# Effects of inflation on wealth distribution: do stock market participation fees and capital income taxation matter?

**Burkhard Heer, Bernd Süssmuth**

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# Effects of Inflation on Wealth Distribution:

## Do stock market participation fees and capital income taxation matter?


Burkhard Heer* and Bernd Süssmuth†

* Department of Economics, University of Bamberg, Feldkirchenstrasse 21, 96045 Bamberg, Germany, Burkhard.Heer@sowi.uni-bamberg.de, and CESifo

† Department of Economics, University of Bamberg



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**Abstract:**
The effects of a permanent change of 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 of 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 tax income 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. First, it is straightforward to argue that changes in the size and composition of wealth are associated with the domestic rate of inflation of an economy. Given that households from lower income groups do not have access to stock markets, it is only the higher income group that is able to protect itself against inflation by shifting its portfolio from money to indexed assets. This reasoning may be justified on the grounds that a minimum amount of entrance costs is generally required to participate in the stock markets. Many younger and poorer households do not hold equities at all.[1] This fact may be explained if there is a fixed cost of participating in the equity market. Second, we introduce taxation of nominal interest income. An increase in the inflation rate results in higher real interest rate taxes and reduces savings.

In order to study the effects of inflation on the distribution of wealth, we analyze the households' optimal portfolio allocation over the life cycle in an economy with fixed stock market participation costs. Contrary to studies that examine the popular redistributional wealth effect from (net) creditors to debtors, which is based on unanticipated inflation and average income, we explicitly investigate a permanent, anticipated change of the inflation rate. A further preconception of our analysis is that "any theory of equality must account for the dynamic features of earnings, income, and wealth distributions, i.e., the mobility of individual (heterogeneous) households up and down the economic scale," (cf. Díaz-Giménez et al., 1997, p. 10). For this reason, we introduce (stochastic) heterogenous productivity into our model so that our model is able to match both the Gini coefficient of US labor income and the Gini coefficient of US wealth very closely. As our main result from our computational analysis, we demonstrate that higher inflation increases wealth inequality.

[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).

Given that wealth is positively correlated with earnings and income, it seems straightforward, with regard to surveying the existing evidence, to refer also to studies on the relationship between inflation and income inequality for the US. A comprehensive survey of this literature is given in Galli and van der Hoeven (2001). Accordingly, the majority of studies finds a significant progressive effect of inflation on the US income distribution, though mostly small in quantitative terms. About half of the studies, however, does not find a statistically significant effect once some basic control variables are considered. Additionally, the reader should be aware of two rather strong caveats with regard to applying this evidence for the income distribution to the redistributional effects of inflation on the wealth distribution: First, in case of the US, the correlation between wealth and earnings and income, though positive, is far from strong (see Díaz-Giménez et al., 1997) and may change over time. Second, a lot of applied work on the relation of inflation and income distribution is ambiguous and sometimes even statistically insignificant.

The more specific quantitative literature on inflation and its effects on the distribution of wealth has two central dimensions: First, there are those studies concerned with the differences in wealth holdings of relatively disaggregated demographic and/or racial groups that also discriminate between different types of assets, e.g. as in Bach and Ando (1957), Budd and Seiders (1971), Bach and Stephenson (1974), and Wolff (1979).[2] Second and more recently, there are very few quantitative studies based on general equilibrium models that underpin their findings with popular measures of inequality like Bhattarcharya (2001), while, e.g., the related study by Erosa and Ventura (2002) concentrates on average capital stock outcomes for skilled relative to unskilled workers. The present study is more closely related to the latter strand of literature. In Erosa and Ventura (2002), 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 amounts of goods purchased. In this (realistic) case, high-income and wealth-rich households face lower additional costs of higher inflation

[2]The broad overall picture conveyed in this early strand of empirical literature is that during the mid 1950s to mid 1970s period inflationary effects induced a drop in the level of wealth inequality. 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 an, even though in quantitative terms negligible, progressive effect of unanticipated inflation through the popular nominal debtor channel.

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 the ones of low-income households.[3] Bhattarcharya (2001) develops a monetary general equilibrium model with imperfect capital market. In his model, inflation increases the external finance premium and, in case the government redistributes the inflation tax to the households, increases the aggregate capital stock. In our model, the opposite result holds due to the taxation of nominal interest income, and higher inflation reduces the aggregate capital unanimously.

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. Four sectors can be depicted: households, production, the government, and the central bank. Household 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 unfunded public pensions and government consumption. The money growth rate is set by the central bank and seignorage is redistributed lump-sum to households.

[3] While our model is similar to the one of Erosa and Ventura (2002), we stress a completely different channel of redistribution as resulting from inflation. In particular, we introduce taxation of nominal interest income and stock market participation fees. Contrary to Erosa and Ventura (2002), we also allow for higher income mobility and assume finite lifetime so that our model is able to match the empirical inequality of the wealth distribution more closely.

## 2.1 Households

Every year, a generation of equal measure is born. 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 life 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 labor $l$ elastically. After $T$ years, retirement is mandatory. Agents maximize life-time utility:

$$E_0 \left[ \sum_{j=1}^{T+T^R} \beta^{j-1} \left( \Pi_{i=1}^{j} s_i \right) u(c_j, m_j, 1-l_j), \right] \tag{1}$$

where $\beta$, $c_j$, and $m_j$ denote the discount factor, consumption at age $j$, and real money balances at age $j$, respectively. The instantaneous utility function $u(c, m, 1-l)$ is the CRRA (constant relative-risk aversion) function:

$$u(c, m, 1-l) = \begin{cases} \gamma \ln c + (1-\gamma) \ln m + B \ln(1-l) & \text{if } \sigma = 1 \\ \frac{\left(c^{\gamma} m^{1-\gamma}\right)^{1-\sigma}}{1-\sigma} + B \ln(1-l) & \text{if } \sigma \neq 1 \end{cases} \tag{2}$$

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

Workers are heterogeneous with regard to their labor earnings per working hour. The worker's labor productivity $e(z, j)$ is stochastic and depends on individual age $j$ and an idiosyncratic labor productivity shock $z$.

Furthermore, agents are born without wealth, $a_1 = 0$, and cannot borrow, $a_j \geq 0$ for all $j$. Wealth $a$ is composed of real money $m$ and capital $k$. Capital or, equally, equity $k$ earns a real interest rate $r$, but it is costly to enter the stock market. Following Campbell et al. (2001), we assume that once the fixed cost $F$ has been paid, there are no additional costs of adjusting the capital stock $k$.[4] We further assume a short-sale constraint $k \geq 0$. Parents do not leave altruistic bequests to their children. All accidental bequests are confiscated by the state.

[4]Chatterjee and Corbae (1992) study a monetary general equilibrium model (without production sector and an exogenous labor income), where agents have to pay a fixed cost each period they enter the asset market. They show that a subset of agents hold currency even when it is dominated in return by a competing asset and even if it does not yield direct utility.

The $j$-year old agent $i$ receives income from capital $k^i_{j,t}$ and labor $l^i_{j,t}$ in period $t$. The nominal budget constraint of the working agent is given by:

$$\begin{aligned} P_t k^i_{j+1,t+1} - P_{t-1}k^i_{j,t} + M^i_{j+1,t+1} - M^i_{j,t} &= (1-\tau_i)i_t P_{t-1}k^i_{j,t} + (1-\tau_w)P_t w_t e(z^i,j)l^i_{j,t} + P_t tr_t \\ &\quad + P_t seign_t - P_t c^i_t - (f^i_{j+1,t+1} - f^i_{j,t})P_t F, \qquad (3) \end{aligned}$$

where $w_t$ and $\pi_t = \frac{P_t - P_{t-1}}{P_{t-1}}$ denote the wage rate per efficiency unit labor and the inflation rate, respectively. $P_t$ is the price level in period $t$. Nominal interest and wage income are taxed at rate $\tau_i$ and $\tau_w$, respectively. In addition, the households receive transfers $seign_t$ and $tr_t$ from the central bank and the government, respectively. $f$ denotes a binary variable that equals zero until the investor pays the fixed cost $F$ of entering the stock market and equals one thereafter. In steady state, the wage rate $w$, the nominal interest rate $i$, the inflation rate $\pi$, governmental transfers $tr$ and seignorage $seign$ are constant so that we omit the time index $t$.

Dividing (3) by $P_t$ and noticing that $m_t = M_t/P_t$ results in:

$$\begin{aligned} k^i_{j+1,t+1} + m^i_{j+1,t+1}(1+\pi) &= \frac{1+(1-\tau_i)i}{1+\pi}k^i_{j,t} + m^i_{j,t} + (1-\tau_w)we(z,t)l^i_{j,t} + tr \\ &\quad + seign - c^i_{j,t} - (f^i_{j+1,t+1} - f^i_{j,t})F. \qquad (4) \end{aligned}$$

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 $\pi$ 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 in the literature on the welfare effects of inflation.

During retirement, agents receive public pensions $pen$ irrespective of their employment history and the budget constraint of the retired agent at age $j = T+1, \ldots, T+T^R$ is given by

$$\begin{aligned} k^i_{j+1,t+1} + m^i_{j+1,t+1}(1+\pi) &= \left(1 + \frac{(1-\tau_i)i}{1+\pi}\right)k^i_{j,t} + m^i_{j,t} + pen + tr \\ &\quad + seign - c^i_{j,t} - (f^i_{j+1,t+1} - f^i_{j,t})F. \qquad (5) \end{aligned}$$

## 2.2 Production

Firms are of measure one and produce output with effective labor $N$ and capital $K$. Let $l_j(k,m,z,f)$ and $\phi_j(k,m,z,f)$ denote the labor supply and the measure of the j-year old agent with wealth $a = k+m$, previous equity holdings indicator $f \in \{0,1\}$, and idiosyncratic productivity $z$. Effective labor $N$ is given by:

$$N = \sum_{j=1}^{T} \sum_{f=0,1} \int_k \int_m \int_z l_j(k,m,z,f) e(z,j) \phi_j(k,m,z,f)\, dz\, dm\, dk. \tag{6}$$

Effective labor $N$ is paid the wage $w$. Capital $K$ is hired at rate $r$ and depreciates at rate $\delta$. Production $Y$ is characterized by constant returns to scale and assumed to be Cobb-Douglas:

$$Y = F(K,N) = K^{\alpha} N^{1-\alpha}. \tag{7}$$

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

$$w = (1-\alpha) K^{\alpha} N^{-\alpha}, \tag{8}$$

$$r = \alpha K^{\alpha-1} N^{1-\alpha} - \delta. \tag{9}$$

## 2.3 Government

The government uses the revenues from taxing labor and nominal income as well as from aggregate accidental bequests $Beq$ in order to finance its expenditures on aggregate social security $Pen$, government consumption $G$ and government transfers $Tr$:

$$\frac{\tau_i i K}{1+\pi} + \tau_w w N + Beq = Pen + G + Tr. \tag{10}$$

## 2.4 Monetary Authority

Nominal money grows at the exogenous rate $\theta$:

$$\frac{M_t - M_{t-1}}{M_{t-1}} = \theta. \tag{11}$$

The seignorage is transferred lump-sum to the households:

$$seign_t = \frac{M_t - M_{t-1}}{P_t}. \quad (12)$$

## 2.5 Stationary Equilibrium

The concept of equilibrium applied in this paper uses a recursive representation of the consumer's problem following Stokey et al. (1989). Let $V_j(k, m, z, f)$ be the value of the objective function of the $j$-year old agent with equity $k$, real money $m$, idiosyncratic productivity level $z$, and either prior stock market participant $f = 1$ or not $f = 0$. $V_j(k, m, z, f)$ is defined as the solution to the dynamic program:

$$V_j(k, m, z, f) = \max_{k', m', f', c, l} \{u(c, m, 1 - l) + \beta s_{j+1} E[V_{j+1}(k', m', z', f')]\} \quad (13)$$

subject to (4) or (5) and $k, m, k', m' \geq 0$. $k'$, $m'$, $f'$ and $z'$ denote the next-period value of $k$, $m$, $f$ and $z$, respectively. Optimal decision rules at age $j$ are a function of $k$, $m$, $z$, and $f$, i.e. consumption $c_j(k, m, z, f)$, labor supply $l_j(k, m, z, f)$, next-period capital stock $k_{j+1}(k, m, z, f)$, next-period real money balances $m_{j+1}(k, m, z, f)$, and next-period stock market participation $f_{j+1}(k, m, z, f)$.

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

*Definition*
A stationary equilibrium for a given government policy $\{\tau_i, \tau_w, pen, G, tr\}$ and central bank policy $\theta$ is a collection of value functions $V_j(k, m, z, f)$, individual policy rules $c_j(k, m, z, f)$, $l_j(k, m, z, f)$, $k_{j+1}(k, m, z, f)$, $m_{j+1}(k, m, z, f)$, and $f_{j+1}(k, m, z, f)$, 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:

$$K = \sum_{j=1}^{T+T^R} \sum_{f=0,1} \int_k \int_m \int_z k \; \phi_j(k, m, z, f) dz \; dm \; dk, \quad (14)$$

$$C = \sum_{j=1}^{T+T^R} \sum_{f=0,1} \int_k \int_m \int_z c_j(k, m, z, f) \; \phi_j(k, m, z, f) \; dz \; dm \; dk, \quad (15)$$

$$Beq = \sum_{j=1}^{T+T^R} \sum_{f=0,1} \int_k \int_m \int_z (1 - s_{j+1})\, a_{j+1}(k,m,z,f)\phi_j(k,m,z,f) dz\; dm\; dk, \quad (16)$$

$$Pen = \sum_{j=T+1}^{T+T^R} \sum_{f=0,1} \int_k \int_m \int_z pen\; \phi_j(k,m,z,f)\; dz\; dm\; dk, \quad (17)$$

$$\frac{M}{P} = \sum_{j=1}^{T+T^R} \sum_{f=0,1} \int_k \int_m \int_z m\; \phi_j(k,m,z,f)\; dz\; dm\; dk, \quad (18)$$

where $a_{j+1}(k,m,z,f) \equiv k_{j+1}(k,m,z,f) + m_{j+1}(k,m,z,f)$ and aggregate effective labor $N$ is given by (6).

2. Relative prices $\{w, r\}$ solve the firm's optimization problem by satisfying (8) and (9).

3. Given relative prices $\{w, r\}$, the government policy $\{\tau_i, \tau_w, pen, G, tr\}$, and the monetary policy $\theta$, the individual policy rules $c_j(.)$, $k_{j+1}(.)$, $m_{j+1}(.)$, $l_j(.)$, and $f_{j+1}(.)$ solve the consumer's dynamic program (13).

4. The government budget (10) is balanced.

5. Money grows at the exogenous rate $\theta$ and the seignorage (12) is transferred lump-sum to the households.

6. The goods market clears:

$$K^\alpha N^{1-\alpha} = C + G + \delta K + \sum_{j=1}^{T+T^R-1} \int_k \int_m \int_z F \cdot f_{j+1}(k,m,z,0)\phi_j(k,m,z,0)\; dz\; dm\; dk. \quad (19)$$

In particular, stock market participation fees are a social cost.

# 3 Calibration

Periods correspond to years. We assume that agents are born at real lifetime age 20 which corresponds to $j = 1$. Agents work $T = 40$ years corresponding to a real lifetime age of 60. They life a maximum life of 60 years ($T^R = 20$) so that agents do not become older than real lifetime age 80. The sequence of conditional survival probabilities $\{s_j\}_{j=1}^{59}$ is set equal to the Social Security Administration's survival probabilities for men aged 20-78 for the year 1994.[5] The survival probabilities decrease with age, and $s_{60}$ is set equal to zero.

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

Table 1: Calibration of parameter values for the US economy

| Description | Function | Parameter |
|---|---|---|
| utility function | $U = \gamma \ln c + (1-\gamma)\ln m + B\ln(1-l)$ | $\gamma = 0.984$, $B = 1.64$ |
| discount factor | $\beta$ | $\beta = 1.002$ |
| production function | $Y = K^{\alpha} N^{1-\alpha}$ | $\alpha = 0.36$ |
| depreciation | $\delta$ | $\delta = 0.08$ |
| stock market participation fee | $F$ | $F = 0$ |
| money growth rate | $\theta$ | $\theta = 0.05$ |
| labor income tax | $\tau_w$ | $\tau_w = 40.0\%$ |
| capital income tax | $\tau_i$ | $\tau_i = 36.0\%$ |
| government consumption | $G$ | $G/Y = 21.0\%$ |
| pension replacement rate | | $\frac{pen}{(1-\tau)w\bar{l}} = 0.50$ |
| labor endowment process | $z_t = \rho z_{t-1} + \epsilon_t$, $\epsilon_t \sim N(0, \sigma_\epsilon)$<br>$\ln e(z,1) \sim N(\bar{y}_1, \sigma_{y_1})$ | $\rho = 0.96$, $\sigma_\epsilon = 0.045$<br>$\sigma_{y1} = 0.38$ |

In our benchmark case, we choose the case of log-linear preferences $\sigma = 1$. For this calibration, money is superneutral in the representative-agent, infinite-lifetime Sidrauski model, and we expect the effect of inflation on wealth distribution to be of small magnitude in our OLG model with heterogeneous agents. Furthermore, there is no stock market participation fee in the benchmark, i.e. $F = 0$. The model parameters are presented in table 1.

The calibration of the parameters $\alpha$, $\delta$, $\theta$ and the Markov process $e(z, j)$ is chosen in accordance with existing general equilibrium studies: Following Prescott (1986), the capital income share $\alpha$ is set equal to 0.36. The annual rate of depreciation is set equal to $\delta = 0.08$. The annual money growth rate $\theta$ is set equal to 5% in our benchmark case.

The labor endowment process is given by $e(z,j) = e^{z_j+\bar{y}_j}$, where $\bar{y}_j$ is the mean 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, the model is able to replicate the cross-section age distribution of earnings of the US economy. Following İmrohoroğlu et al. (1998), we normalize the average efficiency index to one. The age-productivity profile is hump-shaped and earnings peak at age 50.

The idiosyncratic productivity shock $z_j$ follows a Markov process:

$$z_j = \rho z_{j-1} + \epsilon_j, \tag{20}$$

where $\epsilon_j \sim N(0, \sigma_\epsilon)$. Huggett (1996) uses $\rho = 0.96$ and $\sigma_\epsilon = 0.045$. Furthermore, 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 log normally in the literature.

The calibration of the government parameters $\{\tau_i, \tau_w, G\}$ follows Lucas (1990). In particular, the nominal interest income tax is set equal to $\tau_i = 36\%$, the labor income tax rate equals $\tau_w = 40\%$, and the share of government consumption in GDP is $G/Y = 21\%$. The replacement ratio of pensions to net average earnings amounts to 50%.[6] The transfers $Tr$ are computed endogenously and amount to 5.09% of GDP. In the following, we analyze two different scenarios. Following an increase of money growth, the inflation and, hence, the interest rate tax increases. In the first case, the increase in taxes is redistributed lump-sum by an equivalent increase of $Tr$. In the second case, the increase of tax income is used in order to reduce the labor income tax rate $\tau_w$. In both cases, the level of government consumption $G$ is kept constant.

The remaining three parameters $\beta$, $B$, and $\gamma$ from the utility function are chosen to match the following characteristics of the US economy as closely as possible: i) the capital-output ratio $K/Y$ amounts to 3.0 as found by Auerbach and Kotlikoff (1995), ii) the average labor supply of the working households equals approximately one third of available time, and iii) the average velocity of money $PY/M$ corresponds to the annual velocity of M1 during

[6]İmrohoroglŭ et al. (1998) apply a value of 60%. Aaron et al. (2001) report an average replacement rate of 42 percent.

1960-2001, which is equal to 5.18. Our calibration $\beta = 1.002$, $B = 1.64$, and $\gamma = 0.984$ implies a capital-output ratio equal to 3.01, an average labor supply $\bar{l} = 0.327$, and an annual velocity of money equal to 5.20. In our sensitivity analysis, we also study the case $\sigma = 2$. In order to replicate the empirical findings (i)-(iii) from above, we need to choose $\beta = 0.9963$, $B = 6.70$, and $\gamma = 0.9892$. For this calibration, the capital-output ratio, the velocity of money, and the average labor supply amount to $K/Y = 3.00$, $PY/M = 5.18$, and $\bar{l} = 0.332$, respectively.

# 4 Results

In this section, we study the effects of a change of the money growth rate $\theta$ or, equally, the inflation rate $\pi$ on the accumulation and distribution of wealth. First, we report findings for the benchmark case as described by the parameterization in table 1. Second, we analyze the effects of a stock market participation fee. Finally, we consider the sensitivity of our results with regard to the assumption of log-linear utility.

## 4.1 The benchmark case

In our benchmark equilibrium, the annual inflation rate is equal to 5% and there are no fixed stock market participation fees, $F = 0$. The endogenous equilibrium values of the benchmark are reported in the first row of table 2. The aggregate capital stock $K$ amounts to 2.17, while effective labor $N$ and the average supply $\bar{l}$ (not reported) are equal to 0.388 and 0.327, respectively, implying a real interest rate $r$ of 3.96%.

In our model, the productivity process is taken as exogenous. As, however, the agent optimizes his lifetime utility by choice of his labor supply, both the distribution of labor income, $(1-\tau)we(z,t)l$, and the distribution of wealth, equity $k$ plus real money $m$, are endogenous. The Gini coefficient of the labor income distribution amounts to 0.535[7] and is close to the values observed empirically: Díaz-Giménez et al. (1997) find a value of 0.51 for households aged 36-50, while Henle and Ryscavage (1980) estimate an average US earnings Gini coefficient for men of 0.42 in the period 1958-77.[8]

[7]For higher risk aversion, $\sigma = 2$, the Gini coefficient drops to 0.448.

[8]Income transfers are excluded in the respective definition of earnings.

Table 2: Inflation rate $\pi$, savings, and distribution
no stock market participation costs

| $\pi$ | $F$ | $\tau_w$ | $\tau_i$ | $tr$ | $K$ | $M/P$ | $Y$ | $Gini_a$ | $SMP$ | $\Delta_c$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 5% | 0 | 0.40 | 0.36 | 0.0509 | 2.168 | 0.139 | 0.721 | 0.641 | 68.0% | 0 |
| 10% | 0 | 0.40 | 0.36 | 0.0594 | 1.753 | 0.0868 | 0.662 | 0.692 | 61.7% | -0.163% |
| 10% | 0 | 0.372 | 0.36 | 0.0509 | 1.788 | 0.0874 | 0.673 | 0.690 | 61.2% | -0.135% |

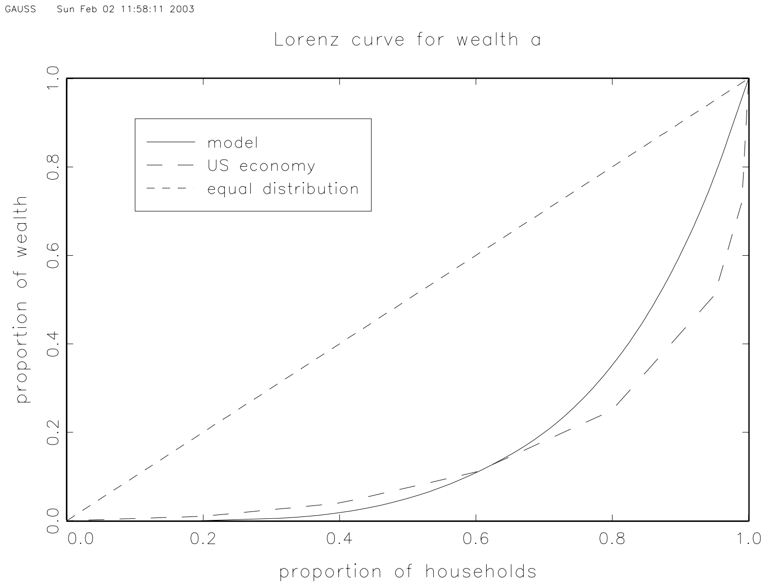
Empirically, wealth is distributed much more unequally than income. Greenwood (1983), Wolff (1987), Kessler and Wolff (1992), and Díaz-Giménez et al. (1997) estimate Gini coefficients of the wealth distribution for the US economy in the range of 0.72 (single, without dependents, female household head) to 0.81 (nonworking household head). Our model is able to replicate these findings in good approximation. In particular, the Gini coefficient of wealth is equal to $Gini_a = 0.641$, while the Gini coefficient of equity is even higher and amounts to $Gini_k = 0.659$. The Lorenz curve for the benchmark case of our model and for the US economy are displayed in figure 1.[9] The empirical distribution that is presented by the broken line displays a higher concentration of wealth among the very wealth-rich agents than the model distribution, while the number of households with no wealth is lower in the US economy than in our model. In particular, only $SMP = 68.0\%$ of all households participate in the stock market in our model.[10] 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.[11]

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

[10] From 1983-98, between 86 and 90% of all US households held interest bearing accounts. In 1998, 38% of households held (tax-deferred) equity. Figures are based on data from SCF (see Poterba and Samwick, 2001). One possible reason that, in our model, the percentage of the households that own stocks is higher than observed empirically is the negligence of investment in housing. In particular, a leveraged position in residential estate may keep younger and poorer households from investing in the stock market (see Cocco, 2001).

[11] 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.

Figure 1: Lorenz curve of model and US wealth $a$




In the Sidrauski model with infinite lifetime and a representative household, money is superneutral for our log-linear functional form of the utility function with $\sigma = 1$. In our model, superneutrality does no longer hold as higher inflation rates are associated with higher taxation of interest income. Following an increase of inflation $\pi$ from 5% to 10%, government tax income increases by approximately 1% of GDP for given constant government expenditures. We analyze two different scenarios: (i) the government increases lump-sum transfers $tr$ (row 2 of table 2), and (ii) the government reduces wage income taxes $\tau_w$ (bottom row of table 2) in order to keep its budget balanced.

As is obvious from inspection of table 2, savings decrease substantially after an increase of inflation. Following a 5 percentage point increase of the inflation rate, savings drop by approximately 20% and 17% in cases (i) and (ii), respectively. In case (ii), the effect of higher interest rate taxes on savings is reduced. The decrease of the wage income tax $\tau_w$ results in a rise of the labor supply and, hence, higher equilibrium employment and income. Consequently, the capital intensity $K/N$ and the marginal product of capital increase and agents accumulate higher savings.

In addition, higher capital taxation reduces the stock market participation of households. The stock market participation rate $SMP$ falls from 68.0% to 61.7% and 61.2% in cases

i) and ii), respectively. As less agents enter the stock market, the distribution of wealth becomes more unequal. This effect is reflected in an increase of the Gini coefficient of wealth from 0.641 to approximately 0.69. The concentration of wealth is even slightly higher under the policy (i) than under policy (ii). This result seems surprising at first glance as policy (i) increases lump-sum transfers and hence redistributes income from the wealth-rich to the income-poor, while policy (ii) increases wage income and hence predominantly redistributes income from the capital owners to the high-productivity workers. Under policy (i), however, all agents decrease their precautionary savings in order to ensure against the bad luck of income loss due to a decrease in productivity and this fall of precautionary savings is even more pronounced among the low-productivity workers than among the high-productivity workers. However, quantitative effects are small as the two Gini coefficients of the wealth distribution in case (i) and (ii), 0.692 and 0.690, almost coincide.

We also analyze steady-state welfare for the different monetary policy regimes $\theta$. In order to compare the welfare effects, we compute the expected discounted lifetime utility of the newborn generation for the different values of $\theta$. To quantitatively assess the effects, we take the benchmark equilibrium as presented in table 1 as our reference economy. The change in welfare $\Delta_c$ 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 (i) and (ii). An increase of the inflation tax from 5% to 10% has two basic detrimental effects on welfare. First, the opportunity costs of holding money increase and, second, the accumulation of savings is even more distorted. Consequently, welfare decreases by 0.169% and 0.146% of total consumption for cases (i) and (ii), respectively. Of course, the welfare losses are smaller in case (ii) than in case (i) as the distortion in the labor market is reduced in the former case.

Our quantitative welfare effects of inflation are in contrast with the findings of İmrorohoğlu (1992). She finds that reducing steady-state inflation from 10% to 0% results in a considerable welfare gain equivalent to an increase of income equal to 1.07%. Similar to the model in the present 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 can only take the value zero (unemployment) or one (employment). Different from our economy, however, agents can accumulate savings only in the form of non-interest bearing money. In our model, some households enter the stock market and also use equity in order to smooth consumption intertemporally, while the other agents do not pay the stock market participation fee so that they accumulate savings, if any, in the form of money. For this, as we believe, more realistic description of the savings behavior of individual agents, we find that welfare losses from higher anticipated inflation are smaller.[12]

## 4.2 Stock market participation fees

Transactions costs of 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 motivation to introduce fixed stock market fees into our model is the idea 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* if higher inflation also results in higher stock market participation. On the one hand, the reduction of the fixed costs of entering the stock market relative to the inflation tax makes capital a more attractive investment than money. On the other hand, agents may have accumulated small wealth in the form of money if their productivity $z$ is low and, in case of a transitory positive productivity shock, they may not have accumulated enough wealth to pay the fixed stock market costs.

Our results for the model with transaction costs are presented in table 3. Like Campbell et al. (2001), we choose a fixed stock market fee $F$ equal to 10% of average annual income as the upper bound for stock market participation costs. Compared to the benchmark case without these costs, stock market participation declines, even though only by mere 2 percentage points. The equilibrium values of the aggregate capital stock $K$, output $Y$, and effective labor $N$ are hardly affected (compare the first rows of table 2 and 3). Similarly,

[12]In fact, welfare losses from inflation are quantitatively negligible once we omit the effect from nominal interest income taxation. In the working paper version of the paper (Heer and Süssmuth, 2003), we study an economy without nominal interest income taxation and without the government sector. In this case, the welfare effects are smaller by the magnitude of 100 compared to those found by İmrorohoğlu (1992).

Table 3: Inflation rate $\pi$, savings, and distribution
stock market participation costs $F$

| $\pi$ | $F$ | $\tau_w$ | $\tau_i$ | $tr$ | $K$ | $M/P$ | $Y$ | $Gini_a$ | $SMP$ | $\Delta_c$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 5% | 0.0720 | 0.40 | 0.36 | 0.0508 | 2.157 | 0.139 | 0.720 | 0.644 | 66.3% | -0.011% |
| 10% | 0.0660 | 0.40 | 0.36 | 0.0594 | 1.730 | 0.0849 | 0.660 | 0.699 | 58.8% | -0.179% |
| 10% | 0.0672 | 0.372 | 0.36 | 0.0509 | 1.783 | 0.0869 | 0.672 | 0.695 | 59.2% | -0.156% |

the distribution only becomes slightly more unequal and the Gini coefficient increases from 0.641 to 0.644. Also, the welfare effect of stock market participation fees is small as these costs have only to be incurred once in a lifetime. Welfare declines by only 0.01% of total consumption (which is approximately equal to total stock market participation costs). Notice further that an increase of inflation from 5% to 10% results in almost the same change in welfare for $F = 0$ and $F = 0.10 \cdot Y$.

In sum, the introduction of fixed stock market fees has only negligible effects. Similarly, welfare effects of higher inflation are almost the same with and without stock market participation costs. As a consequence and according to our results, financial development does not have a profound effect on the welfare costs of inflation. Even though financial development and easier access to equity markets helps wealth-poor agents to allocate their small savings more efficiently in our model, it does not make an economically significant difference on their well-being if inflation increases and, hence, if agents should increase the relative share of equity in their wealth.

## 4.3 Sensitivity analysis

In this subsection, we examine the sensitivity of our results with regard to the choice of the utility parameter and we will analyze the case $\sigma = 2$. Table 4 presents our numerical results for a change in the utility parameter $\sigma$.

For higher risk aversion $\sigma = 2$, agents increase their precautionary savings and their labor supply. For this reason, we recalibrated our model in order to have the same average labor supply and the same capital-output ratio as in our benchmark case. In particular, the

Table 4: Sensitivity analysis for $\sigma = 2.0$

| $\pi$ | $F$ | $\tau_w$ | $\tau_i$ | $tr$ | $K$ | $M/P$ | $Y$ | $Gini_a$ | $SMP$ | $\Delta_c$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 5% | 0 | 0.40 | 0.36 | 0.0426 | 1.717 | 0.1105 | 0.5727 | 0.650 | 66.3% | 0% |
| 10% | 0 | 0.40 | 0.36 | 0.0543 | 1.415 | 0.0635 | 0.5367 | 0.693 | 60.4% | -0.214% |
| 10% | 0 | 0.3602 | 0.36 | 0.0426 | 1.468 | 0.0653 | 0.5475 | 0.694 | 59.9% | -0.195% |

relative weight of the utility from leisure $B$ has been increased and the discount factor $\beta$ has been decreased, as has been already pointed out in section 3. With higher risk aversion, the labor supply of the low-income group increases relative to the one of the high-income group resulting in a drop of the labor income heterogeneity. The Gini coefficient of labor income decreases from 0.535 in the benchmark case with $\sigma = 1$ to 0.448 in the case with $\sigma = 2$. Notice that this strong decrease in income inequality is not accompanied by a proportional change in the wealth inequality, which, according to the Gini coefficient of wealth $a$, even increases from 0.641 to 0.650 (compare table 2 and table 4 for the two cases $\sigma = 1$ and $\sigma = 2$). For $\sigma = 2$, high-income households increase their precautionary savings by a higher percentage than small-income households.

All our numerical results are analogous to those in the case of $\sigma = 1$. In particular, an increase of inflation by 5 percentage points from 5% to 10% results in i) a considerable decrease of aggregate capital $K$, ii) a noticeable increase of wealth inequality as measured by the Gini coefficient, and iii) a welfare loss in the magnitude of approximately 0.1%-0.2% of total consumption. However, quantitative welfare effects are more pronounced in the case of higher risk aversion. Again, the consideration of fixed stock market participation fees does not alter our qualitative results and, for this reason, are not reported.

# 5 Conclusion

Quantitative evidence on 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[13] decreases wealth inequality, Erosa and Ventura (2002) find

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

a wealth inequality increasing effect of 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. As our main result, we confirm Erosa and Ventura (2002), though 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 stock market participation fees is rather small.

In our model, we concentrated on the effects of anticipated inflation on the equality of the wealth distribution. As is often argued in the literature, unanticipated inflation will redistribute income from the lender to the borrower and, as the borrower is wealth-poor compared to the lender, reduces the inequality of the wealth distribution. Hence, according to this view, our result derived in the present paper might not carry over to an economy with stochastic inflation. We consider the analysis of unanticipated inflation as an interesting extension of our study and, to conclude, mention our plans of future research. In particular, we suppose that the above conjecture on the beneficial effects of unanticipated inflation on wealth inequality need not hold univocally. Consider the case that loans are primarily demanded by entrepreneurs. Entrepreneurs, 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. As, however, unanticipated inflation increases, the real interest burden of entrepreneurs might well decline and subsequent profits will 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).

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# 6 Appendix: Computation

The solution algorithm is described by the following steps:

1. Parameterize the model.
2. Make initial guesses of the aggregate capital stock $K$, aggregate effective labor $N$, aggregate real money $M/P$, and the wage income tax rate $\tau$.
3. Compute the values of $w$ and $r$ that solve the firm's Euler equations. Compute the pension $pen$ so that the replacement rate of average pensions is equal to the empirical value. Compute the transfers $tr$.
4. Compute the household's decision functions by backwards iteration.
5. Compute the steady-state distribution of the state variable $\{k, m, z, f\}$ by forward induction.
6. Compute the aggregate capital stock $K$, aggregate real money balances $M/P$, and aggregate accidental bequests $Beq$ and pensions $Pen$. Update $K$, $M/P$, $N$, and $\tau$ and return to step 2 until convergence.

We discretize the state space $(k, m, z, f)$ using an equispaced grid over the capital stock $k$, the money balances $m$, and the individual productivity $z$. The upper grid points $k_{max} = 10.0$ and $m_{max} = 0.3$ are found to be 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.

In step 4, a finite-time dynamic programming problem is to be solved. We use piecewise linear functions in order to approximate the policy functions. For the working agent, we also have to compute the optimal labor supply from his budget constraint and his first-order condition:

$$u_{1-l}(c, m, 1-l) = u_c(c, m, 1-l)(1-\tau)e(z, j)w. \tag{21}$$

As the household is born without any assets, his first-period wealth and his real money balances are zero. As a consequence, the value function would take the value $-\infty$ as $m_1 = 0$. For computational purposes, therefore, we slightly change the utility function and introduce a small constant $\psi$ into (2), $\tilde{u} = u(c, m + \psi, 1 - l)$.

## References


Aaron, H., A. Blinder, A. Munnell, and P. Orszag, 2001, Perspectives on the Draft Interim Report of the President's Commission to Strengthen Social Security, unpublished manuscript.

Auerbach, A. and L. Kotlikoff, 1995, *Macroeconomics: An Integrated Approach*, South-Western College Publishing, Cincinnati, OH.

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., 2001, Portfolio Theory in the Presence of Housing, working paper, *London Business School*.

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.

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.

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.

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 B. Süssmuth, 2003, Inflation and Wealth Distribution, *CESifo working paper*, No. 835.

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.

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.

Lucas, R.E., 1990, Supply-Side Economics: An Analytical Review, *Oxford Economic Papers*, vol. 42, 3-42.

Poterba, J.M. and A.A. Samwick , 2002, Taxation and Household Portfolio Composition: U.S. Evidence from the 1980s and 1990s, forthcoming in *Journal of Public Economics*.

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.

Romer, C.D. and D.H. Romer , 1998, Monetary Policy and the Well-Being of the Poor, *NBER Working Paper Series*, Working Paper 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

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.