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Inequality in the Welfare Costs of Disinflation*

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Abstract

We use an incomplete markets economy to quantify the distribution of welfare gains and losses of the US “Volcker” disinflation. In the long run households prefer low inflation, but disinflation requires a transition period and a redistribution from net nominal borrowers to net nominal savers. Welfare costs may be significant for households with nominal liabilities. When calibrated to match the micro and macro moments of the early 1980s high-inflation environment and the actual changes in the nominal interest rate and inflation during the Volcker disinflation, nearly 60 percent of all households would prefer to avoid the disinflation. This share depends negatively on the liquidity value of money, positively on the average duration of nominal borrowing, and positively on the short-run increase in the real interest rate.

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1 Introduction

In most environments, households would prefer an economy with low and stable inflation over one with persistently high inflation.\footnote{Exceptions could include economies with seigniorage financed transfers under incomplete markets where the insurance value of transfers to low income households might exceed losses from an inflation tax. Aiyagari (1990) provides an excellent summary of the costs and benefits in general equilibrium of reducing inflation.} Even putting aside costs from relative price dispersion and inflation uncertainty, high inflation imposes resource costs as consumers alter their savings and consumption behavior in order to economize on nominal liquid assets subject to an inflation tax. US households in the late 1970s faced a substantial inflation tax, with inflation in excess of 10 percent. These households would have preferred the low and stable price inflation now routine in the US. But, one cannot switch from one environment to another without some transition, or disinflation period, with its own benefits and costs. Paul Volcker, Chair of the Federal Reserve from 1979 to 1987, publicly committed to reducing inflation and largely succeeded by the mid 1980s. The period of tight monetary policy designed to tame high inflation became known as the “Volcker” disinflation.

We characterize one essential aspect of this disinflation, namely its unequal costs and benefits across households. The debate over the costs of disinflation typically centers on an aggregate sacrifice ratio, or the short-run loss in output or employment necessary to reduce the rate of price inflation. But the focus on aggregates necessarily abstracts from the underlying heterogeneous effects. We fix our sights on quantifying in a precise way the redistributive costs and benefits of this large disinflation.

The effects are potentially large. Households typically borrow in nominal contracts with long durations and hold a mix of real and nominal assets. A sudden decrease in inflation and inflation expectations accompanying an increase in the real interest rate increases the real burden of net nominal borrowers and redistributes resources towards net nominal savers. In their seminal paper, Doepke and Schneider (2006a) carefully measure the distribution of US households’ net nominal liabilities, and they show the scope for disinflation-based redistribution is quantitatively significant. Their analysis considers the first-order effects on the wealth distribution, but without an equilibrium model the analysis cannot, on its own, address welfare. This is especially important since disinflation lowers the burden of the inflation tax whose incidence varies across households with heterogeneous money demand. Moreover, the Volcker disinflation was characterized by a short-run increase and long-run decline in real interest rates, each with their own welfare costs and distributional implications.

To isolate the welfare costs imposed by a sudden disinflation, we build a monetary economy with incomplete markets. We extend a Bewley-Imrohoroglu-Huggett-Aiyagari economy to include money, valued for its liquidity services, and a durable good. Households face idiosyncratic earnings shocks as in a standard income fluctuation problem but now also face a portfolio choice problem. They must allocate resources between money, a long-term interest-bearing nominal asset and investment in durable goods. They also have access to secured borrowing against their durable
stock in the form of a long-term nominal contract. This allows us to capture a common feature of household balance sheets: a fixed-rate mortgage secured by a house or other secured loans, such as those for automobiles. The nominal interest rate and inflation rate are jointly determined by the fiscal and monetary authorities with the monetary authority setting nominal rates and the fiscal authority determining inflation through the choice of nominal government debt. Price-level determinacy is assured under incomplete markets through the demand theory of the price level developed in Hagedorn (2016).

We calibrate the model to match key features of the US economy just before the Volcker disinflation. Then, we construct a disinflation equilibrium path as the economy’s dynamic response to a sudden shift in the monetary and fiscal policy stance. We calibrate the monetary and fiscal policies to match the exact sequence of nominal interest rates and inflation observed during the Volcker disinflation. This path includes a short-run increase in the real interest rate before nominal interest rates and inflation fall to their permanently lower level. Though we abstract from sticky prices and thus there is no Phillips curve implied trade off between output and inflation, there will nevertheless be an output decline along the disinflation path due to the temporary increase in the real interest rate, consistent with the recession generated by Volcker disinflation.

The unanticipated policy shift endogenously redistributes resources away from borrowers and towards savers. Borrowers also experience a sudden increase in their continued borrowing costs due to the rise in the real interest rate. Borrowers deleverage in response to their unexpectedly large real debt burden, while savers further increase their savings to smoothly consume the real value of their windfall over future periods. At the same time, all households rebalance their portfolios as a reduced inflation tax lowers the cost of holding real balances.

The full welfare effects of the disinflation will be determined jointly by the benefit of the lower inflation tax, the cost of the redistribution, and the changes in the real interest rate. For savers, the immediate impact of the transition is unambiguous. They receive a windfall from the redistribution while also benefiting from the lower inflation tax and the higher real interest rate. However, in the long run they dislike the permanent decline in real interest rates. For borrowers, the welfare benefit depends on whether the lower inflation tax and the long-run decrease in the real interest rate is enough to compensate them for both the wealth lost in the redistribution and the short-run increase in the real interest rate. In our baseline calibration, 58.4 percent of households prefer to remain in the high inflation steady state rather than face the costs of the redistribution and the temporary increase in real borrowing costs. This suggests that the long-run benefits of the lower inflation tax and lower real interest rate are not enough to compensate most borrowers for their losses during the transition.

The costs and benefits of the Volcker Disinflation are borne unequally across the income distribution. In an up or down vote, 37.4 percent of low income households and 81.2 percent of middle income households would choose to live with high inflation despite the high inflation tax. In the

\footnote{Hagedorn (2011) shows that this temporary increase in nominal rates may not have been an optimal strategy depending on the level of credibility of the central bank.}
long run, if they could skip the redistribution and disinflation period, most of these households would prefer the low-inflation equilibrium. Only 8.5 percent prefer to remain in the high-inflation equilibrium in the long run. These are all wealthy saver households who dislike the decline in the long-run real interest rate.

We then explore the sensitivity of the welfare results to three alternative experiments. First, we ask how these welfare results depend quantitatively on the burden of the inflation tax, which is determined by the liquidity value of money. We compare our baseline welfare results to a calibration of an economy with no money. Without any offsetting gains from the reduction of the inflation tax, all borrower households are sufficiently hurt by the redistribution that they would prefer to remain in the high-inflation steady state.

Second, we compare the welfare results from the baseline calibration to a version with a one-period duration for nominal borrowing, as opposed to the 4.5 year duration in the baseline calibration. The shorter duration substantially decreases the size of the redistribution. Because the redistribution is smaller, borrowers are more willing to face the burden of the redistribution in exchange for the benefit of the lower inflation tax. However, the borrowers are still hurt by the short-run increase in the real interest rate. In this economy only, although the welfare costs for most households are less than half of the baseline model, most would still prefer to stay in the high-inflation steady state because of the changes in the real interest rate during the disinflation.

Third, we compare our results to a version in which there is no change in the real interest rate along the disinflation path. This eliminates both its short-run increase during the disinflation and its eventual permanent decline. Although borrowers no longer face a temporary increase in their borrowing cost, they are still hurt by the redistribution, and most borrowers still prefer to remain in the high-inflation steady state. The differences between the baseline calibration and the alternative experiments highlight the importance of capturing all three channels—the redistribution, the decrease in the inflation tax, and the changes in the real interest rate—when considering the welfare costs of the Volcker disinflation.

In light of concerns since the Great Recession about a low inflation target (amid continued low real interest rates) leaving monetary policy close to the zero lower bound on nominal interest rates (Ball, 2014; Coibion, Gorodnichenko, and Wieland, 2012), we apply our framework to consider an increase in the inflation target. The debate about raising the inflation target generally ignores the distributional effects of transitioning to higher inflation and the cost of a higher inflation target. We re-calibrate our model to mimic the economic environment in 2019. We then ask what the welfare effects would be if the monetary and fiscal authorities cooperated to slowly raise inflation over the course of five years to a target of 5 percent while maintaining a constant real rate. As in the case of the disinflation, we find the costs and benefits of an inflationary period are unevenly distributed across the income and wealth distributions. Despite the fact that 57.1 percent of households hold nominal debt and will benefit from the redistribution, only 48 percent of households prefer to go

\[3\] In an experiment with no redistribution and no changes in the real interest rate, the welfare costs are unambiguous. Everyone benefits from the lower inflation tax and would prefer the disinflation.
through the inflationary period. As with the disinflation, the costs and benefits of the inflation are not borne equally across the distribution; 54.4 percent of low-income and 96.5 percent of high-income households, while only 32.7 percent of middle-income households, prefer low inflation. This is because middle-income households have the largest nominal liabilities and benefit the most from the devaluing of their nominal debt, which compensates them for the higher inflation tax. High income households, on the other hand, are savers and therefore are hurt by the redistribution and the higher inflation tax.

After discussing the previous literature, in Section 2 we describe our model and in Section 3 we describe the data and model calibration. In Section 4 we describe the transition period for our baseline experiment: a surprise disinflation calibrated to match the paths of nominal interest rates and inflation during the Volcker disinflation, and discuss the welfare effects of the disinflation. Section 5 compares the results from our baseline calibration to a cashless economy, an economy with only one-period borrowing, and a transition with no change in the real interest rate. Section 5 also considers the welfare costs of raising the inflation target. Section 6 concludes.

**Contribution to the literature**

Our analysis of the Volcker disinflation highlights the importance of considering three channels to understand the welfare costs of a disinflationary period: the revaluation of nominal assets, the change in the inflation tax, and the changes in the real interest rate. We discuss the literature on each of these three channels below. A key contribution of our work is that we are the first to consider this question in a model with a rich enough portfolio choice problem on the household side to jointly consider all three channels.

We include money explicitly to allow for long-run benefits of reducing steady state inflation. With money, inflation serves as a tax, which directly affects households’ demand for real balances and consumption. The idea of inflation as a consumption tax is well established, and the effects can be significant for welfare. Allais, Algan, Challe, and Ragot (2020) and Cao, Meh, Rios-Rull, and Terajima (2018) consider the welfare consequences of an inflation tax in models with incomplete markets, but they do not examine the redistribution consequences of a change in inflation along the transition path. The long-run equilibrium effects of inflation on the real interest rate are developed in Dotsey and Ireland (1996) and Aiyagari et al. (1998). They introduce a channel where inflation draws resources away from production and into credit services to avoid an inflation tax, inducing a general equilibrium effect on the real interest rate.

The redistribution or Fisher channel has been most recently studied in work by Auclert (2019) and Doepke and Schneider (2006a). They show that an unexpected shock to the inflation rate will revalue nominal assets causing a redistribution between borrowers and savers. Doepke and

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4While Lucas (2000) and Bailey (1956) find small estimates of the welfare costs of inflation from integrating under an estimated money demand curve in a representative agent economy. Chatterjee and Corbae (1992) and Imrohoroglu (1992) find that incomplete market arrangements can significantly amplify welfare costs of an inflation tax over the earlier complete markets estimates. Attanasio et al. (2002) and Erosa and Ventura (2002) also show that transaction costs from inflation vary considerably across households.
Schneider (2006a) reinvigorated an early literature on inflation and redistribution (see for example Bach and Stephenson, 1974) by documenting the economically significant net nominal exposure of various cohorts and sectors in the US economy and conducting a reduced form calculation of the redistribution from a surprise inflation episode. Adam and Zhu (2016) perform a similar analysis for Euro Area households, and they further consider redistributive effects across countries within the currency union.

Several papers have also examined the effect of the Fisher channel quantitatively in a heterogeneous agent model with incomplete markets, but they exclude the long-run benefits of lower inflation. Doepke and Schneider (2006b) and Meh, Rios-Rull, and Terajima (2010) do this by treating a surprise inflation as an exogenous redistribution of wealth and examine the resulting transition path back to the stationary equilibrium. Instead, we model inflation directly and consider the portfolio choice problem by households that captures the long-run welfare effects of the lower inflation tax. Without the inflation tax, changing the steady state rate of inflation amounts to a simple redistribution of wealth with no long-run benefits.

Recent work considers the transmission of monetary policy in an incomplete markets framework. However, the goal of this literature is distinct from our own. These papers are interested in characterizing how heterogeneity will affect the central bank’s ability to use monetary policy as a tool to counteract short-term business cycle fluctuations. In contrast, we are interested in characterizing the redistribution effects of a long-run change in monetary and fiscal policy. Kaplan, Moll, and Violante (2018), Gornemann, Kuester, and Nakajima (2016) and Mitman, Manovskii, and Hagedorn (2017) extend these models to include a New Keynesian block on the production side. Their focus is also on the transmission of monetary policy rather than the distributional consequences of a large permanent shock to steady state inflation. An interesting exception is Sterk and Tenreyro (2018) who use an incomplete markets model with money to consider the effect of a redistribution between households and government on the pass-through of monetary policy.

Our project also relates to a recent debate on whether central banks should increase the steady state rate of inflation in order to avoid hitting the zero lower bound (Ball, 2014; Coibion, Gorodnichenko, and Wieland, 2012). While we do not directly consider the welfare benefits of avoiding the zero lower bound, we use our framework to consider the welfare costs of raising the inflation target, including both the long-run welfare costs of the higher inflation tax and the costs along the transition path from the redistribution. Central banks should weigh these costs against the benefit of avoiding the zero lower bound when considering a high inflation target.

Finally, we build on the work of Hagedorn (2016) and Hagedorn (2018) who prove price-level determinacy under incomplete markets. They show that when the government issues nominal debt, even for an arbitrary interest rate rule, price-level determinacy is assured by equating the real value of government debt with household net asset demand to clear the asset, or equivalently

\footnote{For example, Wong (2015), Cloyne, Ferreira, and Surico (2020), Garriga, Kydland, and Šustek (2017) and Ozkan, Mitman, Karahan, and Hellund (2017) show that part of the consumption response to a monetary policy or inflation shock will take place through the refinancing of household debt or the effect of interest rate changes on households with adjustable rate mortgages.}
the goods, market—a demand theory of the price level. This is feasible since precautionary motives under incomplete markets break Ricardian equivalence and make net asset demand a well-defined increasing function of the real interest rate. The demand theory is particularly well-suited for our analysis since it allow us to jointly characterize the fiscal and monetary policies that implement the actual path of inflation and nominal interest rates during the Volcker disinflation.

2 Monetary economy with heterogeneity

We start by extending an Bewley-Imrohoroglu-Huggett-Aiyagari economy to include money, durable goods, and long-term secured nominal lending contracts.\(^6\) As in the standard model, households cannot perfectly insure idiosyncratic shocks to their labor productivity, but may trade in cash, interest-bearing nominal assets and durable goods, of which the latter may also serve as collateral. We first consider a stationary environment with high inflation. To study the welfare effects of a disinflation, we quantify the response of this high-inflation economy to an unanticipated tightening of the monetary policy stance intended to permanently reduce inflation. Since prices are perfectly flexible, there is no output gap created by nominal frictions as inflation adjusts to its lower level. Nevertheless, the economy is no longer stationary. Instead, it converges in finite time to a new stationary distribution with low inflation. We can then measure both the short-run and long-run benefits and costs of inflation across the evolving distribution of households along the equilibrium path.

2.1 Preliminaries

Time is discrete. The economy consists of a large number of dynastic households indexed by \(i\) and represented by the unit interval \(i \in [0, 1]\). Each supplies labor inelastically to a single production sector; a government implements fiscal and monetary policy.

This is a monetary economy where money, \(\hat{m}\), is together a numeraire, a store of value and a source of liquidity services to the households. As numeraire we define the money price of period \(t\) output as \(P_t\) and denote the real value of money balances as \(m = \hat{m}/P\). Throughout, we use the \(\hat{}\) notation to indicate a nominal variable. We capture the liquidity value of money by including real balances \(m\) directly in the household’s preferences, although the economy would be little changed if demand for real balances were instead determined by shopping time or cash-in-advance constraints.\(^7\)

\(^6\)Money is included solely to incorporate the welfare costs of economizing on the liquidity it provides under high inflation. Price level determinacy is ensured under incomplete markets through the demand theory of the price level (Hagedorn, 2016) as we describe in Section 2.6.

\(^7\)With some small alterations to the timing assumptions our model would be equivalent to cash-credit or shopping time microfoundations of money demand. We would expect similar results in any model where inflation generates utility or resources costs to economizing on liquid assets.
Preferences and endowments. Households have identical preferences over sequences of non-durable consumption, \( c_t \), real balances, \( m_t \), and the service flow from durables, \( d_{t-1} \), ordered by

\[
E_0 \left[ \sum_{t=0}^{\infty} \beta^t u (c_t, m_t, d_{t-1}) \right],
\]

with discount factor \( \beta \) and standard assumptions on \( u \). The expectation is over only the household’s idiosyncratic labor efficiency; there is no aggregate uncertainty. Each household has one unit of raw labor that it supplies inelastically to a production sector. Its efficiency \( z_t \in \{z_1, \ldots, z_{N_e}\} \) follows a Markov chain with constant transition matrix \( P = [p_{jk}] \) initialized from its stationary distribution \( \bar{p} \in \mathbb{R}^{N_z} \). Since draws are independent across households, a law of large numbers implies that the aggregate quantity of efficiency units of labor \( N \) is constant and equal to \( E[z_t] \).

Production The production sector consists of a representative firm that uses the installed capital stock, \( K_{t-1} \), and (anticipating labor market clearing) constant \( N \) efficiency units of labor to produce output with a stationary constant returns to scale technology:

\[
Y_t = F(K_{t-1}, N).
\]

Throughout, we use capital letters to denote aggregate quantities. Aggregate output, \( Y_t \), may consumed by households, \( C_t \), invested, either in the capital stock, \( I^K_t \), or durables, \( I^D_t \), or purchased by the government, \( G_t \), so that the aggregate resource constraint is:

\[
Y_t = C_t + I^K_t + I^D_t + G_t. \tag{2}
\]

Given aggregate investment, \( I^K_t \), the capital stock depreciates at rate \( \delta^K \) and follows the law of motion:

\[
K_t = (1 - \delta^K) K_{t-1} + I^K_t. \tag{3}
\]

Durable investment may vary across households. Given aggregate durable investment, \( I^D_t = \int_{0}^{1} i^D_t \, di \), the aggregate durable stock follows the law of motion:

\[
D_t = (1 - \delta^D) D_{t-1} + I^D_t + \int_{0}^{1} \Psi_t \, di, \tag{4}
\]

The last term sums the household-level durable adjustment cost, \( \Psi(d_{it}, d_{it-1}) \) across households so the aggregate adjustment cost will depend on the underlying distribution of durable investment across households.

2.2 Market arrangements

There are competitive labor and capital rental markets with prices \( P_t W_t \) (per efficiency unit) and \( P_t V_t \), respectively. Financial intermediation is through a representative mutual fund, which owns
the capital stock and makes secured long-term nominal lending contracts to households and the government.

**Household borrowing and saving.** We distinguish borrower and saver households by their nominal financial net worth, $\tilde{a}$, and we further assume that they cannot simultaneously borrow and save. Borrower households, $\tilde{a} < 0$, borrow from the mutual fund. These loans may be used to purchase durable goods, which are pledged as security. There is no unsecured borrowing.

To match the higher duration borrowing observed for U.S. households, we build on Hatchondo and Martinez (2009) and Auclert (2019) and allow the mutual fund to offer long-term secured nominal debt contracts with a duration that depends on parameter $\rho$. A household who borrows $P_t \tilde{L}_t$ towards a purchase of durable goods agrees to a perpetual stream of payments $\tilde{l}_t, \tilde{l}_t \rho, \tilde{l}_t \rho^2, \ldots$ that decay at rate $\rho$, where $P_t \tilde{L}_t$ is the price of the loan. With $\rho = 0$ this is a one period loan, but increasing $\rho$ stretches the duration of the loan, mimicking longer-term borrowing such as mortgages.

With borrowing, where $\tilde{a} = -P_t \tilde{L}_t < 0$, the secured lending constraint,

$$-\tilde{a} \frac{\tilde{L}_t}{P_t} (1 + \rho P_{t+1}) \leq \mu (1 - \delta^D) d_t P_{t+1},$$

ensures that value of the security can be used to repay the loan. The left hand side is the nominal value of the household’s borrowing in period $t + 1$, and the right hand side is some fraction $\mu \leq 1$ times the nominal value of the households remaining durables in period $t + 1$.

Saver households, $\tilde{a} \geq 0$, hold equity, $\tilde{e}_t$, in the mutual fund. In general then, $\tilde{a} = \tilde{e}_t - P_t \tilde{L}_t$ with restriction that the household cannot simultaneously borrow and save, $\tilde{e}_t \tilde{L}_t = 0$.

**Government.** We treat the government symmetrically to households. The government has a stock of nominal government debt $\tilde{B}_t$. When $\tilde{B}_t > 0$, the government borrows $\tilde{B}_t = P_t \tilde{L}_t G_t$ from the financial intermediary with the same perpetual coupon structure. Unlike household borrowing, government debt is not subject to a collateral constraint since it is backed by future tax revenues. In case the government is a saver, $\tilde{B}_t \leq 0$, (like households) it holds its savings as equity, $\tilde{E}_G$, in the mutual fund so that, in general, $-\tilde{B}_t = \tilde{E}_G - P_t \tilde{L}_G$ with $\tilde{E}_G \tilde{L}_G = 0$.

**Mutual fund.** Financial intermediation is through a mutual fund. The fund is financed entirely through its equity, $\tilde{E}_t = \int \tilde{e}_t di + \tilde{E}_G$, which is invested in capital, $P_t K_t$, and in lending, $P_t \tilde{L}_t = P_t \int \tilde{l}_t di + P_t \tilde{L}_G$, to households and the government. Capital purchased at price $P_t$ is rented to firms the following period at rate $P_{t+1} V_{t+1}$. Including the value of the undepreciated capital, the

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8It will not be sufficient to simply track net financial assets. Although expected rates of return on household borrowing and saving are equivalent in equilibrium, as we explain below in the following section on market arrangements, an unanticipated disinflation would affect the ex post return on borrowing and saving differently.

9Since the borrowing constraint (5) depends on future prices, an unexpected disinflation may push constrained households beyond their secured borrowing limits ex post. For this reason, we set $\mu$ low enough so the value of the loan will never exceed the full value of the remaining durables.
The gross nominal return on capital investment is:

\[ R_{t+1}^K = \frac{V_{t+1}P_{t+1} + (1 - \delta)P_{t+1}}{P_t} = \Pi_{t+1} (V_{t+1} + 1 - \delta), \]

where \( \Pi_{t+1} = P_{t+1}/P_t \) is the gross inflation rate, which converts the real return on capital to a nominal return. Given the geometric decay structure of the long-term debt contract, the gross nominal return on the fund’s investment in lending is:

\[ R_{t+1}^L = 1 + \frac{\rho P_{t+1}^L}{P_t^L}. \]

Increases in \( \rho \) increase the duration of the loan portfolio and thus the sensitivity of its value to the nominal interest rate.

Since the mutual fund is financed entirely by equity, total equity, \( \hat{E}_t \), equals total assets, \( P_t^L \hat{L}_t + P_tK_t \). We let \( \phi_t \equiv \frac{P_t^L \hat{L}_t}{P_t^L \hat{L}_t + P_tK_t} \) denote the share of the fund’s assets (and equity) held in loans. Then, the gross nominal return on mutual fund equity can be written as the share-weighted average:

\[ R_{t+1}^{\hat{E}} = \phi_t \frac{1 + \rho P_{t+1}^L}{P_t^L} + (1 - \phi_t) \Pi_{t+1} (V_{t+1} + 1 - \delta). \]  

We consider an equilibrium where the mutual fund holds both capital and loans in its portfolio, \( \phi_t \in (0, 1) \), thus a no arbitrage condition ensures the expected return on bank equity must equal the expected return on its loan and capital investments:

\[ E_t [R_{t+1}^{\hat{E}}] = \frac{1 + \rho E_t [P_{t+1}^L]}{P_t^L} = E_t [\Pi_{t+1}] (V_{t+1} + 1 - \delta). \]  

With no fluctuations in aggregate productivity and a constant labor supply, the future rental rate \( V_{t+1} \) is measurable in period \( t \). Under perfect foresight, prices \( P_{t+1}^L \) and inflation \( \Pi_{t+1} \) the expectation operator may appear unnecessary. However, we write them this way to emphasize how if realized prices were to differ from their expected values, e.g. an unanticipated disinflation, the ex post return on equity in (6) would be different than its expected return in (7).

The modeling choice of equity over debt financing for the intermediary is important in this case. A lower than expected realization of inflation reduces the nominal return on capital but not the return on lending. And if \( \rho > 0 \), the nominal return on lending actually increases. In this event, for example, with a constant gross nominal return \( R \), in equilibrium \( P_t^L = \frac{1}{\rho R} \) and the duration of the lending portfolio would be \( \frac{1}{\rho R - \rho} \). To see this, note that the Macaulay duration is defined as the horizon weighted average of discounted future cash flows relative to the price. In this case:

\[ D = \sum_{k=1}^{\infty} k \left( \frac{1}{R} \right)^k \rho^{k-1}/P_t^L = \frac{R - \rho}{\rho} \sum_{k=1}^{\infty} k \left( \frac{\rho}{R} \right)^k = \frac{R}{R - \rho}. \]

The third equality follows from the convergent power series \( \sum_{k=1}^{\infty} k z^k = z/(1 - z)^2 \).

Because capital is a real asset and lending is a nominal asset, the loan share \( \phi_t \) is also the nominal share of assets.
the ex post return on mutual fund equity simply adjusts according to (6). If the intermediary were instead financed by nominal debt, such as a bank deposits, the increases in the nominal return on long-term lending might not offset the reduction in the nominal return on capital and the intermediary would not be able to pay the interest owed on deposits. If the return to paid to deposits matched the return on lending, the intermediary’s insolvency would be assured.

2.3 Household behavior

Given these arrangements, the timing is as follows. In each period \( t \), a household begins with its nominal savings \( \tilde{m}_{t-1} + \tilde{a}_{t-1} \) and its remaining durables \( (1 - \delta^D) d_{t-1} \). The current price level \( P_t \) is realized. Households earn a nominal wage \( P_t W_t \) per efficiency unit of labor. They may purchase consumption, \( c_t \), and invest in durable goods, \( i_t^D \), both at price \( P_t \). They can also adjust their money holdings, \( \tilde{m}_t \), and borrow \( -\tilde{a}_t = P_t \tilde{l}_t \) in loans \( \tilde{l}_t \) sold at price \( P_t \tilde{L} \) subject to borrowing constraint (5) or save through the purchase of equity, \( \tilde{a}_t = \tilde{e}_t \) (but not both), \( a_t = \tilde{e}_t - P_t \tilde{l}_t \) with \( \tilde{l}_t \tilde{e}_t = 0 \). Using (4) to substitute for \( i_t^D \) and dividing by \( P_t \) to express in terms of output, the household is subject to a sequence of real budget constraints:

\[
c_t + m_t + a_t + d_t + \Psi (d_t, d_{t-1}) = z_t W_t + \frac{a_{t-1}(1 + 1_{\{a_{t-1} < 0\}} \rho P_t^L) + m_{t-1}}{\Pi_t} + (1 - \delta^D) d_{t-1} \tag{8}\]

where \( a_t = \tilde{a}_t / P_t \) is real non money net financial assets. Given initial real savings \( a_{-1} + m_{-1} \) and durable stock \( d_{-1} \), each household maximizes (1) subject to sequences of borrowing (5) and budget constraints (8) for \( t \geq 0 \).

To characterize household behavior, it is helpful to rewrite its sequence problem recursively. We first define the household’s real net worth in period \( t \) after inflation, \( \Pi_t \) is realized:

\[
q_t \equiv \frac{m_{t-1} + a_{t-1}(1 + 1_{\{a_{t-1} < 0\}} \rho P_t^L) + e_{t-1}}{\Pi_t} + (1 - \delta^D) d_{t-1}. \tag{9}\]

For all \( t \geq 0 \), given real net worth \( q_t \), accumulated durables \( d_{t-1} \), and labor efficiency \( z_t \) we let \( V_t (q_t, d_{t-1}, z_t) \) denote the value of a household in period \( t \). Then for all \( t \geq 0 \), \( V_t \) satisfies a sequence of Bellman equations:

\[
V_t(q_t, d_{t-1}, z_t) = \max_{c_t, m_t, d_t} \left\{ U(c_t, m_t, d_{t-1}) + \beta E \left[ V_{t+1}(q_{t+1}, d_t, z_{t+1}) | z_t \right] \right\}, \tag{10}\]

each subject to a real budget constraint,

\[
c_t + a_t + d_t + \Psi (d_t, d_{t-1}) + m_t = q_t + z_t (1 - \tau_t) W_t,
\]

and a real borrowing constraint,

\[
- \frac{a_t}{P_t^L} (1 + P_t^L \rho) \leq \Pi_{t+1} (b + \mu (1 - \delta^D) d_t). \]
Next period $q_{t+1}$ is determined according to (9). The value functions depend on $t$ through interest rates, $i_t$, wages, $W_t$ and fiscal and monetary policy, which may vary over time. We abuse notation slightly and label the policy functions that satisfy the Bellman equation as $c_t(q_t, d_{t-1}, z_t)$, $m_t(q_t, d_{t-1}, z_t)$, $a_t(q_t, d_{t-1}, z_t)$, $e_t(q_t, d_{t-1}, z_t)$ and $d_t(q_t, d_{t-1}, z_t)$.

### 2.4 Firm behavior

The production sector is straightforward and provides an elastic demand for capital: a representative firm rents capital and efficiency units of labor in a competitive market at real prices $V_t$ and $W_t$, respectively. Imposing market clearing in the labor market, profit maximization requires:

$$F_k(K_{t-1}, N) = V_t; \quad F_n(K_{t-1}, N) = W_t.$$  \hspace{1cm} (11)

### 2.5 Aggregating over heterogeneous households

Before characterizing an equilibrium, we first define a measure to keep track of the distribution of households. Let $\psi_t(q, d, z)$ be the measure of households that begin period $t$ with $q_t \leq q$, $d_{t-1} \leq d$ and efficiency $z_t = z$. For $t \geq 0$, given household policy rules $a_t$, $m_t$ and $d_t$, this measure must satisfy the law of motion:

$$\psi_t(q', d', z_j) = \sum_{k=1}^{N_z} \int \int 1 \left\{ \left( \frac{a_{t-1}(q, d, z_k)(1 + 1_{\{a_{t-1} < 0\}}P_t^\rho)}{\Pi_t} + m_{t-1}(q, d, z_k) + (1 - \delta_D)d_{t-1}(q, d, z_k) \right) \right.$$  

$$\leq q' \cap d_{t-1}(q, d, z_k) \leq d' \right\} \psi_{t-1}(\partial q, \partial d, e_k) \right\} p_{kj}. \hspace{1cm} (12)$$

This captures the evolution of real net worth and durables given each household’s choices and the realization of the Markov state $z$. The dependence on $t$ is through the household policy rules, which are themselves functions of equilibrium prices.

Using $\psi_t$, we can define aggregate quantities for consumption

$$C_t \equiv \sum_{k=1}^{N_z} \int \int c_t(q, d, z_k) \psi_t(\partial q, \partial d, z_k) \bar{p}_k,$$

demand for real balances,

$$M^d_t \equiv \sum_{k=1}^{N_z} \int \int m_t(q, d, z_k) \psi_t(\partial q, \partial d, z_k) \bar{p}_k,$$

durables,

$$D_t \equiv \sum_{k=1}^{N_z} \int \int d_t(q, d, z_k) \psi_t(\partial q, \partial d, z_k) \bar{p}_k,$$
and aggregate savings,

\[ S_t \equiv \sum_{k=1}^{N_k} \left[ \int \int a_t(q,d,z_k) \left( 1 + 1_{\{a_t<0\}} \rho P_t^L \right) \psi_t(\partial q, \partial d, z_k) \right] \bar{p}_k. \]

The outer sum in each definition is over the distribution of \( z \), which is stationary.\(^{12}\)

### 2.6 Government

The government is a consolidated fiscal and monetary authority. It sets the nominal rate of return, \( R_{L_t} \), and nominal borrowing, \( \hat{B}_t \), and provides a perfectly elastic supply of money, \( \hat{M}_t \), to satisfy household demand for real balances at the realized price level. Rather than through money market clearing, the price level is determined by equating the real value of government debt, with the net real asset demand from households.\(^{13}\) The government achieves its desired path of inflation through its choice of the nominal stock of government debt (Hagedorn, 2016).

Specifically, given initial nominal liabilities \( \hat{M}_{-1} \) and \( \hat{B}_{-1} \), and an inflation target \( \Pi^* \), a fiscal and monetary policy is a sequence for \( t \geq 0 \) of labor income taxes, \( \{\tau_t\} \), nominal interest rates, \( \{R_{L_t}\} \), and nominal government debt, \( \{\hat{B}_t\} \). In each period, for a given realization of the price level, \( P_t \), the nominal money stock, \( \hat{M}_t \), is determined endogenously by demand for real balances,

\[ \hat{M}_t = P_t \hat{M}_t^d, \tag{13} \]

and nominal government expenditures, \( P_t G_t \), are determined endogenously by the government’s budget constraint,

\[ P_t G_t = \hat{M}_t - \hat{M}_{t-1} + \hat{B}_t - R_{L_t} \hat{B}_{t-1} + \int \tau_t z_i P_t W_t d_i, \tag{14} \]

given the path of its borrowing along with its seignorage and tax revenue.\(^{14}\) The price level, \( P_t \), will be determined in equilibrium to clear the asset market:

\[ \frac{\hat{B}}{P_t} = S_t - K_t. \tag{15} \]

In the long run, the government can ensure it implements its inflation target, \( \Pi^* \) by choosing a path of nominal bonds that grows at the same rate as desired inflation.

---

\(^{12}\)Recall that the transition matrix of the Markov chain for labor efficiency \( z \) is defined \( P = [p_{ij}] \) and the chain is initialized from its unique ergodic distribution \( \bar{p} \in \mathbb{R}^{N_z} \).

\(^{13}\)Under incomplete markets, precautionary motives ensure this net asset demand is well defined and increasing in the real interest rates.

\(^{14}\)Alternatively, government expenditures could be specified exogenously, and a lump sum transfer would adjust (passively) to maintain budget balance. However, lump sum transfers provide partial insurance to households, and any changes would have direct effects on welfare. We abstract from these effects by allowing government expenditures, which are separable from household preferences, adjust instead.
2.7 Stationary high-inflation equilibrium

We define the stationary high-inflation equilibrium as follows. Given a fiscal and monetary policy with constant nominal interest rate, $R^L$, nominal debt, $\tilde{B}_{t+1} = \Pi^H \tilde{B}_t$, growing at the target rate of inflation, and constant labor income tax, $\tau$, a stationary high-inflation equilibrium is:

1. Prices $P_t$, $P_t^L$, $P_t^{\tilde{e}}$ that grow at constant inflation rate, $\Pi = \Pi^H$, and constant prices $W$ and $V$ that together satisfy the no arbitrage condition (7) and profit maximization (11).

2. A stationary value function $V(q,d,z)$ that solves the Bellman equation (10) with decision rules $c(q,d,z)$, $m(q,d,z)$, $d(q,d,z)$, and $a(q,d,z)$.

3. A stationary measure $\psi^H$ that satisfies (12) given household decision rules.

4. Aggregate capital demand in (11) and aggregate savings satisfy asset market clearing (15).

2.8 Disinflation equilibrium path

We use the stationary high inflation equilibrium in $t = 0$ as the starting point. What if, in the following period $t = 1$, the monetary and fiscal authorities coordinate to abruptly change their fiscal and monetary policy stance? We consider a scenario where the government abandons its original inflation target $\Pi^H$ and makes a credible commitment to a lower inflation target $\Pi^L < \Pi^H$ achieved through a sequence of nominal interest rates $\{\tilde{R}_t^L\}$ and nominal government debt $\{\tilde{B}_t\}$ for $t \geq 1$. The announcement takes households by surprise as they have already made their portfolio choices in period $t = 0$ in the high-inflation equilibrium.

Redistribution. Any change in the realized level of inflation $\Pi_1$ from its previously anticipated value $\Pi^H$ alters the real value of household net worth across the distribution of households. Moreover, any change in the path of nominal rates changes the realized price $P_1^L$ of long-term loans. With the aggregate real value of assets unchanged, the effect is pure redistribution (Fisher effect). The redistribution sets each household’s real net worth according to:

$$q_1 = \begin{cases} \frac{m_0+a_0(1+P_1^{L}\rho)}{\Pi_1} \left(1 - \delta^D\right) d_0 & \text{if } a_0 < 0 \\ \frac{m_0+(1-\phi_0)\Pi_1^{L} + a_0 (1+P_1^{L}\rho)}{\Pi_1} \left(1 - \delta^D\right) d_0 & \text{if } a_0 \geq 0 \end{cases}.$$

(16)

For households with debt, $a_0 < 0$, the redistribution increases the real value of their nominal liabilities. They had anticipated a real borrowing cost of $R_0^L/\Pi^H$ and find instead the realized borrowing cost between period 0 and 1 is $(1 + \rho P_1^{L})/(P_0^L \Pi_1)$. For households with savings, $a_0 \geq 0$, the redistribution increases the real value of their bank equity, but only for the nominal share of bank assets, $\phi_0$. The surprise disinflation has no effect on the real value of the fraction $1 - \phi_0$ of the bank’s assets invested in the capital stock. The expression $\left((1 - \phi_0)\Pi_1^{L} + a_0 (1+P_1^{L}\rho)\right)$ adjusts the face value of the household’s claim on bank equity to reflect the gain in the real value.
of the bank’s nominal assets. Rather than the expected real return \( 1 + V_1 - \delta \) on bank equity, the household instead earns the realized real return of \( \phi_0 \frac{(1+\Pi^L_t)}{R^L_{t-1}} + (1 - \phi_0) (1 + V_1 - \delta) \).

Given this immediate redistribution, we consider the welfare effects along the exact equilibrium path that converges in finite time to a low inflation stationary equilibrium. The experiment is similar in spirit to Domeij and Heathcote (2004) who popularized this methodology to consider the welfare costs of a one-time change in the capital gains tax rate under imperfect insurance.

**Transition path.** Given an initial high inflation stationary equilibrium as described in Section 2.7 and its stationary measure \( \psi^H \), we characterize the disinflation transition equilibrium as follows. With \( \psi_1 = \psi^H \), then for \( t \geq 1 \), given a monetary and fiscal policy with inflation target \( \Pi^L \) consisting of a sequence of nominal interest rates \( \{R^L_t\} \), nominal government debt \( \{\tilde{B}_t\} \), and constant labor income tax, \( \tau \), a disinflation transition equilibrium is for \( t \geq 1 \)

1. An initial redistribution described by equation (16).

2. A sequence of measures \( \psi_{t+1} \) that satisfy (12).

3. A sequence of prices \( P^L_t, P^e_t, W_t, V_t \), and inflation \( \Pi_t \) that satisfy the no-arbitrage condition (7) and profit maximization (11).

4. Decision rules \( c_t(q,d,z), m_t(q,d,z), a_t(q,d,z), e_t(q,d,z) \) and \( d_t(q,d,z) \) that solve the sequence of Bellman equations (10).

5. Aggregate capital demand in (11) and aggregate savings satisfy asset market clearing (15).

### 2.9 Model solution

For the stationary economy, we use an extended version of the endogenous grid method developed by Hintermaier and Koeniger (2010) to solve for the household decision rules under constant inflation and real prices. For the transition we use an approach similar to Domeij and Heathcote (2004).\(^{15}\)

We work backwards from a stationary low inflation equilibrium. The disinflation equilibrium will converge to the low inflation equilibrium in finite time. We use 200 periods. For a given sequence of nominal interest rates and government debt we can solve backwards from the low inflation equilibrium (using the endogenous grid method to find the sequences of optimal decision rules). Then starting from the distribution of households in the initial high inflation economy, we solve the distribution forwards using the law of motion (12) and the disinflation sequences of policy rules, and we find the sequence of prices, \( \{P_t\} \), and by implication inflation, \( \{\Pi_t\} \), which clears the asset market. Because the monetary and fiscal effectively determines the market clearing real interest rate, no further iteration is necessary.

\(^{15}\)Computing the non-stationary solution for the disinflation equilibrium path is by now relatively standard, and we defer the details on the solution of the stationary and non-stationary to Appendix B.3.
3 Initial high-inflation equilibrium

The starting point for our experiment is the high inflation period in the early 1980s during which Paul Volcker became Chairman of the Federal Reserve. We calibrate our model economy to mimic this macro environment and to match moments of the wealth distribution measured in microdata on household finances around that period.

Our calibration proceeds in two steps. First we set some parameters externally to standard values in the literature. Second, we internally calibrate parameters of the income process and the discount rate to match moments on the wealth distribution and the share of households with nominal debt. After a brief summary of the household balance sheet data in Section 3.1, we discuss the calibration in Section 3.2, and the model fit in Section 3.3.

3.1 Household finance data

To measure the pre-Volcker high-inflation period, our primary source of data is the 1983 Survey of Consumer Finances (SCF) from the Federal Reserve Board. The survey consists of a representative sample of the U.S. population plus a supplemental sample of high income households drawn from a sampling frame of 5000 high-income tax payers estimated to have substantial wealth by the Internal Revenue Service’s (IRS) Statistics of Income Division (SOI). The oversampling of high income households allows for a more accurate representation of the tail of the wealth distribution than comparable surveys.16 Interviews for the 1983 SCF were conducted in person from February to August of 1983, and respondents in many cases were answering questions about their household finances in 1982. Our view is the 1983 SCF is a reasonable approximation to the wealth and income distributions in the high inflation period.17 Although in the model the disinflation is completely credible, in practice inflation expectations even during the early Volcker disinflation remained high. So household finances in 1982 to 1983, especially portfolio positions, reflected in part the high inflation period from the late 1970s.

Using the 1983 SCF we measure components of household wealth. Participants are asked about a variety of asset and debt classes including financial assets, paper assets, liquid assets, the cash value of durable goods, consumer debt and real estate debt. We classify these and calculate the nominal, real, and liquid wealth distributions (See Appendix A).

With one exception, this measurement is similar to Doepke and Schneider (2006a) for a different time period. We differ by only identifying direct nominal positions at the household level. Doepke and Schneider (2006a) use the Flow of Funds data from the Federal Reserve Board to correct for the indirect nominal positions of households, where indirect nominal wealth includes the nominal positions of the businesses on which the household has claims. They determine the indirect position

---

16 See Avery et al. (1988) for a complete description of the 1983 SCF survey and methodology.

17 Ideally we would have household finance data measured during the exact high inflation period. Unfortunately, we are not aware of any reliable household finance data covering this time period. The predecessor to the SCF was conducted in 1970 and again in 1977. In 1976 and 1977 inflation had also abated somewhat, so it is not ideal. Also, the 1983 survey design was the first to include the high income oversample needed to precisely estimate the distribution of wealth.
using the nominal leverage ratio of the U.S. business sector which they define as the nominal debt position per dollar of equity. This correction is well suited to their goal of characterizing the aggregate nominal position of the household sector and cohorts of the household sector, but it will be substantially less accurate for characterizing the distribution of the nominal wealth among households. We do not make an adjustment, because we believe that any bias from indirect nominal positions at the household level will be small. In the 1983 SCF only 34.9% of households have any claims to public or private equity, and of those, the median equity share of net worth was only 16.6%.

3.2 Calibration of high-inflation equilibrium

**Interest rates and inflation.** To calibrate nominal interest rates and inflation for the initial high inflation steady state, we use the year 1981.\(^\text{18}\) Gross inflation, measured by the CPI-Urban, had reached a high of \(\Pi^* = 10.4\%\), and the 30-year mortgage rate was \(i = 16.4\%\). Both series are downloaded from FRED. We use the 30-year mortgage rate rather than the Federal Funds Rate since the 30-year mortgage rate is a better indicator of the rates at which households would have been able to borrow during this period. As in the demand theory of the price level described in Section 2, we assume that the central bank sets the nominal interest rates and that inflation is determined by outstanding government bonds.

**Period length and debt duration.** The period length is one year. To capture the longer duration of household debt contracts we use the perpetual coupon structure with a constant decay rate governed by \(\rho\). If \(\rho\) is equal to 0 then debt is equivalent to a one-period bond that is typical in this literature. In our baseline calibration we set \(\rho = .89\), which implies a duration of 4.5 years to match the average duration of household nominal liabilities in the U.S. for this period as documented by Doepke and Schneider (2006a).

**Preferences.** We specify household preferences with relative risk aversion \(\sigma\) over a CES aggregate of consumption, real balances and durables so that:

\[
u (c_t, m_t, d_{t-1}) \equiv \frac{1}{1-\sigma} \left( \left( \omega c_t^{\eta \theta \eta \theta} + (1-\omega) m_t^{\eta \theta \eta \theta} \right)^{\eta \theta \eta \theta \theta} d_{t-1}^{1-\theta} \right)^{(1-\sigma)} \quad (17)
\]

With these preferences the elasticity of substitution between consumption and real balances \(\eta\) will turn out to be the interest elasticity of money demand, since unconstrained households would choose:

\[
m = \left( \frac{1 + i_t (1-\omega)}{i_t \omega} \right)^{\eta} c . \quad (18)
\]

\(^{18}\)The Volcker disinflation begins in the second half of 1981 with inflation finally achieving a sustained fall starting in September.
Lucas (2000) finds $\eta = 0.5$ to be a reasonable approximation for the aggregate interest elasticity of demand for M1, and he uses this value when computing the welfare costs of inflation. Other estimates put the elasticity closer or equal to 1.\footnote{See Hoffman et al. (1995), Holman (1998), Lucas (2000) and citations therein.} We choose $\eta = 0.5$ and examine the sensitivity of our results to alternative elasticities. The parameter $\omega \in [0,1]$ scales the liquidity value of real balances with $\omega = 1$ implying no liquidity value of money and thus zero demand for real balances. With $\eta$ fixed, we set $\omega = 0.988$ to target the ratio of real balances to output in the high inflation stationary distribution. In line with the literature, we set the coefficient on relative risk aversion, $\sigma$, to be 2. Following Fernández-Villaverde and Krueger (2011) we set $\theta = .81$ to target a share of the household budget spent on non-durables of 20%. Finally, in our calibration routine, we choose the discount factor $\beta$ to match the share of households that are nominal borrowers. In the 1983 SCF, 45% of households have negative net nominal positions.

**Durable goods.** We follow Hintermaier and Koeniger (2010) and set quadratic adjustment costs for durables:

$$
\Psi (d_t, d_{t-1}) = \frac{\kappa}{2} \left( \frac{d_t - (1 - \delta_d)d_{t-1}}{d_{t-1}} \right)^2 d_{t-1} 
$$

(19)

The parameter $\kappa$ represents the cost of adjusting durable holdings. Like Hintermaier and Koeniger (2010), we set $\kappa$ to .05 to represent the typical transaction costs for buying or selling a home. The depreciation rate on durable goods we set to .03 in line with standard values from the literature (Sterk and Tenreyro (2018) set durable depreciation to .04 while Hintermaier and Koeniger (2010) set it to .02). We set the securitization rate on durable goods, $\mu$, to be .8 as in Kaplan et al. (2020).

**Production.** For production we use a Cobb-Douglas production function

$$
F (K, N) = K^\alpha N^{1-\alpha}
$$

with capital share $\alpha = 0.33$, which is roughly in line with long run average of capital income to output. We choose an annual depreciation rate, $\delta^K = .06$, as in Castaneda et al. (2003).

**Government taxation.** We set $\tau$ to be 0.2 to target a government spending to GDP ratio of approximately 0.2. Government spending, $G$, adjusts with the change in seigniorage revenue as discussed in Section 2.6. In practice, the change in seigniorage revenue results in small change in government spending as a share of output since most government spending is financed by tax revenue.

### 3.3 Model fit in the high-inflation equilibrium

We calibrate the parameters of the Markov chain governing idiosyncratic labor efficiency to match moments on the distribution of wealth in the data. We follow Castaneda et al. (2003) and choose a 4 state Markov chain with a relatively high productivity state with less persistence. We choose
the values of the productivity states and the probability transition matrix to match moments on the wealth distribution. Appendix B.1 provides further details on the calibration of this process.

<table>
<thead>
<tr>
<th>Percent of total</th>
<th>Lowest by net worth</th>
<th>Highest by net Worth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10%</td>
<td>50%</td>
</tr>
<tr>
<td><strong>Net worth</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>data</td>
<td>−0.1</td>
<td>3.8</td>
</tr>
<tr>
<td>model</td>
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<td></td>
</tr>
<tr>
<td>data</td>
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<td>−34.8</td>
</tr>
<tr>
<td>model</td>
<td>−2.0</td>
<td>−41.1</td>
</tr>
<tr>
<td><strong>Real wealth</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>data</td>
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<td>6.3</td>
</tr>
<tr>
<td>model</td>
<td>0.3</td>
<td>6.2</td>
</tr>
</tbody>
</table>

Table 1: Distribution of Wealth: Data and Model

Note: We keep the ordering by net worth constant for all asset classes. Data on the wealth distribution and the share of households with net negative nominal wealth is from the 1983 Survey of Consumer Finances. Adjusted net worth is total net worth less the value of any durable assets or secured borrowing against these assets (Appendix A).

In Table 1 we compare the wealth distribution of households in the 1983 SCF with our calibrated high inflation economy. Instead of expressing the distribution in dollars, we instead describe points along the Lorenz curve. For example, in the 1983 SCF, the top 10 percent of households ordered by their net worth, owned 66.7 percent of total net worth, and the bottom 50 percent of households owned only 3.8 percent of total net worth. We hold the ordering by net worth fixed across all of the variables.

In 1983, as in other years, the distribution of net worth is skewed, with the top one percent of households owning 31.2 percent of total net worth. The precautionary savings motive in our model and the use of a superstar state (as in Castaneda et al., 2003) is able to generate this extreme wealth inequality. We miss some of the debt accumulation for the poorest 10% of the households whose share of net worth in the data is negative.\(^{20}\) However, the model does a good job of matching the distribution of nominal assets including nominal debt.

In the data, net nominal positions are negative for 45 percent of the population versus 58.1 percent in the high inflation steady state in our model. This reflects secured borrowing in the form of mortgages, which is captured in our model by secured borrowing against durables. This is important when thinking about welfare since households with nominal debt contracts stand to lose in a sudden disinflation. In a model that incorporates secured nominal borrowing against durable real assets, this means welfare losses occur across the income distribution, not just among the poor. The calibration generates too many households with net nominal debt. This is necessary for the model to match the debt accumulation in the bottom half of the net-worth distribution.

\(^{20}\)With no unsecured borrowing, the model is unable to generate negative net worth positions.
4 The welfare costs of the Volcker disinflation

We now use the model to quantify the welfare costs of the Volcker disinflation period. The model starts in a high-inflation equilibrium which we calibrate to match the average interest and inflation rate in 1981 described in Section 3.\footnote{The exact timing of when the Volcker disinflation begins is up for debate. In the summer of 1981 the central bank re-raised the federal funds rate to a high of 19.1 percent after several unsuccessful attempts to tame inflation throughout the 70s and in 1980. As a result of these previous failed attempts inflation increases in 1981 before finally starting a sustained fall that September. Thus we choose to calibrate the initial steady to 1981 and start the perfect foresight shock in 1982. Goodfriend and King (2005) recount the course of events and policy commitments leading up to and through the “incredible Volcker disinflation.” See also Lindsey et al. (2005).} We treat the Volcker disinflation as a perfect foresight shock where at the beginning of 1982 the government announces a new path of nominal interest rates and government bonds in order to achieve a new, lower inflation target of 3.1 percent. Figure 1 plots the path implied by the Volcker disinflation shock (broken line) for the nominal interest rate and inflation against the data (solid line). We calibrate the announced monetary and fiscal policy sequence of nominal interest rates $\{R_t^L\}$ and nominal debt $\{B_t\}$ to match the exact path of nominal interest rates and inflation rates during Volcker’s remaining 7 years of his term as Chairman. Thereafter, we assume monetary and fiscal policy maintains a constant nominal rate and inflation rate, which we set to match the average over Chairman Alan Greenspan’s terms (Aug 1987 to January 2006). We now examine the the short- and long-run effects of this policy across the distribution of households.\footnote{For the aggregate dynamics see the discussion in Appendix D and Figure D.1.}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{Interest rates and inflation during the Volcker disinflation}
\end{figure}

Note: Figure shows the path of interest rates and inflation in the data (the solid lines) and the path that is fed into the perfect foresight shock in the model (the broken lines). For interest rates we use the 30-year mortgage rate and for inflation we use CPI-U. The initial steady state is calibrated to the rate of inflation and interest rate in 1981 right before the Volcker disinflation and the final steady state averages inflation and interest rates during Alan Greenspan’s tenure as Chairman.

All things equal, everyone benefits from a lower inflation tax, but the unexpected change in the price level and future path of nominal rates imposes a one-time wealth redistribution. Those with net nominal liabilities find the real burden of their liabilities unexpectedly higher. Those with
Wealth Equivalence, $q$

Figure 2: Permanent wealth equivalent of Volcker disinflation as percent

Note: Figure shows the wealth equivalent needed to make households indifferent between the disinflation and the high inflation steady state plotted against their initial nominal wealth position (see equation 20). Two households with similar initial nominal wealth positions may have different welfare costs because of differences in their initial durables position. A negative value means households would sacrifice some of their initial wealth to avoid the disinflation.

net nominal savings receive an unexpected windfall. More concretely, both saver and borrower households had expected to receive a real return or pay real interest of 5.6 percent on their savings or debt. According to equation (16), the realized real return on equity in the first period of the transition is 8.4 percent for savers, while borrower households unexpectedly pay 28.1 percent on their debt. The effects are asymmetric because the mutual fund also invests in capital whose real value is unaffected by the disinflation. Borrowers and savers are also affected differently by the changes in the real interest rate, which increases significantly during the disinflation before settling at a new lower level in the long run. For each household, the welfare costs of the disinflation will depend on whether the benefit of the lower inflation tax is enough to compensate them for the effects of the redistribution and changes in the path of real interest rates.

4.1 Short-run conditional welfare

We compute a conditional welfare measure that asks on the eve of the inflation reform what wealth equivalent each household would require to be indifferent between the economy with the disinflation and a counterfactual economy which remains in the high inflation equilibrium permanently.

Since the unanticipated disinflation begins in period $t = 1$, we define $V_{t}^{L}(q_{1}, d_{0}, z_{1})$ as the value of a household in period $t = 1$ with real resources real resources $q_{1}$ already reflecting redistribution from the unexpected change in $\Pi_{1}$ according to equation (16). The value $V_{t}^{L}$ can be written as a function of sequences of consumption, real money balances and durables determined along the
disinflation equilibrium path

\[
V_1^L (q_1, d_0, z_1) = E \left[ \sum_{k=0}^{\infty} \beta^k u \left( c_{t+k}^L, m_{t+k}^L, d_{t+k-1}^L \right) \mid t = 1, z_1 \right].
\]

Relative to what was anticipated under high inflation, \( q_1 \) reflects a one-time windfall gain to those with positive net worth and a loss to borrowers.

Next, we define for the same household the counterfactual value \( V_1^H (q_1', d_0, z_1) \) of remaining in the high inflation environment forever. Here \( d_0 \) and \( z_1 \) are identical, but \( q_1' \) is counterfactual real net worth if inflation had remained high. This value \( V_1^H \) can be written as a function of sequences of consumption, real money balances and durables in the economy where inflation remains high:

\[
V_1^H (q_1', d_0, e_1) = E \left[ \sum_{k=0}^{\infty} \beta^k u \left( c_{t+k}^H, m_{t+k}^H, d_{t+k-1}^H \right) \mid t = 1, z_1 \right].
\]

Because the initial high inflation environment is stationary \( V_0^H = V_1^H \).

We define implicitly the wealth equivalent conditional welfare change \( \Delta_q (q_1, d_0, z) \) as the adjustment to their initial real wealth needed to make the counterfactual environment equivalent to a transition to a new low inflation steady state

\[
V_1^H \left( (1 + \Delta_q) q_1', d_0, e_1 \right) = V_1^L (q_1, d_0, z_1).
\]  

(20)

When \( \Delta_q < 0 \), this implies that they would be willing to sacrifice fraction \( \Delta_q \) of their wealth in order to avoid going through the transition while \( \Delta_q > 0 \) means they need to be compensated with an additional fraction \( \Delta_q \) of their resources to stay in the high inflation steady state. We plot in Figure 2 the wealth equivalent for each household versus the initial nominal wealth position of the household from a simulation of the model with 5000 households.

The gains from the Volcker disinflation are not spread equally across the distribution. It is apparent from Figure 2 that nominal borrowers bear the cost from the disinflation with low and middle income nominal borrowers bearing the worst costs—up to 200% of their wealth for the poorest households.

In Table 2 we tally who would vote for the Volcker disinflation. Since 58.1 percent of households are borrowers, most stand to lose from the redistribution and from the short-run increase in the real interest rate. Compensating borrowers for the redistribution and short-run increase in borrowing costs are the decline in the inflation tax and the long-run decline in real interest rates. However, only a few of these borrowers, concentrated among the low and middle earners who have little nominal debt, are willing to go through the disinflation.
Table 2: Preference for Disinflation Policy

<table>
<thead>
<tr>
<th></th>
<th>Percent that prefer high inflation</th>
<th>Percent of borrowers</th>
<th>Percent of Population</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Short run</td>
<td>Long run</td>
<td></td>
</tr>
<tr>
<td>Total economy</td>
<td>58.4</td>
<td>8.5</td>
<td>58.1</td>
</tr>
<tr>
<td>Borrowers</td>
<td>98.6</td>
<td>0.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Low income</td>
<td>37.4</td>
<td>29.6</td>
<td>38.4</td>
</tr>
<tr>
<td>Middle income</td>
<td>81.2</td>
<td>4.4</td>
<td>82.4</td>
</tr>
<tr>
<td>High income</td>
<td>10.5</td>
<td>6.1</td>
<td>5.7</td>
</tr>
<tr>
<td>Very high income</td>
<td>0.0</td>
<td>100.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

We have calculated the welfare results assuming perfect credibility of the monetary and fiscal authorities to implement the new path of nominal rates and inflation. When the new path or rates is announced, households believe they will be implemented and adjust their portfolio holdings accordingly. In Appendix C, we explore the sensitivity of our welfare results to an environment in which households do not adjust their inflation expectations in response to the shock. We do this using the method of adaptive expectations as in Evans and McGough (2020). Because households do not anticipate the realized path of inflation, they are not able to adjust their portfolios optimally and, as a result, the disinflation period is costlier. However, the differences are small; 61 percent of households prefer the high inflation equilibrium versus 58 percent in the baseline model.

Our results only allow households to differ by their assets and income. In the data, the asset and income levels that determine the welfare costs of the disinflation systematically vary by demographics. Young households, who may have just purchased their first home, tend to have large nominal debt positions while older households, who have saved for retirement have much higher levels of wealth. Similarly, the data shows large differences in assets and income by race, gender and immigration status. Thus, the disinflation implemented by the government will generate a large redistribution of wealth between these groups. While we do not model all these demographic differences explicitly, it is possible to understand the implications for each demographic group of interest by mapping their populations by income and assets to our model.

4.2 Long-run measures

We then ask whether households would choose differently if they could immediately reach the low-inflation equilibrium. To do this we examine the same individuals in the counterfactual and disinflation economies long after the disinflation has concluded and the economy has reached its low-inflation stationary equilibrium. In Table 2 we report the same vote far into the future, and see that about 91.5 percent of households now prefer the low inflation and low real interest rate equilibrium. We note that our experiment does include the initial redistribution and the short-term increase in the real interest rate, but many years have passed and households have sufficient time to readjust their savings.
Most prefer the low-inflation economy given the lower cost of liquidity from the reduction in the inflation tax and the lower real interest rate. What may be surprising is the 8.5 percent of households that would still prefer to remain in the high-inflation economy. These are saver households who dislike the long-run decline from 5.6 to 4.7 percent in the real interest rate in the low-inflation equilibrium; had the long-run real interest rate been unaffected, these households would also prefer low inflation in the long run. This long-run real interest rate effect is most pronounced among the very high income households, which are all savers. Without the benefits of the disinflation period’s high real interest rates, they prefer, despite the inflation tax, to remain in the high-inflation equilibrium because of its permanently higher real interest rate.

5 Sensitivity of welfare to alternative calibrations

The baseline welfare results depend on the trade-off between the benefit from lowering the inflation tax, the cost of the redistribution, and the time path of the real interest rate. In this section, we explore the sensitivity of our results to shutting down each of these channels. We also apply the quantitative framework to a different setting and use it consider the distribution of welfare effects from an increase in the inflation target.

5.1 Description of alternative calibrations

No inflation tax. The more money held by households, the greater the burden of the inflation tax. To generate demand for money, we include it directly in the household’s utility function. When unconstrained, a household’s money demand is proportional to their consumption (as shown in equation (18)). We interpret the demand for money as demand for liquidity: households need money in order to consume and pay bills. The amount of money held will be determined by $\omega$. When $\omega = 1$, households hold no money and are unaffected by the inflation tax. We compare our baseline welfare results from Section 4 to the same calibration with no liquidity value of money, $\omega = 1$. In this calibration, the results are solely driven by the effect of the redistribution and changes in the real interest rate. Households get no benefit from the lower inflation tax.

One-period loans. The duration of the debt contracts will determine the size of the redistribution. In the model, the duration is governed by $\rho$. When $\rho = 0$ households borrow in one-period contracts. The effect of increasing $\rho$ can be seen in the law of motion for wealth, equation (9). When $\rho = 0$ and there is an unexpected disinflation, households are only affected by the change in $\Pi_t$. When $\rho > 0$ they are also affected by the unexpected change in the price of nominal lending $P^L_t$. As nominal interest rates fall during the disinflation, the price $P^L_t$, will increase. For borrowers, the increase in $P^L_t$ implies an increase in their real debt burden. Below we present the welfare results from a calibration that uses one-period nominal loans instead of the longer duration loan with the

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\[ \omega \rightarrow 1. \]
geometric coupon structure. We compare the welfare results to our baseline calibration in which the duration was set to 4.5 years to match the average duration of nominal liabilities in the U.S. as documented by Doepke and Schneider (2006a). With one-period nominal debt, the size of the redistribution will be smaller and households are more likely to be compensated by the benefit of the lower inflation tax.

**Constant real interest rate.** Finally, we compare the baseline results to a calibration in which there is no change in the real interest rate. During the Volcker disinflation the real interest rate rises sharply as the monetary and fiscal authority increase nominal interest rates and decrease the supply of government bonds in order to decrease inflation. During the subsequent Greenspan period, real interest rates settle at an average rate of 4.7 percent, lower than the 5.6 percent before the disinflation. We ask what the effects of the disinflation would have been if the central bank set nominal interest rates to keep real rates constant at 5.6 percent while the fiscal authority adjusted bonds to lower inflation. This allows us to isolate the welfare effect of the Volcker disinflation that was generated by the change in real rates rather than the redistribution or the decrease in the inflation tax.²⁴

### 5.2 Welfare results

For each economy, Table 3 presents the results from a straight up or down vote of whether households prefer to go through the disinflation or remain in the high inflation steady state.

<table>
<thead>
<tr>
<th>Percent that prefer high inflation</th>
<th>baseline</th>
<th>no inflation tax</th>
<th>1-period loans</th>
<th>constant r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total economy</td>
<td>58.4</td>
<td>63.4</td>
<td>57.7</td>
<td>54.5</td>
</tr>
<tr>
<td>Borrowers</td>
<td>98.6</td>
<td>100.0</td>
<td>97.2</td>
<td>93.9</td>
</tr>
<tr>
<td>Low income</td>
<td>37.4</td>
<td>39.4</td>
<td>36.5</td>
<td>35.2</td>
</tr>
<tr>
<td>Middle income</td>
<td>81.2</td>
<td>83.9</td>
<td>80.2</td>
<td>79.2</td>
</tr>
<tr>
<td>High income</td>
<td>10.5</td>
<td>23.3</td>
<td>11.1</td>
<td>1.0</td>
</tr>
<tr>
<td>Very high income</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Table 3: Alternative Experiments: Preference for Disinflation Policy

**No inflation tax.** There is a stark difference between our baseline calibration and the economy with no money. Without money, there is no decrease in the inflation tax. The only effect of the disinflation is to redistribute wealth away from borrowers towards saver households, increase the real interest rate in the short-run, and decrease the real interest rate in the long-run. Without the lower inflation tax only the long-run decline in real rates can compensate borrowers for their

²⁴We note that a constant (expected) real interest rate does not eliminate redistribution. The realized real rate in the initial period of the disinflation still adjusts because of the change in inflation relative to what had been expected and through the price of the long-term asset, which adjusts as the path of nominal interest rates change. See discussion of equation 16.
loss in the redistribution and the short-run increase in borrowing costs, as a result, 63.4 percent of households would prefer to remain in the high inflation steady state versus 58.4 percent in our baseline calibration. The biggest increase in the share voting for high inflation is concentrated amongst high-income households. These households are savers and do not like the long run decline in the real interest rate. Without the lower inflation tax to compensate them, they prefer to remain in the high inflation steady state, despite their windfall from the redistribution.

**One-period loans.** In the economy with one-period loans, instead of the 4.5 year duration in the baseline economy, the size of the redistribution induced by the disinflation is smaller. As a result, the decline in the inflation tax and the long-run decline in real interest rates are more likely to compensate borrower households for their losses during the disinflation. Consistent with this, the share of households that vote to remain in the high-inflation steady state falls. On the other hand, the share of high income households who vote for the redistribution increases as they receive a smaller windfall from the redistribution. Amongst borrowers, a substantial amount, 97.2 percent, still prefer to remain in the high inflation steady state driven by the short-run increase in the real interest rate.

**Constant real interest rate.** Finally, we consider the welfare results if there were no change in the real interest rate along the transition path. In this case, the share of households that vote for the high inflation steady state falls. The biggest change is for high-income households, mostly savers, who do not like the long-run decline in real interest rates. Only 1.0 percent of them would vote for the high-inflation steady state had real rates remained constant. Borrowers also see a large decline in the share voting for high inflation (93.9 percent versus 98.6 percent in the baseline model). This is because borrowers, who are concentrated amongst low- and middle-income households, are particularly hurt by the short-run increase in the real interest rate more than they benefit from its long run decline.

### 5.2.1 Comparing the distributions of welfare costs

Next, we turn our attention to the distribution of the welfare costs. For each experiment, we rank households by the cost of the disinflation using the wealth equivalents, $\Delta_q$, as described in Section 4.1. This ranking places households who are harmed the most by the disinflation at the top of the distribution and households who benefit at the bottom. We then compute moments of the distribution of these welfare costs in Table 4.
In the baseline model, at the 90th percentile of welfare costs, households would sacrifice 70 percent of their wealth to stay in the high inflation economy.\textsuperscript{25} Whereas at the 10th percentile households benefit from the disinflation; for these households, the disinflation is equivalent to a 13 percent gain in their net worth under high inflation. On average the welfare cost is equivalent to 41 percent of net worth. Eliminating the benefits from the reduction in the inflation tax increases the welfare costs (or reduces the benefits) across the distribution, increasing the average welfare cost to almost 44 percent of net worth. However, because the incidence of the inflation tax is largest for low income households the change in welfare is not uniform.

By moving to only one-period debt, the average welfare cost falls to just under 17 percent of wealth. The reduction in welfare costs stems primarily from borrowers who are in the right of the distribution. This is because in the baseline the long duration of nominal liabilities amplifies the effects of the disinflation. Relative to an expected real borrowing cost of 5.6 percent under high inflation, the unanticipated shift in $\Pi_1$ and $P_{1L}^L$ results in a realized borrowing cost in the first period of the disinflation of 28.1 percent (see discussion of equation (16)). Under one-period debt, by eliminating the effects of the future path of nominal interest rates through $P_{1L}^L$, the realized borrowing cost is reduced to 9.8 percent. The effects on savers, who are in the left of the distribution, of moving to one-period debt are only slightly smaller than the baseline. They realize a real return on equity of 8.4 percent in the baseline, which is cut to 6.1 percent under one-period loans. Recall that their windfall from the redistribution is always diluted by the (real) share of the mutual fund’s assets in capital.

A constant real interest rate also decreases the average welfare costs of the redistribution for borrower households to a little over 20 percent of wealth. The costs are substantially smaller for borrower households who no longer face a short-term increase in their future borrowing cost. It is important to emphasize that even when the government maintains a constant 5.6 percent real interest rate throughout the disinflation, there is still a redistribution. The real interest rate is the cost of borrowing between the current and future periods. The realized real borrowing cost and return on equity still diverge from the expected 5.6 percent because of the unanticipated change in inflation to $\Pi_1$ and unexpected change in the price of loans to $P_{1L}^L$. Collectively, the differences between the baseline calibration and the alternative experiments highlight the importance of capturing all three channels (the redistribution, the decrease in the inflation tax, and the increase in the real interest rate) when considering the welfare costs of the Volcker disinflation.

\textsuperscript{25}By the 95th percentile, households would give up all their net worth to avoid the disinflation.
5.3 Raising the inflation target

We now use our model to consider a final experiment. In light of recent concerns about low inflation leaving monetary policy close to the zero lower bound on interest rates, we consider the welfare consequences of an increase in the inflation rate. Though we do not model the benefit that may arise from avoiding the zero lower bound, our analysis can characterize precisely the heterogeneous welfare costs of an increase in the inflation target to be considered alongside any potential aggregate benefit.\(^{26}\) Specifically, we examine a coordinated effort by the monetary and fiscal authorities to raise the inflation rate, while keeping the real interest rate constant.

To do this, we first re-calibrate our model using data on the wealth distribution from the 2019 SCF. The details of the calibration and the model fit are in Appendix B.2. We assume the economy starts in a steady state with an inflation rate of 1.8 percent and a nominal interest rate of 3.9 percent. These correspond to the 2019 average CPI inflation and 30 year mortgage rates, respectively. We then consider the following coordinated fiscal and monetary policy to raise the inflation target: a new path of nominal government bonds and nominal rates to slowly increase inflation and nominal rates 0.64 percentage points per year for five years until inflation reaches a rate of 5 percent and the nominal interest rate reaches 7.1 percent, after which both remain constant. Throughout the transition, the real interest rate remains unchanged at 2.1 percent.\(^{27}\)

Table 5 shows the results from an up or down vote on whether or not to increase the inflation target. 52.4 percent of households prefer to remain in the low-inflation equilibrium rather than bear the cost of the increased inflation tax. However, as borrowers stand to benefit from the redistribution, only 16.6 percent prefer the low-inflation steady state. With no changes in the real interest rate, households are weighing the cost of the increase in the inflation tax with their gains or losses from the redistribution. In this experiment, there is no long-run benefit to higher inflation so all households prefer the low-inflation steady state in the long run.

<table>
<thead>
<tr>
<th>Percent that prefer low inflation</th>
<th>Percent borrowers</th>
<th>Percent of population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total economy</td>
<td>52.4</td>
<td>100.0</td>
</tr>
<tr>
<td>Borrowers</td>
<td>16.6</td>
<td>100.0</td>
</tr>
<tr>
<td>Low income</td>
<td>54.4</td>
<td>100.0</td>
</tr>
<tr>
<td>Middle income</td>
<td>32.7</td>
<td>100.0</td>
</tr>
<tr>
<td>High income</td>
<td>96.5</td>
<td>100.0</td>
</tr>
<tr>
<td>Very high income</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Table 5: Vote on increasing the inflation target

\(^{26}\)Coibion et al. (2012) in a New Keynesian model find the benefit of increasing steady state inflation to be modest because of the overall low probability of a binding zero lower bound episode.

\(^{27}\)As we discuss Section 4.1 this does not prevent redistribution since the realized real interest rate initially diverges from the 2.1 percent that had been anticipated upon the policy announcement.
As in our baseline experiment, the welfare costs and benefits are distributed unequally across the distribution; 54.4 percent of low-income households and 96.5 percent of high-income households prefer to remain in the low-inflation steady state while only 32.7 percent of middle-income households prefer low-inflation. Figure 3 presents a scatter plot of the short-run wealth equivalent measure from equation (20) using a simulation of the inflationary experiment. For some of the poorest households, the benefit from decreasing their real debt burden is large and more than offsets the increase in the inflation tax. Their welfare gains from the inflationary period reach up to 50 percent of their wealth.

![Figure 3: An Inflationary period](image)

A recent literature (Auclert, 2019 and Ozkan et al., 2017) has argued that an inflationary period could stimulate consumption and aggregate demand by redistributing resources towards borrowers who have high marginal propensities to consume. In our model, the presence of money reverses the stimulative effects of an inflationary period on consumption. Even though the poorest households with high marginal propensities to consume gain from the redistribution, overall, aggregate consumption declines. The inflation tax, by increasing the cost of liquidity, implicitly makes it more costly to consume. The effects on output are slightly positive as households rebalance their portfolios away from money and towards assets causing aggregate savings to increase slightly (a version of the Tobin (1965) effect). Thus, the presence of money reduces the stimulative effects on consumption of an accommodating monetary policy shock.

6 Conclusion

We examine the welfare effects of a permanent and unexpected change in the monetary and fiscal policies of the government to reduce inflation. The unexpected in the inflation rate redistributes wealth from nominal borrowers towards savers, but it also lowers the burden of the inflation tax

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28We show the path of aggregate variables along the inflationary transition path in Appendix Figure D.2.
for all households. In the case of the Volcker disinflation, the combined effect of the monetary and fiscal policies also entailed a short-run increase and long-run decline in the real interest rate. We quantity the welfare effects stemming from each of these channels.

Our analysis relies on an Bewley-Imrohoroglu-Huggett-Aiyagari model extended to include a consumer portfolio choice between nominal savings or debt, real durable goods, and money. change in the path of inflation. Nominal borrowing is secured against real durable goods meaning that even wealthy households can have negative nominal wealth positions, as is often the case for US households with a nominal fixed rate mortgage. The change in the inflation rate redistributes wealth from households with net nominal liabilities towards those with positive net nominal assets.

We calibrate the model to consider the Volcker disinflation of the early 80s. We compare the welfare results from several calibrations. In the baseline, we calibrate the duration of nominal debt and the liquidity value of money to match characteristics of the US wealth distribution in the early 1980s. The disinflation redistributes wealth from borrowers to savers and also increases the short-run borrowing costs for debtors. As a result, even though they are compensated by the lower inflation tax, almost all debtor households, 58 percent, prefer to remain in the high inflation steady state rather than go through the disinflation. Middle income households, who have large nominal debt positions secured against their durables, are most likely to prefer the high inflation steady state (81 percent) rather than face the disinflation.

We then consider three alternative versions of our baseline model: a version with no money in which there is no benefit from a lower inflation tax, a version with only short term nominal borrowing in which the size of the redistribution is smaller, and a version in which the real interest rate remains constant throughout the redistribution. The percent of households who prefer to stay in the high inflation steady state remains high (≈ 55%) in the experiments with a constant real interest rate and a one-period nominal debt. This is because borrowers, who make up 58.1 percent of the population are hurt both by the redistribution and by the short-run increase in the real interest rate. Undoing only one of these channels will decrease the welfare costs of the disinflation, but not undo them. In the cashless version of the economy, more household prefer to remain in the high-inflation steady state. Without the lower inflation tax, there is nothing to compensate borrowers for their losses during the disinflation and 63.4 percent of households prefer to remain in the high inflation steady state. These results suggests that it is crucial to capture the duration of assets, the change in the real interest rate, and the change in the inflation tax when considering the welfare consequences of changing the inflation rate.
References


A Data appendix

Table A.1 reports the real and nominal categorization of assets and liabilities measured in the SCF.

<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Nominal assets and liabilities</strong></td>
<td><strong>Secured borrowing:</strong></td>
</tr>
<tr>
<td>Liquid:</td>
<td>Amount owed against land contract notes</td>
</tr>
<tr>
<td>Cash in checking accounts</td>
<td>Home mortgages</td>
</tr>
<tr>
<td>Cash in savings or share accounts</td>
<td>Amount outstanding on other property mortgages</td>
</tr>
<tr>
<td>Money market and call accounts IRA or Keogh accounts Certificates of Deposit U.S. Savings Bonds</td>
<td></td>
</tr>
<tr>
<td>Non liquid:</td>
<td>Unsecured borrowing:</td>
</tr>
<tr>
<td>Face value of bonds Loans owed to household and gas leases Aggregate gross value of land contracts and notes Thrift type pension account assets</td>
<td>Amount outstanding on loans other than mortgages(^1) Credit card debt Amount owed on lines of credit</td>
</tr>
<tr>
<td><strong>B. Real assets</strong></td>
<td><strong>Financial:</strong></td>
</tr>
<tr>
<td><strong>Durables:</strong></td>
<td>Stocks and mutual funds Trust accounts</td>
</tr>
<tr>
<td>Home Other properties Vehicles</td>
<td></td>
</tr>
</tbody>
</table>

Table A.1: Categorization of SCF household assets and liabilities

Note: classification of assets and liabilities variables in 1983 Federal Reserve Board Survey of Consumer Finances.

\(^1\) Also subtracts loans against life insurance policies.

B Model Appendix

B.1 Calibration of Markov Process

The calibration of the Markov process follows Castaneda et al. (2003). We choose the parameters of the probability transition matrix, the income states and the discount rate to match moments on the wealth distribution. Specifically, we choose the parameters to minimize the sum of the squared difference between a set of moments in the model and the data:

\[
\min_P (X_{\text{model}} - X_{\text{data}}) (X_{\text{model}} - X_{\text{data}}) \quad (B.1)
\]
where $\mathbb{P}$ is the set of parameter and, $X$ is a vector of moments. The moments targeted along with the model fit are summarized in Table 1.

Equation (B.2) gives the income states for our productivity process. There are four income groups with the income of the lowest group normalized to $0.0381$.

$$z \in [0.0381; 0.3383; 0.9876; 38.60]$$ (B.2)

Equation (B.3) gives the transition matrix describing how households transition between states. An element of the matrix $\pi_{ij}$ describes the probability that the household transitions between from state $i$ to state $j$.

$$\begin{array}{cccc}
  z_1 & z_2 & z_3 & z_4 \\
  z_1 & .9606 & .0207 & .0187 & 0 \\
  z_2 & .0036 & .9912 & .0052 & 0 \\
  z_3 & .0118 & .0104 & .9747 & .0031 \\
  z_4 & .0774 & .0719 & .0626 & .7881 \\
\end{array}$$ (B.3)

Given the transition matrix, in steady state, 13.4 percent of the population will be low income, 62.6 percent will be middle income, 23.6 percent high income, and 0.4 will be very high income. As described in Table 1, the process does a good job of replicating the distribution of income and wealth across households.

## B.2 Calibration to 2019 SCF

For the experiment considering an increase in the inflation rate, we calibrate our model to the 2019 SCF data. The calibration follows the same procedure as in the baseline calibration, but using moments from the 2019 SCF data. The model fit is shown in Table B.1. The model again fits the data very well.

<table>
<thead>
<tr>
<th>Percent of total</th>
<th>Lowest*</th>
<th>Highest*</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Wealth distribution</td>
<td>10%</td>
<td>50%</td>
</tr>
<tr>
<td><strong>Net worth</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>data</td>
<td>-0.55</td>
<td>1.49</td>
</tr>
<tr>
<td>model</td>
<td>0.06</td>
<td>2.76</td>
</tr>
<tr>
<td><strong>Nominal wealth</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>data</td>
<td>-10.51</td>
<td>-26.91</td>
</tr>
<tr>
<td>model</td>
<td>-0.24</td>
<td>-2.61</td>
</tr>
<tr>
<td><strong>Real wealth</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>data</td>
<td>.73</td>
<td>5.16</td>
</tr>
<tr>
<td>model</td>
<td>0.22</td>
<td>5.69</td>
</tr>
</tbody>
</table>

Table B.1: Distribution of Wealth: Data and Model

*Ordered by new worth. We keep the ordering constant for all asset classes. Note: Data on the wealth distribution and the share of households with net negative nominal wealth is from the 2019 Survey of Consumer Finances. Adjusted net worth is total net worth less the value of any durable assets or secured borrowing against these assets.

The calibrated income states and transition matrix are as follows:
\[ z \in [0.0381; 0.2547; 0.5265; 41.0531] \quad (B.4) \]

\[
\begin{array}{cccc}
z_1 & z_2 & z_3 & z_4 \\
0.9618 & 0.0200 & 0.0170 & 0.0012 \\
0.0078 & 0.9996 & 0.0036 & 0 \\
0.0119 & 0.0105 & 0.9751 & 0.0025 \\
0.0556 & 0.0534 & 0.0478 & 0.8432
\end{array}
\quad (B.5)\]

### B.3 Model Solution

#### B.3.1 Household Decision Rules

Let \( V_t(q_t, d_{t-1}, z_t) \) be the value function of an individual with real net worth \( q_t \), existing durables \( d_{t-1} \), and labor efficiency \( z_t \). Then \( V_t \) satisfies the Bellman equation given by equation (10) subject to the individual’s budget constraint (8) and real borrowing constraint (5). In addition, we enforce and Inada conditions give non negativity constraints

\[ m_t \geq m_0 \geq 0 \quad \text{and} \quad d_t \geq d_0 \geq 0 \quad (B.6) \]

The law of motion for resources is given by equation (9).

To simplify notation we define the discounted expected continuation value

\[ f_t(q', d_t, z_t) \equiv \beta E[V_{t+1}(q', d_t, z_{t+1}) | z_t, t] \quad (B.7) \]

Let \( \nu_t \) be the multiplier on the secured borrowing constraint, and let \( \kappa_t \) and \( \chi_t \) be the multipliers on the non negativity constraints for money and durables respectively. Then the KKT conditions (omitting the budget constraint and multiplier \( \lambda_t \)) are

\[
\frac{f_{q_t} + \nu_t}{\Pi_{t+1}} = \frac{u_{ct}}{1 + i_t} \quad (B.8)
\]

\[
u_t \left( \frac{a_t}{\Pi_{t+1}} + b + \mu (1 - \delta_D) d_t \right) = 0 \quad \nu_t \geq 0
\]

\[
\kappa_t (m_t - m_0) = 0 \quad \kappa_t \geq 0
\]

\[
\chi_t (d_t - d_0) = 0 \quad \chi_t \geq 0
\]

Combining the Euler equations for savings (B.8) and durables (B.10) we can write an equation for the multiplier \( \nu_t \) given \( q_{t+1}, d_t, z_t \) and possibly \( \chi_t \)

\[ f_{q_t} (1 - \delta_D) + f_{dt} + \nu_t \mu (1 - \delta_D) + \chi_t = (1 + i_t) \frac{f_{q_t} + \nu_t}{\Pi_{t+1}} (1 + \Psi_{1t}) \]

\[
u_t \left( \frac{1 + i_t}{\Pi_{t+1}} (1 + \Psi_{1t}) - \mu (1 - \delta_D) \right) - \chi_t = -f_{q_t} \left( \frac{1 + i_t}{\Pi_{t+1}} (1 + \Psi_{1t}) - (1 - \delta_D) \right) + f_{dt} \quad (B.11)
\]
We can determine \( f_{qt} \) and \( f_{dt} \) from envelope conditions

\[
\begin{align*}
  f_{qt} (q_{t+1}, d_t, z_t) &= \beta E_t \left[ u_{ct+1} \right] \quad \text{(B.12)} \\
  f_{dt} (q_{t+1}, d_t z_t) &= \beta E_t \left[ u_{dt+1} - u_{ct+1} \Psi_{2t+1} (d_{t+1}, d_t) \right] \quad \text{(B.13)}
\end{align*}
\]

**CES Preferences** We use a CES specification for utility given in equation 17. For notation we define

\[
\Upsilon_t \equiv \omega c_t \cdot \eta^{-1} - \eta + (1 - \omega) m_t \cdot \eta^{-1}
\]

so

\[
\begin{align*}
  u_{ct} &\equiv \Upsilon_t^{1 - 1\cdot(1-\theta)} - \eta \cdot (1 - \theta) \quad \theta \omega c_t \cdot \eta^{-1} \\
  u_{mt} &\equiv \Upsilon_t^{1 - 1\cdot(1-\theta)} - \eta \cdot (1 - \theta) \cdot (1 - \omega) m_t \cdot \eta^{-1} \\
  u_{dt} &\equiv \Upsilon_t^{1 - 1\cdot(1-\theta)} - \eta \cdot (1 - \theta) \cdot (1 - \theta)
\end{align*}
\]

Now we can write equations (B.8) and (B.9) as

\[
\begin{align*}
  \frac{f_{qt}}{\Pi_{t+1}} + \nu_t &= \frac{\Upsilon_t^{1 - 1\cdot(1-\theta)} - \eta \cdot (1 - \theta) \cdot (1 + i_t) \cdot \theta \omega c_t \cdot \eta^{-1}}{1 + i_t} \quad \text{(B.14)} \\
  \frac{f_{qt}}{\Pi_{t+1}} + \kappa_t &= \frac{\Upsilon_t^{1 - 1\cdot(1-\theta)} - \eta \cdot (1 - \theta) \cdot (1 - \theta) \cdot (\omega c_t \cdot \eta^{-1} - (1 - \omega) m_t \cdot \eta^{-1})}{\left(1 - \rho \cdot (1 - \delta_{D})\right) \left(1 + \Psi_1 t \right)} \quad \text{(B.15)}
\end{align*}
\]

**Adjustment Costs** We use the a quadratic specification for adjustment costs given in equation (19) as in Hintermaier and Koeniger (2010) and

\[
\Psi_1 (d_t, d_{t-1}) = \rho \left( \frac{d_t}{d_{t-1}} - (1 - \delta_d) \right)
\]

and

\[
\Psi_2 (d_t, d_{t-1}) = \frac{\rho}{2} \left( (1 - \delta_d)^2 - \left( \frac{d_t}{d_{t-1}} \right)^2 \right)
\]

so that with \( \nu_t = 0 \) then

\[
1 + i_t \cdot \rho = \frac{-f_{qt} \left( \frac{1 + i_t}{\Pi_{t+1}} (1 - \rho (1 - \delta_{D})) - (1 - \delta_{D}) \right) + f_{dt}}{f_{qt}d_t}
\]

with \( \nu_t \geq 0 \) then

\[
1 + i_t \cdot \rho = \frac{f_{dt} - \frac{1 + i_t}{\Pi_{t+1}} (1 - \rho (1 - \delta_{D})) \left( f_{qt} + \nu_t \right) + (1 - \delta_{D}) \left( f_{qt} + \mu \nu_t \right)}{d_t \left( \nu_t + f_{qt} \right)}
\]

**B.3.2 Interior Solution**

When all constraints are slack use (B.11) to show

\[
\begin{align*}
  f_{dt} &= f_{qt} \left( \frac{1 + i_t}{\Pi_{t+1}} (1 + \Psi_1 t) - (1 - \delta_{D}) \right)
\end{align*}
\]
so that given \( q_{t+1}, z_t, d_{t-1} \) and functions \( f_{qt}(q_{t+1}, d_t, z_t) \) and \( f_{dt}(q_{t+1}, d_t, z_t) \) one can solve for \( d_t \).

Also with non negativity constraints on \( m_t \) and \( d_t \) slack using (B.14) and (B.15) we have

\[
\frac{m_t}{c_t} = \left( \frac{1 + i_t}{i_t} \right)^{\eta} \left( 1 - \frac{1}{\omega} \right). \tag{B.16}
\]

We can substitute back into (B.14) and solve for consumption in terms of \( q_{t+1}, z_t, d_t, d_{t-1} \)

\[
c_t = \left( \frac{\omega + (1 - \omega) \left( \frac{1 + i_t}{i_t} \right)^{\eta - 1}}{1 - \eta + \eta \theta - \eta \theta \theta} \right)^{\frac{1}{1 - \eta + \eta \theta - \eta \theta \theta}} \left( d_{t-1} \right)^{(1 - \theta) (1 - \sigma)} \theta \omega^{\frac{1}{1 - \eta + \eta \theta - \eta \theta \theta}}. \tag{B.17}
\]

Money demand (B.16) will be proportional to consumption (B.17). Given \( q_{t+1} \) and now \( m_t \) and \( d_t \) we can solve for \( a_t \) using (9) as

\[
a_t = \Pi_{t+1} \left( q_{t+1} - (1 - \delta_D) d_t \right) - m_t \tag{B.18}
\]

and given \( q_{t+1}, c_t, a_t, d_t \) and \( d_{t-1} \) using the budget constraint (8)

\[
q_t = c_t + \frac{a_t}{1 + i_t} + d_t + \Psi (d_t, d_{t-1}) + m_t - w_t z_t (1 - \tau_t) - T_t. \tag{B.19}
\]

### B.3.3 Binding Collateral Constraint

Note that given \( q_{t+1} \) from the collateral and non negativity constraints we know \( d_t \) must lie in the interval

\[
d_t \in \left[ d_0, \frac{q_{t+1} - m_t}{\Pi_{t+1} (1 - \delta_D) (1 - \mu)} \right].
\]

If the interior solution for \( d_t \) is above the upper bound we know that the RHS of (B.11) is positive over the interval and the collateral constraint binds \( \nu_t > 0 \).\(^{29}\) In this event, we look for a solution where the collateral constraint is binding and both non negativity constraints are slack.

**Slack non negativity conditions** We first look for a solution where \( \kappa_t = \chi_t = 0 \). If the economy were cashless we could determine \( d_t \) and thus \( \nu_t \) directly from the borrowing constraint. In the monetary economy \( d_t \) and \( m_t \) are jointly determined with the borrowing constraint placing a restriction on their relationship. Suppose we knew \( \nu_t > 0 \), then from (B.11) we can determine \( d_t \) and thus \( f_q \). From (B.14) with \( \nu_t > 0 \), and (B.9) with \( \kappa_t = 0 \) we have

\[
\frac{m_t}{c_t} = \left( \frac{\omega}{1 - \omega} \left( 1 - \frac{1}{1 + i_t} \frac{f_{qt}}{f_{qt} + \nu_t} \right) \right)^{-\eta}
\]

\(^{29}\)Since \( \chi_t \geq 0 \) and \( \nu_t > 0 \) when the collateral constraint binds, this requires of course that \( \mu < \frac{1 + i_t}{\Pi_{t+1}} \frac{1 + \Psi_{1t}}{1 + \Psi_{10}} \), i.e. that the secured borrowing constraint cannot be too loose. An Inada condition on \( d \) and our choice of \( d_0 \) sufficiently small will ensure that \( d_t \geq d_0 \). If there were some autonomous level of durable consumption, as in Hintermaier and Koeniger (2010), sufficiently large, we would need to verify that \( d_t \) does not violate its lower bound with the collateral constraint slack.
In this event

[Inada conditions on \( u \) ensure that non negativity constraints on \( m \) and \( d \) are never binding. However, in practice we choose very small but positive numbers as lower bounds for \( m \) and \( d \). We make these sufficiently small so that the lower bounds would never bind before the collateral constraint. Since \( q_1 \) is chosen to reflect the lower bounds for \( a, m, \) and \( d \), when \( q_{t+1} = q_1 \) at least one of the lower bounds will be binding.

Again \( q_{t+1} = q_1 \) requires that \( d_t \) and \( m_t \) be chosen at their lower bounds. In this case at least one of the non negativity constraints must bind. In all other cases, if \( m_0 \) and \( d_0 \) are chosen sufficiently small, Inada conditions should keep these constraints from binding.

We implicitly assume that the constraint on money binds first, in which case we can look for a solution where \( \kappa > 0 \) and \( \chi \leq 0 \) (constraint on \( d \) is just binding).\(^{30}\) In this event \( d_t = d_0 \) and \( m_t = m_0 \) and

\[
\nu_t (m) = \frac{-f_q (q_t, d_t (m), z_t) \left( \frac{1+\iota}{\Pi T+1} (1 + \Psi_1 (d_t (m), d_{t-1})) - (1 - \delta_D) \right) + f_d (q_t, d_t (m), z_t) \left( \frac{1+\iota}{\Pi T+1} (1 + \Psi_1 (d_t (m), d_{t-1})) - \mu (1 - \delta_D) \right)}{\left( \frac{1+\iota}{\Pi T+1} (1 + \Psi_1 (d_t (m), d_{t-1})) - \mu (1 - \delta_D) \right)}. \quad (B.20)
\]

determines \( \nu \). Then use (B.14) to find a fixed point equation for \( c_t \)

\[
c_t = \left( \left( \frac{\eta - 1}{\omega c_t} + (1 - \omega) m_0 ^{-\eta} \right) \frac{\eta - 1}{\eta - 1} d_t (1 - \sigma) \theta \omega \left( \frac{1+\iota}{\Pi T+1} \right)^{\eta} \right) ^{\eta} \]

with \( d_t, c_t, m_t \) and \( q_{t+1} \) then \( a_t \) follows from the law of motion (9) and \( q_t \) follows from the budget constraint (8).

### B.3.4 Cashless Economy

In a cashless economy where \( \omega = 1 \) little changes, but the solution is much simpler.

\(^{30}\)In practice it could be the opposite, but we verify that the candidate solution does not violate any of the KKT conditions.
CES Preferences  We use the parametric specification
\[ u(c_t, d_{t-1}) = \frac{1}{1-\sigma} \left( c_t^{\theta} d_{t-1}^{1-\theta} \right)^{(1-\sigma)} \]
so
\[ u_{ct} = \left( c_t^{\theta} d_{t-1}^{1-\theta} \right)^{-\sigma} c_t^{\theta-1} d_{t-1}^{1-\theta} \theta \]
\[ u_{dt} = \left( c_t^{\theta} d_{t-1}^{1-\theta} \right)^{-\sigma} c_t^{\theta} d_{t-1}^{1-\theta} (1-\theta) . \]

Now we can write equation (B.8) as
\[ \frac{f_{qt} + \nu_t}{\Pi_{t+1}} = \frac{\left( c_t^{\theta} d_{t-1}^{1-\theta} \right)^{-\sigma} c_t^{\theta-1} d_{t-1}^{1-\theta} \theta}{1 + i_t} \]  
(B.21)

Interior solution  With \( \nu_t = 0 \) then given \( f_{qt} \)
\[ c_t = \left( \frac{\theta a_t^{-1-s}(1-\theta)}{f_{qt}^1 \Pi_{t+1}^{1+s}} \right)^{\frac{1}{1-s(1-\theta)}} \]

Binding collateral constraint  We know \( d_t \) is within
\[ d_t \in \left[ d_0, \frac{q_{t+1} + b}{(1-\delta)(1-\mu)} \right] \]
so if \( d_t \) exceeds the upper bound then we set \( d_t = \bar{d}_t \), determine \( \nu_t \geq 0 \) as before.

B.3.5 Numerical Solution

First, define exogenous grid \( D = \{d_1, \ldots, d_{N_d}\} \) (which will be the lagged values of \( d \)) and then define exogenous grid \( Q = \{q_1, \ldots, q_{N_q}\} \) where \( q_1 = -b + d_0 (1-\mu) (1-\delta D) + \frac{m_u}{\Pi} \). The policy functions will be defined over a \( S \times Q \times D \) grid.

We describe the solution with backwards induction in preparation for the non stationary solution. Of course letting \( T \to \infty \) with constant prices we find the stationary policy rules. To find \( f_{qt}(q_{t+1}, d_t, z_t) \) and \( f_{dt}(q_{t+1}, d_t, z_t) \) we start with an initial guess for \( m_{t+1}(q_{t+1}, d_t, z_{t+1}) \) and \( c_{t+1}(q_{t+1}, d_t, z_{t+1}) \), and then use the envelope conditions (B.12) and (B.13) and the transition matrix \( P_s \) for \( z \) to compute \( f_{qt}(q_{t+1}, d_t, z_t) \) and \( f_{dt}(q_{t+1}, d_t, z_t) \) over the exogenous grid. Then for every \( q \times z \) solve (B.11) for \( d_t^N(q_{t+1}, z_t) \). Solve for the adjustment costs
\[ \Psi(d_t^N(q_{t+1}, z_t), d_{t-1}) = \rho \left( \frac{d_t^N - (1-\delta_d) d_{t-1}}{d_{t-1}} \right)^2 d_{t-1} \text{ and } \Psi_1(d_t^N(q_{t+1}, z_t), d_{t-1}) = \rho \left( \frac{d_t^N}{d_{t-1}} - (1-\delta_d) \right) \]

Next using \( f_{qt}(q_{t+1}, d_t^N, z_t) \) and \( d_t^N(q_{t+1}, z_t) \) look for an interior solution for \( c_t^N(q_{t+1}, d_{t-1}, z_t) \)
using \((B.17)\) and

\[
\begin{align*}
m_t^N(q_{t+1}, d_{t-1}, z_t) &= \left( \frac{1 + i_t}{i_t} \right)^{\eta} c_t^N \\
a_t^N(q_{t+1}, d_{t-1}, z_t) &= \Pi_{t+1}(q_{t+1} - d_t^N(1 - \delta_D)) - m_t^N \\
n_t^N(q_{t+1}, d_{t-1}, z_t) &= e_t^N + \frac{a_t^N}{1 + i_t} + d_t^N(q_t, e_t) + \Psi(d_t^N(q_t, z_t), d_{t-1}) \\

&\quad + m_t^N - w_t z_t (1 - \tau_t) - T_t
\end{align*}
\]

**Check the borrowing constraint** Next check whether the interior solution for \(a_t^N\) would violate the collateral constraint (or check \(d_t^N\)). If

\[
\frac{a_t^N(q_{t+1}, d_{t-1}, z_t)}{\Pi_{t+1}} < -\mu (1 - \delta_D) d_t^N(q_{t+1}, z_t)
\]

then the collateral constraint binds so that \(\nu > 0\). When \(\nu > 0\) we consider two cases, for all \(q_{t+1} > q_1\) we look for a solution where \(\nu > 0\) but the non negativity constraints are slack. For \(q_{t+1} = q_1\) we look for a solution for at least one of the non negativity constraints binds as described above. When the collateral constraint binds and \(d_t^N(q_t, z_t)\) is updated, the adjustment cost, \(\Psi_t\), and the multiplier on the borrowing constraint, \(\nu_t\), will also need to be updated.

**Interpolating over the exogenous grid** Finally, using the policy functions defined over the endogenous grid, interpolate over the exogenous \(Q\) gridpoints, and correct for any \(q < q_t^N(q_1, d, z)\), which requires that the collateral, money, and durable constraints all bind (the Inada conditions should prevent this if \(m_0^N\) and \(d_0^N\) are sufficiently small). In which case, policy can be determined directly from the constraints. Use the policy functions \(c(q, d, z)\) and \(m(q, d, z)\) over the exogenous grid \(Q \times D \times S\) to update \(f_q\) and \(f_d\) via the envelope conditions. Iterate until the policy functions converge.

### C Adaptive expectations

The welfare results in the baseline model are calculated assuming that the Volcker disinflation is perfectly credible. In practice, the Volcker disinflation was plagued by credibility issues. In this section, we explore the sensitivity of the welfare results to a model in which household inflation expectations adapt slowly to the path of actual inflation in the economy. Specifically, we assume that expected inflation in period \(t + 1\) is an average of this periods realized inflation and the rate of inflation announced by the central bank, \(E_t[\Pi_{t+1}] = (\Pi_t + \Pi_{t+1}^a)\). In reality, realized inflation will be equal to the target rate announced by the central bank, \(\Pi_{t+1}^a\). Specifically, households will use \(E_t[\Pi_{t+1}]\) when making their decisions over today’s consumption and money and tomorrow’s durable stock, equations \((B.8)\) through \((B.10)\). However, realized inflation rate, \(\Pi_{t+1}^a\), will be used in calculating the law of motion of the households wealth, equation \((9)\), and the law of motion for the distribution, \((12)\).

Table \(C.1\) shows the results from a vote of whether households would prefer to remain in the high-inflation steady state for the baseline model versus the environment with adaptive expectations. When households error on the path of inflation, the disinflation is costlier than the baseline model. The share of households who prefer high-inflation increases with the biggest change concentrated amongst high-income households. This is because high-income households under-invest in their
savings when they believe inflation will remain high and the real return will be low relative to the baseline steady state where they correctly predict the short-run increases in the real interest rate.

<table>
<thead>
<tr>
<th></th>
<th>Percent that prefer high inflation</th>
<th>Percent of borrowers that prefer high inflation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>baseline</td>
<td>adaptive expectations</td>
</tr>
<tr>
<td>Total economy</td>
<td>58.38</td>
<td>61.26</td>
</tr>
<tr>
<td>Low income</td>
<td>37.40</td>
<td>37.56</td>
</tr>
<tr>
<td>Middle income</td>
<td>81.23</td>
<td>81.82</td>
</tr>
<tr>
<td>High income</td>
<td>10.54</td>
<td>21.09</td>
</tr>
<tr>
<td>Very high income</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Table C.1: Adaptive Expectations: Preference for Disinflation Policy

D Path of aggregate variables

In Figure D.1 we compute the response of the aggregate variables along the transition path between the high and low inflation steady states, plotted as the solid line. The broken line indicates the new low inflation long-run values. The reduction in inflation induces an economy wide portfolio rebalancing. The portfolio rebalancing creates an increase in the level of real balances as the central bank responds to households’ additional demand for liquid assets. Although this outcome may be surprising, we see a similar movement in 1983 when, empirically, household expectations of lower inflation seemed to first stick.

During the disinflation, as real interest rates rise, output falls consistent with the change in output during the Volcker disinflation, which created a recessionary period. Nondurable consumption on the other hand rises as demand for durables falls and the inflation tax on nondurable consumption falls. In the long run, output and durable consumption increase due to the long-run fall in the real interest rate.

In Figure D.2 we show the response of aggregate variables to the inflationary period. As the inflation tax rises, aggregate demand for money falls and consumption decreases. Output goes up as households rebalance their portfolios towards savings equity as opposed to money (this is known as the Tobin (1965) effect). The stimulative effects on money of the inflationary shock that come from redistributing resources towards houses with large MPCs is dampened by the increasing cost of money.
Figure D.1: Path of aggregate variables

Note: figure shows the path of aggregate variables in response to the Volcker disinflation. All variables are normalized relative to the initial steady state. The blue line shows the path of aggregate variables in the model along the transition and the orange dashed line shows the aggregate variables in final steady state in the model with money.
Figure D.2: Path of aggregate variables in the inflationary period

Note: figure shows the path of aggregate variables in response to an inflationary period. All variables are normalized relative to the initial steady state. The blue line shows the path of aggregate variables in the model along the transition and the orange dashed line shows the aggregate variables in final steady state in the model with money.