Productivity Gains from Progressive Taxation of Labor Income*

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Abstract

I show that, in the absence of complete insurance markets, progressive taxation of labor income may provide productivity and welfare gains as compared to a revenue-equivalent proportional tax. In order to increase income in the future, individuals have to forgo income today by accepting lower wages while accumulating human capital or when destroying specific human capital in order to build it elsewhere. I first show analytically that a progressive tax system encourages people to make these temporary sacrifices despite the increased tax burden when wages are high. Next, I measure the quantitative importance of this channel in a calibrated general equilibrium model.

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1 Introduction.

In this paper I explore a channel via which progressive taxation of labor income provides productivity and welfare gains compared to a flat tax. In order to increase earnings in the future individuals often have to accept a temporary decline in wages while they accumulate human capital, or when they destroy the accumulated specific human capital in order to build it elsewhere. I show that in the absence of complete insurance market for earnings risks a progressive tax system encourages risk-averse workers to make these temporary sacrifices despite the increased tax burden when wages are high.

Human capital represents a substantial fraction of total wealth in modern developed economies (Davies and Whalley (1990)). Not surprisingly, then, a number of papers have asked the question of how tax policy affects human capital accumulation (e.g., Trostel (1993) and references therein). Most of the research has focused on the effects of proportional taxes. Papers that have looked on the impact of progressive earnings taxation suggest that it discourages investment in human capital (e.g., Dupor et al. (1996), Poterba (2002), Gentry and Hubbard (2002)). The argument in those papers is that with a progressive tax schedule the returns to human capital accumulation are taxed at a higher rate than the tax rate at which forgone earnings can be deducted.

I show analytically, however, that progressive taxation of earnings may in fact encourage human capital accumulation through on-the-job training. The crucial - and empirically plausible - assumptions omitted in the earlier work are the relatively low elasticity of intertemporal substitution of consumption coupled with the lack of insurance markets. Relative to a flat tax, progressive taxes decrease both the benefit of training and its cost in terms of consumption since individuals are not taxed as much when their income is low. With an empirically plausible elasticity of intertemporal substitution, in utility terms, the decline in costs outweighs the decline in benefits.[1]

Caucutt et al. (2002) suggest that an increase in tax progressivity discourages investment in human capital even in the environment with liquidity constrained risk-averse agents. They study of the effects of tax progressivity on economic growth and employ a description of the economy with two types of workers facing two type-specific tax rates. I show that their result does not carry over to an environment with a more general specification of the tax function and richer worker heterogeneity.

Tax policies have a perhaps even more economically important effect on the decision to destroy specific human capital. Recent work by Kambourov and Manovskii (2002b) suggests that human capital is largely occupation specific. In other words, they document that human capital is accumulated while a worker remains in her occupation. Occupations are defined using the three-digit U.S. Census classification that contains around 400 occupations (e.g., truck driver, cook, accountant).[2] This finding implies that not only the amount of human

[1]Acemoglu and Shimer (1999, 2000) also emphasize the importance of imperfect insurance against labor market risks. In particular, they identify a productivity enhancing role of unemployment insurance in an economy with risk-averse agents and incomplete insurance. I discuss the relationship between progressive taxation and unemployment insurance in detail later in the paper.

[2]Following Ben-Porath (1967), most of the research concentrated on general human capital since it allows to explain the observed average life-cycle earnings profile through accumulation of unobserved general human

capital but its allocation as well is a determinant of output, productivity and welfare. Very little work has been done, however, on the allocation of specific human capital, and the effects of tax policies on the decisions to build and to destroy specific human capital are virtually unexplored.[3]

The occupational mix used in the economy varies substantially over time (Kaboski (2001)). It is important that workers respond to changing environment and reallocate to highly productive occupations. Kambourov and Manovskii (2002c) find that the fraction of workers switching occupations in a year is as high as 17% of the labor force. It is well documented, however, that wages decline precipitously upon an occupation switch (Parrado and Wolff (1999), Poletaev (2000), Amaral (2002)).[4] This implies that without a high degree of risk sharing risk-averse individuals do not switch occupations enough and often remain "locked" in unproductive occupations. Progressive labor income taxation improves the allocation of human capital across occupations by encouraging higher occupational mobility.

A natural question is why a worker would choose to switch an occupation if such a switch entails a wage cut. Connolly and Gottschalk (2002) argue that a large fraction of workers who voluntarily quit their employers obtain a lower wage immediately after a quit but face a higher wage growth. In other words, a worker may accept a temporary cut in wages but have a higher expected value of the new job.[5] Progressive taxation helps people make these choices.

Gentry and Hubbard (2002) present evidence that increased tax progressivity decreases the probability of individuals switching to higher paying jobs. This is intuitive: tax progressivity decreases benefits of finding a higher paying job, and, consequently, may reduce the on-the-job search intensity. The analysis has little to say, however, about the effects of tax progressivity on the decision to switch occupations, destroy specific experience, and accept temporarily lower wages.[6]

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capital. The results in Kambourov and Manovskii (2002b) imply that a substantial fraction of the average life-cycle profile of wages can be explained by rising average occupational experience over the life-cycle of a cohort of workers who entered labor market at the same time.

[3]Poterba (2002) also suggests that an assessment of the effect of fiscal policies on the type of human capital that is acquired is warranted. One existing strand of research has investigated the effects of taxation on the decision whether to enter self-employment or paid employment (e.g, Chari et al. (2002) and Meh (2002). Gentry and Hubbard (2001) review the earlier literature).

[4]The estimates of the decline in wages upon an occupation switch range from 10% to 27% for various subgroups of population. In the near future I plan to obtain my own estimates from the PSID using the methodology for identifying genuine occupational switches in the noisy data developed in Kambourov and Manovskii (2002b). I am particularly interested in the workers who report a quit as a reason for the employer/position switch coinciding with the occupation change.

[5]Nosal and Rupert (2002) also present evidence that almost a half of voluntary job switches is accompanied by a decline in wages. They rationalize this finding by assuming that total compensation consists of a tied wage and amenity package. Early in life liquidity constrained workers choose high wage - low amenity jobs, and, after they build up enough savings, they look for high amenity jobs with a possible decline in wages. It is not clear if this theory can explain the decline in wages upon occupational switches, however.

[6]Gentry and Hubbard (2002) use an "upside" measure of tax progressivity in their analysis, i.e., they measure by how much marginal tax rate a worker faces would increase if her income were to grow by 10% through 200% over a three year period. It would be insightful to incorporate the possibility of "downside" income mobility in their measure of tax progressivity as well.

Since progressive taxation induces both higher creation and higher destruction of human capital, the relative magnitude of these effects is ex-ante ambiguous and thus an empirically grounded quantitative general equilibrium model is called for. The model I develop is based on the island economy abstractions of Lucas and Prescott (1974), Alvarez and Veracierto (2000) and Kambourov and Manovskii (2002a). In difference to the earlier models I shut down the market for employment lotteries that provides agents with insurance against idiosyncratic labor market uncertainty, and introduce on-the-job training.

The basic features of the model are as follows. Islands are interpreted as occupation, and are subject to idiosyncratic productivity shocks. Newcomers to an island have no island-specific experience. Accumulation of experience is a function of the amount of time invested in on-the-job training. When an individual switches islands, she loses the experience accumulated on her previous island. Workers age stochastically. As in Alvarez and Veracierto (2000), search is undirected. This assumption is motivated by the empirical finding that workers who switch their occupations tend to switch several times in a row. This feature of the data suggest additional potential benefits to progressive taxation: it helps liquidity constrained risk-averse agents in the process of searching for a suitable career.

I develop two versions of this model. In the first one, island production function is characterized by decreasing returns in labor and capital. Output and wages on each island are a function of the employed amount of labor, capital, and the idiosyncratic productivity shock. In the first version of the model I do not allow workers to self-insure by accumulating assets. Bénabou (2002) and Caucutt et al. (2002) also make this assumption in related papers. The reason for this restriction is that in a "pure" island-economy model the distribution of workers over asset holdings on each island is a state variable in consumer's problem, making the solution to this problem very complicated.[7]

I show that in this model there are substantial losses of productivity (2.5%) and welfare (9%) caused by a revenue neutral switch from a mildly progressive US tax system to a proportional one. The results are driven by a decline in occupational mobility of about 7%. Despite longer expected stay in an occupation the average time in training remains virtually unchanged since the additional incentives to accumulate human capital provided by progressive taxation are eliminated. As one may expect, I also find that progressive taxation reduces after-tax income inequality. By increasing occupational mobility, however, progressive taxation reduces the pre-tax wage inequality as well.[8]

In addition to welfare improvement due to increased productivity, progressive taxation yields welfare gains relative to a flat tax system by providing workers with a partial income smoothing mechanism. This effect was highlighted in Petersen (2001). He shows numerically that a progressive tax system is welfare-improving over a flat tax in an environment where workers experience uninsurable idiosyncratic shocks to their labor earnings and are borrowing

[7]One can think of this model as describing the effects of progressive taxation in a transitional economy or an economy that is hit by an unexpected disturbance requiring a substantial labor reallocation across occupations, such as a fundamental trade reform or an unexpected arrival of a new general purpose technology.

[8]The assumption of the decreasing returns plays an important role in this finding. In Sinn (1996), under constant returns to risk taking, progressive taxation actually increases both pre- and after-tax inequality by stimulating risk taking behavior.

constrained. This happens despite the decline in output due to distortion in the labor-leisure choice caused by tax progressivity. I identify the relative magnitude of these two sources of welfare improvement in the analysis below.

Next, I extend the model to allow for precautionary savings and labor-leisure choice. I eliminate the distribution of workers over assets holdings as a state variable describing each island by restricting to a constant returns to scale production function on each island. In this case wages on an island are a function of the productivity shock and the interest rate only (the latter is needed to pin down the amount of capital allocated to the island). This version of the model combines features of the island-economy environment and of a Bewley-type model with uninsurable idiosyncratic risk. I do not yet have quantitative results from this version of the model but expect to have them soon.

The inclusion of labor-leisure choice and precautionary savings is likely to weaken the results from the first version of the model. The effect of precautionary savings would be mitigated, however, by the empirical fact that about a half of the aggregate occupational mobility in the US is accounted for by workers younger than 30. These are the workers who do not have time to accumulate a substantial buffer stock of savings.

A number of authors have recently argued that decreasing the progressivity of the US income tax code or replacing the existing progressive tax system with a proportional one may result in a substantial increase in output (see Ventura (1999), Conesa and Krueger (2002), Erosa and Koreshkova (2001), Castañeda *et al.* (1998), among others). The results from the second version of the model that incorporates most of the trade-offs in these papers are likely to suggest that the gains may not be as large as previously thought. I should emphasize that in this paper I assume that government can distinguish labor from capital income for tax purposes. While I suggest that progressive taxation of labor income may yield productivity and welfare gains, the argument does not apply to the taxation of capital income.

The channel I emphasize in this paper is related but distinct from the effect of progressive taxation on risk taking described in a number of other papers (see Sinn (1996) for a review). A typical argument in that literature is that progressive taxation stimulates income generating risk taking, but also generates detrimental moral hazard effects by inducing agents to take on too much risk. The mechanism I describe does not rely on the investment having a stochastic return. In addition, since occupational mobility is too low in laissez faire, it is precisely this "moral hazard" effect that drives the increase in productivity.

In what follows I will first provide the intuition on the effects of progressive taxation on making temporary sacrifices in a simple model in section 2. Next, I describe the general equilibrium economy model with specific human capital and define its equilibrium in sections 3 and 4, respectively. After describing the experiment performed in this paper in section 5 I discuss the some of the modelling choices in section 6. I describe the preliminary calibration of the model parameters in section 7. Sections 8 and 9 present preliminary results and a brief discussion. In section 10 I introduce individual savings and labor-leisure choice into the model and define its equilibrium in section 11. In section 12 I discuss a few issues regarding robustness of the findings. The concluding section 13 contains the summary of the finding and the extensions of the paper I am working on.

2 The Effects of Progressive Taxation in a Simple Model

In this section I derive the qualitative effects of progressive taxation on the decision to forgo some earnings today in order to receive higher earnings in the future in a simple model. Although I write down the model in terms of investment in human capital, it may also be interpreted in terms of the decision whether to destroy some human capital in order to build it in a more productive occupation (and accept a temporary decline in wages).

An agent lives for two periods and is endowed with one unit of time each period. In both periods she can receive a fixed wage rate of $w_1 > 0$ per unit of time supplied to work. In the first period of life the agent can invest a fraction of her time, $0 \le e \le 1$, in training. The returns to training are stochastic and allow the agent to receive a wage rate of $w_2 > w_1$ in the second period with probability $p(e)$. The function $p : [0, 1] \to [0, 1]$ is assumed to be twice continuously differentiable, increasing, strictly concave, and $p(0) = 0$. The government imposes a tax scheme, such that the after tax income of an individual with earnings w is given by a function $\Omega(w) \le w$, $\Omega'(w) > 0$. There are no capital or insurance markets in this economy.

The individual chooses the fraction of time allocated to training, e, in order to maximize the expected utility:

$$EU(e) = U(\Omega(w_1(1-e))) + p(e)U(\Omega(w_2)) + (1-p(e))U(\Omega(w_1)), \tag{1}$$

where $U : R_+ \to R$ is twice continuously differentiable in its arguments, is increasing, and is strictly concave.

Suppose that the after tax income function is given by $\Omega(w) = bw^h$, $0 < b \le 1$, $0 < h \le 1$. Note that the case of $h = 1$ and $b < 1$ describes a proportional tax system, while $h < 1$ defines a progressive tax scheme with the degree of progressivity identified with h. In particular, if $h_1 < h_2$ the tax scheme characterized by h_1 is more progressive.[9]

The following proposition establishes in the case of isoelastic utility that *if the utility function is sufficiently concave, progressive taxation induces workers to increase their investment in human capital.*

Proposition 1 *If* $U(c) = \frac{c^{1-\sigma}}{1-\sigma}$ *for* $\sigma > 0$, $\sigma \ne 1$ *and* $U(c) = log(c)$ *for* $\sigma = 1$, *then:*

1. $\frac{de}{db} = 0$.
2. $\sigma > 1 \Rightarrow \frac{de}{dh} < 0$; $\sigma = 1 \Rightarrow \frac{de}{dh} = 0$; $\sigma < 1 \Rightarrow \frac{de}{dh} > 0$.

Proof. See appendix I.

The intuition behind this result is as follows. Suppose proportional taxes are introduced into the world with no taxes. When the only input into the production of human capital is time, the cost of human capital production is forgone wages. The benefit of investing time

[9] The after tax income function $\Omega_1(w)$ is defined to be more progressive than $\Omega_2(w)$, if at any two positive income levels $w_1 < w_2$, $\frac{d\Omega_1(w_2)}{d\Omega_1(w_1)} < \frac{d\Omega_2(w_2)}{d\Omega_2(w_1)}$.

into human capital accumulation is increased wages in the future. Thus a proportional wage income taxation reduces the cost and the return by the same fraction and has no impact on the fraction of time devoted to human capital accumulation, e.[10]

Since proportional taxes do not affect the choice of e, consider now the introduction of progressive taxes into the economy with a flat tax. Relative to the proportional tax, progressive taxes decrease the benefit of training but they also decrease the cost of training in terms of consumption. With a concave enough utility function ($\sigma > 1$), in utility terms, the decline in costs outweighs the decline in benefits.[11]

3 The Equilibrium Model with Specific Human Capital

I now consider an equilibrium model of a small open economy, which contains the effects of progressive taxation on accumulation of human capital demonstrated in the previous section, but also incorporates the decision to destroy accumulated human capital. Since progressive taxation induces both higher creation and higher destruction of human capital (the latter by decreasing the utility cost of switching occupations), a calibrated general equilibrium model is required to evaluate the relative magnitude of these effects.

The economy is populated by a measure one of ex-ante identical agents who die each period with probability δ and are replaced by newly-born workers. Individual preferences are given by the utility function:

$$E\sum_{t=1}^{\infty}\beta^{t-1}(1-\delta)^{t-1}U(c_t), \tag{2}$$

where c_t is consumption at time t, $0 < \beta < 1$ is the discount factor, $U : R_+ \rightarrow R$ is continuously differentiable in its arguments, is increasing, is strictly concave, and $\lim_{c\rightarrow 0} U'(c) = \infty$.

Production takes place on a continuum of islands of measure one that experience auto-correlated idiosyncratic productivity shocks $z \in [\underline{z}, \overline{z}]$. These shocks follow a Markov process characterized by the transition function $Q(z, \cdot)$. Realizations of z are independent across islands. The Markov process for z is assumed to possess an invariant distribution ξ that satisfies $\xi(Z) = \int Q(z, Z)\xi(dz)$, where Z denotes sets of idiosyncratic productivity shocks. All islands produce the same homogeneous goods.

Each worker on an island is endowed with one unit of time and is either experienced or inexperienced. Let L_1 and L_2 represent the total amount of labor supplied to the production

[10]This argument was made by Lucas (1990), and Davies and Whalley (1991), among others.

[11]The result does not appear specific to the model with probabilistic accumulation of human capital, although this is the easiest case to prove analytically. I simulated the model numerically and the result holds in a deterministic version of the model, when the second period earnings are given deterministically as $Y(e) = w_1 + y(e)$, $y(0) = 0$, and $y(\bullet)$ strictly concave. Moreover, numerically the same result holds for CARA utility function with any coefficient of absolute risk aversion. The difficulty with proving the result with CARA utility lies in the fact that even proportional taxation increases investment in human capital in that case (Eaton and Rosen (1980)).

of output on an island by inexperienced and experienced individuals, respectively. The total supply of effective labor on an island is given by $L = \theta_1 L_1 + \theta_2 L_2$, $0 < \theta_1 < \theta_2 < 1$, $\theta_2 = 1 - \theta_1$, where $\frac{\theta_2}{\theta_1}$ denotes the relative productivity of experienced workers.

There is a large number of competitive firms on each island that have access to a production technology given by:

$$y_t = F(L, K, z) = zL^{\alpha}K^{\gamma}, \tag{3}$$

where K represents the total amounts of capital supplied to the production of output on an island, $0 < \gamma < \alpha$, $\alpha + \gamma \leq 1$.[12]

Since spot factor markets on every island are assumed to be competitive, wages are given by the marginal productivities of each type of labor and return on capital is given by its marginal product.

Physical capital is owned by foreigners who do not work in this economy but lend capital to firms. Capital is assumed to be perfectly mobile across islands, and thus its rental rate, r, is equalized across all islands. This implies that the amount of capital allocated to an island with labor supply equal to L is given by

$$K = \left[\frac{r}{z\gamma}\right]^{\frac{1}{\gamma-1}} L^{\frac{\alpha}{1-\gamma}}. \tag{4}$$

Wages for a unit of time supplied by a worker with experience i are then given by

$$w_i(L, z; r) = \theta_i z^{\frac{1}{1-\gamma}} \left[\frac{r}{\gamma}\right]^{\frac{\gamma}{\gamma-1}} L^{\frac{\alpha+\gamma-1}{1-\gamma}}. \tag{5}$$

An individual who arrives on an island starts with the lowest level of experience. Each period an inexperienced employed individual becomes experienced with probability $p(e)$, where $0 \leq e \leq 1$ denotes the fraction of time allocated to occupational training. The function $p : [0, 1] \to [0, 1]$ is assumed to be twice continuously differentiable, increasing, strictly concave, and $p(0) = 0$. Once an individual becomes experienced she remains experienced until she chooses to leave the island, in which case she loses all of her occupation-specific experience and starts as inexperienced on a new island. Given that workers do not value leisure in this version of the model, experienced workers supply all their time to the production of output.

At the end of a period, the distribution of workers present on an island can be summarized by the set $\psi = \{\psi_1, \psi_2\}$, where ψ_i denotes the measure of workers with experience level i. The distribution ψ and the current period productivity shock z completely describe an island. The individuals can leave their islands at the end of the period if they choose to do so. As in Alvarez and Veracierto (2000), search is undirected in the sense that island switchers arrive uniformly across all islands in the economy. Denote the distribution of workers who choose not to leave island (ψ, z) at the end of a period as $\tilde{g}(\psi, z) \equiv \{\tilde{g}_1, \tilde{g}_2\}$.[13] At the beginning of

[12] The presence of physical capital is not essential for this version of the model. I introduce it here in order to make the results comparable with the model that allows for precautionary savings in section 10.

[13] I adopt a convention that tilde over any variable denotes its island-wide value.

the next period an island is fully described by the distribution $\tilde{g}$ and the new productivity shock z'.

The government in this economy taxes labor income of individuals. Let $\Omega(\bullet)$ denote the after tax income of an individual. I assume that the government revenues and the returns to the fixed factor are thrown away.[14]

Define S to be the measure of workers switching occupations. Since workers start on a new island as inexperienced, if $\tilde{g}$ is the distribution of workers who remain on the island at the end of the period, ψ' for each z' is given by:

$$\psi'(\psi, z) = \{(\tilde{g}_1 + \delta + S)(1 - p(\tilde{e}(\tilde{g}, z')))(1 - \delta), (\tilde{g}_2 + p(\tilde{e}(\tilde{g}, z'))(\tilde{g}_1 + \delta + S))(1 - \delta)\}. \quad (6)$$

This law of motion implies that the measure of inexperienced workers present on the island at the end of the following period (for each z') is given by the measure of inexperienced workers who remain on the island at the end of this period, $\tilde{g}_1$, plus the newcomers to the island who switch their occupations, S, and the measure δ of the newborn workers, who will not become experienced, $(1-p(\tilde{e}(\tilde{g}, z')))$, and will not die, $(1-\delta)$. The measure of experienced workers present on the island at the end of the following period is defined similarly.

Consider the decision problem of an individual with experience level i who finds herself at the end of the period on an island (ψ, z). She has to decide whether to remain on the island for the next period or leave it and work next period elsewhere. The value of leaving the island is denoted by V^s. The value of remaining on the island if shock z' is realized tomorrow is $M(\tilde{g}, z')$, given the expected total effective labor supply determined by $\tilde{g}$ and $\tilde{e}(\tilde{g}, z')$[15], and the physical capital rental rate, r. Then,

$$V_i(\psi, z) = \max \left\{ V^s, \int M_i(\tilde{g}, z') Q(z, dz') \right\}, \quad (7)$$

where

$$\begin{aligned} M_1(\tilde{g}, z') = \max_{0 \le e \le 1} \{ & U(\Omega(w_1(\tilde{g}, z')(1 - e))) \\ & + \beta(1 - \delta) \left[(1 - p(e)) V_1(\psi', z') + p(e) V_2(\psi', z') \right] \}, \end{aligned} \quad (8)$$

and

$$M_2(\tilde{g}, z') = U(\Omega(w_2(\tilde{g}, z'))) + \beta(1 - \delta) V_2(\psi', z'). \quad (9)$$

Corresponding to $M_1(\tilde{g}, z')$ there exists an individual policy function $e(\tilde{g}, z')$ that determines the fraction of time allocated to training.

4 Equilibrium

Definition. An open economy stationary equilibrium consists of

[14]This assumption is discussed in section 6.2.

[15]The labor supply on an island $(\tilde{g}, z')$ is given by $L_1 = (1 - \tilde{e}(\tilde{g}, z'))(\tilde{g}_1 + \delta + S)$ and $L_2 = \tilde{g}_2$.

- end of the period value functions $V_1(\psi, z)$ and $V_2(\psi, z)$,
- beginning of the period value functions $M_1(\tilde{g}, \cdot)$ and $M_2(\tilde{g}, \cdot)$,
- island employment rules $\tilde{g}_1(\psi, z)$ and $\tilde{g}_2(\psi, z)$,
- individual policy function $e(\tilde{g}, \cdot)$,
- island-invariant measures $\mu(\psi, z)$ and $\lambda(\tilde{g}, z')$,
- the value of search V^s,
- the measure S of workers switching islands, and
- factor price functions r and w,

such that:

1. Given V^s, $\tilde{g}(\psi, z)$, $\tilde{e}(\tilde{g}, \cdot)$ and S, $V_1(\psi, z)$, $V_2(\psi, z)$, $M_1(\tilde{g}, \cdot)$ and $M_2(\tilde{g}, \cdot)$, maximize individual's utility (solve corresponding functional equations with e as the associated policy function).

2. Wages are determined competitively, i.e. workers with a given level of experience are paid their marginal product.

3. The rental rate of capital, r, is determined by the one in the rest of the world.

4. The island employment rule $\tilde{g}(\psi, z)$ is consistent with individual decisions:

$$\tilde{g}_i(\psi, z) < \psi_i \Rightarrow V_i(\psi, z) = V^s,$$
$$\tilde{g}_i(\psi, z) = \psi_i \Rightarrow V_i(\psi, z) \geq V^s \text{ for } i = 1, 2.$$

5. The individual training decision $e(\tilde{g}, \cdot)$ is consistent with the aggregate training level:

$$e(\tilde{g}, \cdot) = \tilde{e}(\tilde{g}, \cdot).$$

6. Individual decisions are compatible with the invariant distributions:

$$\begin{aligned} \mu(\Psi', Z') &= \int_{\{(\psi, z): \psi' \in \Psi'\}} Q(z, Z') \mu(d\psi, dz), \\ \lambda(G', Z') &= \int_{\{(\tilde{g}, z): \tilde{g}' \in G'\}} Q(z, Z') \lambda(d\tilde{g}, dz). \end{aligned}$$

7. For an island (ψ, z), the feasibility conditions are satisfied:

$$0 \leq \tilde{g}_i(\psi, z) \leq \psi_i \qquad \text{for } i = 1, 2.$$

   The aggregate feasibility condition is satisfied:

$$S = 1 - \int \left[\psi_1 - \tilde{g}_1(\psi, z) + \psi_2 - \tilde{g}_2(\psi, z)\right] \mu(d\psi, dz).$$

8. V^s is generated by M_1 and λ:

$$V^s = \int M_1(\tilde{g}, z') \lambda(d\tilde{g}, dz').$$

5 The Experiment

I first calibrate the model with the current mildly progressive US tax schedule. Next, I replace the tax system with a proportional one in a revenue neutral manner and study the implications for output, productivity, wage and income inequality, and welfare.

6 Discussion of the Modelling Choices

6.1 Undirected Search

I have assumed that search is undirected and workers are required to stay for one model period in an occupation they arrive to. This assumption is motivated by the empirical finding that workers who switch their occupations at least once in a four-year period in the US switch 1.7 times on average. This number is estimated on the annual PSID data and is likely to understate the average number of switches since some workers may switch several times within a year, but it is not possible to identify those switches with only annual observations.[16] The assumption of undirected search helps match these data. It generates a friction that makes workers occasionally try several times before finding an occupation they choose to remain in.

6.2 Redistribution of the Tax Revenue

In order to focus the analysis on the effects of progressivity of the income tax code I have assumed that the government tax revenues are thrown away. The alternative assumption is that the revenues are, say, uniformly redistributed back to the individuals. With the CRRA utility such redistribution affects the willingness of individuals to switch occupations and to invest in the specific human capital (by reducing the relative riskiness of these choices). Thus to maintain the focus of the analysis on the effects of tax policies I choose to abstract from the redistribution.

7 Preliminary Calibration

Calibration details reported in this section are very preliminary. The model period is chosen to be 6 month. Probability of an individual dying is fixed at $\delta = .0125$ to represent the expected working lifetime of 40 years.

7.1 Preferences

I assume that preferences over consumption can be represented by a period utility function of the following form:

$$U(c) = \frac{c^{1-\sigma}}{1-\sigma}.$$

[16]Topel and Ward (1992) document a similar tendency among employer switchers to "try and try again".

I fix the coefficient of relative risk aversion to $\sigma = 2$. Sensitivity of the results to σ ranging from 1 to 4 will be presented in the next draft.

7.2 Production function parameters

I set the distribution parameters of the production function $\theta_1 = 0.44$ and $\theta_2 = 0.56$. This choice implies occupational experience premium of 27%. Given that it is difficult to construct reliable measures of occupational tenure in the data due to a relatively short duration of most panel data sets and the amount of measurement error in identifying occupation switches, this choice appears reasonable. Kambourov and Manovskii (2002b) document that the lower bound of the returns to 10 years of occupational experience is 19%. I follow Veracierto (2002) and select labor and capital share parameters of the production function to be $\alpha = 0.64$ and $\gamma = 0.26$, respectively.

7.3 Productivity shocks

The idiosyncratic occupational productivity shocks z are assumed to evolve according to the following AR(1) process:

$$\ln(z') = \phi \ln(z) + \epsilon',$$

where $\epsilon' \sim N(0, \sigma_\epsilon^2)$ and $0 < \phi < 1$. I choose the shock values z_i and the transition matrix $Q(z, \cdot)$ for a 30-state Markov chain $z = \{z_1, z_2, ..., z_{30}\}$ intended to approximate the continuous-valued autoregression above.[17] I restrict $\overline{z}$ and $\underline{z}$ as implied by three unconditional standard deviations of $\ln(z')$ above and below the unconditional mean of the process, respectively.

I calibrate the persistence of the productivity shocks, ϕ, and the standard deviation of its innovations, σ_ϵ to match the following observations from the PSID data.

1. The fraction of workers in the US who switched their occupation defined at a three-digit level in 1989 was equal to 0.19.

2. The average number of switches for those who switched a three-digit occupation at least once in the period between 1986 and 1989 (inclusive) was equal to 1.66.

These time periods are chosen to be consistent with the tax system calibration discussed below. Since there is no direct analytical relation between ϕ and σ_ϵ, and the corresponding observations, I search numerically over these parameters' space until a good fit is found.[18]

[17] To discretize the shock process the method described in Tauchen (1986) was used.

[18] To be consistent with the PSID data used to obtain the targets that has annual frequency, I pretend that each individual is observed in the model only every second period.

7.4 Rental rate and discounting

I set the discount factor $\beta = 0.9804$ and the rate of return on physical capital $r = 0.06$ to be consistent with the annual depreciation rate of physical capital of 0.08% and the interest rate of 0.04%, roughly the average of the return on bonds and the return on equity in the United States.[19]

7.5 Progressive taxation

The progressive tax schedule in the model comes from Gouveia and Strauss (1994) who estimate the 1989 U.S. effective total tax function as:

$$\tau(y) = c_0(y - (y^{-c_1} + c_2)^{-1/c_1}),$$

where y is a taxable income of an individual, $\tau(y)$ is a corresponding tax bill, $c_0 = 0.258$, $c_1 = 0.768$, and $c_2 = 0.031$.[20]

Unfortunately, the concept of income used by Gouveia and Strauss (1994) includes not only labor earnings but capital income as well. Since they estimate the effective tax function, this difference may matter if capital income is treated differently from the point of various available deductions and exclusions. Note as well that the effects of progressive taxation reported in the next section are of a conservative nature since the estimated effective tax function is considerably less progressive than the statutory one.

In addition, the effective marginal tax function estimated by Gouveia and Strauss (1994) becomes almost flat for the incomes above the mean. Since most of the investment in human capital in the model is done by high wage workers (these are the workers in highly productive occupations that are likely to remain highly productive for a relatively long periods of time), this tax function has almost no effect on human capital accumulation of these workers.

An alternative way to parameterize the tax function is to use the statutory tax rates. This is appropriate under the assumption that it is much harder to avoid taxes on labor income than on capital income. Cassou and Lansing (2002) estimate the statutory average personal tax rates, Θ, in the US in 1994 to be given by

$$\Theta = 0.2528(\text{Income Ratio})^{0.2144},$$

where "Income Ratio" is defined as the ratio of personal taxable income and its mean level.[21]

[19]Setting $\beta = 1/(1+i)$, where i represents an interest rate net of depreciation may not be entirely appropriate in this environment where workers experience idiosyncratic uninsurable risk. Given that workers are not allowed to save in this version of the model, this assumption is a reasonable first pass.

[20]Parameter c_2 in the tax function is normalized so that average tax rate in the model is the same as in the U.S. in 1990. (See Erosa and Koreshkova (2001)).

[21]The estimates take into account the effects of the federal individual income tax, the earned income tax credit, and employee and employer contributions to Social Security and Medicare.

7.6 Experience accumulation

I assume that, as a function of time allocated to training by an inexperienced worker, the probability of that worker becoming experienced is given by $p(e) = \frac{e^{\lambda_1}}{\lambda_2}$ and set $\lambda_1 = 0.5$ and $\lambda_2 = 4$.[22] These choices imply that:

1. A worker who devotes all his time to training will expect to become experienced in two years.

2. A worker who invests 8% of his time in training (a rough estimate of the average fraction of working time devoted to training) will expect to become experienced in 7 years (wage profiles as a function of occupational experience in the data flatten out considerably after a worker spends $7 - 10$ years in an occupation).

8 The Impact of Progressive Taxation: Preliminary Results from Quantitative Analysis

Replacing (in the revenue neutral manner) the current progressive tax system by a flat tax of approximately 12.5% has the following implications in this version of the model.

- Output and productivity decline by 2.5%.
- Welfare declines by 9%.[23]
- After-tax income inequality increases by 2 Gini points.
- Wage inequality increases slightly.

The results are driven by a decline in occupational mobility of about 7%. Despite longer expected stay in an occupation the average time in training remains virtually unchanged since the additional incentives to accumulate human capital provided by progressive taxation are eliminated.

9 Discussion of the Results

Replacing the current progressive tax system by a flat tax in the model results in a substantial decline in occupational mobility. There are several features of the model that drive this result.

1. Destruction of human capital upon a switch.

2. Investment in human capital after a switch (temporarily pushes earnings down).

[22] Caucutt et al. (2002) also use this functional form.

[23] Welfare is measured as the proportional change in consumption of all workers and in all states required to make workers indifferent between being born into the steady states of the model implied by the two tax regimes.

3. Undirected search and a temporary inability to escape low wages.

The third feature above is important for understanding the results. A small probability of having to receive very low wages (for one period) could be a serious deterrent of mobility. Under a progressive tax system those earning would almost not be taxed while under a proportional system they are taxed at a flat rate. The utility costs of proportional taxation for those individuals could be very large. Although this is not the effect of progressive taxation that I put the main emphasis on in this paper, it may nevertheless be important empirically.

The decrease in productivity is driven mainly by the decline in occupational mobility. This happens because, without the incentives provided by the progressive tax system, some workers choose to remain in the relatively unproductive occupations.

The decline in welfare is explained by the decrease in productivity and by eliminating the only smoothing mechanism (progressive taxation) available to the agents in this version of the model. To identify the fraction of the decline in welfare due to the elimination of income smoothing only, I conduct a fixed policy experiment in which the progressive tax schedule is replaced by a proportional one but the decisions of workers are assumed to remain the same as under the progressive tax system. The results of this experiment will be provided in the next draft.

The model does not match the data in one important dimension. Upon a switch, individual wages in the model on average do not decline nearly as much as they do in the data.[24] Thus the reported effect of replacing progressive with flat tax on occupational mobility is likely to be conservative. In the next draft I would fix this problem by assuming that there are three experience levels on an island. The idea is as follows. Income is taxed on an annual basis. Earnings in a year of occupational switch may be low since a worker may go through a period of unemployment, or may work part-time, or not work at all while receiving initial training in the new occupation. In this case the introduction of an entry-level experience level in an occupation will help me match the data. The relative productivity of the entry-level workers will be calibrated to match the decline in wages of the occupation switchers. I will not give occupation newcomers a choice of the fraction of time in training but will assume that they exogenously (probabilistically) leave that state in a relatively short period of time, say, a year.

10 The Equilibrium Model with Specific Human Capital, Labor-Leisure Choice and Savings

In this section I modify the model by assuming that workers can (partially) self-insure against earnings uncertainty by accumulating assets they can draw on when wages are low. When workers have access to this additional income smoothing mechanism the welfare gains from progressive taxation may turn out to be lower than the ones identified above. In addition, the

[24] This is not driven by the assumption that the decisions are taken at the end of a period. A beginning of the period model, like Alvarez and Veracierto (2000), has the same property.

major criticism of progressive taxation is based on the fact that it distorts the labor/leisure choice. In order to determine whether the productivity gains from progressive taxation that I emphasize are large enough to overcome the productivity losses due to the distortion in the leisure choice, I include this margin into the model as well.

Allowing for precautionary savings directly in the model of section 3 is complicated since the distribution of wealth on each island affects individual decisions. In order to simplify the analysis I restrict the island production function to exhibit constant returns in labor and capital, or $\alpha + \gamma = 1$. In this case wages for a unit of time supplied by a worker with experience i are given by

$$w_i = \theta_i z^{\frac{1}{1-\gamma}} \left[\frac{r}{\gamma}\right]^{\frac{\gamma}{\gamma-1}}. \tag{10}$$

Note that, with the constant returns production function, costless and instantaneous capital mobility makes wages on an island independent of the measure and of the distribution of workers on the island. Thus, given the rental rate, r, an island is now fully characterized by the value of its productivity, z.

In order to better match the pattern of occupational mobility over the life-cycle I assume that workers in the model can be either young, middle-aged, or old. Let j denote workers' age: $j = 1$ if a worker is young, $j = 2$ if a worker is middle-aged, and $j = 3$ if a worker is old. Young workers face a constant probability, δ_1, of becoming middle-aged, middle-aged workers face a constant probability, δ_2 of becoming old, while old workers face a constant probability, δ_3, of dying.

There is an annuities market in this economy. An individual of age j who invests an amount a this period has a claim to $(1 + q_j)a$ next period conditional on being alive.[25]

I assume that workers can have one of three experience levels indexed by i. The total supply of effective labor on an island is given by $L = \sum_{i=1}^{3} \theta_i L_i$, $0 < \theta_1 < \theta_2 < \theta_3 < 1$, $\sum_{i=1}^{3} \theta_i = 1$, where θ_i implies the productivity of a worker with experience i.

When an individual arrives on an island she starts with the lowest level of experience. Each period an inexperienced individual becomes experienced with probability $p_i(e)$, where $0 \leq e \leq 1$ denotes the fraction of time allocated to occupational training. The functions $p_i : [0, 1] \to [0, 1]$ are assumed to be twice continuously differentiable, increasing, strictly concave, and $p_i(0) = 0$. Once an individual reaches the highest level of experience ($i = 3$) she remains at that level of experience until she chooses to leave the island. By assumption, specific human capital does not depreciate.

I assume that preferences over consumption and leisure $\{c_t, (1 - l_t)\}_{t=1}^{\infty}$ are representable by a standard time-separable utility function of the form

$$E \sum_{t=1}^{\infty} \beta^{t-1} (1 - \delta)^{t-1} \frac{(c_t^{\nu} (1 - l_t)^{1-\nu})^{1-\sigma}}{1 - \sigma}, \tag{11}$$

where ν is a share parameter measuring the importance of consumption relative to leisure.

[25]One can think that there are competitive banks in this economy that lend capital to firms at the rate r and accept one-period deposits from individuals at the rate q_j. The banks' borrowing and lending rates differ because banks keep assets of the deceased.

Consider the decision problem of an individual of age j who has assets of a and finds herself at the end of the period on an island z with experience level i. Each individual has to decide whether to stay on the island or look for a new one. Those who stay on the island choose what fraction of time to work, l, what fraction of working time to allocate to occupational training, e, and how to allocate their income between consumption, c, and saving, a'. These decisions are constrained by:

$$c + a' \leq \Omega(w_i(z)(1-e)l) + (1+q_j)a, \tag{12}$$

$$0 \leq l \leq 1, \tag{13}$$

$$0 \leq e \leq 1, \tag{14}$$

$$c \geq 0, a' \geq 0. \tag{15}$$

Let $V_{ij}(a,z)$ be the expected value of an individual of age j who finds herself at the end of a period with experience i and assets a on an island z. Each worker faces the value of leaving the island $V_j^s(a)$. The value of leaving is not indexed by the experience level since a switcher starts on a new island as an inexperienced worker. The value of remaining on the island if shock z' is realized tomorrow is $M_{ij}(a,z')$, given rental rate, r. Then,

$$V_{ij}(a,z) = \max_{leave,stay} \left\{ V_j^s(a), \int M_{ij}(a,z')Q(z,dz') \right\}, \tag{16}$$

where

$$\begin{aligned} M_{i<3,j<3}(a,z') = \max_{c,a',l,e} \{ & U(c,1-l) + \beta(1-\delta_j)\left[(1-p_i(e))V_{ij}(a',z') + p_i(e)V_{i+1,j}(a',z')\right] \\ & + \beta\delta_j \left[(1-p_i(e))V_{i,j+1}(a',z') + p_i(e)V_{i+1,j+1}(a',z')\right] \}, \end{aligned} \tag{17}$$

$$\begin{aligned} M_{i<3,j=3}(a,z') = \max_{c,a',l,e} \{ & U(c,1-l) \\ & + \beta(1-\delta_3)\left[(1-p_i(e))V_{ij}(a',z') + p_i(e)V_{i+1,j}(a',z')\right] \}, \end{aligned} \tag{18}$$

$$M_{i=3,j<3}(a,z') = \max_{c,a',l} \{ U(c,1-l) + \beta\left[(1-\delta_j)V_{ij}(a',z') + \delta_j V_{i,j+1}(a',z')\right] \}, \tag{19}$$

and

$$M_{i=3,j=3}(a,z') = \max_{c,a',l} \{ U(c,1-l) + \beta(1-\delta_3)V_{i=3,j=3}(a',z') \}. \tag{20}$$

Corresponding to each $V_{ij}(a,z)$, there exist individual policy functions $g_{ij}(a,z)$ that dictate the individuals whether to stay or leave the island. Corresponding to each $M_{ij}(a,\cdot)$, there exist individual policy functions $c_{ij}(a,\cdot)$, $a'_{ij}(a,\cdot)$, $l_{ij}(a,\cdot)$, and $e_{ij}(a,\cdot)$ that govern individual consumption, investment, labor supply, and the fraction of time allocated to training, respectively.

11 Equilibrium

Definition. An open economy stationary competitive equilibrium consists of the value functions of search $V_j^s(a)$, individual value functions $V_{ij}(a,z)$, $M_{ij}(a,\cdot)$, individual policy functions $g_{ij}(a,z)$, $c_{ij}(a,\cdot)$, $a'_{ij}(a,\cdot)$, $l_{ij}(a,\cdot)$, $e_{ij}(a,\cdot)$ for all i,j, an invariant measure $\mu(i,j,a,z)$, and factor prices r and w, such that:

1. Given $V_j^s(a)$ and r, $V_{ij}(a,z)$ and $M_{ij}(a,\cdot)$, for all i,j, maximize individual's utility and the corresponding individual policy functions are $g_{ij}(a,z)$, $c_{ij}(a,\cdot)$, $a'_{ij}(a,\cdot)$, $l_{ij}(a,\cdot)$, and $e_{ij}(a,\cdot)$.

2. Wages are determined competitively, i.e. workers with a given level of experience are paid their marginal product.

3. The rental rate of capital is determined by the one in the rest of the world.[26]

4. The value of leaving an island, $V_j^s(a)$, is generated by $M_{1j}(a,\cdot)$ and $\xi(z)$:

$$V_j^s(a) = \int M_{1j}(a,z')\xi(dz'). \tag{21}$$

5. Individual decisions are compatible with the invariant distribution

$$\mu(I',J',A',Z') = \sum_i \sum_j \int \Big[\chi_{\{(i=I'-1,j,a,z):a'\in A'\}} p_i(e(i=I'-1,j,a,z)) \\ +\chi_{\{(i=I',j,a,z):a'\in A'\}}(1-p_i(e(i=I',j,a,z)))\Big]\,\pi(j,J')Q(z,Z')\mu(i,j,da,dz), \tag{22}$$

where χ denotes the indicator function.

12 Discussion

12.1 Unemployment Insurance

As discussed in section 9, there are three features of the model that give a mobility-enhancing role to progressive taxation. First, wages often decline upon an occupation switch since a worker destroys human capital in his former occupations and starts as an inexperienced worker in the new one. Second, after a switch the inexperienced worker invests a fraction of his time in accumulating human capital, thus pushing his earnings down temporarily. Unemployment insurance does not directly encourage making these choices because they are made by the employed individuals.

Finally, search is assumed to be undirected and workers are required to stay for one model period in an occupation they arrive to. This feature of the model suggests that unemployment insurance may play a mobility-inducing role as well. In particular, when

[26]This assumption simplifies computation of the model. Although it is not unreasonable, even for the US, I would probably later look for a market clearing rental rate, r (in a closed economy version of the model).

switchers arrive on an island with a very low productivity, they may choose not to work and claim unemployment benefits for that period. Unemployment insurance system in the US, however, is characterized by a relatively low level of benefits, short duration of benefits, and high ineligibility rate. Note also that unemployment benefits are typically taxed and the average tax rate that unemployed individuals face is likely to be lower under a progressive tax system. Consequently, unemployment insurance and progressive taxation are complementary policies in encouraging occupational mobility.

12.2 Tax Brackets

I have assumed that the marginal tax function is continuously differentiable and concave everywhere. The statutory marginal tax rates in the US are represented by a step function with just 4-6 steps in recent years, however. I do not know if the effective marginal tax rates are represented by a step function as well, or if they are well approximated by a "smooth" function. Results in Gouveia and Strauss (1994) seem to indicate that such an approximation is valid.[27]

In order to illustrate the importance of marginal tax function continuity, it is instructive to re-examine the finding in Caucutt et al. (2002) who argue that even in the presence of liquidity constraints, increase in tax progressivity decreases investment in human capital. In their model there are only high-skilled workers facing a high tax rate and low-skilled workers facing a low tax rate. In terms of the simple model of section 2, this tax structure could be described as $h = 1$, $b = b_1$ if $w = w_1$, and $b = b_2$ if $w = w_2$, $b_1 < b_2$. The following lemma proved in appendix II establishes that, for a given b_2, an increase in b_1 (or the increase in tax progressivity in the sense of Caucutt et al. (2002)) decreases the investment in human capital.

Lemma 1 *If $U(c) = \frac{c^{1-\sigma}}{1-\sigma}$ for $\sigma > 0$, $\sigma \neq 1$ and $U(c) = log(c)$ for $\sigma = 1$, then $\frac{de}{db_1} < 0$.*

A decline in the tax rate in low-wage workers has two opposing effects on their investment in human capital. On the one hand, there is a "liquidity effect" that makes these workers richer and thus makes it less costly in terms of utility to invest in human capital. On the other hand, there is an "intertemporal effect" that makes acquiring skills relatively less attractive. With this coarse modelling of the progressive tax system the intertemporal effect dominates. Note that in this setup a change in the amount of time allocated to human capital accumulation leaves tax rates unchanged. This would not be the case if marginal tax function was continuous or if the decisions to forgo income today involved a change of the tax bracket.

[27]Gouveia and Strauss (1994) suggest that the effective average tax function is better approximated by a strictly concave function than by a more flexible polynomial of degree five. This implies that the effective marginal tax function defined as the derivative of the estimated effective total tax function must be smooth as well.

13 Concluding Remarks

I have shown that, in the absence of complete insurance markets, progressive taxation of labor income may provide productivity and welfare gains as compared to a revenue-equivalent flat tax.[28] In order to increase income in the future, individuals have to forgo income today by accepting lower wages while accumulating human capital or when destroying specific human capital in order to build it elsewhere. A progressive tax system encourages people to make these temporary sacrifices because progressive taxes decrease the consumption benefit of the sacrifice but they also decrease its cost since individuals are not taxed as much when their income is low. With a plausible intertemporal elasticity of substitution in consumption, in utility terms, the decline in costs outweighs the decline in benefits.

Preliminary quantitative results from a calibrated general equilibrium model that does not allow for precautionary savings suggest that there could be significant productivity (2.5%) and welfare (9%) losses from replacing a existing progressive U.S. tax system with a flat one. This is due to a substantial decline in occupational mobility (7%) under a flat labor income tax, and due to the elimination of the incentives to invest in human capital accumulation provided by the progressive tax.

In the very near future I would obtain quantitative results from the version of the model in section 10. These results would indicate whether the channel identified in this paper is important enough to overcome the detrimental productivity effect of the distortions in labor-leisure choice caused by tax progressivity. In addition, agents in that model are able to self-insure by accumulating assets. Inclusion of these two channels will make the results comparable to other papers that looked at the effects of moving to a flat tax. I expect the results from the second version of the model to suggest that the gains may not be nearly as large as previously thought.

In the near future I would also like to obtain data on changes in annual earnings for individuals switching occupations in the PSID. I am particularly interested in the changes in earnings for workers reporting a quit as a reason for the employer/position switch coinciding with the occupation change.

One longer term modification of the model I am considering involves allowing for a heterogeneous quality of match between workers and occupations. I assume that this quality is learned by a worker after a period of working in an occupation and remains constant as long as the worker remains in the occupation. Suppose that match quality affects workers' utility but not their productivity. This may imply that (young) workers may leave high productivity shock but low match quality occupations in search of potentially lower wage but high match quality ones. Such a model will do a better job matching the facts on career mobility of young workers documented by Keane and Wolpin (1997) and Neal (1999).

In future work I would like to attempt some positive analysis of the effects of tax progressivity. This may include either an investigation of the response of occupational mobility to changes in tax progressivity, or a study of the cross-country differences in tax progressivity and occupational mobility.

[28] I should emphasize that, while I suggest that progressive taxation of labor income may yield productivity and welfare gains, the argument does not apply to the taxation of capital income.

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APPENDICES

I Proof of Proposition 1.

The first order condition of utility maximization with respect to e is:

$$-w_1hb[w_1(1-e)]^{h-1}(b[w_1(1-e)]^h)^{-\sigma} + p'(e)\left[\frac{[bw_2^h]^{1-\sigma} - [bw_1^h]^{1-\sigma}}{1-\sigma}\right] = 0.$$

Rearranging,

$$p'(e)(1-e)^{1-h(1-\sigma)} = \frac{h(1-\sigma)}{\left(\frac{w_2}{w_1}\right)^{h(1-\sigma)} - 1}. \tag{A1}$$

Note that the optimal choice of e is independent of b thus implying the first part of Proposition 1.

To prove the second part of the proposition, denote the left hand side of equation A1 as LHS and the corresponding right hand side as RHS.

Observation 1. $\frac{\partial LHS}{\partial e} < 0$. This follows from:

$$\frac{\partial LHS}{\partial e} = (1-e)^{-h(1-\sigma)}\left[(1-e)p''(e) - (1 + h(\sigma-1))p'(e)\right] < 0$$

Note that this implies the sufficiency of the first order condition.

Observation 2.

$$\frac{\partial LHS}{\partial h} = p'(e)(\sigma-1)(1-e)^{1-h(1-\sigma)}ln(1-e).$$

Thus

1. $\sigma < 1 \Rightarrow \frac{\partial LHS}{\partial h} > 0$,
2. $\sigma = 1 \Rightarrow \frac{\partial LHS}{\partial h} = 0$,
3. $\sigma > 1 \Rightarrow \frac{\partial LHS}{\partial h} < 0$.

Consider now the right hand side of equation A1.

$$\frac{\partial RHS}{\partial h} = \frac{(1-\sigma)\left[\left\{\left(\frac{w_2}{w_1}\right)^{h(1-\sigma)}\left(1 - h(1-\sigma)ln\left(\frac{w_2}{w_1}\right)\right)\right\} - 1\right]}{\left[\left(\frac{w_2}{w_1}\right)^{h(1-\sigma)} - 1\right]^2} \tag{A2}$$

In order to determine the sign of $\frac{\partial RHS}{\partial h}$ we need to sign the numerator of equation A2. Consider the sign of the expression in square brackets of equation A2.

$$1 - h(1-\sigma)ln\left(\frac{w_2}{w_1}\right) \quad vs. \quad \left(\frac{w_2}{w_1}\right)^{h(\sigma-1)} \tag{A3}$$

Denote the left hand side of expression A3 $LHS1$ and its right hand side $RHS1$. Note that $\frac{\partial LHS1}{\partial \sigma} = hln\left(\frac{w_2}{w_1}\right)$ and $\frac{\partial RHS1}{\partial \sigma} = h\left(\frac{w_2}{w_1}\right)^{h(\sigma-1)} ln\left(\frac{w_2}{w_1}\right)$. Since $w_2 > w_1$:

1. $\sigma < 1 \Rightarrow \frac{\partial LHS1}{\partial \sigma} > \frac{\partial RHS1}{\partial \sigma}$,
2. $\sigma = 1 \Rightarrow \frac{\partial LHS1}{\partial \sigma} = \frac{\partial RHS1}{\partial \sigma}$,
3. $\sigma > 1 \Rightarrow \frac{\partial LHS1}{\partial \sigma} < \frac{\partial RHS1}{\partial \sigma}$.

Together with the observation that $LHS1 = RHS1$ at $\sigma = 1$ this implies[29]:
Observation 3.

1. $\sigma \neq 1 \Rightarrow RHS1 > LHS1$,
2. $\sigma = 1 \Rightarrow RHS1 = LHS1$.

The expression in square brackets of equation A2 is multiplied by $1 - \sigma$, an expression that changes its sign at $\sigma = 1$. Together with Observation 3 this implies that in equation A2:

1. $\sigma < 1 \Rightarrow Numerator < 0$,
2. $\sigma = 1 \Rightarrow Numerator = 0$,
3. $\sigma > 1 \Rightarrow Numerator > 0$.

Jointly with Observation 2 this means that LHS and RHS of equation A1 move in opposite directions as h changes. Together with Observation 1 this finally implies the second part of Proposition 1:

1. $\sigma > 1 \Rightarrow \frac{de}{dh} < 0$,
2. $\sigma = 1 \Rightarrow \frac{de}{dh} = 0$,
3. $\sigma < 1 \Rightarrow \frac{de}{dh} > 0$.

QED.

[29]As a function of σ, the graph of $RHS1$ lies above the graph of $LHS1$ everywhere, except at $\sigma = 1$, where the graphs coincide.

II Proof of Lemma 1.

The first order condition of utility maximization with respect to e is:

$$p'(e)(1-e)^{\sigma} = \frac{1-\sigma}{\left(\frac{b_2 w_2}{b_1 w_1}\right)^{(1-\sigma)} - 1}. \tag{A4}$$

Note that the optimal choice of e is unaffected by the tax policy if $b_1 = b_2$. Denote the left hand side of equation A4 as LHS and the corresponding right hand side as RHS. Since $\frac{\partial LHS}{\partial e} < 0$ (indicating the sufficiency of the first order condition) and $\frac{\partial RHS}{\partial b_1} > 0$, $\frac{\partial e}{\partial b_1} < 0$. *QED*.