.

Consider first the social insurance problem. The income tax system causes the marginal rate of substitution of consumption intertemporally to be below the gross interest rate. In fact, the progressivity of the income tax system, previously documented in Figure **??**, implies that within the model the intertemporal wedge is greatest for high productivity agents. These are the agents who end up receiving high incomes.

Consider next the intratemporal wedge. Figure **??** graphs the ratio of the intratemporal marginal rate of substitution to the agents wage for each value of the permanent shock.[42] Any deviation of this ratio from unity will be labeled a wedge.

Figure 3.8: Consumption - Labor Wedge Social Insurance



Labor productivity $w(s,j)$ increases in the shock s. There are five possible shock values $s_1 < s_2 < s_3 < s_4 < s_5$.

Within an age group, Figure **??** shows that this wedge increases as an agent's wage and productivity increases. The wedge is smallest for low productivity agents for two reasons. First, these agents have relatively low incomes and marginal income tax rates are relatively low at low income levels. Second, the nature of the social security system implies that at any age the marginal tax rate on additional earnings arising from social security increases as an agent's productivity shock increases.

This second point merits some discussion. The marginal tax rate mentioned above equals

[42]Recall from section 3.3 that the wage rate in the permanent-shock model is $w\omega(s,j) = w\mu_j exp(s^1)$ and that there are five equally-spaced shock values $s_1^1 < s_2^1 < ... < s_5^1$.

the social security tax rate τ less the present value of marginal social security benefits incurred from an extra unit of earnings. This applies to agents who are below the maximum taxable earnings level. This second component differs across agents within the same age group. The reason is that agents in the model will anticipate ending up on different sections of the social security benefit function. High productivity agents will end up on the flat part of the social security benefit function and thus will incur a low marginal benefit in present value. The situation is reversed for low productivity agents as they will end up on the steep part of the benefit function. This reasoning implies that marginal tax rates arising from social security increase with productivity within the model.[43]

We now analyze the nature of wedges that arise in a solution to the planning problem. Solutions to the planning problem will involve some incentive compatibility constraint binding. As a consequence, at a solution it will not be true that all marginal rates of substitution are equated to marginal rates of transformation.

While there is an intertemporal wedge in the model social insurance problem arising from the income tax there is no intertemporal wedge in a solution to the planning problem. This difference accounts for some of the welfare gains. To see why there is no intertemporal wedge in the planning problem, assume that there is a solution with a wedge. If so, then it is possible to deliver both the same expected utility and the same ex-post utilities at lower expected present value cost, without changing the labor allocation. This can be done by eliminating the intertemporal wedge. The extra resources saved can then be used to make a uniform increase in utility to agents receiving all shocks while preserving incentive compatibility.[44]

[43]A previous version of this chapter calculated how the marginal tax rate arising from the model social security system varied with age for a median productivity agent. Early in life the marginal tax rate is slightly below $\tau = .106$. It decreases with age but remains positive at all ages. Broadly, our results are similar to the marginal social security tax rates calculated by Feldstein and Samwick (1992, Table 1).

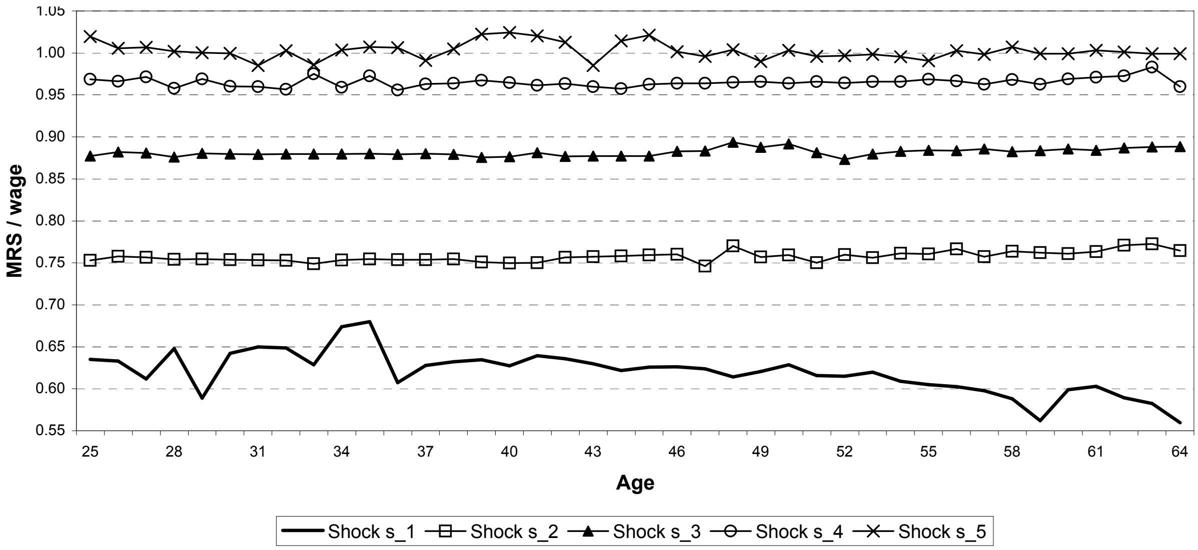
[44]Rogerson (1985) and Golosov, Kocherlakota, and Tsyvinski (2003) present a necessary condition on this margin in planning problems with a more general structure of shocks. Their main result is the “inverse” Euler equation. The result stated in the text is a special case of their result as the inverse Euler equation reduces to the claim made above, absent period-by-period shocks. With period-by-period shocks, a solution to the planning problem will have an intertemporal wedge.

Now consider the intratemporal wedge. The intratemporal marginal rate of substitution will differ from an agent's wage rate in a solution to the planning problem depending on which incentive constraints bind. It turns out that only the local downward incentive constraints hold with equality in a solution. These constraints require that an agent with a given permanent shock weakly prefers his/her own allocation to the allocation received by pretending to have the next lowest shock. An important consequence of this (see Theorem A1 in the Appendix) is that the marginal rate of substitution between consumption and labor is then strictly below the wage rate $w\omega(s, j)$ in all periods for all agents except the agent receiving the highest shock.[45] For the agent with the highest shock, there is no gain to distorting the consumption-labor margin at any age. The reason is that no other agent envies the consumption and output allocation of this agent. All other agents get strictly lower lifetime utility by pretending to be the high shock agent and allocating enough labor time to produce the higher output required.

Next, we examine the size of the intratemporal wedge. Figure **??** graphs the ratio of the marginal rate of substitution to the agent's wage rate at each age for each of the five possible values of the permanent shock. Figure **??** shows that the intratemporal wedge is positive for all agents with the exception of the agent with the highest permanent shock. Furthermore, within an age group the magnitude of this wedge decreases as an agent's wage increases.

[45] A similar result holds in the one-period model studied by Mirrlees (1971).

Figure 3.9: Consumption - Labor Wedge Planning Problem



Labor productivity $w(s,j)$ increases in the shock s. There are five possible shock values $s_1 < s_2 < s_3 < s_4 < s_5$.

In the context of the permanent-shock model, we are not aware of any existing theoretical result which describes how the wedge at each age moves as productivity increases. However, for the static Mirrlees model there are theoretical and computational results (see, for example, Tuomala (1990), Saez (2001) and the references cited in these papers). In the Mirrlees model, the lognormal distribution of productivity is important for wedges to decline as productivity increases. We have computed the nature of wedges in the permanent-shock model when we replace the lognormal distribution with a Pareto distribution. The literature has argued that the upper tail of the earnings distribution has fat tails which are more in line with a Pareto distribution. For the Pareto distribution with the same mean and variance, we find that wedges do not decrease as productivity increases.[46]

[46]Following Tauchen (1986), we approximate a Pareto distribution with five equally-spaced points one standard deviation apart. The resulting wedge is positive and displays little variation across ages. The wedge for the lowest four shock levels averages approximately .12, .10, .16 and .20, in order of increasing

We conjecture that the differences in wedges and the differences in lifetime taxation are the key reasons why the maximum welfare gains increase as labor productivity risk increases. There is too little progression in lifetime taxation in the model social insurance system compared to the planners problem as risk increases. Furthermore, the intratemporal wedge on high productivity agents typically increases as risk increases in the model social insurance system whereas the wedge on the highest productivity agents within an age group is always zero in the planning problem.

3.5 Reforming the Social Insurance System

We examine two ways to reform the model social insurance system. Reform 1 is a piecemeal reform in which a component of the social insurance system is changed while maintaining the remainder of the system. In Reform 1 we change the social security benefit function without changing income taxation or the social security tax rate. Reform 2 is a radical reform as social security and income taxation are eliminated and are replaced with a tax on the present value of earnings.

Reform 1 and 2 are optimal parametric reforms. In each case we search over the parameters of the respective tax functions to find the parameter vector which maximizes ex-ante expected utility of the cohort of agents.[47] In each reform the same present value of resources is extracted from the cohort as in the original social insurance system. The Appendix describes computational methods. The Appendix is also useful for understanding how to achieve a tax on the present value of earnings using a period-by-period tax system. We note that a present-value tax is compatible with the provision of retirement benefits as such a tax can be achieved with very different timings of taxes and transfers over the lifetime.

productivity. The wedge for the highest productivity level is approximately zero in computations.

[47]Our analysis of optimal parametric reforms is similar in some respects to the work of Conesa, Kitao, and Krueger (2009). They choose the parameters of a labor income tax function and a linear capital income tax to maximize ex-ante lifetime utility in steady state.

3.5.1 Motivation

The policy literature is full of discussions of piecemeal reforms. In the social security literature, it is common to find the suggestion that the value of marginal social security benefits incurred by extra earnings should be more closely linked with marginal taxes paid in order to improve efficiency or a welfare measure. These considerations motivate the analysis of Reform 1 which is an optimal piecemeal reform that flexibly changes the benefit function.

The motivation for Reform 2 is that it is simple and that there are reasons to think that it might work well within the permanent-shock model. Within the permanent-shock model, a present-value tax has two important properties. First, it imposes no intertemporal wedge. Second, it imposes an age-invariant wedge on the intratemporal margin that can be made to flexibly differ across agents.[48] The previous section argued that the first property holds in a solution to the planning problem and that the second property is approximately supported in computations.

3.5.2 Analysis

The welfare gain to each reform is given in Table **??**. Welfare gains are stated in terms of the permanent percentage increase in consumption in the allocation in the model without the reform which is equivalent to the expected utility delivered under the optimal reform. Welfare gains are calculated for both the full model (i.e the model with permanent, persistent and temporary shocks) and the permanent-shock model.

We first discuss the results for the permanent-shock model. For Reform 1, we calculate

[48] Werning (2007) shows that a present-value tax system is optimal in some contexts. Specifically, he shows that such a tax implements a solution to a planning problem in the context of an infinitely-lived agent model where labor productivity takes on two possible values, labor productivity is private information and preferences are of the constant Frisch elasticity of labor form.

Table 3.10: Welfare Gains to Optimal Parametric Reforms

Type of Reform	Permanent-Shock Model	Full Model
Reform 1: Change the Benefit Function	0.18	1.15
Reform 2: Tax the Present Value of Earnings	3.95	-0.07
Reform 3: Eliminate Capital Income Taxation	0.22	-0.22
Maximum Possible Gain	4.09	unknown

NOTE: The benefit function is $b(x;\alpha) = \sum_{i=1}^{3} \alpha_i x^{i-1}$, where x is average lifetime earnings. The present-value tax function $T(pv;\alpha)$ is a class of step functions in the permanent-shock model and is a class of piecewise-linear functions in the full model. See the Appendix.

the best constant benefit, the best linear benefit and the best quadratic benefit as a function of average lifetime earnings. The best constant benefit function in the permanent-shock model leads to a welfare gain of 0.14 percent. A constant social security benefit increases the progressivity of lifetime earnings taxation but also increases marginal earnings taxes across earnings levels. The best linear benefit function has a positive intercept and a negative slope and leads to a welfare gain of 0.18 percent. The best quadratic benefit function that we find does not improve welfare over the best linear function. This class of reforms achieves only a small fraction of the maximum possible welfare gain. This occurs because these reforms are poorly focused: greater progression in lifetime taxation is achieved by imposing an even larger intratemporal wedge on high productivity agents and the change in the benefit function does not eliminate the wedge on the intertemporal consumption margin.

In contrast, an optimal present-value tax leads to a large welfare gain worth a 3.95 percent increase in consumption. We obtain this result when the class of tax functions are increasing step functions. This reform achieves nearly all of the maximum possible welfare gain in the permanent-shock model.

We highlight two reasons why the optimal present-value earnings tax works well in the permanent-shock model. First, it allows for a flexible choice of lifetime taxation. Indeed, the graph of the present value of consumption as a function of the present value of earnings which turns out to be optimal is essentially the pattern in the planning problem - previously displayed in Figure ??. Second, the present-value tax is able to closely approximate the pattern of intratemporal and intertemporal wedges found in a solution to the planning problem.[49]

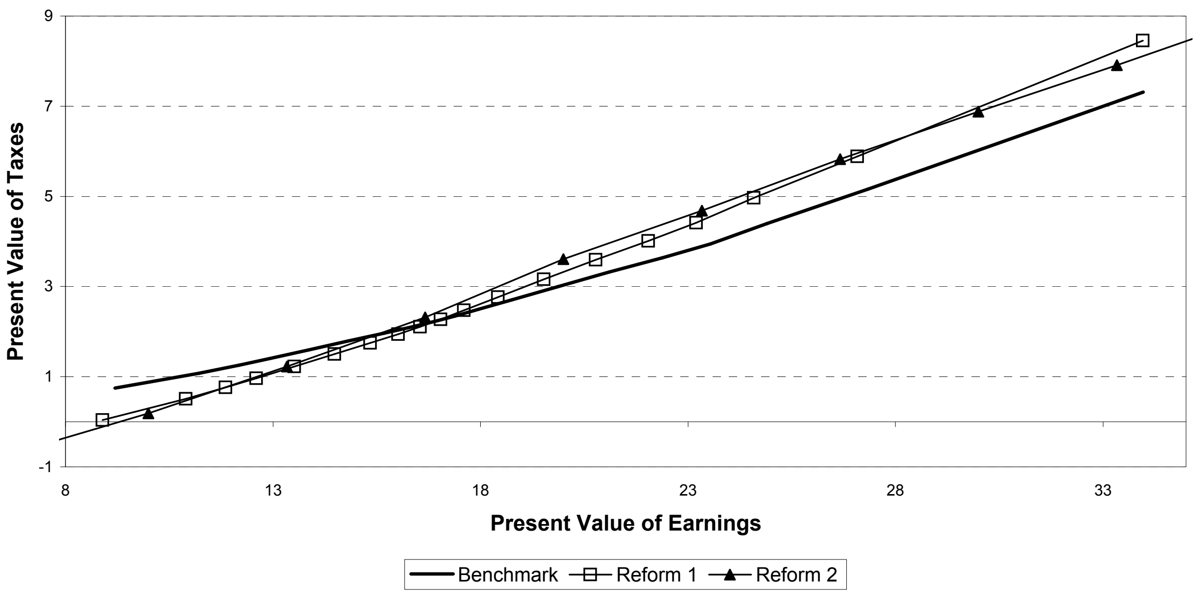
We now discuss results for the full model. For Reform 1, the best constant, linear, and quadratic benefit functions lead to gains worth a $0.56, 1.07$ and 1.15 percent increase in consumption, respectively. The best quadratic benefit function has a positive intercept, but negative values for the coefficients on the slope and quadratic terms. Thus, the piecemeal reform that maximizes ex-ante welfare does not involve more closely linking the value of marginal benefits received to marginal taxes paid. Greater progression in lifetime taxation is achieved within this reform by increasing intratemporal wedges. For Reform 2 we find that in the full model the best present-value tax that is within the piecewise-linear class leads to a small welfare loss equivalent to a 0.07 percent decrease in consumption. Thus, even though a present-value tax is both a simple and well-focused reform within the permanent-shock model, this class of reforms does not lead to welfare gains within the richer idiosyncratic shock structure of the full model.

To get some insight into what is behind these results, we first examine the pattern of lifetime taxation. Figure ?? shows that the progression in lifetime taxation is greater in

[49] At a deeper level, a present-value tax may work well within these economies for two quite different reasons. First, one might conjecture that interior solutions to the planning problem with (i) constant Frisch elasticity of labor preferences (i.e. $u(c_j, l_j) = u(c_j) + \phi \frac{l_j^{1+\gamma}}{1+\gamma}$) and (ii) permanent proportional productivity differences have the property that only local downward incentive constraints bind. If so, such allocations can always be implemented by a present-value tax system. A key property of such a solution, given assumptions (i)-(ii), is that the intratemporal wedge is age invariant - see the proof of Theorem A1(iii) in the Appendix. Second, the preferences used in Table ?? may effectively be close to those with constant Frisch elasticity of labor.

Reform 1 and Reform 2 than in the benchmark model.[50] Moreover, the pattern of lifetime taxation is broadly similar in both reforms over much of the domain. So the difference in welfare gain between Reform 1 and Reform 2 does not seem to come from differences in this measure of tax progression. The optimal present-value tax function in Reform 2 is roughly linear over most of the domain but is eventually flat well past the 99th percentile of the distribution - this occurs at a present value of earnings equal to 45.

Figure 3.10: Lifetime Taxation: Full Model



The results for the Benchmark model and Reform 1 are constructed by calculating the average present value of taxes paid for agents whose lifetime earnings fall in different lifetime earnings bins.

We now describe how the reforms impact consumption. Both reforms produce a downward shift in the distribution of the present value of earnings compared to the benchmark model. The result is that mean consumption at almost all ages is lower in both reforms than in the

[50]The 10th, 50th and 90th percentile of the present value of earnings distribution in the benchmark model occur at values 10.7, 17.4 and 26.1 in Figure ??.

benchmark model but, perhaps surprisingly, only Reform 1 substantially reduces measures of the dispersion in consumption at all ages compared to the benchmark model. This implies that the component of expected utility due to consumption is slightly lower in Reform 1 compared to the benchmark model but is even lower in Reform 2 compared to Reform 1 or to the benchmark model.

Next we describe how the reforms impact work hours. Reform 1 reduces the mean hours of work at all ages compared to the benchmark model and it produces about the same coefficient of variation in hours at all ages. Thus, the ex-ante utility from leisure is greater in Reform 1 than in the benchmark model. Reform 2 reduces mean hours of work at all ages below that in the benchmark model and below that in Reform 1. However, Reform 2 nearly doubles the coefficient of variation of hours early in the life cycle compared to the benchmark model. The overall effect of Reform 2 is to increase the ex-ante utility from leisure compared to the benchmark model. Both reforms increase the correlation between work hours and labor productivity at all ages compared to the benchmark model. Figure **??** suggests that different income effects on high and low lifetime earnings agents is partly behind the increase in correlation. This increase in correlation is a key part of the mechanism within the permanent-shock model for achieving the maximum possible welfare gain.

We now consider Reform 3 to determine if an important part of the welfare gain obtained by Reform 2 in the permanent-shock model comes simply from eliminating capital income taxation and the associated intertemporal wedge. Reform 3 is a piecemeal reform that maintains social security and income taxation but exempts capital income from entering into taxable income. An additional proportional labor income tax is added to satisfy the present-value resource constraint. Eliminating capital income taxation in this way produces a welfare gain of 0.22 percent in the permanent-shock model and a welfare loss of -0.22 percent in the full model. Thus, simply eliminating intertemporal wedges in this crude way, without substantially increasing the progressivity of lifetime taxation or altering the pattern of intratemporal wedges, does not go very far towards producing the maximum welfare gain in the permanent-shock model.

All of the analysis in the chapter is based upon the assumption that factor prices are fixed and do not change as the social insurance system is changed. We now take a step towards determining how a closed-economy analysis might differ by simply calculating how the aggregate capital and labor evolve over time at fixed factor prices within the full model. We assume that each reform applies only to each successive cohort of newborn agents and that all other agents who are alive at the start of the reform face the original social insurance system. The original social insurance system was calibrated to be consistent with a steady state in the full model with no government debt. We view any change in the capital-labor ratio over time as reflecting a need for factor prices to adjust in a closed-economy analysis. An increase in the ratio is viewed as a force which depresses the interest rate and raises the wage rate.

In Reform 1 the capital-labor ratio changes by well under one percent over the first 40 periods. In contrast, Reform 2 and 3 show much larger movements. After 40 periods this ratio falls by 10 percent in Reform 2 and increases by 18 percent in Reform 3. This is due almost entirely to the movement in the numerator - total asset holdings less government debt. We conjecture that little of the welfare gains we find for Reform 1 would vanish in a closed-economy analysis simply because the large effects at the individual level wash out almost entirely for factor inputs both within age group and at the aggregate level. It is less clear whether or not the results for Reform 2 and 3 would continue to hold.

In closing this section, we think that finding parametric tax systems that work well within the full model is a useful problem. This problem connects the policy literature to the literature on optimal taxation. We acknowledge that the tax systems that we have explored can be improved upon as both reforms violate the inverse Euler equation which is a necessary condition on the intertemporal margin for a solution to the planning problem.[51] Further theoretical and computational work that give insight into wedges arising in planning problems would be useful for finding parametric tax systems that produce larger welfare gains.

3.6 Conclusion

The question of whether to or how to fundamentally redesign social security systems has been and continues to be a major policy issue in the U.S. and in many other countries. One's position on this issue is likely to depend upon one's view of the rationale for social security and for social insurance more broadly. One standard rationale is the provision of insurance for risks that are not easily insured in private markets.

We provide a quantitative analysis of the U.S. social insurance system within a framework with important idiosyncratic, labor-market risks. We find that large welfare gains to changing the social insurance system are possible. Systems that can achieve such welfare gains need not be more complicated than the current U.S. system. Specifically, we find that an optimal tax on the present value of earnings does this within the model with only permanent shocks and that changing only the social security benefit function does this within the model with permanent, persistent and purely temporary productivity shocks of the nature found in U.S. wage rate data. These results are based upon maximizing ex-ante utility for a cohort. Thus, the objective reflects an insurance role both for productivity differences present at the start of the working lifetime as well as for productivity shocks occuring throughout the working lifetime.

We mention three directions to pursue in future work. First, it would be valuable to know quantitative properties of the solution to the planning problem within the full model. This

[51] Rogerson (1985) and Golosov et al. (2003) present the inverse Euler equation result. Kocherlakota (2005) provides an implementation theorem for solutions to planning problems using this result.

would require important theoretical and/or computational advances.[52] Second, this chapter treats labor productivity as being unaffected by the social insurance system. We expect that human capital models (e.g. Huggett, Ventura, and Yaron (2007)) will be central both as positive models of inequality and as models for the analysis of social insurance issues. Because skill acquisition responds to policy in human capital models, labor productivity will not be policy invariant. Whether the gains to adopting superior systems are even larger within such models is an open question. Third, future work might expand the analysis of the social insurance system to go beyond income taxation and social security as well as provide a closed-economy analysis to complement the open-economy analysis pursued in this work.

[52]Fernandes and Phelan (2000) provide a recursive formulation of a planning problem with persistent shocks. Such a formulation is not computationally viable for the full model described in Table **??**.

3.A Appendix

The Appendix contains two sections. Section 3.A.1 describes our methods for computing solutions to the planning problem, the social insurance problem and the parametric planning problems. Section 3.A.2 proves Theorem A1. In the Appendix the labor-productivity function is sometimes set to $\omega(s_j, j) = s_j$ solely to shorten and simplify expressions. FORTRAN programs that compute solutions to all the problems analyzed in the chapter are available upon request.

3.A.1. Computation

3.A.1.1. Social Insurance Problem

The social insurance problem is stated below as a dynamic programming problem. This involves reformulating the present value budget constraint as a sequence of budget constraints where resources are transferred across periods with a risk-free asset. Risk-free asset holding must then always lie above period and shock specific borrowing limits $\underline{a}_j(s)$ consistent with solvency at the terminal age. The state variable is $x = (a, s, z)$, where a is asset holdings, s is the period shock vector determining productivity and z is average past earnings. The functions T_j and F_j describe the tax system and the law of motion for average past earnings. The shock is Markovian with transition probability $\pi(s'|s)$.

$V_j(a, s, z) = \max_{(c,l,a')} u(c, l) + \beta \sum_{s'} V_{j+1}(a', s', z')\pi(s'|s)$

(1) $c + a' \leq a(1 + r) + w\omega(s, j)l - T_j(x, w\omega(s, j)l)$

(2) $c \geq 0, a' \geq \underline{a}_j(s); l \in [0, 1]$

(3) $z' = F_j(z, w\omega(s, j)l)$

This problem is solved computationally by backwards induction. The value function V_j is computed at selected grid points (a, s, z) by solving the right-hand-side of Bellman's equation. We use the simplex method (see Press et al (1994)). Evaluating the right-hand-side of Bellman's equation involves a bi-linear interpolation of the function $V_{j+1}(a', s', z')$ over the asset and average past earnings dimensions: (a', z'). We set the borrowing limit to a fixed value $\underline{a}$ in each period. We then relax this value so that it is not binding. This is a device for imposing period and state specific limits $\underline{a}_j(s)$. To use this device, penalties are imposed for states and decisions implying negative consumption.[53]

We compute ex-ante, expected utility V^{us} and the expected cost, denoted $Cost$, of running the social insurance system by simulation, under the assumption that an agent starts out with no assets. Specifically, we draw a large number (100,000) of lifetime labor-productivity profiles, compute realized utility and realized cost for each profile, using the computed optimal decision rules, and then compute averages. The same 100,000 histories are used in the calculation of expected utility and expected cost in the analysis of reforms.

3.A.1.2. Steady State Calibration

We calibrate the discount factor β using the algorithm below. This algorithm is based on computing a stationary equilibrium. To set up this framework, we assume that (i) there is an aggregate production function $Y = F(K, L) = K^{\alpha}L^{1-\alpha}$ stated in terms of aggregate capital K and labor L, (ii) physical capital depreciates at rate δ and (iii) population growth is n.

We define an equilibrium using the recursive language - see Huggett (1996). To keep track of agent heterogeneity, we use probability measures ψ_j to describe the fraction of age j agents that have a state vector $x = (a, s, z)$ lying in particular subsets of the state space X. The relative size of different age cohorts is given by ϕ_j, where $\phi_{j+1} = \phi_j/(1 + n)$ and $\sum_j \phi_j = 1$. Denote aggregate capital, labor and government spending and consumption

[53] The backward induction procedure takes as given a value for average earnings in the economy. This value is used to determine the tax function T_j. Thus, an additional loop is needed so that guessed and implied values of average earnings coincide.

(K, L, G, C): $K \equiv \sum_j \phi_j \int a d\psi_j$, $L \equiv \sum_j \phi_j \int \omega(s,j) l(x,j) d\psi_j$ and $C \equiv \sum_j \phi_j \int c(x,j) d\psi_j$. The probability measures must be consistent with one another. This is captured by the recursion $\psi_{j+1} = \Gamma_j(\psi_j)$, where $\Gamma_j(\psi_j)(\cdot) \equiv \int P(x, j, \cdot) d\psi_j$, and P is a transition function induced by the transition probabilities on shocks and by the period j decision rules. We do not write down all the details associated with the construction of this transition function partly because the algorithm below calculates the relevant integrals by simulating a large number of histories rather than by calculating probability measures on a rich collection of subsets of the state space and then integrating. However, details of how to do so are in Huggett (1996).

Definition: A stationary equilibrium is $(c(x,j), l(x,j), a(x,j), w, r, G)$, *tax-transfer functions* $(T_1, ..., T_J)$ *and probability measures* $(\psi_1, ..., \psi_J)$ *such that*

1. *(c,l,a) solve Bellman's equation (Appendix A.1.1), given* (w, r) *and* T_j.

2. $w = F_2(K, L)$ *and* $r = F_1(K, L) - \delta$

3. $\psi_{j+1} = \Gamma_j(\psi_j), \forall j$

4. $G = \sum_j \phi_j \int T_j(x, w\omega(s,j) l(x,j)) d\psi_j$

5. $C + K(n + \delta) + G = F(K, L)$

Algorithm:

1. Fix $(\alpha, \delta, n) = (.33, .06, .01)$.

2. Set $r = .042$ and $w = 1.19461$. Given (r, α, δ), equilibrium condition 2 pins down the wage w at the value stated and pins down the capital-labor ratio K/L.

3. Guess the discount factor and average earnings $(\beta, \bar{e})$.

4. Compute decision rules (c, l, a) solving Bellman's equation, given the information in steps 1-3 using the procedures described in Appendix A.1.1.

5. Calculate implied values of aggregates $(K', L', \bar{e}', \sum_j \phi_j \int T_j(x, w\omega(s,j)l(x,j))d\psi_j)$ via simulation using the decision rules.

6. If $K'/L' = K/L$, $\bar{e}' = \bar{e}$ and $\sum_j \phi_j \int T_j(x, w\omega(s,j)l(x,j))d\psi_j > 0$, then stop. Otherwise, update $(\beta, \bar{e})$ and repeat steps 4-5.

Comments:

1. We compute β for the full model at the parameters listed in Table **??** and fix this value for all subsequent analysis.

2. The initial value of β in step 3 is set to $\beta = 1/(1+r)$. In carrying out this algorithm we first adjust average earnings $\bar{e}$ in steps 3-6 until $\bar{e}' = \bar{e}$. The value of β is increased until step 6 approximately holds. We choose $\bar{e}$ in step 3 because the tax-transfer function is only specified once $\bar{e}$ is known - see section 3.2.4 Social Security.

3.A.1.3. Planning Problem

We show how to compute V^{pp} for the case of permanent shocks, given the value of $Cost$. The strategy is to analyze the Relaxed Problem. The Relaxed Problem is the same as the planning problem with permanent shocks except that only the local downward incentive constraints are imposed rather than all the incentive constraints. The local downward incentive constraints are the constraints stating that truth telling from shock s dominates claiming to be one shock lower, denoted s^-. There are N shock values that are ordered $s_1 < s_2 < ... < s_N$. Below, we let $\omega(s_j, j) = s_j$ solely to shorten and simplify expressions.

Relaxed Problem: $\max_{(l_j(s), c_j(s))} \sum_s [\sum_j \beta^{j-1}(u(c_j(s)) + v(l_j(s)))]P(s)$

subject to

(i) $\sum_s [\sum_j (c_j(s) - wl_j(s)s)/(1+r)^{j-1}]P(s) \leq Cost$

(ii) $\sum_j \beta^{j-1}(u(c_j(s)) + v(l_j(s))) \geq \sum_j \beta^{j-1}(u(c_j(s^-)) + v(l_j(s^-)s^-/s))), \forall s > s_1$

The strategy is to compute solutions to the Relaxed Problem and to verify that at the computed solution all incentive constraints hold. We compute solutions to the Relaxed Problem by solving the Equivalent Problem below. The Equivalent Problem is useful as it reduces the dimension of the control variables. The claimed equivalence follows from several facts about solutions to the Relaxed Problem. Specifically, at a solution (i) the cost constraint must hold with equality, (ii) consumption is chosen without intertemporal distortion (i.e. $u'(c_j(s)) = \beta(1+r)u'(c_{j+1}(s)), \forall j, s$) and (iii) all local downward incentive constraints bind. As the first result is straightforward, we only formally state the last two in Theorem A1. Theorem A1 also provides an additional theoretical insight. Specifically, since the Lagrange multipliers on the incentive constraints are strictly positive, the Kuhn-Tucker conditions imply that at a solution the intratemporal marginal rate of substitution is strictly below labor productivity for all agents at any age except for the agent with the highest productivity shock. This is a generalization of a standard result for the one-period Mirrlees problem.

Theorem A1: Assume $u(c,l) = u(c) + v(l)$, u and v are concave and differentiable, u and v are strictly increasing and decreasing respectively. At an interior solution to the Relaxed Problem the following hold:

(i) all local downward incentive constraints bind,

(ii) $\dfrac{u'(c_j(s))}{\beta u'(c_{j+1}(s))} = 1 + r, \forall j, \forall s$

(iii) $-\dfrac{v'(l_j(s))}{u'(c_j(s))} < ws, \forall j, \forall s < s_N$ *and* $-\dfrac{v'(l_j(s))}{u'(c_j(s))} = ws, \forall j$ *and for* $s = s_N$.

Proof: See Appendix 3.A.2.

In the Equivalent Problem the choice variables are labor and the lifetime utility of consumption $u(s)$. The cost constraint makes use of the function $COST$. $COST(u)$ describes the resource cost of obtaining lifetime utility u from consumption, given that $u'(c_j(s)) = \beta(1+r)u'(c_{j+1}(s))$.[54] As all constraints are equality constraints, it is also possible to reduce dimensionality further by solving these constraints to express lifetime utility of consumption $u(s)$ as a function of all labor profiles l and $Cost$ as follows: $u(s) = g(l, s, Cost)$.

We use the simplex method from Press et al (1994) to solve the Equivalent Problem. This involves maximizing over $(l_1(s), ..., l_{R-1}(s))$, where R is the retirement period. These choices lie in an $(R-1) \times N$ dimensional space as there are $R-1$ labor periods and N possible permanent shocks.

Equivalent Problem: $\max_{(u(s),l_j(s))} \sum_s [u(s) + \sum_j \beta^{j-1} v(l_j(s))] P(s)$

subject to

(i) $\sum_s [COST(u(s)) - \sum_j wsl_j(s)/(1+r)^{j-1}] P(s) = Cost$

(ii) $u(s) + \sum_j \beta^{j-1} v(l_j(s)) = u(s^-) + \sum_j \beta^{j-1} v(l_j(s^-)s^-/s), \forall s > s_1$

3.A.1.4. Optimal Parametric Planning Problems

We examine a number of parametric tax systems. For any parametric tax system we choose the parameters of these tax systems to maximize ex-ante utility, given that agents behave optimally and that the present value resource constraint cannot be violated. We describe how we compute the optimal parametric tax system for the case of a tax on the present value of earnings. The computation of other optimal parametric tax systems is similar.

[54] When $u(c) = c^{1-\rho}/(1-\rho)$ and $\rho \neq 1$, then $COST(u) = (\sum_j a^{j-1})[\frac{(1-\rho)u}{\sum_j b^{j-1}}]^{1/(1-\rho)}$, where $a = \frac{[\beta(1+r)]^{1/\rho}}{1+r}$ and $b = \beta[\beta(1+r)]^{(1-\rho)/\rho}$.

The agent's problem and the planner's problem are described below. The agent's state variable is $x = (a, s, pv)$, where pv is the present value of earnings earned from previous periods. The tax function T_j maps the present value of earnings from previous periods and earnings in period j into the tax paid or transfer received in period j. T_j depends upon a parameter vector α. Solutions to the agent's problem are computed using the methods from section 3.A.1.1.

$V_j(a, s, pv; \alpha) = \max_{(c,l,a')} u(c, l) + \beta \sum_{s'} V_{j+1}(a', s', pv'; \alpha)\pi(s'|s)$

(1) $c + a' \leq a(1 + r) + w\omega(s, j)l - T_j(pv, w\omega(s, j)l; \alpha)$

(2) $c \geq 0, a' \geq \underline{a}_j(s); l \in [0, 1]$

(3) $pv' = pv + \frac{w\omega(s,j)l}{(1+r)^{j-1}}$

Parametric Planning Problem: $\max_\alpha E[V_1(0, s, 0; \alpha)]$

subject to

$$E[\sum_j \frac{c_j(s^j;\alpha) - w\omega(s_j,j)l_j(s^j;\alpha)}{(1+r)^{j-1}}] \leq Cost$$

In the planner's problem the only constraint facing the planner, given agent's choices to any tax system are optimal, is the cost constraint. This is because the allocation induced by a solution to the agent's problem is incentive compatible. We compute solutions to the planner's problem by (i) drawing α, (ii) computing optimal decision rules solving the agent's problem, given α and (iii) simulating these decision rules to determine whether or not the resource constraint is violated at the allocation induced by α. We use the simplex method to search over the space of parameters describing the tax function to maximize the objective function. The objective function is ex-ante utility less a penalty term when the cost constraint is violated.

We now describe how we choose the tax function T_j in the agent's problem. Start with a tax function $T(pv; \alpha)$ mapping the present value of realized earnings over the lifetime into the present value of taxes paid over the lifetime. Define the period tax function

$T_j(pv, w\omega(s,j)l;\alpha)$ as indicated below. The tax paid in period j is based on the increment added to the present value of earnings. By the end of the working lifetime, the present value of taxes paid is simply $T(pv;\alpha)$, where pv is the realized present value of earnings over the working lifetime. This is one way to carry out a present-value tax T with a period-by-period tax system T_j for $j = 1, ..., J$.[55]

$$T_j(pv, w\omega(s,j)l;\alpha) = \begin{cases} [T(pv + \frac{w\omega(s,j)l}{(1+r)^{j-1}};\alpha) - T(pv;\alpha)](1+r)^{j-1} & : \quad j \geq 2 \\ T(w\omega(s,j)l;\alpha) & : \quad j = 1 \end{cases}$$

In our numerical implementation, we focus on two classes of parametric functions T. We use the class of piecewise-linear functions for the full model and the class of increasing step functions T for the permanent-shock model. We choose as many steps as there are permanent shocks.

3.A.2. Theorem A1

Theorem A1: Assume $u(c,l) = u(c) + v(l)$, u is strictly concave and differentiable, v is concave and differentiable, u and v are strictly increasing and decreasing respectively. At an interior solution to the Relaxed Problem the following hold:

(i) all local downward incentive constraints bind,

(ii) $\dfrac{u'(c_j(s))}{\beta u'(c_{j+1}(s))} = 1 + r, \forall j, \forall s$

(iii) $-\dfrac{v'(l_j(s))}{u'(c_j(s))} < ws, \forall j, \forall s < s_N$ *and* $-\dfrac{v'(l_j(s))}{u'(c_j(s))} = ws, \forall j$ *and for* $s = s_N$.

[55] Vickrey (1939) discusses some mechanics for a period-by-period tax system where taxes paid are based upon an average of past years incomes.

Proof:

(i) We study the Lagrange function below. Let $\gamma(s)$ denote multipliers on the local downward incentive constraints and λ denote the multiplier on the resource constraint. A superscript + or − denotes one higher or lower shock, respectively.

$$L = \sum_s [\sum_j \beta^{j-1}(u(c_j(s)) + v(l_j(s)))]P(s) + \lambda[Cost - \sum_s[\sum_j (c_j(s) - wl_j(s)s)/(1+r)^{j-1}]P(s)]$$
$$+ \sum_{s>s_1} \gamma(s) \sum_j \beta^{j-1}[u(c_j(s)) + v(l_j(s)) - u(c_j(s^-) - v(l_j(s^-)s^-/s)]$$

At an interior solution the Kuhn-Tucker conditions $dL/dc_j(s) = 0$ and $dL/dl_j(s) = 0$ hold:

$$\frac{dL}{dc_j(s)} = \begin{cases} \beta^{j-1}u'(c_j(s))[P(s) - \gamma(s^+)] - \lambda P(s)/(1+r)^{j-1} & s = s_1 \\ \beta^{j-1}u'(c_j(s))[P(s) - \gamma(s^+) + \gamma(s)] - \lambda P(s)/(1+r)^{j-1} & s_1 < s < s_N \\ \beta^{j-1}u'(c_j(s))[P(s) + \gamma(s)] - \lambda P(s)/(1+r)^{j-1} & s = s_N \end{cases} \quad (1)$$

$$\frac{dL}{dl_j(s)} = \begin{cases} \beta^{j-1}v'(l_j(s))\left[P(s) - \gamma(s^+)\frac{v'(l_j(s)s/s^+)s/s^+}{v'(l_j(s))}\right] + \frac{\lambda wsP(s)}{(1+r)^{j-1}} & s = s_1 \\ \beta^{j-1}v'(l_j(s))\left[P(s) - \gamma(s^+)\frac{v'(l_j(s)s/s^+)s/s^+}{v'(l_j(s))} + \gamma(s)\right] + \frac{\lambda wsP(s)}{(1+r)^{j-1}} & s_1 < s < s_N \\ \beta^{j-1}v'(l_j(s))[P(s) + \gamma(s)] + \frac{\lambda wsP(s)}{(1+r)^{j-1}} & s = s_N \end{cases} \quad (2)$$

Claims 1-4 establish that in a solution to the Kuhn-Tucker conditions all multipliers on incentive constraints are strictly positive: $\gamma(s) > 0, \forall s$. Theorem A1(i) follows from this result.

Claim 1: For $N \geq 2, \gamma(s_N) > 0$.

Claim 2: For $N > 2, \gamma(s^-) = \gamma(s) = 0$ for any s is impossible.

Claim 3: For $N > 2, \gamma(s^-) > 0, \gamma(s) = 0$ for any s is impossible.

Claim 4: For $N > 2, \gamma(s_2) = 0, \gamma(s_3) > 0$ is impossible.

Proof of Claim 1: If $\gamma(s_N) = 0$, then $dL/dc_j(s) = 0$ and u strictly concave implies $c_j(s_N) \leq c_j(s_{N-1}), \forall j$. If $\gamma(s_N) = 0$, then $dL/dl_j(s) = 0$ and v concave implies $l_j(s_N) > l_j(s_{N-1}), \forall j$. Thus, the downward incentive constraint for the agent with shock s_N is violated.

Proof of Claim 2: Suppose $\gamma(s^-) = \gamma(s) = 0$ for some s. Let s be the greatest s such that this holds. Claim 1 implies that $\gamma(s^+) > 0$. Then $dL/dc_j(s) = 0$ and u concave implies $c_j(s^-) > c_j(s), \forall j$. $dL/dl_j(s) = 0$ and v concave implies $l_j(s^-) < l_j(s), \forall j$. Thus, the downward incentive constraint for the agent with shock s is violated.

Proof of Claim 3: Suppose $\gamma(s^-) > 0, \gamma(s) = 0$ for some s. Let s be greatest s such that this holds. Claim 1 and 2 imply $\gamma(s^+) > 0$. Then $dL/dc_j(s) = 0$ and u concave implies $c_j(s^-) > c_j(s), \forall j$. $dL/dl_j(s) = 0$ and v concave implies $l_j(s^-) < l_j(s), \forall j$. Thus, the downward incentive constraint for the agent with shock s is violated.

Proof of Claim 4: Suppose $\gamma(s_2) = 0, \gamma(s_3) > 0$. Then $dL/dc_j(s) = 0$ and u concave implies $c_j(s_1) > c_j(s_2), \forall j$. $dL/dl_j(s) = 0$ and v concave implies $l_j(s_1) < l_j(s_2), \forall j$. This violates the downward incentive constraint for the agent with shock s_2.

(ii) This is implied by $dL/dc_j(s) = 0, \forall j$.

(iii) $dL/dl_j(s) = 0$ and $dL/dc_j(s) = 0$ imply the equation below. The result then follows from the fact that $\gamma(s) > 0$ (Theorem A1(i)) and from the concavity of v. The result for the case $s = s_N$ is obvious.

$$-\frac{v'(l_j(s))}{u'(c_j(s))} = \begin{cases} ws\dfrac{[P(s)+\gamma(s)-\gamma(s^+)]}{\left[P(s)+\gamma(s)-\gamma(s^+)\dfrac{v'\left(l_j(s)\frac{s}{s^+}\right)\frac{s}{s^+}}{v'(l_j(s))}\right]} & : \quad s_1 < s < s_N \\ ws\dfrac{[P(s)-\gamma(s^+)]}{\left[P(s)-\gamma(s^+)\dfrac{v'\left(l_j(s)\frac{s}{s^+}\right)\frac{s}{s^+}}{v'(l_j(s))}\right]} & : \quad s = s_1 \end{cases}$$

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