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Abstract

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"The basic public policy dilemma is the conflict between the use of early retirement as an instrument for alleviating unemployment among younger workers and the longer term financial viability of pension systems in aging societies". International Labor Organization (1997)

1 Introduction

In recent years, many countries have experienced a significant shift in demographic patterns towards the elderly. The age composition of the labor force is also changing rapidly. There are concomitant changes taking place in individual labor market activity too. People are retiring earlier and living longer after retirement than their counterparts in earlier cohorts. These phenomena in concert pose numerous challenges for the design of public pension programs and labor market policies in general (Diamond 1997, 2001). In response to these changes, some policymakers have called for reduced benefits (or higher taxes to pay for the benefits) while others have argued that it would be more beneficial to eliminate the work disincentives currently embedded in many pension systems.

In light of these demographic changes and the varied policy responses, there has been a recent surge in research activity using general equilibrium models to study some important aspects of social security policies (such as, their implications for income redistribution, private savings, etc.); yet not much work has explored their labor market consequences.[1] There is also a large literature that studies the effects of public pension programs on *individual* labor market outcomes and ignores the aggregate effects.[2] In contrast, the primary goal of this paper is to study the implications of public pension programs for the labor market at the *aggregate* level. To the best of our knowledge, ours is a first attempt at shedding "qualitative general equilibrium" light on classic policy questions, such as, should the earnings test be eliminated or should pension programs induce retirement, or do public pension programs hurt the younger generations by increasing taxes and overall unemployment, etc.— questions that are at the forefront of numerous current public policy debates.

To that end, we develop a model in which there is an explicit separation of the workforce into young and old workers; moreover, unemployment arises as an endogenous outcome. Specifically, we embed a model of the labor market characterized by search and matching frictions, into an overlapping-generations (OG) model with finitely-lived agents. The low-frequency nature of the OG model renders

[1] Principal contributions in this literature include Abel (2000), Auerbach and Kotlikoff (1985, 1987), Boldrin and Rustichini (2001), Cooley and Soares (1999), de Nardi, Imrohoroglu, and Sargent (1999), and Kotlikoff et. al. (1998).

[2] Prominent examples include Gruber and Orszag (2000) and Coile and Gruber (2000a, 2000b), among others.

itself useful for exploring the importance of long term job attachment and firm-specific human capital, both well-known as being important characteristics of modern labor markets. The lifecycle of workers explicit in the OG setup in conjunction with the frictions in the labor market also generates a rich environment in which both young and old workers may find themselves contemporaneously competing for the same jobs. This may produce an inefficient allocation of workers to jobs in the aggregate, and through this channel, open up an efficiency-enhancing role for publicly-induced withdrawal of specific age groups from the labor market.

A few details of the model setup are in order here. At any date, there are some newly-born (young) agents and some old agents. All young agents are unemployed at birth; they will incur some costs before they may search for employment opportunities. Firms post vacancies also at a cost and enter the labor market only if there are profits to be made from doing so. There is a standard economy-wide non-discriminating stochastic matching technology that connects vacancies to people. Once job matches are formed, production takes place. At the end of the period, some job matches will remain intact while other workers will become involuntarily displaced from their jobs.[3] These "displaced" workers may choose to re-enter the labor market to seek employment in the following period. At the start of any date, then, all the young workers, all the displaced workers (who are old), and all the old who did not get matched to jobs when young, enter the labor market seeking employment. The remaining agents in the economy are the old who retained jobs from the previous period. All new matches produce the same amount of gross output. Firms incur training and re-tooling costs if they hire a young worker or an old unemployed worker but not if they continue an employment relationship from the previous period. The surplus produced by a match is shared by the parties under protocols of Nash bargaining.

We incorporate various aspects of real-world age-specific labor market policies, such as public pension programs and long-term old-age unemployment insurance programs, into our model. We allow for social security payments to be tied to a worker's prior earnings (a.k.a, replacement rate). In addition, we capture some of the work disincentives embedded in many public pension programs by asserting that workers who choose to work when old receive only a fraction of benefits due to them. This feature integrates a notion of an "earnings test" in our model. Importantly, taxes required to pay for public policies in our framework are endogenous. That is, our framework explicitly incorporates a government with the power to impose payroll taxes on both firms and workers and use that revenue to finance its

[3] Thus, the expected duration of a job for a young worker is more than one period. The "durability" of a job implies that the benefit of working for a young worker is more than the current wage; it is also the expectation of retaining employment in the future. Davidson, Martin, and Matusz (1994) demonstrate how the durability of jobs results in a social surplus when workers have finite lives in an infinite-horizon economy.

pension program or pay for any subsidies. A key finding here is that policies intended to affect the lives of *workers* have general equilibrium consequences for *firms* (it affects their decision to create vacancies) which in turn affects the welfare of workers. It is this last effect that is rarely stressed in the popular rhetoric or the partial-equilibrium labor economics tradition.[4]

Our main qualitative results may be summarized as follows. First, we identify a sense in which public pensions redistribute bargaining power from young to old workers. Young workers (by virtue of the fact that they have a period of life ahead of them) have higher bargaining power than the old. However, under public pension programs, the state of being employed when young raises the worker's expected net income in the future. The firm realizes that having a job today implies current (and future) benefits to the employee; the firm naturally extracts part of that surplus. Thus, positive replacement rates serve a key social function: they reduce bargaining inequities over the lifecycle and keep young workers' wages and hence labor costs low. At the same time, high replacement rates raise payroll costs because old workers become eligible for higher transfer payments and this raises their bargaining power, wages, and *total* (wages gross of pensions) incomes. Completely eliminating the earnings test improves the redistribution of bargaining power over the lifecycle. Furthermore, at higher replacement rates, the drop in the payroll costs of young workers may outweigh the higher costs of employing old workers so that there is more employment as a result of the redistribution.

Is it ever welfare-improving to induce withdrawal by the old and discouraged workers from the labor force? We find the answer is yes – for a given earnings penalty, we find that policy-induced retirement achieved by increasing the replacement rate and providing young workers with a higher chance of finding long-term employment may improve aggregate labor market welfare. As in many search models of the labor market, workers here impose a congestion externality on the unemployed – for a fixed number of vacancies, an increase in the number of workers renders it less likely that a given worker will find a job. Furthermore, due to the possibility for the accumulation of firm-specific human capital in our setup, allowing young workers to have a greater chance of finding employment improves the allocation of workers to jobs in the economy. However, we find the greatest welfare gains may occur when the earnings test is completely eliminated and old individuals choose to remain active in the labor market.

[4] In related work, Shimer (2001) also studies the implications of population aging for the labor market. In contrast to our work, all workers in his model are infinitely-lived and in each period, a new generation of workers is born. Our methodology is most closely related to Pissarides (1992) who utilizes a two-period overlapping generations model with labor market frictions to study the implications of the loss of productivity that may accompany long-term unemployment. In contrast to our framework, all jobs in his model only last for one period, and there are no costs to labor market participation. While his analysis provides a number of interesting implications for aggregate labor market outcomes, it does not address the important interactions between wages at each stage of the lifecycle, age-targeted labor market policies (such as public pension programs), and retirement decisions.

The plan for the rest of the paper is as follows. In order to provide some helpful background, we begin with a brief survey of the available evidence on population aging, its implications for labor market activity, and age-specific labor market policies in OECD countries in Section 2. In Section 3, we outline the baseline model in which workers of all ages and employment histories choose to participate in the labor market. The next section studies a specific labor market participation pattern, one in which all the old displaced workers are induced to withdraw from the labor market as a result of the work disincentives in pension programs. Section 5 considers some alternative labor market policies, which we refer to as "active labor market programs" aimed at promoting employment in the labor market rather than encouraging old workers to retire. In Section 6 we study the welfare consequences of public pension programs, publicly induced retirement, and some active labor market policies. Section 7 concludes. The appendices contain derivations of some important results as well as a detailed discussion of the algorithm used to compute various equilibria in the model.

2 Stylized Facts and Issues

2.1 Recent Trends in Population Aging and Labor Force Participation

The populations of many developed countries around the world have increasingly become older over the past century. In the United States, for example, while 4% of the population was aged sixty-five years or older in 1900, this number rose to 12.5% in 1994, and is projected to spiral up to 20% by 2050. At the same time, the age composition of the labor force is also changing in a dramatic fashion. The median age of the work force in the United States is expected to cross 40 by 2005 compared to 34.7 in 1979. Many countries have also witnessed large reductions in labor force participation rates of older workers since 1950. In the United States in 1950, 46% of men sixty-five years and older were active in the labor force, compared to only 16% in 1993. These demographic phenomena in tandem pose many challenges for the design of public pension programs and labor market policies in general.

2.2 Age and Individual Labor Market Outcomes

Recent evidence suggests that an individual's age has important implications for their labor market experiences. First, the unemployment rate of younger workers is higher than that of older workers. For example, in 1987, the unemployment rate for male workers under the age of 25 in the US was 12.6% compared to 4.8% for those over the age of 25. In France during the same period, the unemployment rate for younger workers was 19.6%, but only 6.4% for older workers. Second, the incidence of long-

term unemployment is much higher for older workers. In the United States in 1996, while the rate of long-term unemployment for the overall labor force (15 to 64 years) was only 9.3%, this number rises to 14.6% for older workers (between the ages of 45 and 64). In France, the relative frequency of long-term unemployment among the entire workforce is much higher (39.5%); that for workers between the ages of 45 and 64 is as high as 62.0%.

Older workers who experience involuntary job loss are more likely to become permanently separated from their employers. Chan and Stevens (2001, 2002) find re-employment rates of older workers following displacement are significantly lower than nondisplaced workers and that displacement affects the likelihood of retirement. In particular, O'Leary and Wandner (2000) conclude that while less than 10% of displaced workers under the age of 55 permanently exit the labor force, more than 25% of workers between the ages of 55 and 64 and almost half of workers over the age of 65 opt for retirement instead of searching for alternative sources of employment upon displacement.[5,6] Additionally, as discussed in Jacobson et. al. (1993), displaced workers on finding employment receive wages that are about 25% lower than in their previous job.

An important explanation for why older workers face employment difficulties, due to Oi (1962), and further advanced by Hutchens (1986), is that the initiation of an employment relationship requires firms to incur fixed costs thereby increasing the net revenues from employing younger workers.[7] An alternative interpretation is that firms prefer to employ younger workers to allow for more accumulation of firm-specific human capital. It may also be that firms avoid older workers because they are less productive.[8]

The duration of employment also tends to increase with age. Median tenure of older workers aged 45 to 54 was more than three times that of workers age 25 to 34. In fact, 34% of male workers aged 25 and over had worked for their current employer for 10 years or more in February 2000; for workers aged 55-64, 28% had worked for their current employer 20 years or more. Hall (1982) finds that after a job has lasted 5 years, the probability that it will eventually last 20 years or more in all rises to close to 0.5 among workers in their early thirties. These data imply that tenure with a firm is long for many

[5] Diamond and Hausman (1984) discuss how late career job loss affects retirement. Ruhm (1990, 1995) elaborates on the numerous pathways towards retirement.

[6] In Section 4, we formally demonstrate how public pension programs encourage individuals to retire after incurring late-career job loss. That is, the retirement choice is policy-induced.

[7] See also Hurd (1996) and OECD (1994).

[8] Diamond and Hausman (1984), among others, emphasize that older workers are likely to experience employment difficulties due to declining health status. Gruber and Madrian (1995) and Gruber and Wise (1999) also discuss the role of declining health as a prime motive for early retirement for older workers in many OECD countries. Borsch-Supan and Schnabel (1999), Bound (1989, 1991), Gruber (1996), Gruber and Kubik (1997), and Gruber and Wise (2001) consider the role of disability insurance programs for retirement incentives.

Americans.[9]

2.3 Retirement-Inducing Policies Around the World

We summarize some important features of social security (SS) programs that are of relevance for our study. First, SS programs have a significant impact on labor market behavior. Gruber and Wise (1999) attribute the aforementioned large drop in labor force participation rates of older workers to the vast generosity of social security programs, early retirement schemes, and long-term unemployment insurance programs for older workers. Mulligan and Sala-i-Martin (1999a, 1999b) document that of the 94 countries for which this information was available, 91 induce workers to retire – 74 of them mandate retirement in order to collect benefits while the other 17 encourage retirement through tax and benefit formulas.[10] Second, the majority of SS programs are pay-as-you-go (PAYG) systems which are financed with payroll taxes, split between both the employer and employee. SS benefits are generally related in some way to the number of years worked (and amount of taxes paid). In particular, in many OECD countries, eligibility for public pension programs requires a history of labor force attachment.[11] Often, the pensions provided are linked to some measure of accumulated earnings.

The fact that so many SS programs require retirement as a necessary qualification suggests that they are an important tool for regulating the flows in and out of the labor market. In fact, a commonly-held view about social security, is that it is a means to transfer jobs from older, employed workers to young, unemployed individuals.[12] President Franklin D. Roosevelt, in one of his celebrated "fireside chats" clearly indicated that this would be an important goal for social security: "The program for social security now pending before the Congress is a necessary part of the future unemployment policy of the Government...It proposes, by means of old-age pensions, to help those who have reached the age of

[9] Long-term job attachment is an important aspect of the labor market in other coutries too. For example, according to a recent survey [*Labour Market Detachment among Older Men*, C. Beatty and S. Fothergill, Centre for Regional Economic and Social Research, Sheffield Hallam University, 1999], "two-thirds of non-working British men over 50 had spent more than 10 years in their last job and nearly half more than 20 years."

[10] They also provide a very detailed survey of various aspects of public pension programs, both historically and internationally. Their paper also reviews a variety of political economy explanations and efficiency theories for the existence of social security. Mulligan and Sala-i-Martin (2000b) describe how a number of public policies besides social security may be designed to induce retirement.

[11] For example, in Spain, the minimum number of years of contributions required to obtain social security is 15; in Italy, the number is 20. In the United States, workers are eligible for benefits after 40 quarters of covered employment. In Germany, some pension benefits are available for workers after a 45 year earnings history and there are preretirement schemes for workers who have contributed for only 15 years. In France, a common requirement is 37.5 years of contributions for full benefits with reductions for less labor market attachment. (Blanchet and Pele 1999, Boldrin et. al. 1999, Borsch-Schupan and Schnabel 1999, and OECD 1995).

[12] In Bhattacharya, Mulligan, and Reed (2001), we find that although it is possible that policy-induced retirement can promote labor market efficiency, most public pension programs pay the elderly substantially more than labor market search theory implies that their jobs are worth.

retirement to give up their jobs and thus give to the younger generation greater opportunities for work and to give all a feeling of security as they look toward their old age..."(Roosevelt, pp.134-5)[13]

Finally, as documented in Gruber and Wise (1999), many countries have introduced a variety of early retirement schemes and long-term unemployment insurance programs that allow for older, displaced workers to retire well before the normal retirement age. These programs, introduced directly to combat unemployment problems facing younger workers, are fairly generous, providing as much as 60-70% of previous income. An often-cited example is France where the "contrat de solidarite" recognized the "double need to encourage 55-59 year-old workers to stop work and bring young workers into the labor market, as rising youth unemployment was a growing concern to society as a whole." Furthermore, such policies effectively banned the old unemployed workers from the labor market — in order to receive their long-term unemployment insurance, these workers are required to stop seeking employment.[14]

3 The Baseline Model with Complete Labor Market Participation

3.1 Basic setup

We consider an economy consisting of an infinite sequence of two-period lived overlapping generations. The economy is populated by two types of agents, workers and firms. There is no growth in the population sizes of these agents. Workers live only for two periods. There are two types of workers in a period – young and old. Each generation of workers is of equal measure, $\frac{1}{2}$, so that the total population of workers is equal to 1 each period. At birth, all workers are unemployed. Old workers may be in one of three possible states: unemployed, separated (they were employed while young, but have lost their job; see discussion below), or employed. All workers are risk-neutral and share the same rate of time preference, β. There are no private saving instruments. Firms produce a homogeneous consumption good each period using labor as the sole factor of production. Production is the result of a pairwise matching between one worker and a firm. Firms are infinitely-lived with a total population of measure $\mathcal{F}$ in each period. For ease of presentation, we assume that both workers and firms share the same discount factor β. All firms have access to the same technology. Firms maximize the present discounted stream of revenues net of all costs. Finally, there is a government which implements a set of tax and

[13] In Britain, the *Job Release Scheme* which ran between 1977 and 1988, specifically encouraged older workers to "stand down to make way for younger ones." See also the discussion in Layard et. al. (1993), OECD (1994, 1995), Schulz (2001), and the *Social Security Retirement Test* (1991).

[14] For more details, see the OECD (1995) study on "The Labor Market and Older Workers", Gruber and Wise (1999), and the discussion in Bhattacharya, Mulligan, and Reed (2001).

transfer policies and possibly some "active labor market policies" to be described below.

3.2 The Labor Market

The principal alleged benefit of policies aimed at increasing labor force participation from older workers is that they would enlarge the tax base and thereby offset some of the costs of financing public pension programs. On the other hand, according to the "lump of labor" line of thought, a possible cost of encouraging labor market participation among all age-groups is higher unemployment, an effect that has received considerable attention in Europe.[15] To investigate the merits of these arguments, we first consider, as a benchmark case, the labor market implications of public pension programs that exist but do not induce retirement. We start by conjecturing an equilibrium in which all workers (especially, the old) choose to participate in the labor market. We then identify a set of policy parameters which support this conjectured steady-state equilibrium. Under some pension systems, some workers will be better off choosing to retire and therefore the equilibrium fails to exist. This is the algorithm we adopt in order to endogenize labor force participation for workers at each stage of the lifecycle.

The time line is as follows. At the start of each period, the labor market opens. At that time, unemployed workers, be they old or young, choose whether to search for vacancies or not. If they decide to search, they incur a search cost, s, which is expressed in terms of disutility of search. As described in Pissarides (2001), s represents the imputed value of leisure in terms of output (utility). On the other side of the market, firms make the decision whether to pay some upfront costs (described below) and enter the labor market to look for employees. Each firm may employ at most one worker. Let U (F_v) denote the total mass of unemployed workers (unfilled vacancies) at the start of a period.

A stochastic matching technology connects all job seekers with open vacancies. The technology does not discriminate on the basis of age, and therefore, *any* unemployed (old or young) worker faces the *same* probability α of getting matched with a vacancy.[16] Once the labor market opens, firms and workers have at most one opportunity to meet and match. At the end of any period, the employment relationship between a worker and a firm ends involuntarily with a given probability b.[17] Put differently,

[15] A particularly stark example is Belgium. There, in 2000, for every 100 employed persons, 86 people over the age of 20 were without work. More than half of those unemployed people were below the age of 65, and most were receiving social benefits. [Source: Miranda, Penner, and Steuerle, 2002]

[16] Our matching structure bears many similarities to Pissarides (1992). As in his framework, workers and firms may make at most one job contact each period, and the probabilities of matching are the same for each type of worker irrespective of age (i.e., we also assume a *non-discriminating* matching technology). Our matching technology could be interpreted as part of a labor market in which age-discrimination laws are fully enforced.

[17] All job separations in the model are exogenous and outside of the worker's influence. In this sense, b is a measure of the frequency of involuntary job separations, and therefore, parameterizes the degree of job security; see Farber (1997), Gottschalk and Moffitt (1999), and OECD (1997) for related discussion.

a given match lasts for a minimum (maximum) length of one (two) period(s).

At the beginning of the period, an old worker finds himself in one of three possible employment categories: employed [attached to a match from the previous period with probability $\alpha(1-b)$], unemployed [with probability $(1-\alpha)$], or displaced (working when young, but lost the job with probability αb). We also refer to displaced workers as those who have been 'separated' from their previous source of employment. Hence, we use the terms 'separated' and 'displaced' interchangeably. Following Pissarides (1992), we refer to old workers who begin the period unemployed as the 'long-term' unemployed. On-the-job search is disallowed by our assumption regarding timing of labor market openings. For future reference, note that old never-before-employed workers, unlike old displaced workers, have no prior earnings. This will create a distinction between them if governmental transfer payments are tied to past earnings. At the end of the period, young employed workers learn their employment status for the following period (i.e., whether their current match survives to the next period or gets dissolved); at this time, old workers die.

Firms incur costs of posting vacancies, denoted by a. Once they have incurred this cost and searched for workers, all firms are equally likely to find a worker. The probability that a vacancy finds a worker is θ. The probabilities of meeting a given type of worker, however, will depend on the proportion of each type of worker in the labor market. The total measures of young, separated, and long-term unemployed workers are u_y, u_s, and u_o. The total mass of unemployed workers (and hence searching for jobs) is U. The probability of finding a young unemployed worker is $\theta\tilde{u}_y$, where $\tilde{u}_y \equiv \dfrac{u_y}{U}$. Similarly, the probability that a vacancy locates an old separated (long-term unemployed) worker is $\theta\tilde{u}_s$ ($\theta\tilde{u}_o$).

Following the insight of Oi (1962), we posit that there are costs which must be incurred at the beginning of an employment relationship. We refer to these as "hiring" costs, and denote them as h. Let p denote the exogenously-determined market value of the firm's output. Matches with new hires require the firm and the worker to incur the costs of "hiring and training" so that the net output from new matches is $(p-h)$ while net output from a match with an old, retained worker is p. Under this interpretation, one may view h as a cost that is incurred each time a firm makes a new hire. Alternatively, h may proxy a productivity differential between new and old matches. In the latter sense, one may also interpret h as a parameter which reflects the importance of firm-specific human capital. As described in Hutchens (1986), firms therefore derive higher net revenues from employing workers with longer expected tenure.[18]

[18] According to a recent British survey [*Labour Market Detachment among Older Men*, C. Beatty and S. Fothergill, Centre for Regional Economic and Social Research, Sheffield Hallam University, 1999], "... some 49 per cent of employers [in Britain] were reluctant to fund training for older staff because of *shorter payback times* or perceptions about older

The pre-tax wage rate(s) for the different types of workers are determined (see below) in accordance with the protocols of Nash bargaining. The presence of age-targeted labor market policies and the aforementioned accumulation of firm-specific human capital will cause the wages of workers (with different employment histories) to vary.

3.3 Specification of Labor Market Policies

We incorporate various aspects of real-world age-specific labor market policies, such as public pension programs and long-term old-age unemployment insurance programs, into our model. These take a particularly simple and stylized form. Old workers, currently or previously employed (i.e., those who have paid income taxes in the past) are eligible for transfer payments from the government. As is common in many countries, these payments are tied to a worker's prior earnings. In our framework, an old worker's prior earnings is simply her pre-tax wage (received when young), denoted w_y. The replacement rate on a worker's prior earnings is denoted by η.[19] Specifically, old workers who are not currently employed (but were, when young and paid social security taxes) are eligible for publicly-provided pensions in the amount ηw_y.[20]

We also allow for aspects of earnings reductions, as observed in many programs, into our framework. We capture the notion of an "earnings test" by asserting that workers who work when old receive only a fraction δ of benefits due to them.[21] For example, an old worker who retained her job from a previous match and receives a current pre-tax wage of w_o^e receives a total income (based upon wages and pension benefits) of the amount $w_o^e + \delta\eta w_y$. Separated workers who find jobs when old and receive a current

workers' ability to acquire skills."

[19] Replacement rates which compare individuals' initial Social Security benefits with past wages, are frequently used to determine whether or not recent retirees can maintain their preretirement standard of living. Currently in the US, a worker's earnings in her 35 highest-earning years are averaged and used, which maps on to a replacement rate of about 52%. Current replacement rates in Portugal and Germany are as high as 70%. Workers with full-contribution careers in France receive, on average, 80 percent of their last net wages, with the replacement rate varying from 100 percent for low-wage earners to 65 percent for top-wage earners. For more discussion, see OECD (1994).

[20] This is one of the benefits of our deterministic, discrete-time model. Since each worker receives only one job contact each period, it is very easy to trace an old worker's employment status to his employment history. The linkages between eligibility for transfer payments (such as social security) and a worker's prior labor market history are clearly important, yet often ignored in models of the labor market.

[21] The "earnings test" that was applied in the United States until 2000 could be described as follows. In 1999, a worker age 62 to 65 could earn up to $9,600 without the loss of any benefits, then benefits were reduced $1 for each $2 of earnings above this amount; for workers age 65 to 69, the earnings test floor was $15,500 and benefits were reduced at a rate of $1 for each $3 in earnings.

In April 2000, the earnings test was lifted for workers sixty-five and over in the United States. A number of countries are also considering eliminating the earnings test from their SS programs. Although our framework is not suited to capture the specific features of various versions of the earnings test, we can consider its implications, more broadly defined, for retirement behavior and wages of older workers. For a discussion on the implications of the earnings test for the labor supply behavior of older workers, see Baker and Benjamin (1999), Burtless and Moffit (1984), Disney and Tanner (2000), Friedberg (1998), and Gruber and Orszag (2000).

wage of w_o^s earn total income $w_o^s + \delta\eta w_y$. However, old workers who do not search and/or find jobs retain their entire benefits, ηw_y. The long-term unemployed (who will receive a current wage of w_o^u if they find a job) are not eligible for benefits since they have not paid into the system when young.

Transfer payments are financed by payroll taxes (τ), assumed to be imposed equally on both firms and matched workers. The same tax rate also applies to pension benefits. For example, an old worker who retained her job earns a total after-tax income of $(1-\tau)(w_o^e + \delta\eta w_y)$.

Aside from these pension programs, we also incorporate stylized aspects of several alternative policy options ["active labor market policies"]: a) a subsidy to search activity among older workers [reduces search costs by the old by a proportion τ_s and provides old workers with easier access to the labor market], b) worker training programs [those designed to increase the accumulation of firm-specific human capital by the proportion, τ_h], and c) job creation programs [lowers the costs of firm entry by a proportion τ_a]. Analysis of these policies is postponed until Section 5. Finally, we assume that the government balances its budget each period.

3.4 Workers' Payoffs

We begin by computing the stationary ex-ante expected payoffs in utility terms to the different types of workers. Let J_y denote the expected lifetime utility accruing to a worker who decides to search when young, J_o^e the expected utility of an old worker who begins the period employed and continues his employment, J_o^u the expected utility of an old worker who did not get matched when young and is back in the labor market seeking employment, and J_o^s the expected utility of an old separated worker who is again seeking employment. Then, it is easy to see that

$$J_y = -s + \alpha\left[(1-\tau)w_y + (1-b)\beta J_o^e + b\beta J_o^s\right] + (1-\alpha)\beta J_o^u \tag{1}$$

$$J_o^u = -s\left(1-\tau_s\right) + \alpha(1-\tau)w_o^u; \quad J_o^e = (1-\tau)\left[w_o^e + \delta\eta w_y\right] \tag{2}$$

$$J_o^s = -s\left(1-\tau_s\right) + \alpha[(1-\tau)\left\{w_o^s + \delta\eta w_y\right\}] + (1-\alpha)\left(1-\tau\right)\eta w_y, \tag{3}$$

where $\tau_s \in [0,1]$ is a possible subsidy to searching available only to old agents without jobs.

It is instructive to explore the economic interpretation of eq. (1), as the explanations of the other value functions follow straightforwardly. A young worker seeking employment incurs an upfront cost s. Upon entering the labor market, he gets matched with a firm with a probability α. In that case, he gets his after-tax wage $(1-\tau)w_y$ and also the expected continuation payoffs from possible employment and

separation the following period. If he is unsuccessful in finding a job, he will find himself in the state of being unemployed at the start of the following period. In passing, notice that in general, $J_o^u \neq J_o^s$ will hold only because governmental transfer payments will be tied to past earnings. From (1), it is also clear that the value of a job to a young worker is much more than just the after-tax current wage. Because jobs are potentially durable, a match today bestows certain continuation privileges to the worker, a fact that will play a prominent role during the wage-bargaining phase.

3.5 Payoffs to firms

Firms begin each period in one of two possible states. They may have a vacancy, or they may be matched with an old worker from a previous employment relationship and will have a vacancy the following period. Letting Π_v (Π_f) be the expected lifetime profits of a firm that has an unfilled (filled) vacancy at the beginning of the period, the following equations describe the associated expected present discounted profits of a firm in each state:

$$\Pi_v = -a\left(1-\tau_a\right) + \theta\tilde{u}_y\left\{\left[p-\left(1-\tau_h\right)h-\left(1+\tau\right)w_y\right] + (1-b)\beta\Pi_f + b\beta\Pi_v\right\} + \theta\tilde{u}_s\left[p-\left(1-\tau_h\right)h-\left(1+\tau\right)w_o^s + \beta\Pi_v\right. \tag{4}$$

$$\left. +\theta\tilde{u}_o\left\{\left[p-\left(1-\tau_h\right)h-\left(1+\tau\right)w_o^u\right] + \beta\Pi_v\right\} + (1-\theta)\beta\Pi_v\right.$$

$$\Pi_f = p-\left(1+\tau\right)w_o^e + \beta\Pi_v \tag{5}$$

Note that the firm does not incur any hiring costs if the employment relationship from the previous period is retained. As described earlier, τ_a and $\tau_h \in [0,1]$ represent potential subsidies to firms for job posting costs and hiring costs respectively. Firms take the proportions, $\tilde{u}_y, \tilde{u}_s$ and $\tilde{u}_o$, as given when deciding whether to enter the labor market.[22]

The following expression for steady state payoff to entry will be of considerable use below:

$$\Pi_v = \frac{-a\left(1-\tau_a\right) + \theta\tilde{u}_y\left[p-\left(1-\tau_h\right)h-\left(1+\tau\right)w_y\right] + \theta\tilde{u}_y(1-b)\beta\left[p-\left(1+\tau\right)w_o^e\right]}{\left[1-\theta\tilde{u}_y(1-b)\beta^2 - \theta\tilde{u}_y(1-b)b\beta^2 - \theta\tilde{u}_s\beta - \theta\tilde{u}_o\beta - (1-\theta)\beta\right]} \tag{6}$$
$$+\frac{\theta\tilde{u}_o\left[p-\left(1-\tau_h\right)h-\left(1+\tau\right)w_o^u\right] + \theta\tilde{u}_s\left[p-\left(1-\tau_h\right)h-\left(1+\tau\right)w_o^s\right]}{\left[1-\theta\tilde{u}_y(1-b)\beta^2 - \theta\tilde{u}_y(1-b)b\beta^2 - \theta\tilde{u}_s\beta - \theta\tilde{u}_o\beta - (1-\theta)\beta\right]}.$$

3.6 Matching

Unemployed workers and unfilled vacancies are brought together each period through a stochastic matching technology.[23] The matching technology describes the total number of matches, $m = \mu M(U, F_v)$,

[22] Expressions for $\tilde{u}_y, \tilde{u}_s$ and $\tilde{u}_o$ are derived in Appendix A.

[23] Recall that U is the mass of unemployed workers and F_v is the total mass of unfilled vacancies at the beginning of period t.

that are formed at the beginning of each period, depending on the total masses of unemployed workers and unfilled vacancies. Since α represents the probability that an unemployed worker will find any vacancy in the time period and θ is the probability that any unfilled vacancy will find an unemployed worker, it follows that the total number of workers who find employment ($\alpha \cdot U$) must equal the total number of firms that filled their vacancies ($\theta \cdot F_v$): $\alpha \cdot U = \theta \cdot F_v$. It is important to note that α and θ are determined in equilibrium, and that both workers and firms take them as given when making their decisions. Noting that $m = \theta \cdot F_v$, we have

$$\alpha U = \theta F_v = m = \mu M(U, F_v) \tag{7}$$

the *matching condition*. It is standard to assume that the matching technology takes the Cobb-Douglas form: $m = \mu(U)^{\phi}(F_v)^{1-\phi}$ where $\phi \in [0, 1)$. An increase in either the number of unemployed workers or unfilled vacancies increases the number of matches each period, but at a decreasing rate. Ceteris paribus, more matches occur when μ is higher.

3.7 Bargaining and Wage Determination

The friction inbuilt into the job-firm matching process creates the possibility that a firm may remain unproductive or a worker may remain unemployed in any period. Firms and workers must therefore weigh the implications of finding themselves in these states and their outside options when bargaining over their share of current and future surplus produced. Two important things deserve mention here. First, the outside options available to workers are crucially affected by policy, and second, these outside options are dependent on past employment history *and* on one's position in the lifecycle. Below, we will demonstrate the powerful implications of this last observation. To foreshadow, we will establish the presence of a "skewness" in bargaining power towards the young, and the role played by pension programs in "undoing" some of the resultant inequities.

We now turn to the determination of the wage offer functions for both young and old workers. Matches between workers and unfilled vacancies leads to a surplus that is to be divided between the worker and the firm. Nash bargaining dictates that the total match surplus be shared by the firm and the worker; we denote the bargaining weight of the worker by λ, and that of the firm by $1-\lambda$. For an old worker with an unbroken employment relationship from the previous period, the gain from the match is $(1-\tau)\left[w_o^e + \delta\eta w_y\right] - (1-\tau)\,\eta w_y$. The corresponding gain to the firm is $p - (1+\tau)w_o^e + \beta\Pi_v - \beta\Pi_v =$

$p-(1+\tau)w_o^e$.[24] Then, Nash bargaining implies

$$w_o^e = \frac{\lambda p + (1-\lambda)(1-\delta)(1-\tau)\eta w_y}{(1-\lambda)(1-\tau)+\lambda(1+\tau)}. \tag{8}$$

Analogously, it follows that the wages to an old separated worker is given by

$$w_o^s = \frac{\lambda\left[p-(1-\tau_h)h\right]+(1-\lambda)(1-\delta)(1-\tau)\eta w_y}{(1-\lambda)(1-\tau)+\lambda(1+\tau)}, \tag{9}$$

and the wages to an old never-before-employed worker (one who has never paid in to the system) is given by

$$w_o^u = \frac{\lambda\left[p-(1-\tau_h)h\right]}{(1-\lambda)(1-\tau)+\lambda(1+\tau)}. \tag{10}$$

Finally, we turn to the wage determination for a young worker. The gains from trade for the firm are given by

$$\begin{aligned} &p-(1-\tau_h)h-(1+\tau^f)w_y+b\beta\Pi_v+(1-b)\beta\Pi_f-\beta\Pi_v \\ =&\left[p-(1-\tau_h)h-(1+\tau^f)w_y\right]+(1-b)\beta\left[p-(1+\tau^f)w_o^e\right]-(1-b)\beta(1-\beta)\Pi_v \end{aligned}$$

while the young worker's surplus from finding employment is given by

$$(1-\tau)w_y+b\beta J_o^s+(1-b)\beta J_o^e-\beta J_o^u$$

Under non-symmetric bargaining, it follows that w_y may be determined using

$$\begin{aligned} &(1-\lambda)\left[\begin{array}{l} w_y\left[(1-\tau)+b\beta\left(\alpha\delta+1-\alpha\right)(1-\tau)\eta+(1-b)\beta\delta(1-\tau)\eta\right] \\ +\beta s\left(1-\tau_s\right)(1-b)+\beta(1-\tau)\left\{\alpha b w_o^s+(1-b)w_o^e-\alpha w_o^u\right\}\end{array}\right] \\ =&\ \lambda\left[\left\{p-(1-\tau_h)h-(1+\tau^f)w_y\right\}+(1-b)\beta\left\{p-(1+\tau^f)w_o^e\right\}-(1-b)\beta(1-\beta)\Pi_v\right] \end{aligned} \tag{11}$$

3.7.1 Discussion of the wage function for the young

In order to derive additional insight from this wage function, it is instructive to focus on some special cases. Assume for the present that the subsidies, $\tau_a=\tau_h=\tau_s=0$, and that the firm and the worker have equal bargaining power. A few special cases are studied below.

No policy intervention: Suppose public pension programs are absent. In this case, using (8)-(11), we have:

$$w_o^s = w_o^u = \lambda(p-h), \quad w_o^e = \lambda p$$

[24] We assume that even when a match survives on to the second period, wages are determined by a fresh process of bargaining at the start of the second period.

$$w_y = \lambda(p-h) - (1-\lambda)(1-b)\beta w_o^e + \lambda(1-b)\beta(p-w_o^e) + (1-\lambda)(1-b)\beta J_o^u$$
$$-\lambda(1-b)\beta(1-\beta)\Pi_v$$

Note that since a worker can expect that his job will last beyond one period, the wage function for young workers reflects that the value of a job today is more than just the current wage. If the worker lived exactly for one period (or employment is only temporary, $b = 1$), he would earn $\lambda(p-h)$, which is his share of the current surplus he produces. However, employment when young also implies that a worker is more likely to be working when old; this will affect current wages. The term βw_o^e represents the additional surplus that a young worker will obtain in the future if the match is sustained. Since this represents a source of gain from working when young, the firm extracts this future surplus by paying the worker lower wages. In addition, if the employment relationship is sustained, then the firm will have more net revenues next period. Since the discounted surplus, $\beta(p-w_o^e)$, represents additional revenues that the firm will obtain in the future from hiring a young worker, the worker is able to extract his share of that expected surplus $\lambda(1-b)\beta(p-w_o^e)$. In fact, the future match surplus will be higher due to the accumulation of firm-specific human capital. It turns out that, under symmetric bargaining, the worker's share of the firm's expected discounted surplus from remaining matched the next period is the same as the firm's share of the worker's expected surplus so that:

$$w_y = \lambda(p-h) + (1-\lambda)(1-b)\beta J_o^u - \lambda(1-b)\beta(1-\beta)\Pi_v$$

It is apparent that, in the absence of policy intervention, inequities in bargaining power over the lifecycle arise. Young workers, who have the option of searching for jobs when old, will have a higher threat point in negotiating over wages than old workers. However, due to the accumulation of firm-specific human capital, old workers who have retained their jobs earn higher wages than young workers.

100% tax on pension benefits for an old worker ($\delta = 0$): In this case, social security acts as a form of long-term unemployment insurance for older workers.[25] If $\delta = 0$, using (8)-(11), we have:

$$(1-\tau)w_o^e = (1-\tau)\lambda(p + (1-\tau)\eta w_y)$$
$$(1-\tau)w_o^s = (1-\tau)\lambda[(p-h) + (1-\tau)\eta w_y]; \quad (1-\tau)w_o^u = (1-\tau)\lambda(p-h)$$

[25] There are numerous cases of 100% tax rates on pension benefits in public pension programs. Recall that Mulligan and Sala-i-Martin (1999) find that a majority of countries *require* individuals to retire in order to collect pension benefits. The United States, between 1939 and 1971, is another such example. For further details, see Mulligan (1998).

$$(1-\tau)w_y = (1-\tau)[\frac{\lambda(p-h) + (1-\lambda)\beta J_o^u - (1-\lambda)b\beta\{-s + \alpha(1-\tau)w_o^s\} - \lambda(1-b)\beta(1-\beta)\Pi_v}{2\lambda + \lambda b\beta(1-\alpha)(1-\tau)\eta}] \quad (12)$$

These wage equations show how the pension system acts as a form of "unemployment insurance" for older workers. In our setup, it also provides them with a mechanism with which they can "negotiate" higher wages. Social security provides older workers with an independent source of income, and more importantly, one that is not available to young workers. Under the very strict "retirement" test or "earnings" test here, an old worker who earns any income in the labor market will completely forfeit their retirement benefits. This implies a very large tax on elderly work and therefore old workers require higher wages to offset the loss of retirement income. Interestingly, the provision of public pension benefits may serve a key social function by reducing inequities in bargaining power over the lifecycle and lowering payroll costs from employing young workers.

To see how social security achieves redistribution of bargaining power over the lifecycle, recall that young workers (by virtue of the fact that they have a period ahead of them) have higher bargaining power than the old. Also recall that the very state of being employed when young makes individuals eligible for governmental transfers when old. In a world with positive replacement rates, being employed when young therefore raises the worker's expected net income in the future. When bargaining, the firm and the worker take this into account. The firm extracts its share of the discounted net income, $(1-\lambda)b\beta\{-s + \alpha(1-\tau)w_o^s\}$, by paying the young worker lower wages [see eq. (12)]. The bargaining power of the young (arising from their position in the lifecycle) is therefore partially reduced because the firm is aware that having a job today implies current (and future) benefits to the employee; the firm naturally extracts part of that surplus. It is in this sense that public pensions redistribute bargaining power from young to old workers.[26]

No Earnings Test ($\delta = 1$): In this case, there is no tax on pension benefits while individuals earn labor income, and as a result, wages of old workers are unaffected:

$$(1-\tau)w_o^u = (1-\tau)w_o^s = \frac{(1-\tau)(p-h)}{2}$$

$$(1-\tau)w_o^e = \frac{(1-\tau)p}{2}$$

[26] Black (1987) also finds that social security affects age-earnings profiles. In his model, workers would rather receive private pension payments than wages as a result of social security taxes. As workers become older, they switch from pension payments to wages since the returns from pension savings would be lower. Therefore, social security tends to generate upward-sloping age earnings profiles. In his work, the retirement date is exogenous (he does not explore the early retirement incentives in the social security system). In addition, there is no unemployment in his model.

$$(1-\tau)w_y = \frac{(1-\tau)[(p-h)+(1-b)\beta J_o^u - (1-b)\beta(1-\beta)\Pi_v]}{2+\beta\eta(1-\tau)}$$

To gain some insight into the wage effects from completely eliminating the earnings test, it is important to compare old workers' total income across different earnings restrictions. In the case of a 100% tax rate, old workers who retain their jobs obtain the total income of $(1-\tau)w_o^e = (1-\tau)\lambda(p+(1-\tau)\eta w_y)$. In contrast, when the earnings test is completely eliminated, their total income is $(1-\tau)(w_o^e+\eta w_y) = (1-\tau)\lambda p+\eta(1-\tau)w_y$. Thus, for a given tax rate and w_y, *total* income is higher when the earnings test is completely eliminated. Similar insights occur when considering displaced workers. Although pension benefits do not affect the wages of old (and were employed when young) workers, their total incomes will be higher in the case of no earnings restriction. There are also important implications for young wages. By working and paying social security taxes when young, workers become eligible for benefits when they are old. Since workers will obtain higher total income when work disincentives are reduced, young workers choose to work for lower wages. Thus, the design of public pension programs will have an important impact on age-earnings profiles in the economy. By affecting the wage structure across the lifecycle, public pension programs will have a number of general equilibrium effects on labor market activity.

3.8 Government budget

The two sources of revenue for the government are the payroll taxes paid by all the firms:

$$F_v\theta\tilde{u}_o\tau w_o^u + F_v\theta\tilde{u}_y\tau w_y + F_f\tau w_o^e + F_v\theta\tilde{u}_s\tau w_o^s \tag{13}$$

and the payroll taxes paid by the different categories of workers:

$$e_o\tau\left[w_o^e+\delta\eta w_y\right] + u_s\alpha\tau\left[w_o^s+\delta\eta w_y\right] + u_s\left(1-\alpha\right)\tau\eta w_y + u_o\alpha\tau w_o^u + \left(0.5\right)\alpha\tau w_y. \tag{14}$$

where e_o is the number of old people with jobs. The expenditure by the government on workers in the form of pension payments or age-related transfers is given by

$$e_o\delta\eta w_y + u_s\alpha\delta\eta w_y + u_s\left(1-\alpha\right)\eta w_y. \tag{15}$$

The government also potentially finances various subsidies (search subsidies to older workers and entry and hiring subsidies to firms):

$$\left(u_s+u_o\right)s\tau_s + F_v a\tau_a + \theta F_v h\tau_h$$

It is assumed that the government balances its budget each period. Note that wages of all workers, the total number of vacancies (along with filled vacancies), and the total number of workers in each state (separated, employed, and unemployed) are all endogenous variables along with the taxes required to balance the government's budget. In particular, as demonstrated in Section 3.7, the wage functions are functions of the tax rates and government policies.

3.9 Equilibrium

Henceforth we focus exclusively on time-invariant equilibria. This will allow us to investigate the properties of long-run equilibria in the labor market. A steady-state equilibrium with complete labor market participation is formally defined below.

DEFINITION A *A steady-state equilibrium with complete labor market participation consists of wage functions* w_y^*, w_o^{e*}, w_o^{u*}, *and* w_o^{s*} *[defined in* (8)-(11)], *policy parameters,* τ, η, δ, τ_a, τ_h, *and* τ_s, *exogenously specified bargaining weights* λ *and* $(1-\lambda)$ *for the firm and the worker, and a quadruple* $(\alpha^*, \theta^*, U^*, F_v^*)$ *satisfying the following conditions: (i) Nash bargaining; (ii) (Unrestricted Entry for firms):* $\Pi_v^* = 0$ *; (iii) (Steady-State):* $\alpha^* U^* = \theta^* F_v^* = \mu M(U^*, F_v^*)$; *(iv) the government's budget is balanced, and (v) labor market participation constraints hold:* $J_o^u > 0, J_y > \beta J_o^u, (J_o^s, J_o^e) > (1-\tau)\eta w_y$.

The aforementioned steady state matching condition and equilibrium entry condition for firms is derived below.

3.9.1 The Steady-State Matching Condition

Recall [see (7)] that the matching condition for the economy is given by

$$\alpha U = \theta F_v = m = \mu(U)^{\phi}(F_v)^{1-\phi}$$

where $\phi \in [0,1]$. Noting that $U/F_v = \theta/\alpha$, we may therefore write the *steady-state matching condition* as:

$$\theta = \left[\frac{\mu}{(\alpha)^{\phi}}\right]^{\frac{1}{1-\phi}} \tag{16}$$

Note that the steady-state matching condition implicitly defines a relationship between α and θ consistent with steady-state values for U and F_v.

3.9.2 The Equilibrium Entry Condition

Firms enter the labor market in search of employees until all profit opportunities from new jobs are driven to zero. This "free-entry condition" dictates that the expected present value of future profits attributable to filling the marginal vacancy must equal the cost of vacancy-posting and hiring the next worker. Utilizing the wage functions described above, along with $\Pi_v^* = 0$ [see (6)], we have

$$\left(\frac{a}{\theta}\right)\frac{1}{\tilde{u}_y}(1-\tau_a) = [p-(1-\tau_h)\,h-(1+\tau)w_y] + (1-b)\beta\,[p-(1+\tau)w_o^e] \tag{17}$$
$$+\left(\frac{\tilde{u}_o}{\tilde{u}_y}\right)[p-(1-\tau_h)\,h-(1+\tau)w_o^u] + \left(\frac{\tilde{u}_s}{\tilde{u}_y}\right)[p-(1-\tau_h)\,h-(1+\tau)w_o^s]$$

Then, equilibrium values of (α, θ) are derived jointly from (16) and (17).

In order to derive the endogenous market participation decisions of all workers in the presence of policy action, we adopt the following algorithm. We conjecture an equilibrium (see Definition A) in which *all* workers (especially, the old workers) choose to participate in the labor market. We then identify a set of policy parameters will support this conjectured steady-state equilibrium. In other words, we isolate policy parameter values for which $J_o^u > 0, J_y > \beta J_o^u$ and $(J_o^s, J_o^e) > ((1-\tau)\eta w_y, (1-\tau)\eta w_y)$ will hold. It is apparent, for example, that for some levels of pension benefits, a separated old worker will find it in his best interest to withdraw from the labor market; obviously, under these policy parameters, the conjectured equilibrium will no longer be supported. In short, we allow for individual deviations from the equilibrium path under the conjecture that all others are playing the equilibrium strategy, and then check that any such individual deviations do not make anyone better off.[27] We report the results of our numerical exercises below.

3.10 Numerical Experiments in the Benchmark Model

In a similar model with exogenous labor market participations and no government policies, Bhattacharya and Reed (2001) formally prove the existence and uniqueness of the equilibrium. The non-linearities in the steady-state matching condition (condition (iii) in the definition of the equilibrium) and the government budget constraint (condition (iv)) in the current setup make it impossible to obtain general closed-form solutions for each variable. In addition, for each candidate equilibrium, the participation

[27] However, computation of the expected returns to deviation requires us to know the tax rates and other endogenous variables that workers will face in the off-equilibrium path. Since *a* worker is of zero measure, his actions cannot have any effect on aggregate variables. This allows us to use the tax rates and other endogenous variables under the conjectured equilibrium to compute the deviation payoffs.

constraints for the endogenous labor market participation decisions also need to be checked. In what follows, we conduct some numerical experiments aimed at providing *qualitative* insights into the effects of various labor market policies. We fix the values of the following parameters to: $\beta = 0.9$, $s = 0.1$, $a = 0.2$, $\mu = 0.4, \phi = 0.5$, $b = 0.3$, $p = 1$ and $h = 0.3$.[28] Starting from this benchmark set of parameters, we vary a pension-policy parameter of interest in isolation so as to gain some insight into the effect of each factor on aggregate labor market outcomes. For future reference, we define the implicit tax rate as

$$\frac{(1-\delta)(1-\tau)\eta w_y}{\delta(1-\tau)\eta w_y + (1-\tau)w_o^s}$$

This is the implicit tax rate on earnings imposed on separated workers; $(1-\delta)(1-\tau)\eta w_y$ is amount of after-tax benefits that a separated worker would have received if he chose not to work while $\delta(1-\tau)\eta w_y + (1-\tau)w_o^s$ is a separated worker's total after-tax income (which includes her pension benefits, $\delta(1-\tau)\eta w_y$). This is an upper-bound for the actual implicit tax rate, since retained workers earn a higher wage than separated workers. [29]

3.10.1 Varying the replacement rate under symmetric bargaining weights for a fixed earnings penalty rate

We first study the effects of publicly provided pension programs within the context of symmetric Nash bargaining, i.e., we set $\lambda = 0.5$. We begin by considering a case where there is a very high tax on elderly work– in this setting, public pension programs are more like a form of long-term unemployment insurance for older workers.

High penalty rate To be specific, we evaluate the consequences of varying the replacement rate η for a fixed value of $\delta = 0.1$ (corresponding to a 90% penalty rate). Figure 1 summarizes the results. We note that under our set of parameters, workers of all ages and employment histories choose to participate in the labor market when the replacement rate is 81% or lower. When public pension programs become too generous, the displaced older workers choose to accept pension benefits rather than incur the costs of job search, thereby destroying the conjectured equilibrium.

[28] To reiterate, ours is *not* intended to be a fully-developed calibration exercise. While it would no doubt be interesting to extend our framework to many-period OG models, this is not our focus here. The two period framework allows us to easily trace an old worker's current employment status to his previous job history. It therefore provides a relatively tractable framework to analytically demonstrate some important interactions between the design of public pension programs and age-earnings profiles in the economy. The numerical exercises illustrate the general equilibrium effects of such policies. The two period framework provides a means towards providing a departure from standard infinite-horizon models of the labor market. Thus, our parameter choices are not guided by the dictums of proper calibration; there is little available knowledge on these parameters over a 25-30 year horizon, the real life length equivalent of a two-period OG model.

[29] Gruber and Wise (1999) find that the implicit tax rate for older workers varies across countries: while it is relatively low in the United States (around 20%), it is much higher in a number of European countries (as much as 80%).

In this example ($\delta = 0.1$), we find that public pensions lead to less demand for labor and therefore more unemployment in the economy (lower values of α, higher values of θ, and $\mathcal{F}$ (the total mass of firms) lower). This is primarily because pension programs raise payroll costs. At higher values of η, old workers who were employed when young become eligible for higher transfer payments – this raises their bargaining power, wages, and *total* (wages gross of pensions) incomes.[30] Consequently, the gains from working when young become higher and young workers therefore accept lower wages. Under higher replacement rates, the tax rate needed to finance the pension program rises to nearly 3%. As a result, labor costs (on average) increase, and the total number of firms ($\mathcal{F}$) falls. As pension benefits become more generous and workers face more difficulty in finding employment (α lower), more old workers in the economy stay unemployed, and therefore, the young are a smaller share of the unemployed in the economy. The combination of high payroll tax rates, a severe earnings restriction, and high replacement rates raises the the implicit tax rate on elderly earnings to nearly 50% for old and displaced workers. Eventually, as replacement rates continue to rise, old displaced workers find it in their best interest to retire rather than search for employment – the equilibrium under complete labor market participation fails to exist.

Low penalty rate The second experiment focuses on the effects of higher replacement rates when the earnings restriction is much less severe (the earnings penalty rate is only 10%, i.e., $\delta = 0.9$). In many ways, the results are qualitatively similar to the analysis in the first experiment. We find, however, that the equilibrium of complete labor market participation continues to exist for replacement rates through 100%. That is, when the earnings penalty is in place, but relatively mild, public pension programs fail to induce retirement. We present the results of our numerical simulations in Figure 2.

As before, higher replacement rates are associated with higher wages for old workers eligible for benefits. Due to the much lower implicit tax rates on elderly work, the increase in wages associated with more generous benefits is lower since old workers do not lose as much additional income by choosing to work rather than retire. We do find, however, that (for a given replacement rate) the *total* income of old employed and separated workers is higher when δ is higher.

What is the effect on young workers' wages? Since working and contributing to the pension system when young makes workers eligible for higher expected total income when old, a lower earnings tax on

[30] In fact, because of the severe earnings restrictions, the choice of working when old implies higher foregone pension benefits and therefore lower net income from working. As a result, retained and separated old workers are able to extract the loss of benefits from their employers in the form of higher wages. Thus higher pension benefits and higher wages cause total income of old workers to rise.

old income further raises the benefits of employment in the first period and tends to lower young workers' wages. Two general equilibrium effects offset this. First, lower old workers' wages entice more firms to create vacancies which allows workers to find vacancies more easily — this also raises the outside option (to working) for young workers. Second, the higher tax rates required to finance the higher pension benefits under a more lax earnings restriction will prompt young workers to demand higher wages. Overall, our results imply that for a fixed replacement rate, wages of the young are higher under a lower earnings restriction. As the replacement rate rises, young workers will accept lower wages since employment makes them eligible for future higher pension benefits.

The Earnings Test and its Implications Given the recent attention on the earnings test, a study of the effects of removing it, seems in order.[31] When there is no earnings restriction, the implicit tax rate on elderly work falls to zero; as such, old-age wages are no longer related to the replacement rate. The generosity of the pension programs, however, does affect young workers' wages since the higher benefits will raise workers' overall incomes when they reach old age. Not surprisingly, more generous pension programs require higher tax rates. The effects of increasing generosity of benefits with no earnings penalty are illustrated in Figure 3.

Our discussion thus far has highlighted an important effect of the earnings test, namely lower employment. Recall, under the earnings test, higher replacement rates imply higher payroll costs for old workers (more generous pension benefits translate into higher bargaining power for the old) that dominate the lower cost of young workers' wages, thereby reducing aggregate employment. In the absence of an earnings test, as pension programs become more generous, the payroll costs of old workers rise (although old-wages remain constant) and the payroll costs of young workers fall. At low replacement rates, increasing benefits leads to less employment; however, as the replacement rate rises, it turns out that the amount of employment may eventually rise [a point where the aforementioned fall in payroll costs of young workers may dominate the increase in costs of employing old workers.] As Figure 3 demonstrates, we have uncovered a *non-monotonic* relationship between total employment and replacement rates of pension benefits (as observed in the relationships among α, θ, $\mathcal{F}$ and η). Furthermore, this non-monotonicity is present only when the earnings test is absent.

[31] For a discussion on the implications of the earnings test for the labor supply behavior of older workers, see Baker and Benjamin (1999), Burtless and Moffit (1984), Disney and Tanner (2000), Friedberg (1998), and Gruber and Orszag (2000). While these papers have examined the implications of social security design on individual labor market outcomes, our work seeks to determine their overall impact on the labor market at the aggregate level in a general equilibrium setting.

Summary We briefly summarize our main results on the design of public pension programs in the case of symmetric Nash bargaining. In general, more generous provision of pension benefits (higher replacement rates) raises total incomes of workers who are eligible for benefits. When there is a high tax on elderly work (the earnings test is relatively more severe), the increase in bargaining power resulting from the availability of benefits raises wages for retained and separated workers. When there is a low tax on elderly work (the earnings test is relatively less severe), there is less of an effect on old workers' wages, but the increase in pension benefits raises their total incomes. The availability of pension benefits will also causes young workers' wages to fall. In terms of maximizing employment (maximizing $\mathcal{F}$), our results imply that as long as publicly induced retirement does not occur, the best pension program is one that does not tax elderly work (for a given replacement rate). Thus, for any replacement rate, the best pension program is to eliminate the earnings test. However, the best pension program (the combination of δ and η) for maximizing employment in the economy, is one with zero replacement rates — i.e., the pension program that generates the most employment is to not have a pension program.

3.10.2 Varying the replacement rate when workers have a higher bargaining weight

We now proceed to studying the effects of public pension programs when workers have relatively more bargaining power than firms, a feature of many European labor markets. For brevity, we report only on how the results differ across $\lambda = 0.5$ and $\lambda = 0.6$.

High penalty rate ($\delta = 0.1$) We present the numerical results in Figure 4. When the replacement rate (η) increases from 0 to 54%,

1. Old workers' wages respond slightly more to higher replacement rates in the symmetric Nash case than when workers have more bargaining power.

2. This pattern also holds for the total after-tax income of retained workers. However, it is not true for the displaced workers. In the case of symmetric Nash bargaining, separated workers will see their incomes rise almost two and half times their income without public pensions. The increase is much higher (over three times) when workers have more bargaining power. Recall that social security acts as a form of long-term unemployment insurance by providing displaced older workers with a source of income in the event that they do not find employment. As a result, especially

when the penalty rate is high, displaced workers experience a greater increase in after-tax income than old workers who retain jobs from their youth.

3. When $\lambda = 0.6$, there is a greater role for such insurance due to the higher amount of unemployment. As a result, public pension programs have a stronger labor supply effect than under symmetric Nash bargaining. The replacement rate does not need to be as high (only to $\eta = 0.54 < .81$) in order to induce separated workers to retire. This observation suggests that social security-type policies should have a stronger impact on labor supply decisions in European countries than in the United States.

4. Taxes rise more when workers have higher bargaining strength because there is more unemployment and the base for calculating benefits (w_y) is higher. Consequently, young workers' wages fall more under symmetric Nash.

Low penalty rate ($\delta = 0.9$) We present the numerical results in Figure 5.

1. Effect on old retained workers: Recall that in the symmetric Nash case, higher replacement rates translate into higher wages for old retained workers: they forego some pension benefits by working but the implicit tax rate is quite low. In contrast, under higher worker bargaining power, wages of old retained workers actually *fall*. In this case, there is a relatively small loss of income from working due to the low tax on elderly work (the earnings penalty is only 10%). But, with workers gaining a larger share of the total surplus from working, the tax rate required to pay for the increased pension benefits is now higher. This reduces the firm's gains from having a filled vacancy. As a result, old workers with long-term labor market attachment experience a fall in wages. Regardless, the higher replacement rate is associated with higher total income since the loss in wages is small compared to the increase in pension income under higher replacement rates. The increase in total income is slightly less than when $\lambda = 0.5$.

2. Effect on old separated workers: As in the symmetric Nash case, these workers experience a small *increase* in wages.

3. Also, we find that wages of the long-term unemployed fall when workers have more bargaining power, but remain constant under symmetric Nash bargaining. In the symmetric Nash case, an increase in the tax rate simultaneously lowers the gains from trade for both the firm and the worker in the same amount; in the case where workers have more bargaining power, their wage

depends more on the firm's surplus than their own gains from trade. Thus, the wage paid to the long-term unemployed depends more on the firm's net revenues from filling their employment vacancy and therefore the higher tax rate causes their wage to fall.

4. Taxes are somewhat higher and employment falls more when workers have more bargaining power. Despite the fall in employed workers' wages and of the long-term unemployed, payroll costs behave qualitatively the same as under symmetric Nash. Payroll costs from employment of young workers fall more under symmetric Nash, but increase more for all other employment relationships–despite the fact that taxes rise more when λ=.6. Figure 6 reports the results when the earnings test is completely eliminated.

4 Policy-Induced Withdrawal from the Labor Force Among "Discouraged" Workers

The benchmark model studied a setting where independent of age and employment history, all workers chose to participate voluntarily in the labor market. En route to studying the desirability (or lack thereof) of policies that induce workers of all ages and employment histories to participate, we now analyze a setting where a subset of workers are induced to drop out. In particular, we consider the general equilibrium consequences of public policies that induce only the old and separated [hereafter, "discouraged"] workers to leave the labor market.[32] Recall, these are old workers who were employed when young, paid into the system, were involuntarily displaced from their jobs, and are currently eligible for pension benefits.[33]

In terms of deriving the endogenous labor market participation decisions of all workers (in particular, old workers), we adopt the following algorithm. We first condition on a set of strategies where all separated workers have chosen to withdraw from the labor market (rather than incur costs of job search). We then ask what set of policy parameters will support the conjectured steady-state equilibrium. That

[32] In Britain, "the *Job Release Scheme* which ran between 1977 and 1988, specifically encouraged older workers to stand down to make way for younger ones. Once out of employment, changes to the unemployment benefit regime in 1983 removed the requirement for men over 60 to look for work, encouraging them to see themselves as retired." Mulligan (2000) discusses a number of explanations for the design of social security programs. Based on his analysis, he determines that public pension programs emphasize both induced retirement and intergenerational income redistribution. In particular, he finds the induced retirement objectives are much more important in Europe.

[33] "In the past 20 years, the proportion of men between 50 and the State Pension Age (65 for men) who are not working has doubled. A third of men and women in this age range, 2.8 million people, are now not working. ...Almost half receive most of their income in state benefits.... The total economic cost is high. The drop in work rates among the over-50s since 1979 costs the economy about £16 billion a year in lost GDP and costs the public purse £3-5 billion in extra benefits and lost taxes."

is, within the context of the conjectured strategies of withdrawal by discouraged workers, we then verify that under the given set of policy parameters a separated worker is better off choosing to collect pension benefits rather than searching for a job.[34]

4.1 Payoffs

To save on space, we quickly summarize the relevant expressions that are analogues of similar expressions from the benchmark model. First, workers who did not find employment when young, under our equilibrium, search when old and receive

$$J_o^u = -s\left(1-\tau_s\right) + \alpha(1-\tau)w_o^u > 0$$

as in (2) above. The conjectured equilibrium is that discouraged workers do not search implying

$$J_o^s = (1-\tau)\eta w_y.$$

Under the conjectured equilibrium, firms do not have access to the pool of old separated workers. This implies that

$$\begin{aligned}\Pi_v &= -a\left(1-\tau_a\right) + \theta\tilde{u}_y\left\{\left[p-\left(1-\tau_h\right)h-(1+\tau)w_y\right]+(1-b)\beta\Pi_f+b\beta\Pi_v\right\}\\ &\quad +\theta\tilde{u}_o\left\{\left[p-\left(1-\tau_h\right)h-(1+\tau)w_o^u\right]+\beta\Pi_v\right\}+(1-\theta)\beta\Pi_v\end{aligned}$$

and

$$\Pi_f = p-(1+\tau)w_o^e+\beta\Pi_v$$

Then, analogous to (6), we get

$$\begin{aligned}\Pi_v = &\frac{-a\left(1-\tau_a\right)+\theta\tilde{u}_y\left[p-\left(1-\tau_h\right)h-(1+\tau)w_y\right]+\theta\tilde{u}_y(1-b)\beta\left[p-(1+\tau)w_o^e\right]}{\left[1-\theta\tilde{u}_y(1-b)\beta^2-\theta\tilde{u}_y(1-b)b\beta^2-\theta\tilde{u}_o\beta-(1-\theta)\beta\right]}\\ &+\frac{\theta\tilde{u}_o\left[p-\left(1-\tau_h\right)h-(1+\tau)w_o^u\right]}{\left[1-\theta\tilde{u}_y(1-b)\beta^2-\theta\tilde{u}_y(1-b)b\beta^2-\theta\tilde{u}_o\beta-(1-\theta)\beta\right]}\end{aligned}$$

The wage functions, derived in exactly the same manner as in the benchmark model, and analogous to (8)-(11) are collected below:

$$w_o^u = \frac{\lambda\left[p-\left(1-\tau_h\right)h\right]}{\left(1-\lambda\right)\left(1-\tau\right)+\lambda(1+\tau)} \tag{18}$$

[34] Pissarides (1976), in an infinite-horizon model with sequential search, also studies the choice of labor market participation. He derives the optimal number of times individuals will choose to search for jobs before becoming "discouraged" and withdrawling from the labor market. He does not consider, however, the role of the lifecycle in his analysis. His model also does not address how labor market participation is determined by labor market policies.

$$w_o^e = \frac{\lambda p + (1-\lambda)(1-\delta)(1-\tau)\eta w_y}{(1-\lambda)(1-\tau) + \lambda(1+\tau)} \tag{19}$$

The gains to a firm from hiring a young worker is given by

$$p - (1-\tau_h)h - (1+\tau^f)w_y + b\beta\Pi_v + (1-b)\beta\Pi_f - \beta\Pi_v$$

which simplifies to

$$p - (1-\tau_h)h - (1+\tau)w_y - \beta(1-b)(1-\beta)\Pi_v + (1-b)\beta\left[p - (1+\tau)w_o^e\right]$$

The young worker's surplus from finding employment is given by

$$(1-\tau)w_y + b\beta J_o^s + (1-b)\beta J_o^e - \beta J_o^u$$

which simplifies to

$$(1-\tau)w_y + b\beta\left[(1-\tau)\eta w_y\right] + (1-b)\beta\left[(1-\tau)w_o^e + \delta(1-\tau)\eta w_y\right] - \beta\left[-s + \alpha(1-\tau)w_o^u\right]$$

Under non-symmetric bargaining, we have

$$\begin{aligned} & \lambda\left\{p - (1-\tau_h)h - (1+\tau)w_y - \beta(1-b)(1-\beta)\Pi_v + (1-b)\beta\left[p - (1+\tau)w_o^e\right]\right\} \\ = \; & (1-\lambda)\left\{(1-\tau)w_y + b\beta(1-\tau)\eta w_y + (1-b)\beta\left[w_o^e(1-\tau) + \delta(1-\tau)\eta w_y\right] - \beta\left[-s(1-\tau_s) + \alpha w_o^n(1-\tau)\right]\right\} \end{aligned}$$

Under free entry, the expression for the wages of a young worker may be written as:

$$\begin{aligned} w_y = & \frac{\lambda\left[\{p - (1-\tau_h)h\} + (1-b)\beta\{p - (1+\tau)w_o^e\}\right]}{(1-\lambda)\left[(1-\tau) + (1-b)\beta\delta\eta(1-\tau) + \beta b(1-\tau)\eta\right] + \lambda(1+\tau)} \\ & \frac{-(1-\lambda)\left[(1-b)\beta(1-\tau)w_o^e - \{-s(1-\tau_s) + \alpha(1-\tau)w_o^u\}\right]}{(1-\lambda)\left[(1-\tau) + (1-b)\beta\delta\eta(1-\tau) + \beta b(1-\tau)\eta\right] + \lambda(1+\tau)} \end{aligned} \tag{20}$$

Firms, as before, enter until $\Pi_v^* = 0$. So, in a steady-state, similar to (17), we have the "free entry" condition given by

$$\begin{aligned} \frac{a}{\theta}\left(\frac{1}{\tilde{u}_y}\right)(1-\tau_a) = & \left[p - (1-\tau_h)h - (1+\tau)w_y\right] + (1-b)\beta\left[p - (1+\tau)w_o^e\right] \\ & + \left(\frac{\tilde{u}_o}{\tilde{u}_y}\right)\left[p - (1+\tau)w_o^u - (1-\tau_h)h\right] \end{aligned} \tag{21}$$

4.2 Government

Finally, the components of the government's budget constraint may be written as follows. The payroll taxes paid by firms are given by

$$F_v\theta\tilde{u}_o\tau w_o^u + F_v\theta\tilde{u}_y\tau w_y + F_f\tau w_o^e$$

and those paid out by workers are

$$0.5 \cdot \alpha\tau w_y + e_o\tau \left[w_o^e + \delta\eta w_y\right] + \alpha u_o \tau w_o^u + r\tau\eta w_y$$

where r stands for the number of people who withdraw from the labor force. The government spends an amount equal to $e_o\delta\eta w_y + r\eta w_y + u_o\tau_s s$ on workers (the last term is the search subsidy) and an amount $F_v a\tau_a + \theta F_v h\tau_h$ on firms (in the form of subsidies). Again, the government balances its budget each period.

4.3 Equilibrium

A steady-state equilibrium in which all old "discouraged" workers voluntarily withdraw from the labor market is formally defined below.

DEFINITION B *A steady-state equilibrium with no labor market participation from old displaced workers consists of wage functions w_y^*, w_o^{e*}, and w_o^{u*}, [defined in (18)-(20)], policy parameters, τ, η, δ, τ_a, τ_h, and τ_s, exogenously specified bargaining weights λ and $(1-\lambda)$ for the firm and the worker, and a quadruple $(\alpha^*, \theta^*, U^*, F_v^*)$ satisfying the following conditions: (i) Nash bargaining; (ii) (Unrestricted Entry for firms): $\Pi_v^* = 0$; (iii) (Steady-State): $\alpha^* U^* = \theta^* F_v^* = \mu M(U^*, F_v^*)$; (iv) the government's budget is balanced, and (v) labor market participation constraints: $J_o^u > 0, J_y > \beta J_o^u, J_o^e > (1-\tau)\eta w_y$ hold, and the discouraged worker constraint [see Appendix C] is satisfied.*

4.4 Numerical Experiments in the "Discouraged" Worker Economy

In what follows, we fix the values of the following parameters to the same values as those in the benchmark model: $\beta = 0.9$, $s = 0.1$, $a = 0.2$, $\mu = 0.4, \phi = 0.5$, $b = 0.3$, $p = 1$ and $h = 0.3$. Starting from this set of parameters, we vary a pension-policy parameter of interest in isolation so as to gain some insight into the effect of each factor on aggregate labor market outcomes.

In terms of deriving the endogenous retirement decision of older workers, we adopt the following algorithm. To consider the long-run general equilibrium implications of policy-induced retirement, we first condition on a set of strategies where all separated workers accept some level of pension benefits and withdraw rather than incur the costs of job search and participate. We then ask, what set of policy parameters (pension benefits) will support this conjectured equilibrium. We verify that under the stated pension program, all separated workers are indeed better off choosing to withdraw rather than remaining active in the labor market – this is the discouraged worker constraint in Definition B

[for details, see Appendix C.] Importantly, if the earnings test on pension benefits is sufficiently severe and benefits are generous enough (high replacement rates), then a separated worker would be better off choosing to accept pension benefits and retire rather than incur the costs of job search.

4.4.1 Varying the replacement rate under symmetric bargaining weights for a fixed earnings penalty rate

We begin by considering a case where there is a very high tax on elderly work – in this setting, public pension programs mimic long-term unemployment insurance for older workers. Our main focus is on direct comparison between the complete market participation and the discouraged worker economies.

Our first example in which public pension programs induce retirement behavior sets $\lambda = .5$ and studies the consequences of varying the replacement rate η for a fixed penalty rate $\delta = 0.1$. Here, the conjectured discouraged worker equilibrium exists starting with replacement rates equal to 81%. That is, for replacement rates equal to and higher than 81%, all displaced workers choose to withdraw from the labor market rather than incur the costs of job search and participate.[35] It is clear that the lack of labor market participation by the old has a significant impact on aggregate labor market outcomes. Since there are fewer workers searching for jobs, young workers more readily find employment (α higher) under policy-induced retirement. In this sense, the unemployment rate in the economy is lower. This, however, does not imply that there is more employment in the economy – the number of firms that are active in the discouraged worker economy is much lower than when there is active labor market participation among workers from all age groups. We illustrate these results in Figure 7.

In sharp contrast to the aforementioned results from complete market participation economies, increasing the generosity of benefits (higher replacement rates, η) produce lower unemployment rates and more employment in the discouraged worker economies. Why? Under policy-induced withdrawal by the old, the young are a much greater fraction of the labor force. Recall that they are also the lowest cost workers in the economy.[36] Increasing the generosity of the pension system therefore lowers young wages and makes it more profitable for firms to enter the labor market – both an increase in employment and a decrease in the unemployment rate. Nevertheless, even though higher replacement rates increase employment in the discouraged worker economy, total employment would be much higher

[35] Recall that for the same benchmark set of parameters, the conjectured steady-state equilibrium in which *all* workers choose to search for jobs (discussed in the previous section) exists for values of $\eta = 0$ through 82%. In contrast, the discouraged worker economy exists (and there is some retirement) for values of η from 81% and higher. Thus, in this case, for a small set of parameters (η from 81% through 82%), both equilibria exist.

[36] Note that because the young get access to pension benefits when old, they accept lower wages when young.

if the replacement rate were lower and there was no policy-induced withdrawal by the old – in fact, employment would be highest if there were no public pension programs in existence.

What is the effect of policy-induced withdrawal by the old on payroll taxes? The fact that both economies exist when $\eta = 0.82$ allows us to isolate the pure effect of publicly-induced retirement on taxes – the latter alone is responsible for taxes to jump from nearly 3% to over 4.5%, a 50% increase. This is to be expected; after all, the tax rate on the worker and the employer is the same, and there is less employment in the economy under publicly-induced retirement; naturally, taxes must rise. Payroll costs under induced withdrawal are also higher – due to the increased ability of workers to find jobs, young workers obtain higher wages, and that also raises the wages to old retained workers since they give up more pension benefits by working. In addition, the higher taxes cause after-tax labor costs of employment to increase.

4.4.2 Asymmetric Bargaining Weights

We present the results of this case in Figure 8. In contrast to the symmetric case with policy-induced retirement, the long-term unemployed are a much larger part of the labor force when $\lambda = .6$. This is consistent with observations from European labor markets in which there is much concern about youth unemployment – young workers who experience long-term unemployment are more likely to be unemployed when they are older.

As in the case of complete labor market participation, an important aspect of wage determination when workers have more bargaining power is that a worker's wage depends more on the firm's surplus from filling a vacancy than the worker's surplus from obtaining employment. The higher taxes required to pay for the higher pension benefits lower the firm's surplus from employing any of the long-term unemployed, thereby causing w_o^u to fall. As in the case where retirement does not occur, we find that young workers' wages do not fall as much under higher replacement rates. Due to the higher taxes and pension benefits, the payroll costs associated with employing old workers who did not find jobs when young are slightly higher. The payroll costs from employing retained workers are higher as well. Only the payroll costs of employing young workers are lower. This leads to another example of a non-monotonicity between α (which is associated with the amount of vacancy creation) and the replacement rate. Initially, when pension programs become more generous, there is an overall increase in payroll costs so that less firms decided to enter the market. If the replacement rate is sufficiently high, young workers' wages fall enough so that overall payroll costs in the economy are lower, more job vacancies are created, and workers find it easier to find jobs. Despite this non-monotonicity that we observe, these

effects tend to be relatively small compared to the complete labor market participation case.

Summary of the Effects of Policy-Induced Retirement and Public Pension Programs

1. In both the complete participation and retirement economies, the increasing generosity of pension programs will tend to raise old workers' wages. However, there is less of an effect when workers have more bargaining power.

2. In contrast to the complete labor market participation case, the unemployment rate in the economy will be lower when induced retirement occurs. Nevertheless, total employment is higher when all workers are active in the labor market.

3. The employment response to the effects of the replacement rate depends crucially on the retirement choices of older workers. When policy-induced retirement does not occur, more generous pension programs (assuming δ fixed) lead to less employment. Under policy-induced retirement, the employment effects of the replacement rate depend crucially on the degree of workers' bargaining power.

4. The labor supply response to the replacement rate is higher when workers have more bargaining power. Retirement will be observed at lower replacement rates than in the symmetric Nash case. This is mostly a response to the lower returns from job search by old workers due to less vacancy creation.

5. If the replacement rate is large enough, total after-tax incomes of retained and separated workers are higher when retirement takes place. This occurs because of the general equilibrium implications of pension benefits: when separated workers withdraw from the labor market, this lowers the unemployment rate in the economy and drives young workers' wages higher. Consequently, when the young workers become older, their pension benefits are higher since they are proportional to their wages when they were young. Therefore, workers who are eligible for benefits obtain higher net income under policy-induced retirement.

6. Eliminating the earnings test may further improve the income redistribution motive of social security, encourage labor market participation among the elderly, and increase total employment.

5 Alternative Policy Actions

In the preceding sections, we have considered the aggregate labor market implications of pension programs on the labor market. In particular, we have emphasized the general equilibrium effects of policy-induced retirement as a means of regulating labor market activity. The specific inducement studied was one that mimiced a pension program: working individuals and productive firms were taxed and the proceeds were used to pay enough benefits to the displaced workers so that they voluntarily withdrew from the labor market. While pension programs of this type have been widely used (see Section 2.3, "Retirement-Inducing Policies Around the World") to free up jobs for the young, such policies, in the wake of an aging population, now impose an unprecedented tax burden on the current younger generations of working individuals. In response, many countries are considering policies aimed at promoting labor market participation by older workers.[37] In this section, we seek to further evaluate how labor market policy should be designed in light of the implications of the lifecycle for labor market outcomes. While many governments have attempted to regulate labor market activity by manipulating (and, in particular, reducing) the supply of labor, an alternative policy response could be to directly promote employment rather than encouraging older workers to withdraw from the labor market. Below, we examine if labor market policy should be designed to target specific age-groups or if it should ignore the age-composition of the labor force.

We study a few alternative policy options which often are discussed under the rubric of "active labor market policies".[38] One approach would be to promote labor market participation among older workers by attempting to provide them with easier access to the labor market. In this respect, we study the effects of policies that subsidize the costs of job search [an increase in τ_s] among older workers. An alternative would be to encourage more vacancy creation and increase the demand for labor. In this respect, we pursue two types of policies which are general and not age-targeted. The first set falls under the umbrella of worker training programs. These effectively raise the productivity of newly-created matches. In this sense, our worker training programs are designed to increase the accumulation of firm-specific human capital by the proportion, τ_h. Another policy which would increase employment would be to subsidize job creation directly by subsidizing the costs of firm entry. These policies would

[37] See the discussion in OECD (1995, 1998).

[38] "Active labor programs (ALPs) are common in OECD countries, and are increasingly found in transition economies and other middle income countries that are undergoing industrial restructuring and experiencing high levels of unemployment. Government operated ALPs typically include: job counseling and referral services, public works or community employment, wage subsidies, small business creation programs, and retraining. The objective of these programs is to expedite the redeployment of labor, thereby reducing the duration of frictional and structural unemployment, increasing productivity, and reducing expenditures on income support programs." [Fretwell, Benus, and O'Leary, 1999]

effectively lower the costs of firm entry by a proportion τ_a. Finally, it is important to note that because we are interested in contrasting the effects of these alternative policy options to public pension programs, our analysis will consider the effects of the subsidy to job search, worker training programs, and employment subsidies in isolation to each other. In particular, this implies that we conduct our analysis assuming that public pension programs are absent. This allows us to directly compare the effects of the different policy options rather than their combined effects. In particular, we also limit our analysis to the symmetric Nash bargaining case.

We begin with the effects of the programs aimed at reducing the costs of job search among older workers. While these policies encourage labor market participation by old displaced and unemployed workers, there are a number of offsetting general equilibrium effects. In particular, taxes are required to pay for the subsidy. In addition, recall that in the absence of public pension programs, young workers have higher bargaining power than old workers because they have another period of job search available. By reducing the costs of job search among the old, this further raises young workers' outside options when bargaining and therefore raises young workers' wages. Consequently, while the search subsidy is designed to reduce the costs of job search, it also reduces the amount of vacancy creation since it raises taxes and wages of young workers. Thus, the search subsidy actually causes total employment to fall.

We next consider the effects of the policies aimed at promoting labor market activity through worker training programs and employment subsidies. Worker training programs can encourage more vacancy creation and promote labor market activity by making new matches more profitable. Because they raise net revenues from filling vacancies, these policies also causes wages of workers in new matches to increase. So, although worker training programs should lead to more employment, the effects on employment are relatively small. In particular, compared to eliminating the work disincentives in public pension programs, the effects in terms of encouraging more employment are very low. Employment subsidies (by reducing the costs of posting vacancies) raise total employment in the economy, much more than what would occur by eliminating the earnings test. However, while employment subsidies raise total employment significantly, they play no role in terms of income redistribution.

6 "Optimal" Design of Public Pension Programs

6.1 Welfare

We consider the "optimal" design of public pension programs and other labor market policies. We do not attempt to characterize the "first best," but we do consider how the design of public pension programs,

by altering wages and endogenous labor supply decisions in the economy, affects aggregate welfare in the economy. If the decision criterion is maximum employment, we find that, for any replacement rate, the "best" pension program does not have an earnings test. However, the best pension program (the combination of δ and η) for maximizing employment is one with zero replacement rates. A more reasonable welfare criterion would take workers' expected lifetime utility into account. In our economy, we have workers of different age groups and employment histories. Because we are concerned with the general equilibrium effects of different patterns of labor market participation, we choose a population-based average of expected lifetime utility of each group of workers. In particular, we adopt the following measure of social welfare as our welfare criterion:[39]

$$W \equiv \frac{1}{2}J_y + \frac{1}{2}\{\alpha(1-b)J_o^e + \alpha b J_o^s + (1-\alpha)J_o^u\}$$

Our first question is: is it ever welfare-improving to induce withdrawal by displaced workers from the labor force? As Figure 9 demonstrates, we find the answer is yes – for a given earnings restriction (for example, $\delta = 0.1$), policy-induced retirement achieved by increasing the replacement rate may improve aggregate labor market welfare. By effectively allowing young workers to purchase jobs from old individuals, public pension programs can improve the allocation of workers to jobs since young workers will have a higher chance of finding long-term employment. As in many search models of the labor market, workers here impose a congestion externality on the unemployed – for a fixed number of vacancies, an increase in the number of workers renders it less likely that a given worker will find a job. Furthermore, due to the possibility for the accumulation of firm-specific human capital in our setup, allowing young workers to have a greater chance of finding employment improves the allocation of workers to jobs in the economy.

What combinations of η and δ achieve the highest aggregate welfare? We find the following: (i) for a given earnings test (δ fixed), increasing the generosity of public pension programs improves aggregate welfare, and (ii) reducing the severity of the earnings test may also be welfare-enhancing. Completely eliminating the earnings test improves the redistribution of income over the lifecycle. Furthermore, at higher replacement rates, the drop in the payroll costs of young workers outweigh the higher costs of employing old workers so that there is more employment as a result of the redistribution. Thus, for a given earnings test, policy-induced retirement will improve labor market welfare. This occurs for two reasons: (i) allocating a higher proportion of jobs towards young workers leads to a more efficient allocation of workers to jobs due to the accumulation of firm-specific human capital and (ii) public pension

[39] See Davidson et. al. (1994) for a similar welfare criterion. Also, see Azariadis (p.190).

programs play a role in terms of redistribution of bargaining power and income across the lifecycle. In contrast to policy-induced retirement, eliminating work disincentives in pension programs leads to the following: (i) better income redistribution, (ii) more labor market participation, and potentially (iii) more vacancy creation due to the effect of the pension programs on age-earnings profiles in the economy. Therefore, we illustrate that recent policy reforms aimed at reducing work disincentives towards the elderly allow the redistributive role of social security to function more effectively and that the welfare effects of promoting total employment may be more important than improving the quality of employment (by encouraging the elderly to "free up" jobs for the young).

We can also use our structure to investigate the welfare effects of the active labor market programs discussed in Section 5. We find that aggregate welfare rises when there is a subsidy to vacancy creation and costs of job market search. However, these effects are much smaller than when the earnings penalty is eliminated. In particular, although employment subsidies raise total employment in the economy, they do not address the inequities in bargaining power and income that exist over the lifecycle. Thus, our model implies that it may be best to confront the current demographic crisis associated with an aging population by eliminating the current work disincentives embedded in many public pension programs.

7 Concluding Remarks

Many countries are currently experiencing a major demographic shift towards an aging population. Alongside these changes, the age composition of the labor force is also becoming significantly older. Labor force participation decisions further complicate these problems as workers are retiring earlier and living much longer after retirement than their counterparts in earlier cohorts. Policymakers must address how public pension programs and other labor market policies should be designed in reponse to these important developments. In this context, some are calling for reduced benefits (or higher taxes) while others are fighting to reduce the work disincentives embedded in many pension systems.

We believe that careful general equilibrium analysis of the underlying issues can shed important light and offer much needed guidance to policymakers. In this regard, we have ventured to study the efficiency and desirability of publicly-funded pension programs within the context of a dynamic general equilibrium model. In order to consider how age-targeted labor market policies such as social security should be designed in light of the ongoing trend towards an increasingly older population, we adopted the OG setup because it allows a natural and explicit separation of the workforce into young and old workers. The framework captures an important inter-generational conflict between the young and old

since they simultaneously compete for the same jobs; additionally, the bargaining power of the two during wage negotiations are different. Moreover, the OG structure is naturally conducive to studying pension programs that tie in with the lifecycle and other "low frequency" aspects of the labor market, such as, long job tenure, and the accumulation of firm-specific human capital.

We adopted the search framework in the labor market for three important reasons. First, it allows us to endogenize both the supply side (through labor market participation choices) and the demand side (via endogenous creation of vacancies) of the labor market, a clear departure from the "lump-of-labor" line of thought. Second, the retirement literature suggests that social security programs help to reduce labor market congestion problems for the young. The diminished prospects for job search are also a prominent factor in the labor market participation decisions of older workers. Finally, the decentralized notion of wage bargaining used in our framework allows us to study the effects of public pension programs on wage determination at each stage of the lifecycle. This is especially important given the fact that most real-world pension program benefits are generally related in some way to the number of years worked (and amount of taxes paid) and tend to increase with lifetime earnings. In this context, an important new effect that we identify is the role of social security in redistributing bargaining power over the lifecycle. In our setup, younger workers have the option of waiting while older (equally productive) workers do not. This bargaining-power inequity translates into high wages for the young, escalating labor costs (since young workers consitute the largest pool of the unemployed from which firms will have to find workers), and reduces firm entry. Positive replacement rates, raise the lifetime value of working when young and thereby reduces this inefficiency. Our work therefore offers a positive explanation for the prevalence of social security programs around the world.[40]

Our research provides numerous insights into the aggregate labor market implications of the lifecycle and public pension programs. We find that the age composition of the labor force may cause an inefficient allocation of workers to jobs in the labor market thereby creating a welfare-enhancing role for publicly induced retirement. However, despite the potential role of social security for improving the allocation of workers to jobs in the labor market by encouaging the elderly to "free up" jobs for the young, our work suggests that recent policy reforms aimed at reducing work disincentives towards the elderly may be more beneficial. This occurs for essentially three reasons. First, eliminating the earnings test allows the redistiributive role of social security to function more effectively. Second, such policies may lower overall labor costs in the economy through their impact on age-earnings profiles. Third, it is quite possible that aggregate labor market welfare could be improved by adopting labor market policies that simultaneously

[40] For a different "positive theory" of social security, see Sala-i-Martin (1996).

permit the redistributive function of social security to operate and increase *total* employment rather than attempting to improve the *quality* of employment.

Appendix

A Steady state measures of workers and firms in the baseline case

Below, we compute the steady-state measures of active firms and workers that are interacting in the labor market. To that end, it is instructive to collect all the notation in one place. Denote by $u^u_{o,t} \equiv$ mass of unemployed old workers at date t who did not find jobs at date $t-1$, $u^s_{o,t} \equiv$ mass of unemployed old workers at date t who got separated from their jobs at date $t-1$, $e_{o,t} \equiv$ mass of agents who found employment at date $t-1$ and are employed at the start of date t, $u_{y,t} \equiv$ mass of young newborn (unemployed) agents at date t ($u_{y,t} = \frac{1}{2}$ by assumption), $U_t \equiv$ mass of unemployed workers at the start of date t, $\tilde{u}_{y,t} \equiv \dfrac{u_{y,t}}{U_t}$ is the probability that a given unemployed worker is young, $\tilde{u}_{o,t} \equiv \dfrac{u^u_{o,t} + u^s_{o,t}}{U_t}$ is the probability that a given unemployed worker is old. Also recall that $\alpha_t \equiv$ probability that any unemployed worker finds a vacancy, $\theta_t \equiv$ probability that any vacancy (firm) finds an unemployed worker, $b \equiv$ probability that any employed worker gets separated from his job.

Then, it follows that

$$U_t \equiv u^u_{o,t} + u^s_{o,t} + u_{y,t}, \quad e_{o,t} \equiv \alpha(1-b)u_{y,t}, \quad u^u_{o,t} + u^s_{o,t} + e_{o,t} = \frac{1}{2},$$

and the flow into unemployment must satisfy

$$U_{t+1} = (1-\alpha)u_{y,t} + \alpha b u_{y,t} + u_{y,t+1}$$

In a steady state then, it follows that

$$u_s = \frac{\alpha b}{2}, \quad u_u = \frac{(1-\alpha)}{2}, \quad U = \frac{(1-\alpha)}{2} + \frac{\alpha b}{2} + \frac{1}{2} = \frac{2-\alpha(1-b)}{2}$$

and

$$\tilde{u}_y \equiv \frac{u_y}{U} = \frac{1}{2-\alpha(1-b)}, \quad \tilde{u}_o \equiv \frac{u_o}{U} = \frac{1-\alpha}{2-\alpha(1-b)}, \quad \tilde{u}_s \equiv \frac{u_s}{U} = \frac{\alpha b}{2-\alpha(1-b)}$$

Firms take $\tilde{u}_y$ and $\tilde{u}_o$ as given when making their entry decisions.

We now proceed to compute the masses of firms with and without a vacancy. Let $F_t \equiv$ total mass of firms in existence at the start of date t, $F_{v,t} \equiv$ total mass of firms with a vacancy at start of date t, and $F_{f,t} \equiv$ total mass of firms with a filled vacancy at start of date t.

If a firm has a vacancy at t, it can find itself in one of three possible situations at $t+1$. First, a) it does not find a worker at t and hence will have a vacancy at $t+1$, or b) it finds a young worker this period; this worker gets separated with probability b_t in which case the firm will have a vacancy next

period, or the worker does not get separated [with probability $(1-b_t)$] in which case the firm will not have a vacancy at $t+1$, and c) it finds an old worker this period in which case the firm will definitely have a vacancy at $t+1$. Then, it follows that the flow into $F_{v,t+1}$ is given by

$$F_{v,t+1} = F_{f,t} + (1-\theta)F_{v,t} + \theta\tilde{u}_{y,t}bF_{v,t} + \theta\tilde{u}_{o,t}F_{v,t}$$

while the flow into $F_{f,t+1}$ is given by

$$F_{f,t+1} = \theta\tilde{u}_{y,t}(1-b)F_{v,t}.$$

Accounting restrictions require that

$$F_{v,t} + F_{f,t} = F_t$$

hold. It can be easily shown that the steady state masses of firms are as follows:

$$F = \frac{\alpha}{2}\left[\frac{2-\alpha(1-b)}{\theta} + (1-b)\right], \quad F_v = \frac{\alpha}{2\theta}\left[2-\alpha(1-b)\right], \quad F_f = \frac{\alpha(1-b)}{2}$$

where $F_f = e$ has to hold.

B Steady state measures of workers and firms in the discouraged worker case

Analogously, it follows that

$$\tilde{u}_y \equiv \frac{u_y}{U} = \frac{0.5}{\frac{1}{2}+\frac{(1-\alpha)}{2}} = \frac{1}{2-\alpha}; \quad \tilde{u}_o \equiv \frac{\frac{(1-\alpha)}{2}}{\frac{1}{2}+\frac{(1-\alpha)}{2}} = \frac{1-\alpha}{2-\alpha}$$

Retirees (displaced workers who do not search when old):

$$r = \frac{\alpha b}{2}; \quad e_o = \frac{\alpha(1-b)}{2}; \quad F_f = \frac{\alpha(1-b)}{2}$$

$$F_v = \frac{\alpha(1-b)(2-\alpha)}{\theta\left[2(1-b)+\alpha(1-\alpha)\right]}; \quad F = \frac{\frac{\alpha(1-b)}{2}}{\theta\left[1-\frac{b}{2-\alpha}-\frac{1-\alpha}{2}\right]} + \frac{\alpha(1-b)}{2}$$

C The discouraged worker constraint

This refers to the participation decisions of separated workers. In particular, given the assumption that all separated workers choose to retire, we then verify that an individual separated worker would choose not to engage in job search (we make sure the conjectured equilibrium is robust to individual deviations). Of course, we still need to verify that the old-employed still want to work and the young will search for jobs. The algorithm is outlined in the following steps:

1. A young worker with a job contact bargains with his potential employer over the wage he will earn. The gains from obtaining employment will include – (i) wages he will earn if he retains his job when old (w_o^e) and the accompanying pension benefits ($\delta\eta w_y$); (ii) if he should lose his job (the match breaks down), the conjectured equilibrium is that upon reaching old age, he will accept the pension benefits and not search for a job. That is, when a young worker with a job contact is bargaining with the firm, *he cannot commit to looking for a job when old instead of taking the benefits* (this is because in the conjectured equilibrium, you would be better off by taking the benefits). So, the wage for the young worker is the one where as an old worker he will choose to follow the equilibrium path in the future.

2. One possibility is the following: a young worker's job match breaks down (he becomes a separated worker when old). It is conjectured that the separated worker is better off choosing to take the public pension benefits rather than searching for a new job. However, this requires verifying that these participation constraints hold. Thus, we examine the possibility of a separated worker who, individually, considers the returns to search *given that all separated workers do not search.* To do this, he first computes the wage he would earn should he be able to make a job contact (this is off the equilibrium path). Denote this wage as $w^{s,DW}$. At this point, his wages when young are exogenous (they occurred in the prior period). In this manner, we check to see that the conjectured equilibrium is robust to individual deviations. Thus, we have the following "discouraged worker constraint" [alluded to in Definition B in the text]:

$$(1-\tau)\eta w_y > -s + \alpha\left[(1-\tau)w^{s,DW} + \delta\,(1-\tau)\,\eta w_y\right] + (1-\alpha)(1-\tau)\eta w_y \tag{22}$$

where

$$w^{s,DW} = \frac{\lambda(p-h) + (1-\lambda)\,(1-\delta)\,(1-\tau)\,\eta w_y}{(1-\lambda)\,(1-\tau) + \lambda(1+\tau)}$$

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Figure 1.1: Worker Matching Probabilities (δ =0.1)

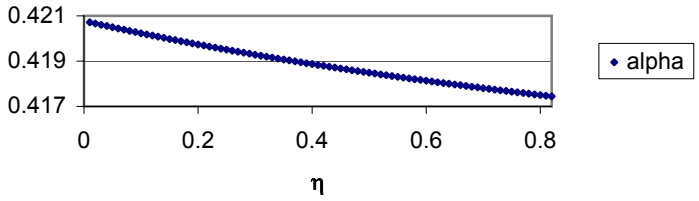

Figure 1.2: Firm Matching Probabilties (δ =0.1)

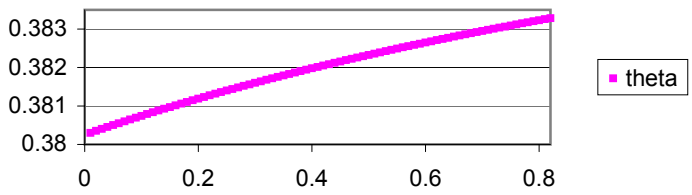

Figure 1.3: Total Number of Firms (δ =0.1)

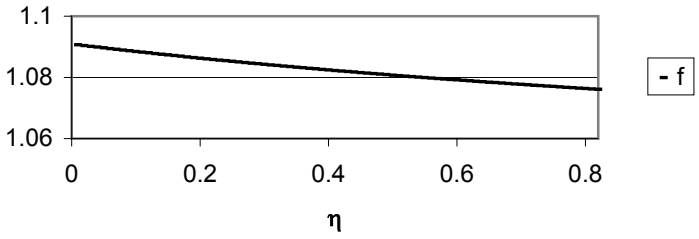

Figure 1.4: Young Wages (δ=0.1)

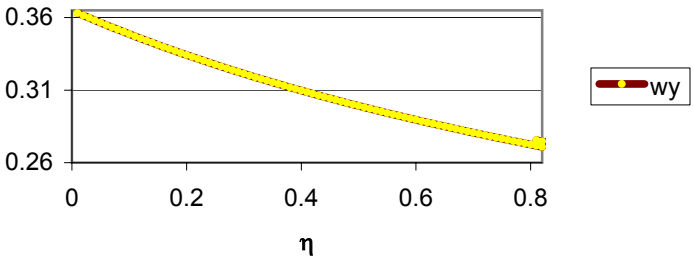

Figure 1.5: Wages of Old Workers (Delta=.1)

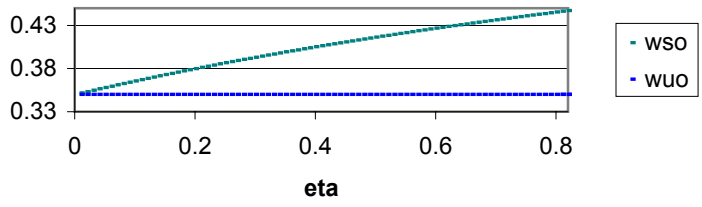

Figure 1.6: Wages of Retained Workers (Delta=.1)

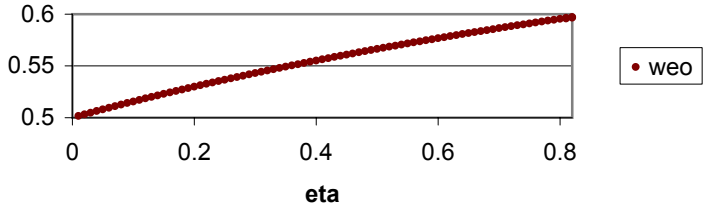

Figure 1.7: Tax Rates (Delta=.1)

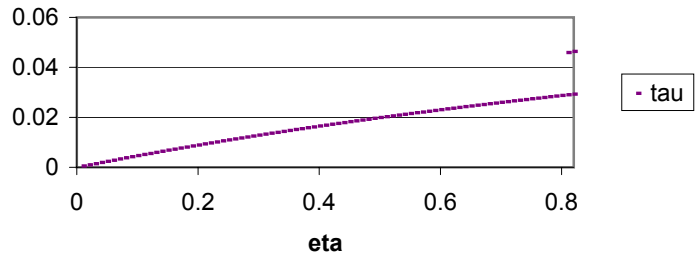

Figure 1.8: Implicit Tax Rate on Old Workers (Delta=.1)

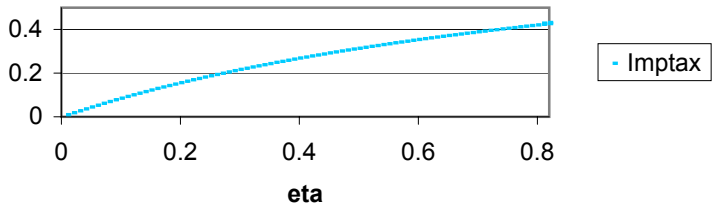

Figure 1.9: Payroll Costs (Delta=0.1)

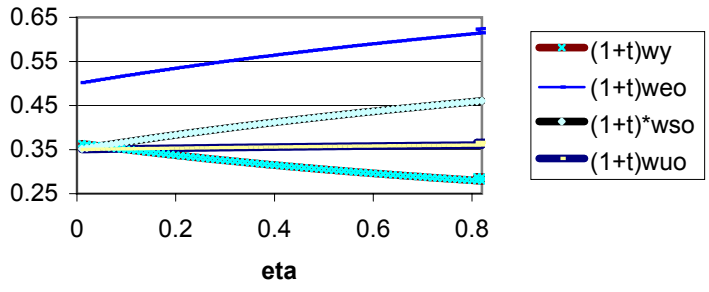

Figure 1.10: Proportions of Unemployed (Delta=0.1)

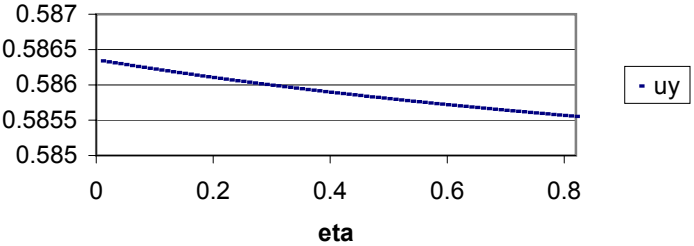

Figure 2.1: Worker Matching Probabilities (Delta=.9)

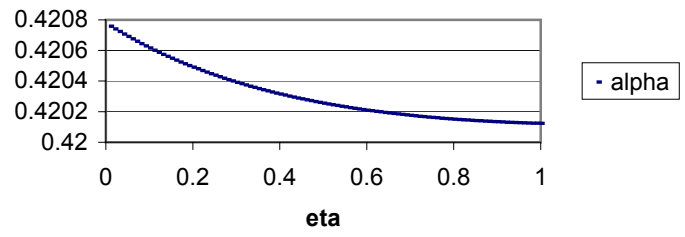

Figure 2.2: Firm Matching Probabilities (Delta=.9)

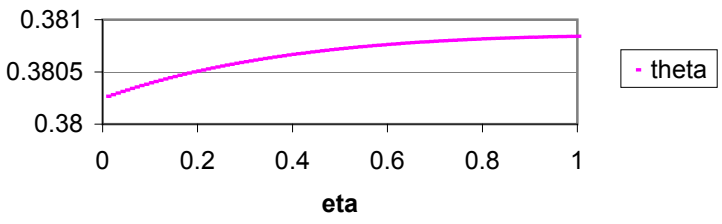

Figure 2.3: Total Number of Firms (δ =.9)

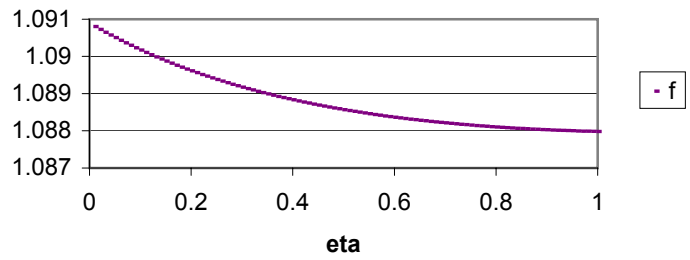

Figure 2.4: Young Wages (δ=.9)

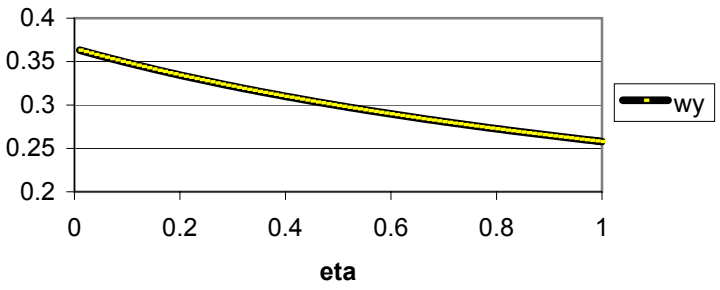

Figure 2.5: Wages of Old Workers (Delta=.9)

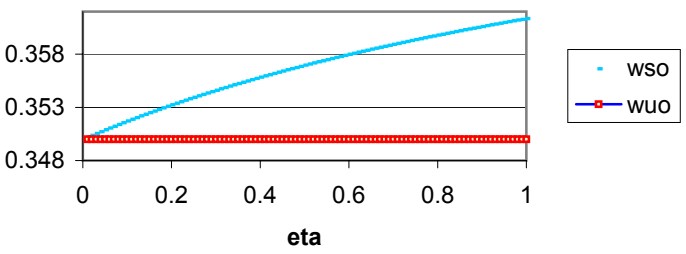

Figure 2.6: Wages of Retained Workers (δ=.9)

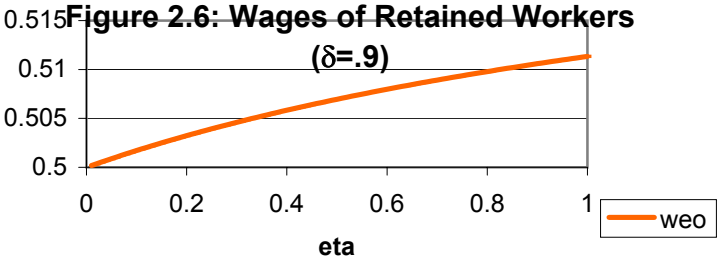

Figure 2.7: Tax Rates (Delta=.9)

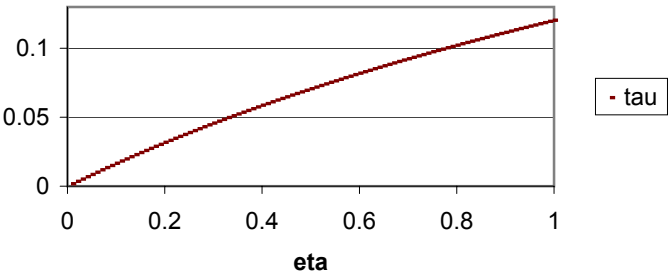

Figure 2.8: Implicit Tax Rate on Elderly Work (Delta=.9)

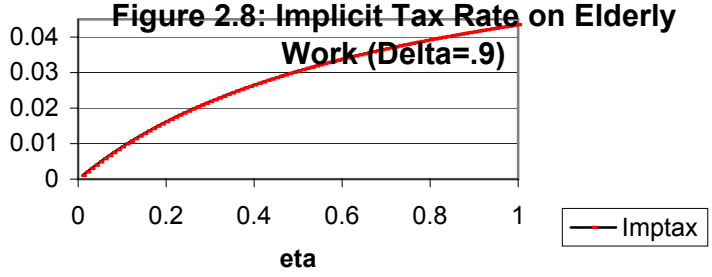

Figure 2.9: Payroll Costs (Delta=.9)

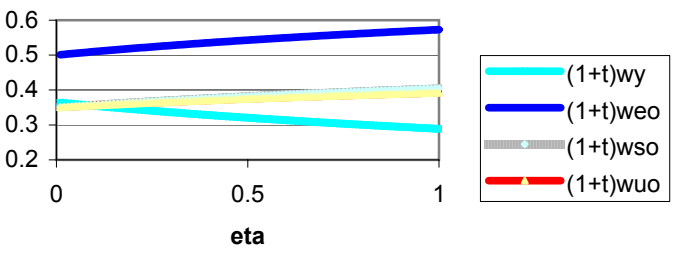

Figure 2.10: Total Retained Income (Delta=.9)

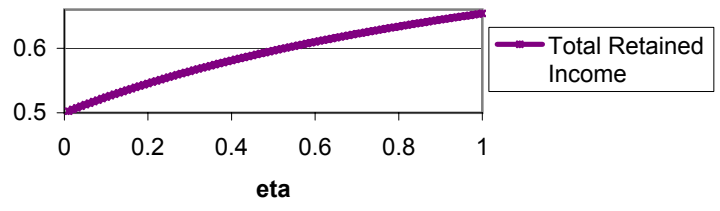

Figure 2.11: Net Separated Income (Delta=.9)

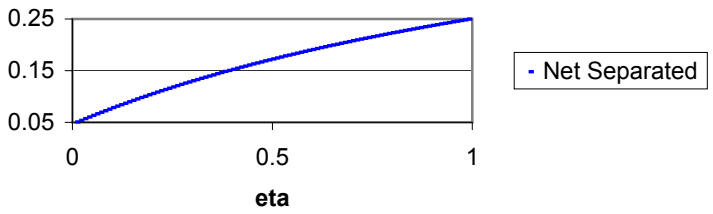

Figure 2.12: Proportion of Unemployed (Delta=.9)

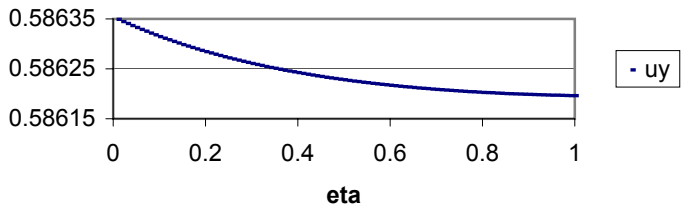

Figure 2.13: Proportion of Separated Workers (Delta=.9)

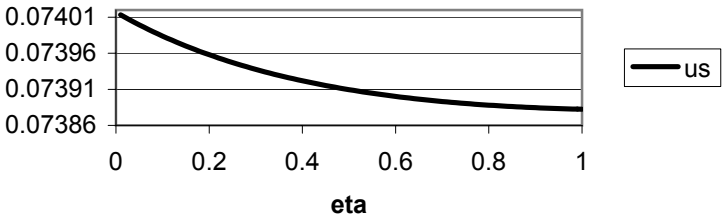

Figure 3.1: Worker Matching Probabilities (Delta=1)

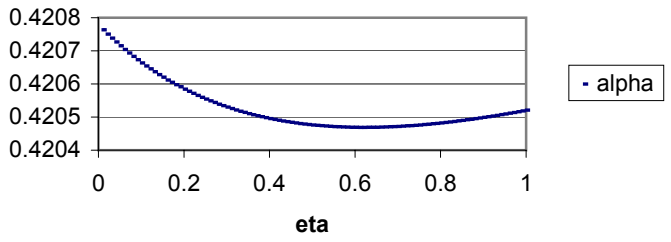

Figure 3.2: Firm Matching Probabilies (Delta=1)

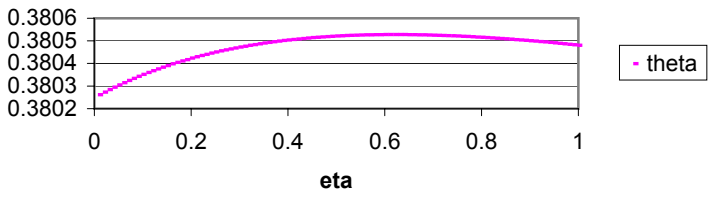

Figure 3.3: Total Number of Firms (Delta=1)

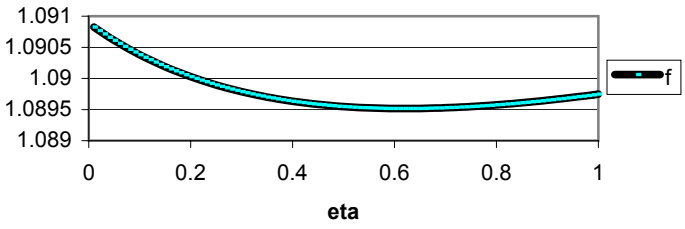

Figure 3.4: Young Wages (Delta=1)

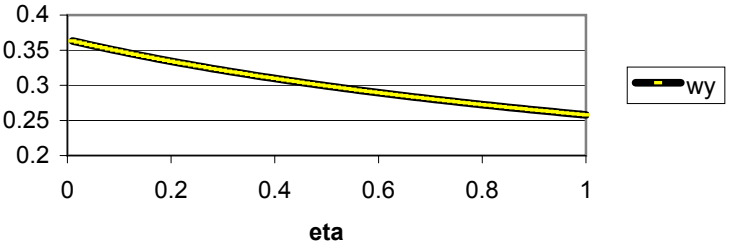

Figure 3.5: Wages of Retained Workers (Delta=1)

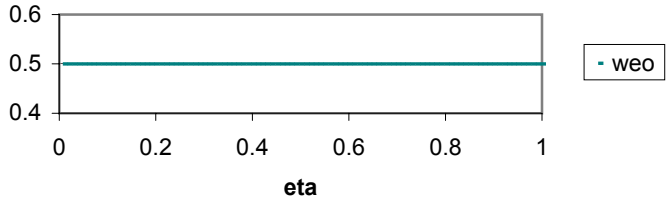

Figure 3.6: Wages of Old Workers (Delta=1)

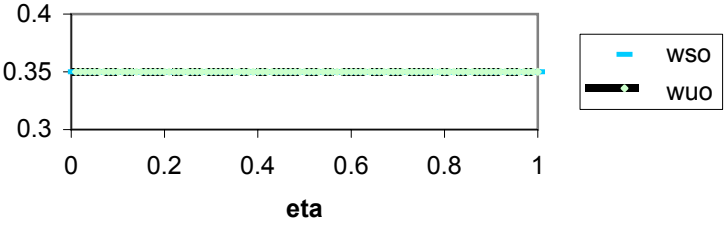

Figure 3.7: Tax Rates (Delta=1)

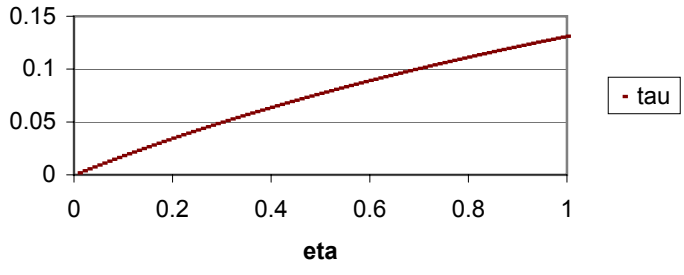

Figure 3.8: Payroll Costs (Delta=1)

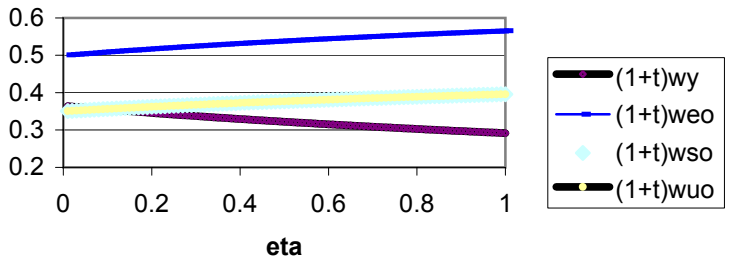

Figure 3.9: Total Retained Income (Delta=1)

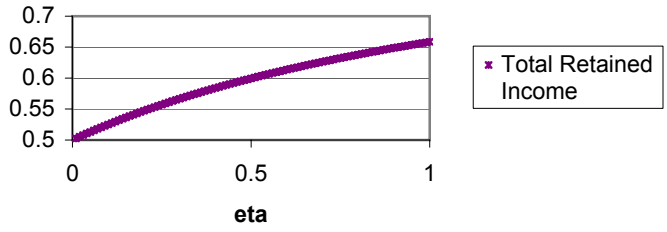

Figure 3.10: Net Separated Income (Delta=1)

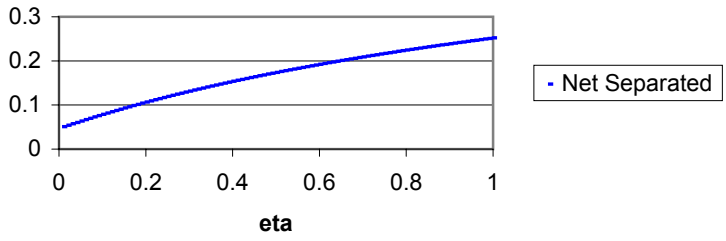

Figure 4.1: Worker Matching Probabilities (delta=.1)

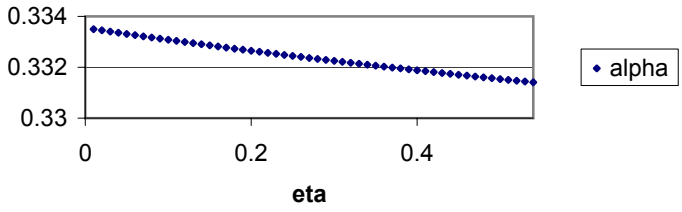

Figure 4.2: Firm Matching Probabilities (Delta=0.1)

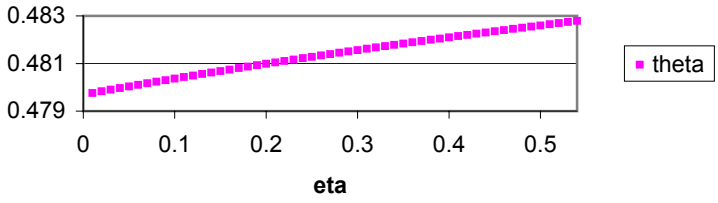

Figure 4.3: Total Number of Firms (Delta=.1)

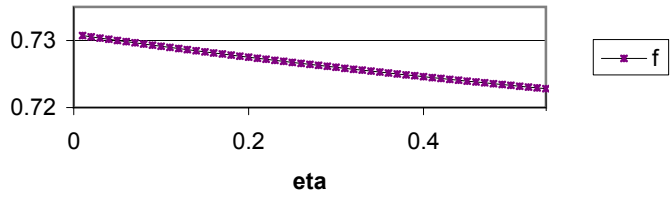

Figure 4.4: Young Wages (Delta=.1)

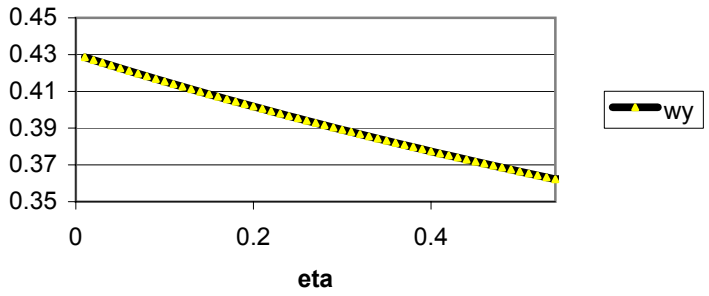

Figure 4.5: Wages of Retained Workers (Delta=.1)

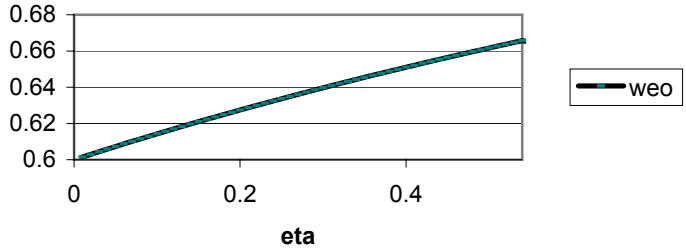

Figure 4.6: Wages of Old Workers (Delta=.1)

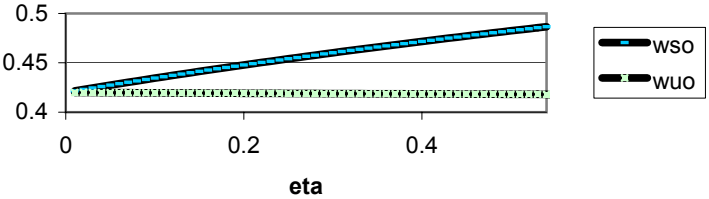

Figure 4.7: Tax Rates (Delta=.1)

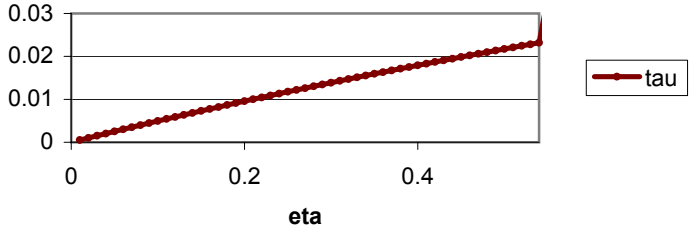

Figure 4.8: Implicit Tax Rate on Old Work (Delta=.1)

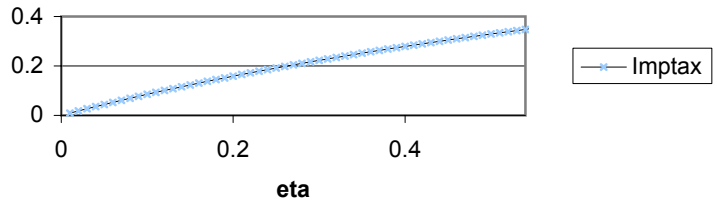

Figure 4.9: Payroll Costs (Delta=.1)

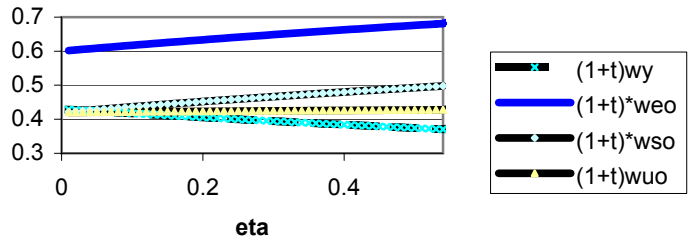

Figure 4.10: Youth Unemployment (Delta=.1)

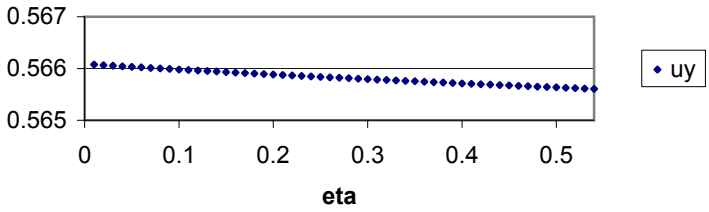

Figure 4.11: Net Separated Income (Delta=.1)

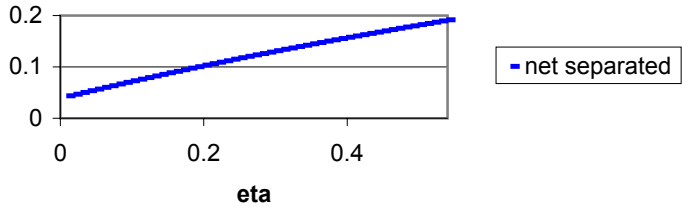

Figure 4.12: Total Retained Income (Delta=.1)

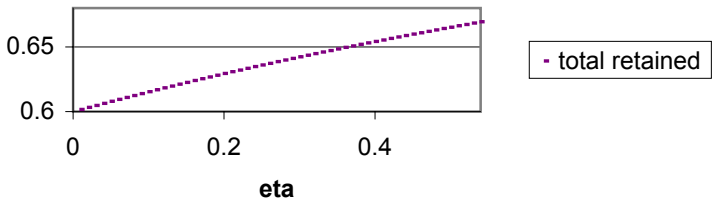

Figure 5.1: Worker Matching Probabilities (Delta=.9)

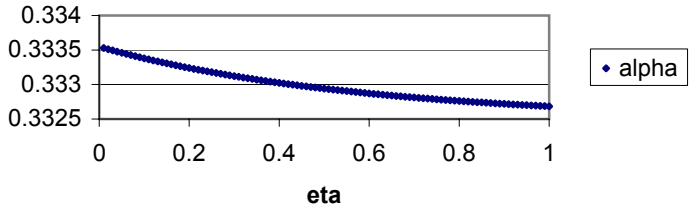

Figure 5.2: Firm Matching Probabilities (Delta=.9)

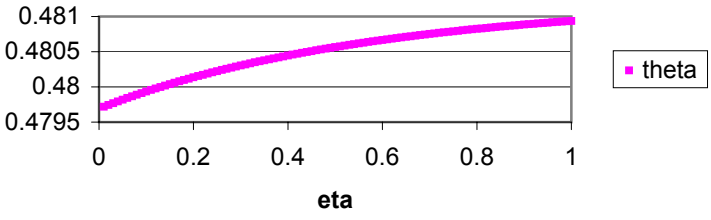

Figure 5.3: Total Number of Firms (Delta=.9)

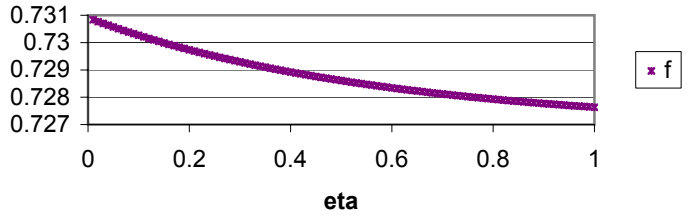

Figure 5.4:Young Wages (Delta=.9)

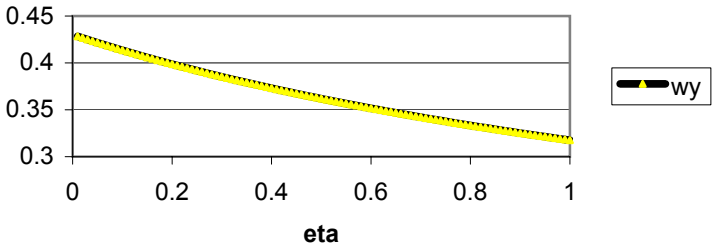

Figure 5.5: Old Workers' Wages (Delta=.9)

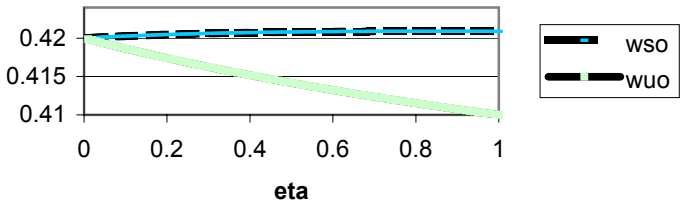

Figure 5.6: Wages of Retained Workers (Delta=.9)

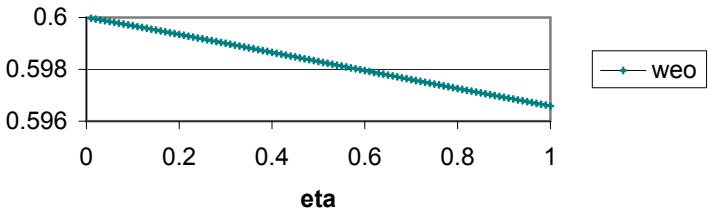

Figure 5.7: Tax Rates (Delta=.9)

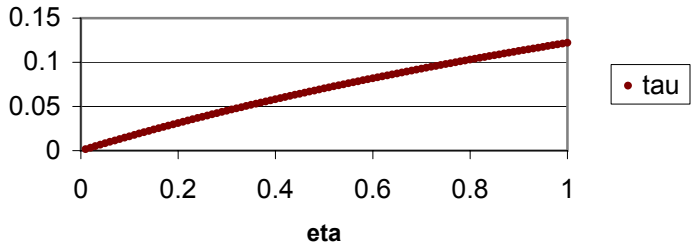

Figure 5.8: Implicit Tax Rate (Delta=.9)

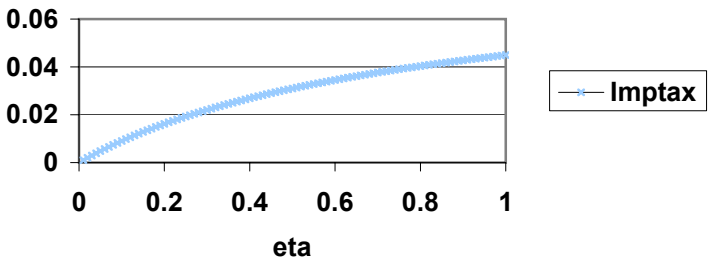

Figure 5.9: Payroll Costs (Delta=.9)

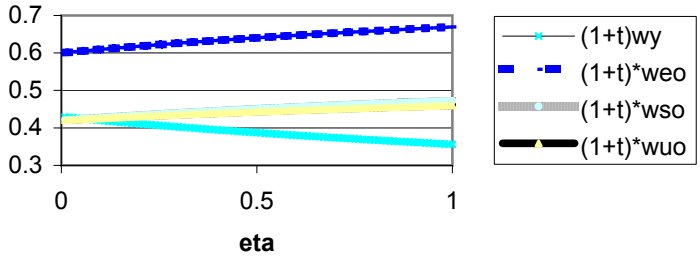

Figure 5.10: Proportion of Unemployed (Delta=.9)

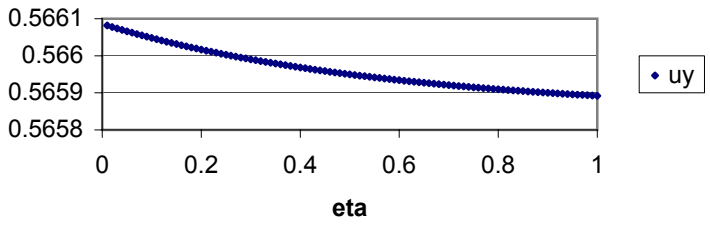

Figure 5.11: Proportion of Separated Workers (Delta=.9)

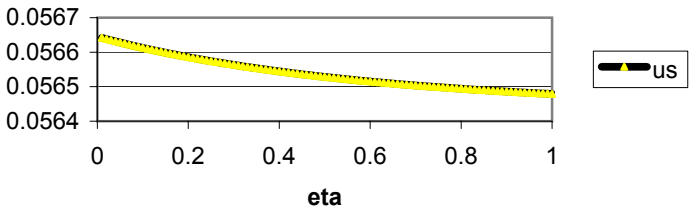

Figure 5.12: Total Retained Income (Delta=.9)

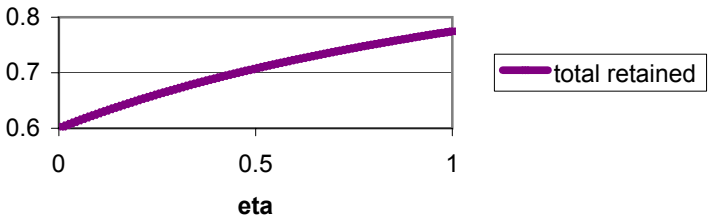

Figure 5.13: Net Separated Income (Delta=.9)

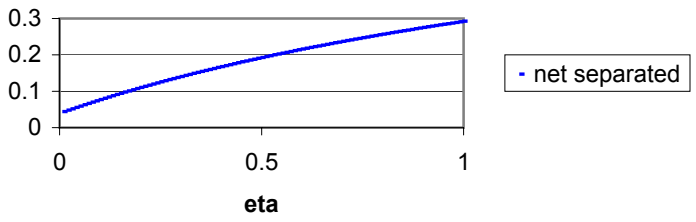

Figure 6.1: Worker Matching Probabilities (Delta=1)

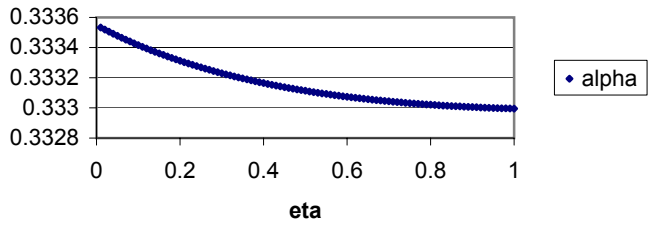

Figure 6.2: Firm Matching Probabilities (Delta=1)

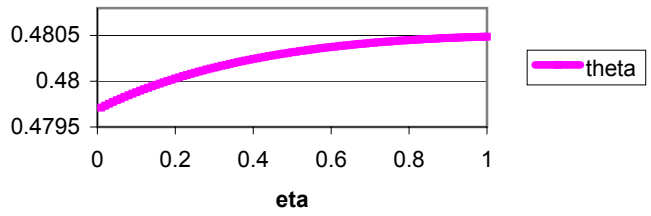

Figure 6.3: Total Number of Firms (Delta=1)

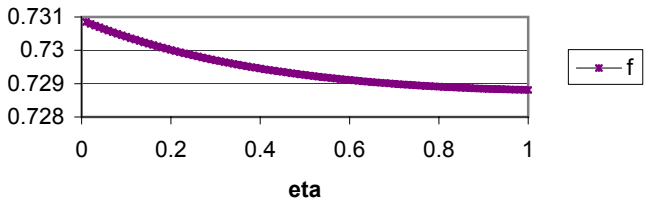

Figure 6.4: Young Wages (Delta=1)

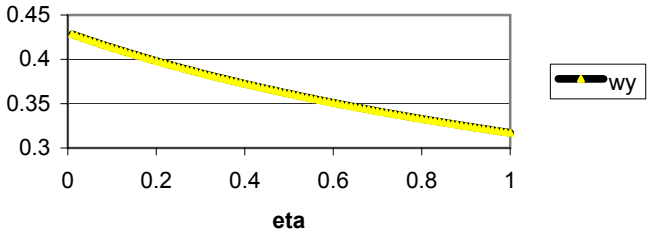

Figure 6.5: Old Workers' Wages (Delta=1)

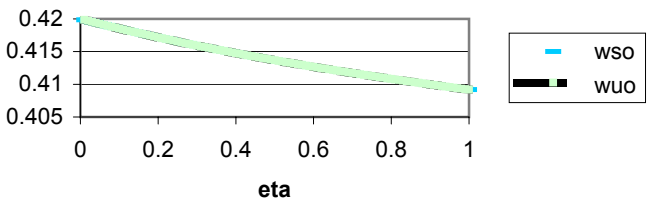

Figure 6.6: Retained Workers' Earnings

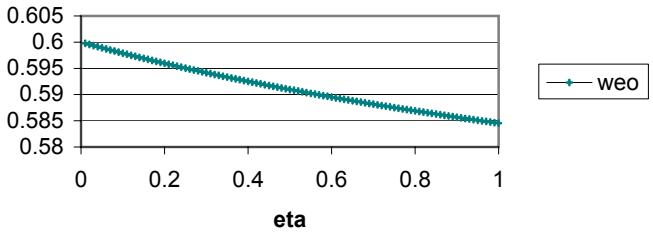

Figure 6.7: Tax Rates (Delta=1)

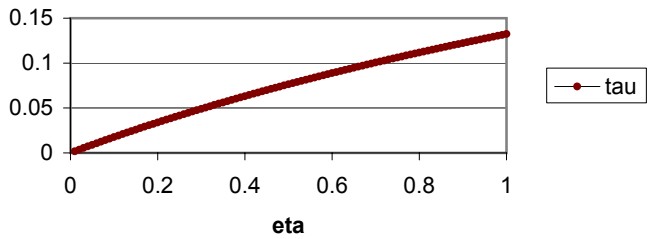

Figure 6.8: Payroll Costs (Delta=1)

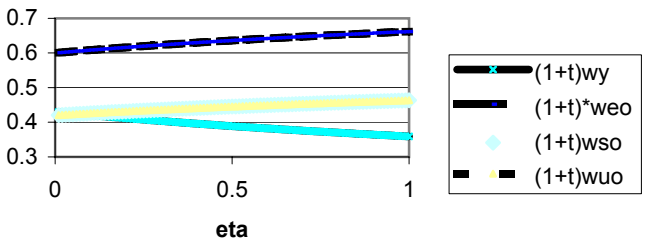

Figure 6.9: Proportion of Unemployed (Delta=1)

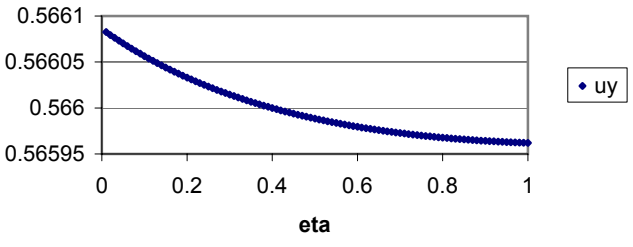

Figure 6.10: Total Retained Income (Delta=1)

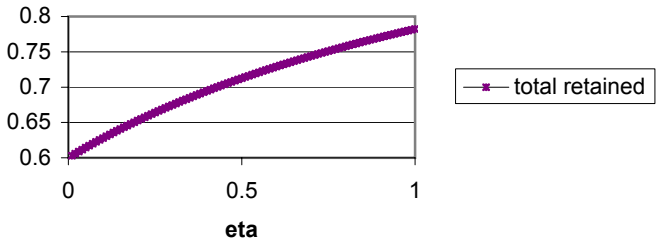

Figure 6.11: Net Separated Income (Delta=1)

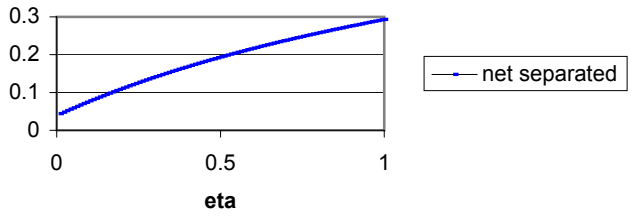

Figure 7.1: Worker Matching Probabilities (Delta=0.1)

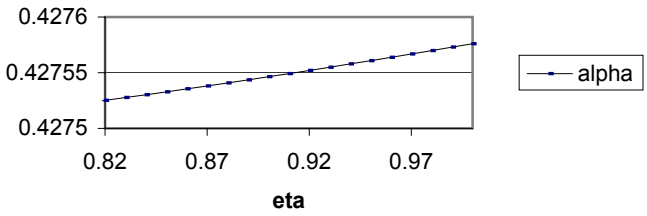

Figure 7.2: Firm Matching Probabilties (Delta=0.1)

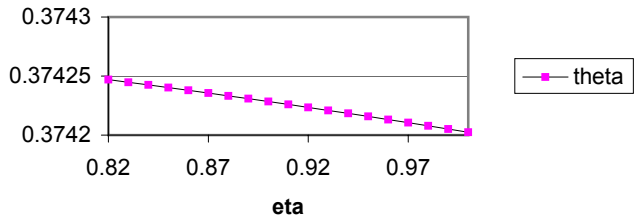

Figure 7.3: Total Number of Firms (Delta=.1)

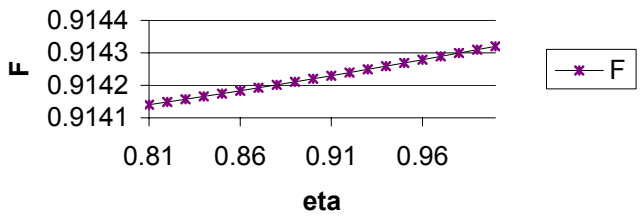

Figure 7.4: Young Wages (Delta=0.1)

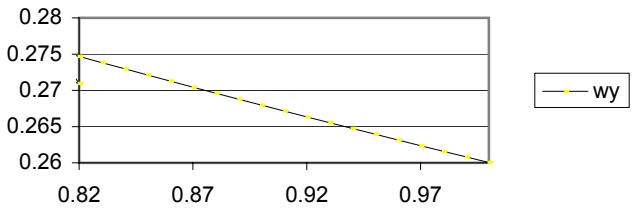

Figure 7.5: Wages of Retained Workers (Delta=.1)

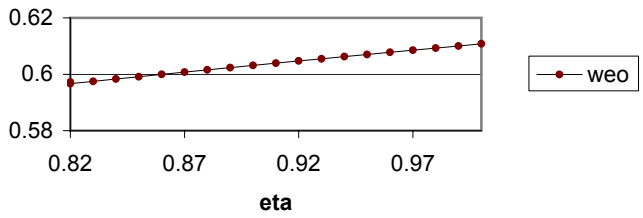

Figure 7.6: Tax Rates (Delta=.1)

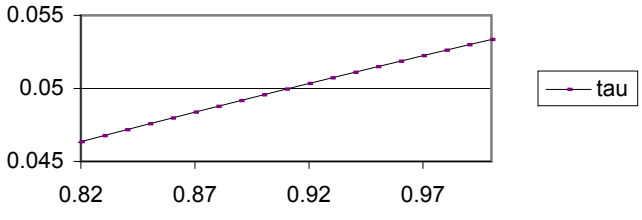

Figure 7.7: Implicit Tax Rate on Old Workers (Delta=.1)

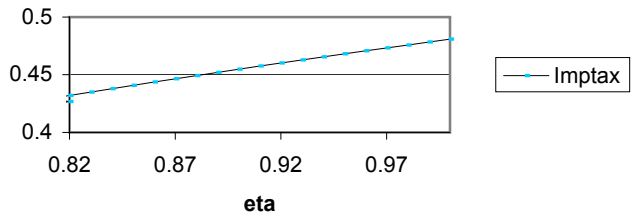

Figure 7.8: Payroll Costs of Young Workers (Delta=0.1)

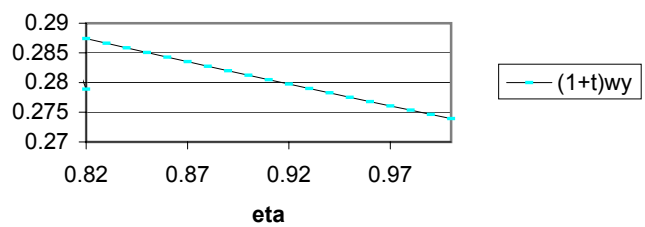

Figure 7.9: Total Income of Retained Workers (Delta=0.1)

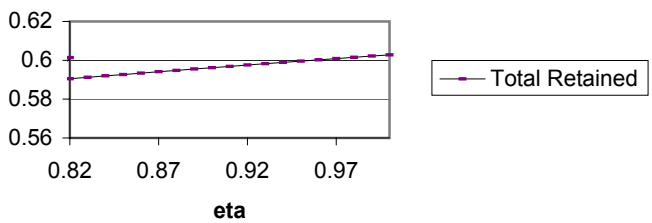

Figure 8.1: Worker Matching Probabilities (delta=.1)

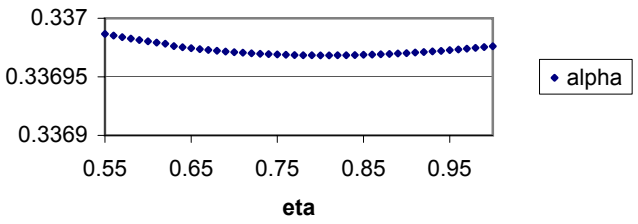

Figure 8.2: Firm Matching Probabilities (Delta=0.1)

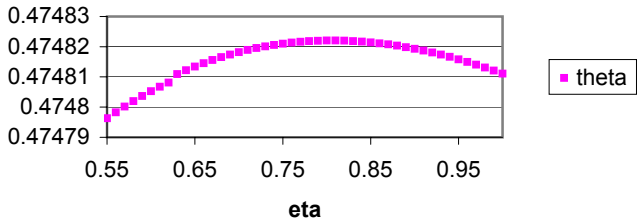

Figure 8.3: Total Number of Firms (Delta=.1)

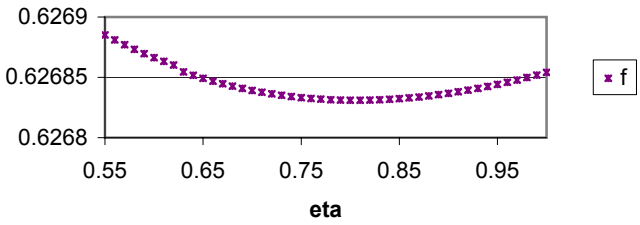

Figure 8.4: Young Wages (Delta=.1)

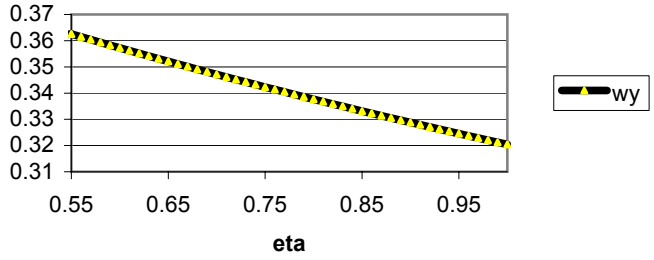

Figure 8.5: Wages of Old Workers (Delta=.1)

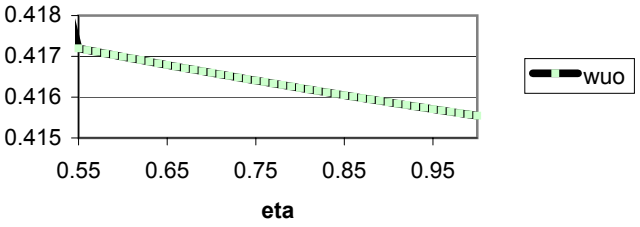

Figure 8.6: Wages of Retained Workers (Delta=.1)

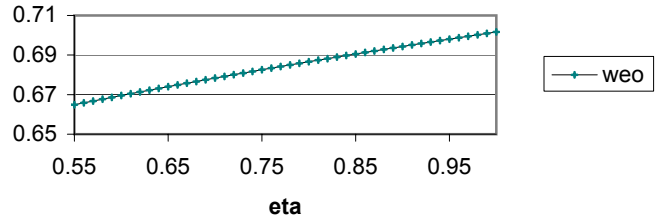

Figure 8.7: Tax Rates (Delta=.1)

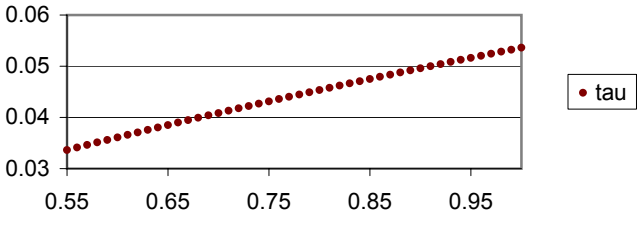

Figure 8.8: Implicit Tax Rate on Old Work (Delta=.1)

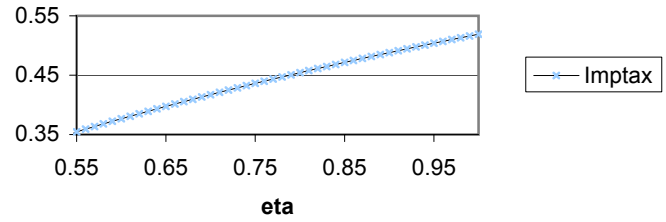

Figure 8.9: Payroll Costs (Delta=.1)

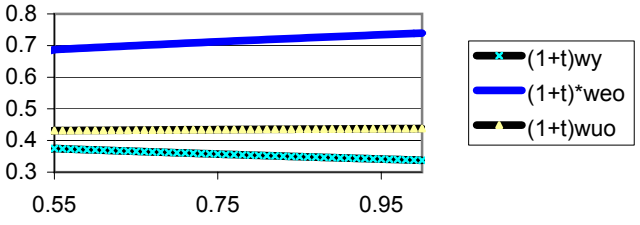

Figure 8.10: Youth Unemployment (Delta=.1)

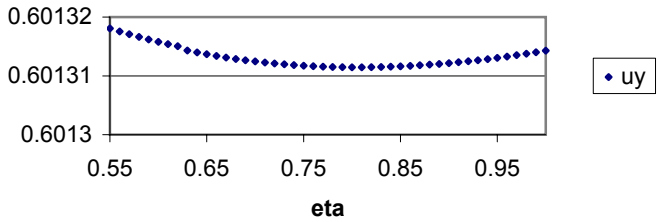

Figure 9.1: Aggregate Welfare (Delta=.1)

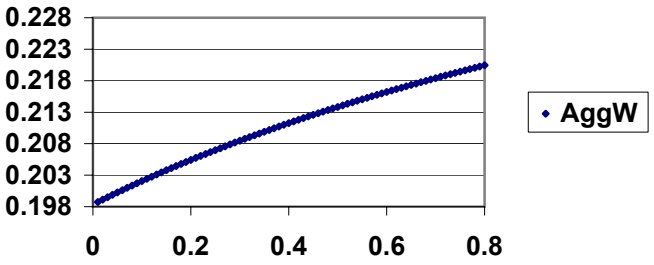

Figure 9.2: Aggregate Welfare (Delta=.1)

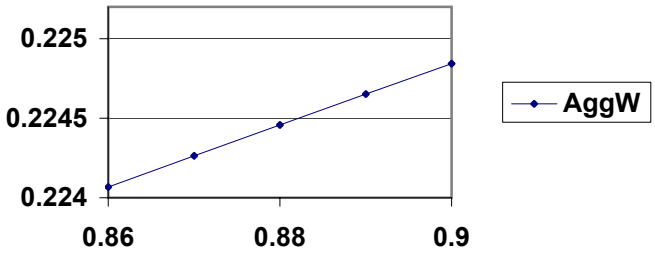

Figure 9.3: Aggregate Welfare (Delta=.9)

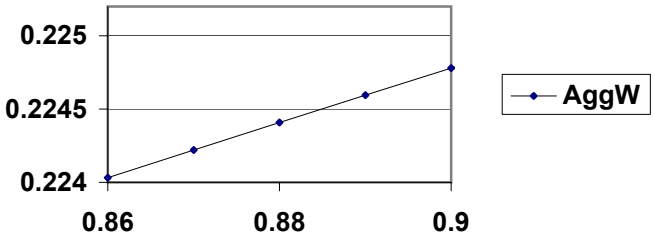

Figure 9.4: Aggregate Welfare (Delta=1)