Effects of Inflation on Wealth Distribution:

Do stock market participation fees and capital income taxation matter?

Burkhard Heer[a,b] and Bernd Süssmuth[c]

[a] Free University of Bolzano-Bozen, School of Economics and Management, Via Sernesi 1, 39100 Bolzano, Italy, Burkhard.Heer@unibz.it

[b] CESifo, Munich, Germany

[c] Munich University of Technology, Department of Business and Economics, Arcisstr. 21, 80333 Munich, Germany, bernd.suessmuth@wi.tum.de

This version: June 14, 2005

JEL classification: D31, E52, E44, E31

Key Words: Inflation, Nominal Interest Taxation, Welfare Costs, Wealth Distribution, Stock Market Participation

Abstract:
The effects of a permanent change in inflation on the distribution of wealth are analyzed in a general equilibrium OLG model that is calibrated with regard to the characteristics of the US economy. Poor agents accumulate savings predominantly in the form of money, while rich agents participate in the stock market and accumulate equity. Higher inflation results in higher nominal interest rates and a higher real tax burden on interest income. Surprisingly, an increase in inflation results in a lower stock market participation rate; in addition, savings decrease and the distribution of wealth becomes even more unequal.

1 Introduction

The literature discusses several channels through which inflation may alter income, earnings, or wealth distributions. Among others, these channels include differential indexation of wages across income groups, disproportionally allocated subsidized loans, the income tax bracket effect, and the Tanzi-Olivera effect on taxes and governmental revenues. This paper aims to examine two different channels that stress the role of capital markets and the portfolio composition of financial wealth in money and equity. Both channels are operative even if a change of inflation is anticipated. First, we model the portfolio decision of households to invest in money and interest-bearing assets endogenously. Our presumption is that in times of high inflation, households may reallocate their wealth from money to capital. Given transaction costs and stock market participation fees, wealth-poor and income-poor agents may experience difficulties in accomplishing such a move. Many younger and poorer US households, in particular, do not hold equities at all.[1] As a consequence, wealth concentration should increase with higher inflation. Second, we introduce the 'Feldstein channel' that occurs through the impact of inflation on the distortionary nominal tax system. As Feldstein (1982) pointed out, loose monetary policy can increase the real capital income tax burden in a nominally based tax system. As a corollary, higher inflation reduces the return on savings. The effect of inflation on the distribution of wealth via the 'Feldstein channel' then depends on the distribution of the savings rates across income.

The effect of inflation on the inequality of the income distribution has been analyzed in numerous empirical studies of the US economy. A comprehensive survey of this literature is given in Galli and van der Hoeven (2001). The majority of these studies finds a significant progressive effect of inflation on US income distribution, although it is of negligible size in quantitative terms. About half of the studies, however, do not find a statistically significant effect once some basic control variables are considered. The effect of inflation on the concentration of wealth is nevertheless much less understood, one possible reason being the lack of equidistant and/or comparable time-series data.[2] We know of only a

[1] Romer and Romer (1998) note that for US households from the quintile reporting the lowest total income only about one fifth holds a positive amount of financial assets, including non-public stocks (figure based on data from the Federal Reserve's 1995 Survey of Consumer Finances, henceforth SCF).

[2] One should also be very careful to apply the evidence for income distribution to the redistributional

few empirical studies that consider the relationship of inflation and wealth heterogeneity, as, for example, Bach and Ando (1957), Budd and Seiders (1971), Bach and Stephenson (1974), or Wolff (1979). These studies mostly compare two different periods only and are concerned with the differences in wealth holdings of relatively disaggregated demographic and/or racial groups with regard to different types of assets. The broad overall picture conveyed in this early strand of empirical literature is that during the mid 1950s to mid 1970s period inflationary effects produced a drop in the level of wealth inequality.[3]

More recently, due to the advances in computer technology, the relationship between inflation and wealth distribution has also been studied quantitatively with the methods of computable general equilibrium analysis. One prominent study in this area is presented by Erosa and Ventura (2002). In their model, consumption goods may be purchased with either cash or credit. Costly credit is provided by financial intermediaries. In this economy, inflation has redistributional effects if the per-unit costs of credits are a non-increasing function of the total amount of goods purchased. In this (realistic) case, high-income and wealth-rich households face lower additional costs of higher inflation than low-income and wealth-poor households. As a consequence, both the welfare and the wealth of high-income households is affected much less than that of low-income households.[4]

In order to study the effects of inflation on the distribution of wealth we analyze the households' optimal portfolio allocation in a calibrated life-cycle model. While our model is similar to the one of Erosa and Ventura (2002), we stress a completely different channel

effects of inflation on the wealth distribution because, at least in the case of the US, the correlation between wealth and income, though positive, is far from strong (see Díaz-Giménez , Quadrini, and Ríos-Rull, 1997) and may change over time.

[3]Similarly, Romer and Romer (1998) investigate the impact of inflation on financial assets and liabilities of the poor from the lowest income quintile (based on 1995 data from the US Board of Governors of the Federal Reserve System); they find a progressive effect of unanticipated inflation through the popular nominal debtor channel, even though this effect is negligible in quantitative terms.

[4]To the best to our knowledge, there exists only one other computable general equilibrium model that studies the effects of inflation on the distribution of wealth. In particular, Bhattarcharya (2001) develops a monetary general equilibrium model with an imperfect capital market where inflation increases the external finance premium; his results, however, are sensitive with regard to the modelling of the government's use of the inflation tax.

of redistribution resulting from inflation.[5] Rather than stressing the different credit costs of wealth-rich agents in comparison with wealth-poor agents, we emphasize both the 'Feldstein channel' and the effect of stock market transaction costs on portfolio allocation. According to the 'Feldstein channel', higher inflation results in a higher real tax burden. In our model this will result in a drop of income, savings, and wealth. The inflation effect on the distribution of savings, therefore, depends crucially on the distribution of wealth, on the one hand, and the distribution of the savings rates among the income-rich and the income-poor agents, on the other. In order to model the empirical distribution of wealth as closely as possible we follow Huggett and Ventura (2000), who have shown that the following three key features are sufficient in order to replicate the cross-section behavior of savings rate in the US economy: (i) age, (ii) permanent income differences, and (iii) the social security system. Even though the agents in our model are characterized by homothetic preferences, the savings rates depend on income due to the presence of credit constraints, transfers, pensions, and idiosyncratic productivity shocks. As a consequence, and according well with the empirical evidence presented by Huggett and Ventura (2000), low-income households save at a lower rate than high-income households in our model.

The second effect of inflation on the distribution of wealth that we emphasise in our work is a portfolio composition effect. As inflation increases, households would like to save more in the form of capital rather than in the form of money. However, households face various forms of transaction costs in order to participate in the stock market. In our model, we consider three different kinds of transaction costs that have been suggested in the literature: i) a fixed entry costs, ii) costs that are associated with maintaining one's asset position, and iii) costs that are associated with the change of one's asset position. Low-wealth households might find these costs prohibitive and, consequently, they do not enter the stock market at all. Our mechanism is in accordance with that of Chatterjee and Corbae (1992). In their general monetary equilibrium model (without a production sector and an exogenous labor income), agents have to pay a fixed cost each time they enter the asset market. They show that a subset of agents holds currency even when it is dominated in return by a competing asset and even if it does not yield direct utility. In such an economy, a permanent increase

[5] Contrary to Erosa and Ventura (2002), we also allow for higher income mobility and assume a finite lifetime so that our model is able to match the empirical inequality of the wealth distribution more closely.

in inflation may have different effects on wealth-poor and wealth-rich agents. All agents reduce their money holdings, but only the rich will shift part of their wealth into capital. As a consequence, wealth heterogeneity may well increase.

In the following study we will compare the effect of a high and a low-inflation regime on the distribution of wealth. In particular, we will look at the two inflation rates, 6.43% and 3.06%, which amount to the average inflation rates during the Volcker (1979-87) and Greenspan eras (1988-2003), respectively. We will show both that savings are lower and the distribution of wealth is more unequal during the high-inflation period. The remainder of the paper is structured as follows. Section 2 introduces the overlapping-generations model with two assets, money and equity. The model is calibrated with regard to the characteristics of the US economy in section 3. Our numerical results are presented in section 4. Section 5 concludes.

2 The model

We study a general equilibrium overlapping generations model with endogenous equity and money distribution. Three sectors can be charted: households, production, and the government. Households maximize discounted life-time utility. Agents can save either with money or with capital. Individuals are heterogeneous with regard to their productivity and cannot insure against idiosyncratic income risk. Firms maximize profits. Output is produced with the help of labor and capital. The government collects taxes from labor and interest income in order to finance its expenditures on government consumption. The government also provides social security and controls the money supply.

2.1 Households

Every year, a generation of equal measure is born. The total measure of all generations is normalized to one. As we only study steady-state behavior, we concentrate on the behavior of an individual born in period 0. Their first period of life is period 1. The total measure of all households is normalized to one.

Households live a maximum of $T + T^R$ years. Lifetime is stochastic and agents face a probability s_j of surviving up to age j conditional on surviving up to age $j-1$. During their first T years, agents supply one unit of labor inelastically. After T years, retirement is mandatory. Household h maximizes her life-time utility:

$$E_0 \left[\sum_{j=1}^{T+T^R} \beta^{j-1} \left(\Pi_{l=1}^{j} s_l \right) u(c_{jt}^h, m_{jt}^h), \right] \tag{1}$$

where β, c_{jt}^h, and m_{jt}^h denote the discount factor, consumption and real money balances of the j-year old household h in period t, respectively. The instantaneous utility function $u(c,m)$ is the CRRA (constant relative-risk aversion) function:

$$u(c,m) = \frac{\left(c^{\gamma} m^{1-\gamma}\right)^{1-\sigma}}{1-\sigma} \tag{2}$$

where $\sigma > 0$ denotes the coefficient of relative risk aversion.

Workers are heterogeneous with regard to their labor earnings. Labor earnings $e(z,j)w_t$ are stochastic and depend on individual age j, an idiosyncratic labor productivity shock z, and the wage rate w_t. Furthermore, agents hold two kinds of assets, real money m and capital k. They are born without any capital, $k_{1t}^h \equiv 0$. For technical reasons, we assume that the first generation is endowed with a small amount of nominal money, $m_{1t}^h = \bar{m}_0$.[6] Capital or, equally, equity k earns a real interest rate r, but it is costly to enter the stock market. We will analyze three different forms of transaction costs. Following Campbell, Cocco, Gomes, and Maenhout (2001) and Gomes and Michaelides (2005), we introduce a fixed cost F of entering the stock market. These costs can be interpreted as the transaction costs from opening a brokerage account and the opportunity costs of acquiring basic information about the functioning of the stock market. Once the fixed cost F has been paid, these costs never accrue again. As a second transaction cost, we also introduce costs of maintaining a given level of equity that are proportional to equity. These costs may reflect the costs of maintaining a deposit and the opportunity costs of information about the stock market. Finally, we consider costs associated with the change of one's asset position. These costs, among others, reflect brokerage fees.[7] We further assume a short-sale constraint $k_{jt}^h \geq 0$.

[6]Otherwise, the level of utility at age 1 is not well-defined.

[7]Vissing-Jørgensen (2002) analyze the contribution of these different forms of transactions costs in order to explain the household portfolio choice.

Parents do not leave altruistic bequests to their children. All accidental bequests are confiscated by the state.

The j-year old agent h receives income from capital $k_{j,t}^h$ and labor $e(z_t^h, j)w_t$ in period t. After retirement agents do not work, $e(z, j) = 0$ for $j > T$. The nominal budget constraint of the j-year old household h in period t, $j = 1, \ldots, T + T^R$, is given by:[8]

$$
\begin{aligned}
&P_t k_{j+1,t+1}^h - P_{t-1} k_{j,t}^h + M_{j+1,t+1}^h - M_{j,t}^h = (1-\tau_i) i_t P_{t-1} k_{j,t}^h + (1-\tau_w-\theta) P_t w_t e(z_t^h, j) \\
&+ P_t tr_t - P_t c_t^h - (f_{j+1,t+1}^h - f_{j,t}^h) P_t F - \kappa P_t k_{jt}^h - \rho P_t (k_{j+1,t+1}^h - k_{j,t}^h) + P_t b(\bar{e}_{jt}^h) \qquad (3)
\end{aligned}
$$

where P_t, $\pi_t = \frac{P_t - P_{t-1}}{P_{t-1}}$, and i_t denote the price level, the inflation rate, and the nominal interest rate in period t, respectively. Nominal interest and wage income are taxed at the income rates τ_i and τ_w, respectively. Labor income is also subject to a social security tax θ. In addition, the households receive transfers tr_t from the government. Social security benefits $b_t(\bar{e}^h, j)$ depend on the agent's age j as well as on an average of past earnings $\bar{e}^h$ of the household h. Following Huggett and Ventura (2000), social security benefits are composed of a lump-sum component and an earnings-related benefit:

$$
b(\bar{e}_{j,t}) = \begin{cases} 0 & \text{for } j \leq T \\ b_0 + b_1(\bar{e}_{j,t}) & \text{for } j > T \end{cases} \qquad (4)
$$

The function $b_1(\bar{e}_{j,t})$ is described in more detail in section 3. The household also pays various forms of transaction costs to participate in the stock market. f denotes a binary variable that equals zero until the investor pays the fixed cost F of entering the stock market and equals one thereafter. Furthermore, transaction costs that are both proportional to the capital stock and to its change accrue at the amount of κk_{jt}^h and $\rho(k_{j+1,t+1}^h - k_{j,t}^h)$,[9] respectively.

[8] At the end of the final period, $k_{T+T^R+1,t}^h = M_{T+T^R+1,t}^h \equiv 0$.

[9] Following He and Modest (1995), we assume the transaction costs to be paid in proportion to the amount traded. Heaton and Lucas (1996) also consider a quadratic cost function, but mainly for computational simplicity. One could also argue that transaction costs on the amount traded are characterized by decreasing returns to scale.

We will only consider the steady state, where the wage rate w, the nominal interest rate i, the inflation rate π, and governmental transfers tr are constant. We therefore omit the time index t of these constant variables in the following. Dividing (3) by P_t and noticing that $m_t = M_t/P_t$ results in:

$$\begin{aligned}&k^h_{j+1,t+1} + m^h_{j+1,t+1}(1+\pi) = \frac{1+(1-\tau_i)i}{1+\pi}k^h_{j,t} + m^h_{j,t} + (1-\tau_w-\theta)we(z^h_t, j) + tr \\ &-c^h_{j,t} - (f^h_{j+1,t+1} - f^h_{j,t})F - \kappa k^h_{jt} - \rho(k^h_{j+1,t+1} - k^h_{j,t}) + b(\bar{e}^h_{jt}). \qquad (5)\end{aligned}$$

Total wealth a is composed of capital k and real money m, $a = k + m$. The relation of the real interest rate r and the nominal interest rate i is described by the 'Fisher equation', $i = (1+r)(1+\pi) - 1$. Notice that an increase in inflation π that leaves the real interest rate unchanged results in a higher real tax burden ceteris paribus, which is the nominal interest effect of inflation emphasized by Feldstein (1982).

2.2 Production

Firms are of measure one and produce output with effective labor N and capital K. Effective labor N is paid the wage w. Capital K is hired at rate r and depreciates at rate δ. Production Y is characterized by constant returns to scale and assumed to be Cobb-Douglas:

$$Y = F(K, N) = K^\alpha N^{1-\alpha}. \qquad (6)$$

In a factor market equilibrium, factors are rewarded with their marginal product:

$$\begin{aligned} w &= (1-\alpha)K^\alpha N^{-\alpha}, & (7)\\ r &= \alpha K^{\alpha-1}N^{1-\alpha} - \delta. & (8)\end{aligned}$$

2.3 Government

The government consists of the fiscal and monetary authority. Nominal money grows at the exogenous rate μ:

$$\frac{M_t - M_{t-1}}{M_{t-1}} = \mu. \qquad (9)$$

The government uses the revenues from taxing nominal income and seignorage as well as aggregate accidental bequests Beq in order to finance its expenditures on government consumption G, government transfers Tr, and transfers to the one-year old households $\tilde{m}$:[10]

$$\frac{\tau i K}{1+\pi} + \tau w N + Beq + \frac{M_t - M_{t-1}}{P_t} = PG + Tr + \tilde{m}. \tag{10}$$

Furthermore, the government provides social security benefits that are financed by taxes.

2.4 Stationary equilibrium

The concept of equilibrium applied in this paper uses a recursive representation of the consumer's problem following Stokey, Lucas, and Prescott (1989). Let $\phi_j(k, m, \bar{e}, z, f)$ and $V_j(k, m, \bar{e}, z, f)$ denote the measure and the value of the objective function of the j-year old agent with equity k, real money m, average earnings $\bar{e}$, idiosyncratic productivity level z, and either prior stock market participation $f = 1$ or not $f = 0$, respectively. $V_j(k, m, \bar{e}, z, f)$ is defined as the solution to the dynamic program:

$$V_j(k, m, \bar{e}, z, f) = \max_{k', m', f', c} \left\{ u\left(c, m\right) + \beta s_{j+1} E\left[V_{j+1}(k', m', \bar{e}', z', f')\right] \right\} \tag{11}$$

subject to (5) and $k, m, k', m' \geq 0$. k', m', f', $\bar{e}'$, and z' denote the next-period value of k, m, f, $\bar{e}$, and z, respectively. Optimal decision rules at age j are a function of k, m, $\bar{e}$, z, and f, i.e. consumption $c_j(k, m, \bar{e}, z, f)$, next-period capital stock $k_{j+1}(k, m, \bar{e}, z, f)$, next-period real money balances $m_{j+1}(k, m, \bar{e}, z, f)$, and next-period stock market participation $f_{j+1}(k, m, \bar{e}, z, f)$.

We will consider a stationary equilibrium where factor prices, aggregate capital, and labor are constant and the distribution of wealth is stationary.

[10] We assume that the first-period money balances are financed by the government from, for example, accidental bequests. Alternatively, we could have modelled an intergenerational structure as in Laitner (1992,1993) and assume that the 50-year old agents (corresponding to $j = 30$) leave their 20-year old children (corresponding to $j = 1$) $\bar{m}_0$. In this case, we would have also made the assumption that agents do not die until age $j = 30$, which is in good accordance with empirical survival probabilities. Our results, however, are not affected by our modelling choice with regard to the financing of $\tilde{m}$.

Definition

A stationary equilibrium for a given government policy $\{\tau_i, \tau_w, \theta, G, tr, b(.), \mu\}$ is a collection of value functions $V_j(k, m, \bar{e}, z, f)$, individual policy rules $c_j(k, m, \bar{e}, z, f)$, $k' = k_{j+1}(k, m, \bar{e}, z, f)$, $m' = m_{j+1}(k, m, \bar{e}, z, f)$, and $f' = f_{j+1}(k, m, \bar{e}, z, f)$, relative prices of labor and capital $\{w, r\}$, and distributions $(\phi_1(.), \ldots, \phi_{T+T^R}(.))$, such that:

1. Individual and aggregate behavior are consistent:

$$\begin{aligned}
N &= \sum_{j=1}^{T} \sum_{f=0,1} \int_k \int_m \int_{\bar{e}} \int_z e(z,j)\phi_j(k, m, \bar{e}, z, f)\, dz\, d\bar{e}\, dm\, dk, \\
K &= \sum_{j=1}^{T+T^R} \sum_{f=0,1} \int_k \int_m \int_{\bar{e}} \int_z k\ \phi_j(k, m, \bar{e}, z, f)\, dz\, d\bar{e}\, dm\, dk, \\
C &= \sum_{j=1}^{T+T^R} \sum_{f=0,1} \int_k \int_m \int_{\bar{e}} \int_z c_j(k, m, \bar{e}, z, f)\ \phi_j(k, m, \bar{e}, z, f)\, dz\, d\bar{e}\, dm\, dk, \\
Beq &= \sum_{j=1}^{T+T^R} \sum_{f=0,1} \int_k \int_m \int_{\bar{e}} \int_z (1 - s_{j+1})\, a_{j+1}(k, m, \bar{e}, z, f)\phi_j(k, m, \bar{e}, z, f) dz\, d\bar{e}\, dm\, dk, \\
\frac{M}{P} &= \sum_{j=1}^{T+T^R} \sum_{f=0,1} \int_k \int_m \int_{\bar{e}} \int_z m\ \phi_j(k, m, \bar{e}, z, f)\, dz\, d\bar{e}\, dm\, dk, \\
\tilde{m} &= \int_{\bar{e}} \int_z \bar{m}_0 \phi_j(0, m_1, \bar{e}, z, 0)\, dz\, d\bar{e},
\end{aligned}$$

   where $a_{j+1}(k, m, \bar{e}, z, f) \equiv k_{j+1}(k, m, \bar{e}, z, f) + m_{j+1}(k, m, \bar{e}, z, f)$.

2. Relative prices $\{w, r\}$ solve the firm's optimization problem by satisfying (7) and (8).

3. Given relative prices $\{w, r\}$ and government policy $\{\tau_i, \tau_w, \theta, b(.), G, tr, \mu\}$, individual policy rules $c_j(.)$, $k_{j+1}(.)$, $m_{j+1}(.)$, and $f_{j+1}(.)$ solve the consumer's dynamic program (11).

4. The government budget (10) is balanced.

5. Social security benefits equal taxes:

$$\theta w N = \sum_{j=T+1}^{T+T^R} \sum_{f=0,1} \int_k \int_m \int_{\bar{e}} \int_z b(\bar{e}, j)\phi(_j(k, m, \bar{e}, z, f)\, dz\, d\bar{e}\, dm\, dk. \quad (12)$$

6. Money grows at the exogenous rate μ.

7. The goods market clears:

$$K^{\alpha}N^{1-\alpha} = C + G + \delta K + TC \tag{13}$$

In particular, stock market transaction costs are a social cost:

$$\begin{aligned} TC \;=\; & \sum_{j=1}^{T+T^R-1} \int_k \int_m \int_{\bar{e}} \int_z F \cdot f_{j+1}(k,m,\bar{e}z,0)\phi_j(k,m,\bar{e},z,0)\; dz\; d\bar{e}\; dm\; dk, \\ & + \sum_{j=1}^{T+T^R-1} \int_k \int_m \int_{\bar{e}} \int_z \rho\left(k'(k,m,\bar{e},z,f)-k\right)\phi_j(k,m,\bar{e},z,f)\; dz\; d\bar{e}\; dm\; dk, \\ & + \sum_{j=1}^{T+T^R} \int_k \int_m \int_{\bar{e}} \int_z \kappa\; k\; \phi_j(k,m,\bar{e},z,f)\; dz\; d\bar{e}\; dm\; dk. \end{aligned} \tag{14}$$

3 Calibration

Periods correspond to years. We assume that agents are born at the real lifetime age 20 which corresponds to $j = 1$. Agents work $T = 40$ years corresponding to a real lifetime age of 60. They live a maximum life of 60 years ($T^R = 20$) so that agents do not become older than the real lifetime age 79. The sequence of conditional survival probabilities $\{s_j\}_{j=1}^{59}$ is set according to the Social Security Administration's survival probabilities for men aged 20-78 for the year 1994.[11] The survival probabilities decrease with age, and s_{60} is set equal to zero.

The calibration of the production parameters α and δ and the Markov process $e(z,j)$ is chosen in accordance with existing general equilibrium studies: Following Prescott (1986), the capital income share α is set equal to 0.36. The annual rate of depreciation is set at $\delta = 0.08$. We consider three models of earnings in order to analyze the contribution of the earnings differences to the effects of inflation on savings. Earnings are the product of real wage per efficiency unit times the labor endowment $e(z,j)$. In the first two models, Models I and II, the labor endowment process is given by $e(z,j) = e^{z_j+\bar{y}_j}$, where $\bar{y}_j$ is the mean

[11] We thank Mark Huggett and Gustavo Ventura for providing us with the data.

lognormal income of the j-year old. The mean efficiency index $\bar{y}_j$ of the j-year-old worker is taken from Hansen (1993) and interpolated to in-between years. As a consequence, Models I and II are able to replicate the cross-section age distribution of earnings of the US economy. Following İmrohoroğlu, İmrohoroğlu, and Joines (1998), we normalize the average efficiency index to one. The age-productivity profile is hump-shaped and earnings peak at age 50. In the Model I, agents differ in log labor endowments at birth and there is no income mobility within an age cohort so that $z_j = z_{j-1}$ for all $j > 1$.[12] In the Model II, the idiosyncratic productivity shock z_j follows a Markov process:

$$z_j = \rho z_{j-1} + \epsilon_j, \tag{15}$$

where $\epsilon_j \sim N(0, \sigma_\epsilon)$. Huggett (1996) uses $\rho = 0.96$ and $\sigma_\epsilon = 0.045$. Furthermore, in both Models I and II, we follow Huggett and choose a lognormal distribution of earnings for the 20-year old with $\sigma_{y_1} = 0.38$ and mean $\overline{y_1}$. As the log endowment of the initial generation of agents is normally distributed, the log efficiency of subsequent agents will continue to be normally distributed. This is a useful property of the earnings process, which has often been described as lognormal in the literature. The Model I and II are also able to replicate the earnings heterogeneity that is observed in US data. Henle and Ryscavage (1980) compute an earnings Gini coefficient for men of 0.42 in the period 1958-77. In the two models, the Gini coefficient also amounts to 0.424.

In Model III, we will use the calibration of the earnings income process as in İmrohoroglu (1992). In her model agents can either be employed ($e = 1$) or unemployed ($e = 0$) and the possibility of a low unemployment income may have important quantitative effects on equilibrium values and welfare.[13] In particular, we follow İmrohoroglu (1992) and assume that the income of the unemployed is 1/4 of the income of the employed worker.[14]

[12] In our Model I, we also dispense of the nonnegativity constraint and allow for $k, k' < 0$. We find the nonnegativity constraint to have only negligible effects in this case (under idiosyncratic certainty) and it allows us to compute the equilibrium values of the model at very high accuracy (10^{-8}) (see also the appendix).

[13] We would like to thank an anonymous referee for suggesting this kind of analysis to us.

[14] In İmrohoroglu (1992) labor income is exogenous. As we prefer to consider a general equilibrium model with endogenous savings and capital accumulation, the wage income is endogenous in our model and also depends on the rate of inflation.

Therefore, we distinguish two kinds of worker with productivities $e^{z_1} = 0.25$ and $e^{z_2} = 1.0$.[15] In our Model III, we further set the matrix of the Markov transition probabilities from this period employment status to next-period employment status in accordance with İmrohoroglu (1992):[16]

$$\begin{pmatrix} 0.9565 & 0.0435 \\ 0.500 & 0.500 \end{pmatrix}^6 = \begin{pmatrix} 0.9207 & 0.07931 \\ 0.9116 & 0.0884 \end{pmatrix},$$

where the first (second) row of the matrix describes the probabilities of becoming employed and unemployed for the employed (unemployed) agent. In the first period of life, 92% of the workers are employed, while 8% of the workers are unemployed.

The social security payment $b(\bar{e}, j)$ is calibrated and parameterized in order to match the US Social Security System and exactly follows Huggett and Ventura (2000).[17] Average earnings $\bar{e}_{j,t}$ of the j-year old in period t accumulate according to:

$$\bar{e}_{j,t} = \begin{cases} \left(\bar{e}_{j-1,t-1}(j-1) + \min\left\{e(z_t^h, j)w_t, e_{max}\right\}\right)/j & \text{for } j \leq T \\ \bar{e}_{j-1,t-1} & \text{else.} \end{cases} \tag{16}$$

Notice that in the US benefits depend on mean earnings that are indexed so that later contributions in life are not discounted. Furthermore, average earnings are only calculated for up to some maximum earnings level e_{max} which amounts to 2.47 times average earnings $\bar{E}$.[18] Following Huggett and Ventura, we set the lump-sum benefit b_0 equal to 12.42% of GDP per capita in the model economy. Finally, benefits are regressive and a concave function of average earnings. Let $\bar{e}^h$ and $\bar{E}$ denote the average earnings of individual h and the average earnings of all workers, respectively. Depending on which earnings bracket the retired agent's average earnings $\bar{e}^h$ were situated, he received 90% of the first $20\% \cdot \bar{E}$, 32% of the next 104% of $\bar{E}$, and 15% of the remaining earnings $(\bar{e}^h - 1.24\bar{E})$ in 1994. Therefore, the marginal benefit rate declines with average earnings. The social security contribution

[15] We further set $e^{\bar{y}_j} \equiv 1$.

[16] Her model is calibrated for a period equal to 1/6 of a year.

[17] For a more detailed description of this procedure please see Huggett and Ventura (2000).

[18] In the US Social Security System, only the 35 highest earnings payments are considered in the calculation of the average earnings. We simplify the analysis by using all 40 working years in our model.

Table 1: Calibration of parameter values for the US economy

Description	Function/Parameter	Parameter Value
utility function	$U = \frac{\left(c^{\gamma} m^{1-\gamma}\right)^{1-\sigma}}{1-\sigma}$	$\sigma = 2.0$, $\gamma = 0.977$ (Model I-II), $\gamma = 0.980$ (Model III)
discount factor	β	$\beta = 1.011$
production function	$Y = K^{\alpha} N^{1-\alpha}$	$\alpha = 0.36$
depreciation	δ	$\delta = 0.08$
stock market transaction costs	F, ρ, κ	$F \in \{0, 0.1Y\}$, $\rho \in \{0, 0.2\%\}$, $\kappa \in \{0, 0.25\%\}$
money growth rate	θ	$\theta = 0.0432$
income tax rates	τ_w, τ_i	$\tau_i = 42.9\%$, $\tau_w = 24.8\%$
government consumption	G	$G/Y = 19.5\%$
social security benefits		
maximum earnings level	e_{max}	$e_{max} = 2.47\bar{E}$
lump-sum benefit	b_0	$b_0 = 0.1241Y$
$b_1(\bar{\epsilon})$	earnings bracket	marginal benefit rate
	$[0, 0.2\bar{E}]$	0.90
	$(0.2\bar{E}, 1.24\bar{E}]$	0.32
	$1.24\bar{E} < \bar{e} \leq e_{max}$	0.15

rate θ is calibrated so that the budget of the social security balances. The remaining parameters of the government policy that we need to calibrate are the two tax rates τ_i and τ_w and government expenditures G. The two tax rates $\tau_i = 42.9\%$ and $\tau_w = 24.8\%$ are computed as the average values of the effective US tax rates over the time period 1965-88 that are reported by Mendoza, Razin, and Tesar (1994). The share of government consumption in GDP is $G/Y = 19.5\%$, which is equal to the average ratio of G/Y in the US during 1959-93 according to the Economic Report of the President (1994). The model parameters are presented in table 1.

We choose the coefficient of risk aversion $\sigma = 2$.[19] The discount rate $\beta = 1.011$ is set equal to the estimate of Hurd (1989). Notice that in finite-life time models the discount rate need not be below 1.0. The remaining parameter γ from the utility function is chosen to match the average velocity of money PY/M. During 1960-2001, the average annual velocity of M1 amounted to 5.18, while the average inflation rate was equal to 4.32%. We set $\gamma = 0.977$ implying a velocity of money in our benchmark model without productivity mobility (our Model I) equal to 5.12 (for $\pi = 4.32\%$). In Model III, average earnings are much lower than in the Model I and II. Therefore, we have to set $\gamma = 0.980$ in Model III so that the velocity of money equals $PY/M = 5.13$ for $\pi = 4.32\%$. The initial endowment with real money $\bar{m}_0$ is chosen so that the age-money profile is smooth.[20]

In our benchmark case, there are no stock market transaction costs in the benchmark, i.e. $F = 0$, $\rho = 0$, and $\kappa = 0$. We choose the values $\rho = 0.2\%$ and $\kappa = 0.25\%$ in accordance with Vissing-Jørgenson (2002). The upper value of F equal to 10% of the annual average income is taken from Campbell et al. (2001). The computation of the model is briefly described in the appendix.

[19] All our qualitative results also hold for the case $\sigma \in \{1, 4\}$.

[20] Therefore, for given initial money holding $\bar{m}_0$, we computed the average money holdings $\{\bar{m}_1, \bar{m}_2, \bar{m}_3, \ldots, \bar{m}_{60}\}$ in our Models I-III and used the money holdings $\bar{m}_i$, $i = 1, \ldots, 4$, in order to approximate the age-money function in the early years of life by a cubic polynomial. From this function, we computed $\bar{m}_0$. We iterated over $\bar{m}_0$ until it converged.

4 Results

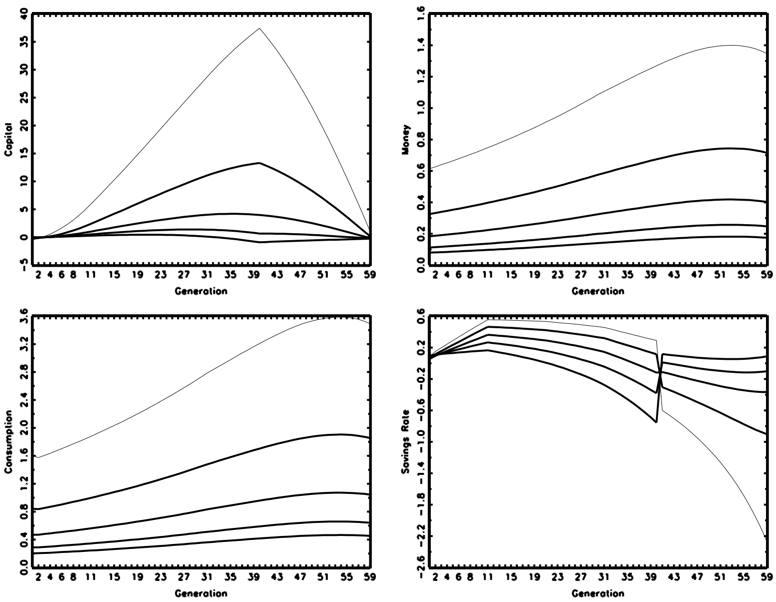
In this section, we study the effects of a change in the money growth rate θ or, equally, the inflation rate π on the accumulation and distribution of wealth. We will examine two different periods of US monetary history. The first period is the years 1988-2003 when Greenspan was (and still is) the chairman of the Fed and the average rate of inflation amounted to 6.43%. We compare our results with those for an inflation rate equal to 3.06% which was the average inflation rate under the chairmanship of Paul Volcker during 1979-87. This section is structured as follows. First, we report findings for the effect of the inflation rates on savings. We show that the magnitude and the direction of the effect depend on the behavior of the capital income tax rate. This behavior is best illustrated in Model I where agents do not switch their productivity type and where we can derive the money-age profiles for individual productivities. Second, we study how inflation affects the distribution of wealth and welfare. For this reason, we also account for productivity mobility which has been pointed to as a major contributing factor in the explanation of the individual savings rate by Huggett and Ventura (2000). So we turn our attention to Model II. In addition, we investigate the effects of stock market costs on savings and the distribution of wealth. Finally, we compare our results with those of İmrohoroğlu (1992) and consider Model III where agents may experience the shock of very low labor income.

4.1 Inflation, savings, and portfolio composition

In our Model I agents are characterized by heterogenous productivity but do not change their productivity type. We therefore plot the behavior of capital, money, consumption, and the savings rate over the life-cycle. Figure 1 describes the behavior of the households in an economy with 5 different productivity types in our benchmark (without credit constraint and stock market transaction costs). The inflation rate is set equal to 3.06% corresponding to the Greenspan era. Savings are defined as the change in wealth, $k_{j+1,t+1} + m_{j+1,t+1} - k_{j,t} - m_{j,t}$, while income consists of net capital income, net wage income or pensions, and transfers.

As typically found in life-cycle models, agents build up capital until retirement, $T = 40$,

Figure 1: Steady State of Model I



and decumulate savings thereafter. Of course the more productive agents build up higher savings during their working life, with a corresponding higher savings rate, and also have a higher rate of dissaving in old age (please see lower right picture in figure 1). Consumption is hump-shaped over the life-cycle (and accords well with empirical observations) as the net interest rate exceeds the inverse of the discount factor β in young years. Since the survival probability declines in old age, the discount factor increases and consumption declines again. The effects of a change in inflation from 3.06% (the Greenspan regime) to 6.43% (the Volcker regime) are illustrated in the second and in the third rows of table 2. In our economy, savings decline with higher inflation. Notice that the effect is very pronounced. An absolute increase in the inflation rate by 3.37% results in a percentage decline of the capital stock by 13.6%. Similar large effects of inflation on savings have also been found in other general equilibrium models as in den Haan (1990) or Altig and Carlstrom (1991).

In order to understand how inflation affects savings in our model, it is most instructive to turn to the standard Sidrauski model. It is a well-known result that money is superneutral in the Sidrauski of an infinitely-lived representative agent model when labor supply is exogenous. This can be easily understood by a look at the first-order condition of the

Table 2: Effect of inflation on savings, Model I

Case	$\{F, \rho, \kappa\}$	π	K	M/P	Y	tr	$Gini_k$
Greenspan	$\{0, 0, 0\}$	3.06%	3.426	0.3487	1.454	0.1496	57.2%
Volcker	$\{0, 0, 0\}$	6.43%	2.959	0.2238	1.380	0.1724	58.9%
Volcker**	$\{0, 0, 0\}$	6.43%	3.495	0.2247	1.4646	0.1532	57.6%

household with respect to capital. For ease of illustration, we will consider the case without transaction costs in the stock market, $F = \rho = \kappa = 0$. In this case the first-order condition of the household h at age j in period t in our OLG model is given by:

$$\lambda_{j,t}^{h} = \beta E_t \left[\lambda_{j+1,t+1}^{h} \left(\frac{1 + (1 - \tau_i) i}{1 + \pi} \right) \right], \tag{17}$$

with

$$\lambda_{j,t}^{h} = u_c \left(c_{j,t}^{h}, \frac{M_{j,t}^{h}}{P_t} \right) = \gamma \left(c_{j,t}^{h} \right)^{\gamma(1-\sigma)-1} \left(m_{j,t}^{h} \right)^{(1-\gamma)(1-\sigma)}.$$

(17) reflects the case of a constant tax rate on nominal interest income, which we find in practice. If nominal interest rate taxes are indexed with regard to inflation so that the tax rate τ_r on real interest income rk is constant, the first-order condition of the household is given by the following equation instead:

$$\lambda_{j,t}^{h} = \beta E_t \left[\lambda_{j+1,t+1}^{h} \left(1 + r(1 - \tau_r) \right) \right]. \tag{18}$$

In the representative-agent economy with an infinitely-lived household, (18) is given by the following familiar Euler equation:

$$\lambda_t = \beta E_t \left[\lambda_{t+1} \left(1 + r(1 - \tau_r) \right) \right]. \tag{19}$$

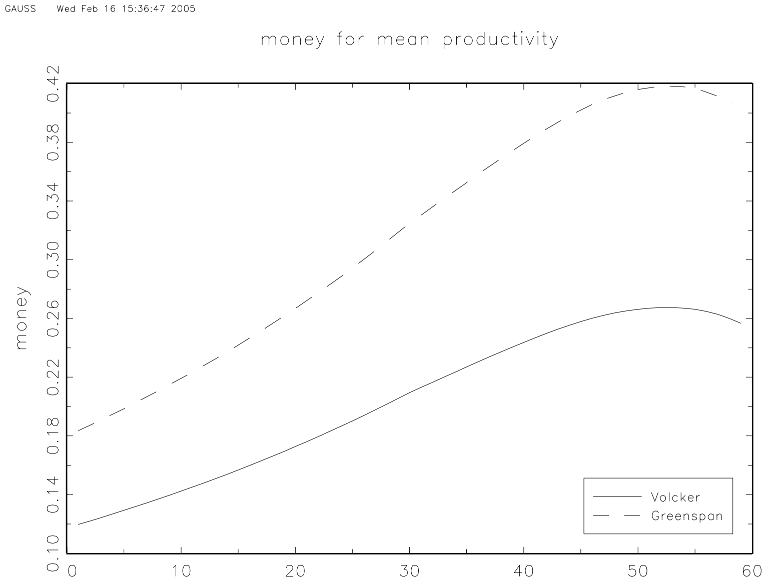
In steady state, $\lambda_t = \lambda_{t+1}$, and the interest rate is pinned down by the values of β and τ_r. As labor supply is exogenous, β and τ_r also determine K via (8). In particular, the real interest rate r in equation (19) does not depend on the inflation rate π. This is the famous super-neutrality result in the Sidrauski model. In the life-cycle model this result does not hold any more. The reason is straightforward. In steady state the real interest rate in (18) also depends on the ratio of the marginal utility of consumption at age j and $j+1$ and, in particular, is a function of m_{j+1}/m_j. If the inflation rate changes, households adjust their portfolio at each age. However the percentage change in the real money balances is not the same at each age. This effect is illustrated in figure 2 for the agent with the mean productivity in Model I. Agents decrease their real money holdings in the Volcker period, but younger agents by a smaller share than older agents. For example, the 2-year old (corresponding to real lifetime age 21) and the 59-year household (corresponding to real lifetime age 78) decrease their money holdings by 34.8% and 36.2% following a increase in the inflation rate from 3.06% to 6.43%, respectively. As a consequence the steady state rate of real interest declines and the capital stock increases. This effect is displayed in the last row of table 2. In the scenario 'Volcker**', we kept the tax rate on the real interest rate constant. The capital stock increases from 3.426 to 3.495 following an increase in inflation from 3.06% to 6.43%.[21]

The empirical evidence, however, supports our assumption that the government does not adjust the nominal capital income tax rate perfectly for inflation and that, therefore, the real capital income tax rate increases with higher inflation.[22] This relationship is considered in the Euler equation (17) that is used for the computation of our results presented in the second row of the table 2 (and the values presented in table 3 in the

[21]Interestingly, steady-state welfare decreases by 0.04% of total consumption following an increase in inflation even though output and savings increase and are sub-optimal in our OLG model due to the presence of lump-sum pensions.

[22]In order to verify this conjecture, we regressed the effective capital income tax rate on the inflation rate. We found the coefficient of the inflation rate significant, both statistically and quantitatively. We used data from the US economy during 1965-98. We computed the effective capital tax rates by following the strategy described in Mendoza et al. (1994). Accordingly, we relied on data obtained from the OECD Statistical Compedium annual series (Revenue Statistics, National Accounts I, and Economic Outlook). For further detail see Mendoza et al. (1994), p. 300-306. As we are aiming to investigate the long-term relationship between the capital income tax rate and inflation, we extracted and analyzed trend components from the respective series. We used an HP filter with a weight of 6.25 as recently suggested for series of annual frequency by Ravn and Uhlig (2002).

Figure 2: Age-money profile in Model I for Greenspan and Volcker era (constant taxes on real capital income)



following section). Obviously, savings decline substantially with a permanent increase in inflation, from $K = 3.426$ to $K = 2.959$. Our results can be interpreted as an upper bound to the empirically observable effect of the 'Feldstein channel'. In our model, we assume that all capital income is imperfectly indexed for tax purposes.[23] As already indicated by Altig and Carlstrom (1991),[24] individuals may "partially escape the distortionary effects of inflation on capital income by changing the way in which claims on capital are structured. We are thinking particulary of shifts between debt and equity."

4.2 Inflation, distribution of wealth, and welfare

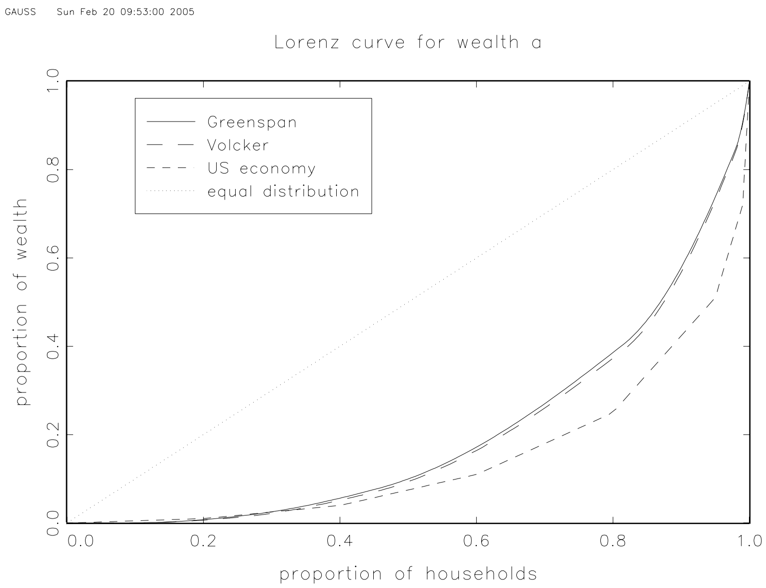
The distribution of wealth In order to study the effects of inflation on the distribution of wealth we turn our attention to Model II where individuals are subject to an idosyncratic

[23]We would like to thank an anonymous referee for pointing this out to us.

[24]We use the same nominal tax structure in our model as Altig and Carlstrom, except that the latter also model progressive income taxation.

productivity shock. The presence of earnings mobility has two opposite effects on the concentration of wealth. On the one hand, earnings mobility decreases wealth inequality because high-income and wealth-rich agents who have high productivity may move down the income ladder and subsequently accumulate less savings. On the other hand, agents build up precautionary savings in order to insure against the risk of productivity and income loss. The second effect dominates, and the Gini coefficient of wealth is higher in Model II (0.615) than in Model I (0.572). The distributions of wealth for the US economy (lower broken line) and for our Model II (the low-inflation era of Greenspan and the high-inflation era of Volcker) are illustrated in figure 3.[25]

Figure 3: Lorenz wealth curve



Empirically, wealth is highly concentrated and is distributed much more unequally than income. Greenwood (1983), Wolff (1987), Kessler and Wolff (1992), and Díaz-Giménez et al. (1997) estimate Gini coefficients of the wealth distribution for the US economy in the range of 0.72 (single, without dependents, female household head) to 0.81 (nonworking household head). Our model is able to replicate these findings and to explain the concentration of wealth to a large extent. However, the empirical distribution that is presented by

[25]The data for the empirical distribution of wealth are taken from Wolff (1987).

the lower broken line in figure 3 displays a higher concentration of wealth among the very wealth-rich agents than the model distribution. The main reason why our model underestimates the high concentration of wealth among the top 5% of the wealthiest households is the negligence of i) self-employment and ii) bequests.[26]

The results for our Model II are summarized in table 3. Notice that the capital stock is much higher in Model II ($K = 4.036$) than in Model I ($K = 3.426$) due to the presence of precautionary savings. An increase in the inflation rate from 3.03% (first row of entries in table 3) to 6.43% (fifth row of entries in table 3) results in a significant decline of the capital stock equal to 12.6%. This huge effect is caused by the increase in the after-tax real interest rate. As a consequence, the wealth distribution also becomes more concentrated because the wealth rich agents reduce their savings by a smaller proportion than the wealth-poor agents. The Gini coefficient of wealth increases from 0.615 to 0.641. The distributions of wealth under the Greenspan and Volcker regimes are graphed in figure 3, respectively. Even though upon inspection the change in the distribution may seem to be quite small, please keep in mind that we only consider a relatively small change of the inflation rate as well. Notice further that even though inflation increases and the return on money relative to that on capital actually declines, fewer agents participate in the stock market. The stock market participation rate SMP as illustrated in the last but one column in table 3 falls from 83.3% to 80.1%. Associated with the increase in inflation is an increase in tax receipts by the government (even though total income falls). As we assume government expenditures to be constant under each regime, transfers increase and a higher proportion of income-poor agents has no incentive to save.

Welfare We also analyze steady-state welfare for the different monetary policy regimes θ. For this reason, we compute the expected discounted lifetime utility of the newborn generation for the different values of θ. To assess the effects quantitatively we take the

[26]For a review of recent studies that explain the wealth distribution in general equilibrium models with, among others, the help of idiosyncratic shocks to labor earnings, business ownership, and changes in health and marital status see Quadrini and Ríos-Rull (1997). Heer (2001) studies the effects of bequests on the distribution of wealth.

Table 3: Effect of inflation and stock market costs on savings, Model II

$\{F, \rho, \kappa\}$	K	M/P	Y	$Gini_k$	SMP	Δ_c
Greenspan: $\pi = 3.06\%$						
$\{0, 0, 0\}$	4.036	0.4162	1.641	61.5%	83.3%	0%
$\{0.1Y, 0, 0\}$	3.964	0.4139	1.630	63.4%	74.6%	-1.31%
$\{0.1Y, 0.002, 0.00\}$	3.956	0.4135	1.629	63.4%	74.6%	-1.41%
$\{0.1Y, 0.002, 0.0025\}$	3.838	0.4120	1.611	64.2%	73.1%	-3.19%
Volcker: $\pi = 6.43\%$						
$\{0, 0, 0\}$	3.528	0.2831	1.563	64.1%	80.1%	-0.67%
$\{0.1Y, 0.00, 0.00\}$	3.478	0.2810	1.555	65.8%	72.0%	-1.70%
$\{0.1Y, 0.002, 0.00\}$	3.473	0.2807	1.554	65.8%	72.1%	-102.02
$\{0.1Y, 0.002, 0.0025\}$	3.382	0.2782	1.539	66.2%	71.6%	-3.54%

Greenspan era without stock market transaction costs as our benchmark case (first row of entries in table 3). The change in welfare Δ_c is computed as the compensation in consumption (relative to the reference economy) required in order to make the average newborn indifferent between the reference economy and the alternative policy regime. As presented in table 3, the steady-state welfare effect of an increase in the anticipated rate of inflation is considerable and amounts to a loss of 0.67% of total consumption. Our welfare result is similar to those obtained in other computable general equilibrium analyses. For example, Lucas (2000) finds that reducing the annual inflation rate from 10% to 0% is equivalent to an increase in real income of slightly less than one percent.

Transaction costs in the stock market Transaction costs in stock markets have been prominently applied in the explanation of the equity premium puzzle, e.g., by He and Modest (1995), or in the study of the effects of pension reform on retirement wealth, e.g., by Campbell et al. (2001). The reason for introducing stock market fees into our model is that the adverse effects of inflation on poor households' wealth and on the wealth distribution are exacerbated. Due to the high costs of entering the stock market most income-poor households hold wealth only in the form of money. As inflation increases these agents are affected more severely by the inflation tax and might reduce their precautionary money savings. In addition, it is not clear *a priori* whether higher inflation also results in higher stock market participation. On the one hand, the reduction in the costs of entering the stock market relative to the inflation tax makes capital a more attractive investment than money. On the other hand, agents who may have accumulated small wealth in the form of money if their productivity z is low, in case of a transitory positive productivity shock, may not have accumulated enough wealth to pay the fixed stock market costs.

The number of households with positive capital stock $k > 0$ amounts to 83.3% in the benchmark case with no stock market participation costs. This number is rather high considering that in 1998 only 38% of households held (tax-deferred) equity.[27] If we also consider the allocation of savings to interest earning bonds, however, the numbers are more favorable. From 1983-98, between 86% and 90% of all US households held interest bearing accounts. One possible reason why in our model the percentage of households participating in the stock market is at the upper limit of those numbers observed empirically is the negligence of investment in housing. Specifically, a leveraged position in residential estate may keep younger and poorer households from investing in the stock market.[28]

Of course, if we also consider stock market transaction costs the number of households participating in the stock market decreases. If we introduce both fixed costs and costs that are proportional to the stock held and the change of the capital stock, the participation rate decreases from 83.3% to 73.1%, as presented in the last but one column in table 3. Notice that the transaction costs imply a huge welfare loss equal to 3.19% of total consumption. The most marked effect on welfare results from the introduction of costs κ that are proportional to one asset's position. In this case, for $k_{j,t}^h > 0$, the first-order condition of the household with respect to capital $k_{j+1,t+1}^h$ changes to

$$\lambda_{j,t}^h (1+\rho) = \beta E_t \left[\lambda_{j+1,t+1}^h \left(\frac{1+(1-\tau_i)i}{1+\pi} + \rho - \kappa \right) \right],$$

and we have a significant drop in the capital stock by 3% from $K = 3.956$ ($\kappa = 0$) to $K = 3.838$ ($\kappa = 0.25\%$). Surprisingly, the introduction of stock market participation costs does not change our results for the effect of inflation on distribution and welfare. In fact,

[27] These figures and the following are based on data from the SCF (see Poterba and Samwick, 2004).

[28] Recently, Cocco (2004) demonstrates this result in a computable general equilibrium model.

the quantitative effect on an increase in the inflation rate from 3.06% to 6.43% is almost the same whether we have transaction costs or not. With transaction costs (fourth and last row of table 3), higher inflation results in a reduction in the capital stock by 4.1%, while in the case without transaction costs this number amounts to 4.9%. Similarly, the percentage drop in the stock market participation rate is almost the same and amounts to approximately 9 and 10 percentage points in both cases, respectively. The total loss in consumption from higher inflation is a little lower in the presence of stock market transaction costs and amounts to 0.45% rather than 0.67%. In summary, stock market participation costs are welfare reducing per se, but they do not contribute to a much higher welfare gain if the monetary authority moves from a high-inflation to a low-inflation policy.

4.3 The effects of a large negative income shock

In her seminal work, İmrohoroğlu (1992) considers the welfare effect of a reduction in the inflation rate from 10% to 0%. She computes a considerable welfare gain equivalent to an increase in total income equal to 1.07%. In the following we would like to study the reasons for this large effect. There are two possible candidates in her model: 1) a very strong negative income shock that corresponds to the state of unemployment or 2) the absence of an interest bearing asset. Similar to the model in our paper, she considers a heterogeneous-agent economy with imperfect insurance. The distribution of wealth is endogenous and agents are also subject to a productivity shock that corresponds to the two states of employment and unemployment. Her model differs from our economy in Model III, however, in that agents can only accumulate savings in the form of non-interest bearing money but not in the form of capital. Furthermore, the government does not impose any taxes. We will, therefore, compare her results with our results for the Model III where we keep taxes 1) on nominal interest payments and 2) on real interest payments constant. We will further consider an increase in the inflation rate from 3.06% to 6.43% rather than from 0% to 10% to be consistent with our prior analysis. Our results for the model without stock market participation costs are summarized in table 4.

If we assume an earnings process in our Model III equivalent to that of İmrohoroğlu

Table 4: Effect of on savings, distribution, and welfare, Model III

case	π	K	M/P	Y	$Gini_k$	SMP	Δ_c
Greenspan	3.06%	0.903	0.0865	0.379	38.9%	95.8%	0%
Volcker	6.43%	0.774	0.0559	0.359	39.3%	95.8%	- 4.01%
Volcker**	6.43%	0.911	0.0571	0.380	38.5%	96.2%	0.42%

(1992), wealth inequality falls relative to the earnings processes in Model I and II. Given that we also assume average productivity to be much lower in Model III than in Model I and II, K and Y are also lower than those values presented in table 2 and 3. If the monetary authority increases steady-state inflation from 3.06% to 6.43%, the capital stock falls, but the wealth inequality is hardly affected. The main result in this section is presented in the last column of table 4. If taxes on nominal interest taxation are kept constant, welfare losses from inflation are tremendous and amount to 4.01% of total consumption. In Model II, the corresponding welfare loss only amounted to 0.67%. Therefore, the presence of even a very strong negative productivity shock has a significant impact on the welfare effects of monetary policy. In addition, we find that even in the presence of constant real capital income taxes higher inflation results in a significant welfare loss. An increase in π from 3.06% to 6.43% implies steady-state welfare equivalent to 0.42% of consumption. In order to compare these results with those of İmrohoroğlu (1992) we assume that welfare costs are linear in the change of the inflation rate. In this case, a change of inflation by 10 percentage points would result in a loss of total consumption equal to 1.25% of total consumption or 0.78% of total income. In this sense, our results accord well with the findings of İmrohoroğlu (1992) even though we allow the agents to accumulate savings in the form of an interest-bearing asset. Our result, therefore, emphasizes the robustness of her findings.

5 Conclusion

Quantitative evidence for the effects of inflation on the distribution of wealth is scarce and ambiguous: While the early strand of literature like, e.g., Wolff (1979) lends support to the hypothesis that inflation[29] decreases wealth inequality, Erosa and Ventura (2002) find a wealth inequality increasing effect in anticipated inflation. This paper contributes to this literature by analyzing a computable general equilibrium model of the wealth distribution with capital income taxation and stock market entry fees. Our main result is to confirm Erosa and Ventura (2002), although on different grounds, finding that higher inflation increases wealth inequality significantly. In our model this result is due to the taxation of nominal interest income, while the effect of transaction costs in the stock market is relatively small.

In our model, we concentrate on the effects of anticipated inflation on the equality of the wealth distribution. It supports the position often argued in the literature that unanticipated inflation will redistribute income from the lender to the borrower and, as the borrower is wealth-poor compared with the lender, reduces the inequality of the wealth distribution. Accordingly, the result we present might not carry over to an economy with stochastic inflation. We consider the analysis of unanticipated inflation an interesting extension of our study and, to conclude, mention our plans of future research. In particular, we suggest that the above conjecture on the beneficial effects of unanticipated inflation on wealth inequality need not hold univocally. Consider the case where loans are primarily demanded by entrepreneurs. Entrepreneurs, as, e.g., in the model of Quadrini (2000), are more productive than workers, on average. Stochastic inflation will result in a higher average external finance premium. However, as unanticipated inflation increases, the real interest burden of entrepreneurs might well decline and subsequent profits correspondingly increase. As a consequence, the wealth distribution will become more unequal as higher unanticipated inflation reduces real interest income of the low and medium-income households and increases profit income of the high-income households (entrepreneurs).

[29] Although not explicitly stated, the suggested mechanisms point in the direction of unanticipated inflationary effects.

Acknowledgements

We thank Michael Burda, Thorvaldur Gylfason, Paul De Grauwe, Werner Hildenbrand, and Kenneth Judd for helpful comments and suggestions. The usual disclaimer applies.

6 Appendix: Computation

The solution algorithm is described by the following steps:

1. Parameterize the model.
2. Compute the aggregate employment N.
3. Make initial guesses of the aggregate capital stock K, aggregate effective labor N, government transfers Tr, and social security taxes θ.
4. Compute the values of w and r that solve the firm's Euler equations and the pension function $b(.)$.
5. Compute the household's decision functions by backwards iteration.
6. Compute the steady-state distribution of the state variable $\{k, m, \bar{e}, z, f\}$ by forward induction.
7. Compute the aggregate capital stock K, aggregate real money balances M/P, and aggregate transfers and pensions. Update K, M/P, Tr, and θ and return to step 3 until convergence.

In step 4, a finite-time dynamic programming problem is to be solved. We discretize the state space $(k, m, \bar{e}, z, f)$ using an equispaced grid over the capital stock k, the money balances m, and the individual productivity z. For the individual accumulated average earnings $\bar{e}$, we only need a grid of 5 points as the pension function is a piece-wise linear function. The upper grid points for capital and money, k_{max} and m_{max}, are chosen in each model so that they are non-binding. For the productivity z, the grid ranges from $-2\sigma_{y_1}$ to $2\sigma_{y_1}$. The probability of having productivity shock z_1 in the first period of life is computed by integrating the area under the normal distribution. The transition probabilities are computed using the method of Tauchen (1986). As a consequence, the efficiency index $e(z, j)$ follows a finite Markov chain. We use 100, 60, 5, and 5 grid points for the state variables k, m, $\bar{e}$, and z, respectively. An increase in the number of points did not result in a significant change in our results. The methods for the computation of the value function and for the computation of the aggregate variables are described in detail in Heer and Maußner (2005). In the case of no income mobility (Model I), we are able to compute the time paths of consumption, money, and capital as the solution of a non-linear equations system. Therefore accuracy is very high (10^{-8}). The problem of how to find a good initial guess is also described in more detail in the book by Heer and Maußner.

References

Altig, D., and C.T. Carlstrom, 1991, Inflation, Personal Taxes, and Real Output: A Dynamic Analysis, *Journal of Money, Credit, and Banking*, vol. 23, 547-71.

Bach, G.L. and A. Ando, 1957, The Redistributional Effects of Inflation, *Review of Economics and Statistics*, vol. 39, 1-13.

Bach, G.L. and J.B. Stephenson, 1974, Inflation and the Redistribution of Wealth, *Review of Economics and Statistics*, vol. 56, 1-13.

Bhattarchaya, J., 2001, Inflation, Real Activity, and Income Distribution, Iowa State University, working paper.

Budd, E.C. and D.F. Seiders, 1971, The Impact of Inflation on the Distribution of Income and Wealth, *American Economic Review Papers and Proceedings*, vol. 61, 128-138.

Chatterjee, S. and D. Corbae, 1992, Endogenous Market Participation and the General Equilibrium Value of Money, *Journal of Political Economy*, vol. 100, 615-46.

Campbell, J., J. Cocco, F. Gomes, and P. Maenhout, 2001, Investing Retirement Wealth: A Life-Cycle Model, in: J.Y. Campbell and M. Feldstein, eds., *Risk Aspects of Investment-Based Social-Security Reform*, Chicago University Press, Chicago, 439-73.

Cocco, J.F., 2004, Portfolio Choice in the Presence of Housing, *Review of Financial Studies*, vol. 18, 535-67.

den Haan, W.J., 1990, The Optimal Inflation Path in a Sidrauski-Type Model with Uncertainty, *Journal of Monetary Economics*, vol. 25, 389-409.

Díaz-Giménez, J., V. Quadrini, and J.V. Ríos-Rull, 1997, Dimensions of Inequality: Facts on the U.S. Distributions of Earnings, Income, and Wealth, *Federal Reserve Bank of Minneapolis Quarterly Review 21*, 3-21.

Erosa, A., and G. Ventura, 2002, On inflation as a regressive consumption tax, *Journal of Monetary Economics*, vol. 49, 761-95.

Feldstein, M., 1982, Inflation, Capital Taxation, and Monetary Policy, in: R.E. Hall (ed.), *Inflation: Cause and Effect*, Chicago, Ill., University of Chicago Press.

Galli, R. and R. van der Hoeven, 2001, Is Inflation Bad for Income Inequality: The Importance of the Initial Rate of Inflation, *International Labor Organization Employment Paper* 2001/29.

Gomes, F., and A. Michaelides, 2005, Optimal Life Cycle Asset Allocation: Understanding the Evidence, *The Journal of Finance*, forthcoming.

Greenwood, D., 1983, An Estimation of US Family Wealth and Its Distribution from Microdata, 1973, *Review of Income and Wealth*, vol. 24, 23-44.

Hansen, G., 1993, The cyclical and secular behavior of the labor input: comparing efficiency units and hours worked, *Journal of Applied Econometrics 8*, 71-80.

He, H. and D.M. Modest, 1995, Market Frictions and Consumption-Based Asset Pricing, *Journal of Political Economy*, vol. 103, 94-117.

Heaton, J., and D. Lucas, 1996, Evaluating the Effects of Incomplete Markets on Risk Sharing and Asset Pricing, *Journal of Political Economy*, vol. 104, 443-87.

Heer, B., 2001, Wealth Distribution and Optimal Inheritance Taxation in Life-cycle Economies with Intergenerational Transfers, *Scandinavian Journal of Economics*, vol. 103, 445-65.

Heer, B., and A. Maußner, 2005, *Dynamic General Equilibrium Modelling: Computational Methods and Applications*, Springer: Berlin.

Henle, P., and P. Ryscavage, 1980, The distribution of earned income among men and women 1958-77, *Monthly Labor Review*, April, 3-10.

Huggett, M., 1996, Wealth distribution in Life-Cycle Economies, *Journal of Monetary Economics*, vol. 17, 953-69.

Huggett, M., and G. Ventura, 2000, Understanding why income households save more than low income households, *Journal of Monetary Economics*, vol. 45, 361-97.

Hurd, M., 1989, Mortality risk and bequests, *Econometrica*, vol. 57, 779-813.

İmrohoroğlu, A., 1992, Welfare Costs of Inflation under Imperfect Insurance, *Journal of Economic Dynamics and Control*, vol. 16, 79-91.

İmrohoroğlu, A, İmrohoroğlu, S., and D.H. Joines, 1998, The Effect of Tax-favored Retirement Accounts on Capital Accumulation, *American Economic Review*, vol. 88, 749-68.

Kessler, D. and E.N. Wolff, 1992, A Comparative Analysis of Household Wealth Patterns in France and the United States, *Review of Income and Wealth*, vol. 37, 249-66.

Laitner, J., 1992, Random Earnings Differences, Lifetime Liquidity Constraints, and Altruistic Intergenerational Transfers, *Journal of Economic Theory*, vol. 58, 135-70.

Laitner, J., 1993, Long-run equilibria with borrowing constraints and altruism, *Journal of Economic Dynamics and Control*, vol. 17, 65-96.

Lucas, R.E., 2000, Inflation and welfare, *Econometrica*, vol. 68, 247-74.

Mendoza, E.G., A. Razin, and L.L. Tesar, 1994, Effective tax rates in macroeconomics: Cross country stimates of tax rates on factor incomes and consumption, *Journal of Monetary Economics*, vol. 34, 297-323.

Poterba, J.M. and A.A. Samwick , 2004, Taxation and Household Portfolio Composition: U.S. Evidence from the 1980s and 1990s, *Journal of Public Economics*, vol. 87, 5-38.

Prescott, E., 1986, Theory Ahead of Business Cycle Measurement, *Federal Reserve Bank of Minneapolis Quarterly Review*, vol. 10, 9-22.

Quadrini, V., 2000, Entrepreneurship, Saving, and Social Mobility, *Review of Economic Dynamics*, vol. 3, 1-40.

Quadrini, V., and J.V. Ríos-Rull, 1997, Understanding the US Distribution of Wealth, *Federal Reserve Bank of Minneapolis Quarterly Review*, vol. 21, 22-36.

Ravn, M. O. and H. Uhlig, 2002, On Adjusting the Hodrick-Prescott Filter for the Frequency of Observations, *Review of Economics and Statistics*, vol. 84, 371-380.

Romer, C.D. and D.H. Romer , 1998, Monetary Policy and the Well-Being of the Poor, NBER working paper, No. 6793.

Stokey, N., J.R. Lucas, and E.C. Prescott, 1989, *Recursive methods in economic dynamics*, Harvard University Press, Cambridge, Ma.

Tauchen, G., 1986, Finite State Markov-Chain Approximations To Univariate and Vector Autoregressions, *Economics Letters*, vol. 20, 177-81

Vissing-Jørgensen, A., 2002, Towards an Explanation of Household Portfolio Choice Heterogeneity: Nonfinancial Income and Participation Cost Structures, NBER working paper, No. 8884.

Wolff, E.N., 1979, The Distributional Effects of the 1969-75 Inflation on Holdings of Household Wealth in the United States, *Review of Income and Wealth*, vol. 25, 195-207.

Wolff, E., 1987, Estimate of household wealth inequality in the US, 1962-1983, *Review of Income and Wealth*, vol. 33, 231-57.