ECONOMIC RESEARCH
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WORKING PAPER SERIES

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Authors	Benjamin Pugsley, and Hannah Rubinton
Working Paper Number	2020-021C
Revision Date	September 2021
Citable Link	https://doi.org/10.20955/wp.2020.021
Suggested Citation	Pugsley, B., Rubinton, H., 2021; Inequality in the Welfare Costs of Disinflation, Federal Reserve Bank of St. Louis Working Paper 2020-021. URL https://doi.org/10.20955/wp.2020.021

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Inequality in the Welfare Costs of Disinflation*

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September 23, 2021

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.

*For their helpful comments, we thank Klaus Adam, Borağan Aruoba, Adrien Auclert, Tony Braun, Jeff Campbell, Yuriy Gorodnichenko, Emi Nakumura, Yongseok Shin, Eric Sims, Jon Steinsson, Andrea Tambalotti, Richard Rogerson, Juan Rubio-Ramirez, Christian Wolf, an anonymous referee, as well as participants in the Columbia macro lunch, 2014 Atlanta Fed conference on Monetary Policy and Inequality, 2014 CEP Bellagio conference on Monetary Policy and Sustainability, and Fall 2015 Midwest Macro meetings. Pugsley gratefully acknowledges financial support from the Ewing Marion Kauffman Foundation.

†Disclaimer: The views expressed herein are solely those of the author and do not necessarily reflect those of the Federal Reserve Bank of St. Louis

1 Introduction

In most environments, households would prefer an economy with low and stable inflation over one with persistently high inflation.[1] 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

[1] 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.

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.[2] 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, 57.8 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, 17.8 percent of low income households and 78.0 percent of middle income households would choose to live with high inflation despite the high inflation tax. In the

[2] 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 13.5 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, 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. This experiment is equivalent to an extreme case where all consumers are able to costlessly refinance; we also consider a more realistic case with only some households refinancing and find results very close to the baseline.

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.[3] 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. Beyond understanding the importance of these channels, we further consider several extensions of the model incorporating imperfect credibility of the monetary authority, nominal borrowing by the corporate sector, and heterogeneous refinancing.

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

[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.

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 69.8 percent of households hold nominal debt and will benefit from the redistribution, only 48 percent of households prefer to go through the inflationary period. As with the disinflation, the costs and benefits of the inflation are not borne equally across the distribution; 58.9 percent of low-income households, while only 19.6 percent of middle-income and 20.5 percent of high-income households, prefer low inflation. This is because middle- and high-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. Low income households, on the other hand, have smaller nominal debt positions and hold a large share of wealth as money. This means they benefit less from the redistribution and suffer more from 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.[4] Allais, Algan, Challe, and Ragot (2020) and Cao, Meh, Ríos-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

[4]While 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.

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 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 redistributional 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, Ríos-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.[5] 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

[5] For example, Wong (2015), Cloyne, Ferreira, and Surico (2020), Garriga, Kydland, and Šustek (2017) and Ozkan, Mitman, Karahan, and Hedlund (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.

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 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 allows 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 a 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, $\tilde{m}$, 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 $m \equiv \tilde{m}/P$. Throughout, we use the $\tilde{\cdot}$ 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

[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.

demand for real balances were instead determined by shopping time or cash-in-advance constraints.[7]

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

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

with discount factor β 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 $P = [p_{lk}]$ 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:

$$Y_t = F\left(K_{t-1}, N\right).$$

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_t^K, or durables, I_t^D, or purchased by the government, G_t, so that the aggregate resource constraint is:

$$Y_t = C_t + I_t^K + I_t^D + G_t. \tag{2}$$

Given aggregate investment, I_t^K, the capital stock depreciates at rate δ^K and follows the law of motion:

$$K_t = \left(1-\delta^K\right)K_{t-1} + I_t^K. \tag{3}$$

Durable investment may vary across households. Given aggregate durable investment, $I_t^D = \int_0^1 i_{it}^D di$, the aggregate durable stock follows the law of motion:

$$D_t = \left(1-\delta^D\right)D_{t-1} + I_t^D + \int_0^1 \Psi_i di, \tag{4}$$

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

[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 resource costs to economizing on liquid assets.

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.[8] 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 ρ. A household who borrows $P_t^{\tilde{L}} \tilde{l}_t$ 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 ρ, where $P_t^{\tilde{L}}$ is the price of the loan. With $\rho = 0$ this is a one period loan, but increasing ρ stretches the duration of the loan, mimicking longer-term borrowing such as mortgages. With borrowing, where $\tilde{a} = -P_t^{\tilde{L}} \tilde{l}_t < 0$, the secured lending constraint,

$$-\frac{\tilde{a}}{P_t^{\tilde{L}}}\left(1 + \rho P_{t+1}^{\tilde{L}}\right) \leq \mu \left(1 - \delta^D\right) d_t P_{t+1}, \tag{5}$$

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 $t+1$.[9]

Saver households, $\tilde{a} \geq 0$, hold equity, $\tilde{e}_t$, in the mutual fund. In general then, $\tilde{a} = \tilde{e}_t - P_t^{\tilde{L}} \tilde{l}_t$ 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 $\tilde{B}_t = P_t^{\tilde{L}} \tilde{L}_t^G$ 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, $\tilde{E}_t^G$, in the mutual fund so that, in general, $-\tilde{B}_t = \tilde{E}_t^G - P_t^{\tilde{L}} \tilde{L}_t^G$ with $\tilde{E}_t^G \tilde{L}_t^G = 0$.

Mutual fund. Financial intermediation is through a mutual fund. The fund is financed entirely through its equity, $\tilde{E}_t = \int \tilde{e}_{it} di + \tilde{E}_t^G$, which is invested in capital, $P_t K_t$, and in lending, $P_t^{\tilde{L}} \tilde{L}_t =$

[8] It 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.

[9] Since 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 μ low enough so the value of the loan will never exceed the full value of the remaining durables.

$P_t^{\tilde{L}} \int \tilde{l}_{it} di + P_t^{\tilde{L}} \tilde{L}_t^G$, 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 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:

$$R_{t+1}^{\tilde{L}} = \frac{1 + \rho P_{t+1}^{\tilde{L}}}{P_t^{\tilde{L}}}.$$

Increases in ρ increase the duration of the loan portfolio and thus the sensitivity of its value to the nominal interest rate.[10]

Since the mutual fund is financed entirely by equity, total equity, $\tilde{E}_t$, equals total assets, $P_t^{\tilde{L}}\tilde{L}_t + P_t K_t$. We let $\phi_t \equiv \frac{P_t^{\tilde{L}}\tilde{L}_t}{P_t^{\tilde{L}}\tilde{L}_t + P_t K_t}$ denote the share of the fund's assets (and equity) held in loans.[11] Then, the gross nominal return on mutual fund equity can be written as the share-weighted average:

$$R_{t+1}^{\tilde{E}} = \phi_t \frac{1 + \rho P_{t+1}^{\tilde{L}}}{P_t^{\tilde{L}}} + (1-\phi_t) \Pi_{t+1} (V_{t+1} + 1 - \delta). \tag{6}$$

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:

$$E_t \left[R_{t+1}^{\tilde{E}}\right] = \frac{1 + \rho E_t \left[P_{t+1}^{\tilde{L}}\right]}{P_t^{\tilde{L}}} = E_t [\Pi_{t+1}] (V_{t+1} + 1 - \delta). \tag{7}$$

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, the expectation operator over prices $P_{t+1}^{\tilde{L}}$ and inflation Π_{t+1} may appear unnecessary. However, we write them this way to emphasize how if realized prices were to differ from their expected values, e.g. because of an unanticipated disinflation, the ex post return on equity in (6) would be different than its expected return in (7).

[10] For example, with a constant gross nominal return R, in equilibrium $P_t^{\tilde{L}} = \frac{1}{R-\rho}$ and the duration of the lending portfolio would be $\frac{R}{R-\rho}$. To see this, note that the Macauly duration is defined as the horizon weighted average of discounted future cash flows relative to the price. In this case:

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

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

[11] Because capital is a real asset and lending is a nominal asset, the loan share ϕ_t is also the nominal share of assets.

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, 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 paid on 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 $\left(1-\delta^D\right) d_{t-1}$. 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 $-\tilde{a}_t = P_t^{\tilde{L}} \tilde{l}_t$ 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, $a_t = \tilde{e}_t - P_t^{\tilde{L}} \tilde{l}_t$ 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:

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

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, Π_t is realized:

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

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

$$\mathcal{V}_t\left(q_t, d_{t-1}, z_{it}\right) = \max_{c_t, m_t, d_t} \left\{ U\left(c_t, m_t, d_{t-1}\right) + \beta E\left[\mathcal{V}_{t+1}\left(q_{t+1}, d_t, z_{t+1}\right) | z_t\right] \right\}, \tag{10}$$

each subject to a real budget constraint,

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

and a real borrowing constraint,

$$-\frac{a_t}{P_t^{\tilde{L}}}(1+P_t^{\tilde{L}}\rho) \leq \Pi_{t+1}\left(b+\mu\left(1-\delta^D\right)d_t\right).$$

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 $c_t\left(q_t, d_{t-1}, z_t\right)$, $m_t\left(q_t, d_{t-1}, z_t\right)$, $a_t\left(q_t, d_{t-1}, z_t\right)$, $e_t(q_t, d_{t-1}, z_t)$ and $d_t\left(q_t, d_{t-1}, z_t\right)$.

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:

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

2.5 Aggregating over heterogeneous households

Before characterizing an equilibrium, we first define a measure to keep track of the distribution of households. Let $\psi_t\left(q, d, z\right)$ 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:

$$\begin{aligned}\psi_t\left(q', d', z_j\right)=\sum_{k=1}^{N_z}\Bigg[\iint \mathbf{1}\Bigg\{\Bigg(&\frac{a_{t-1}\left(q, d, z_k\right)\left(1+\mathbf{1}_{\{a_{t-1}<0\}}P_t^{\tilde{L}}\rho\right)+m_{t-1}\left(q, d, z_k\right)}{\Pi_t}+(1-\delta_D)d_{t-1}(q,d,z_k)\Bigg)\\ &\leq q' \bigcap d_{t-1}\left(q, d, z_k\right) \leq d'\Bigg\}\psi_{t-1}\left(\partial q, \partial d, e_k\right)\Bigg]p_{kj}.\end{aligned} \tag{12}$$

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 ψ_t, we can define aggregate quantities for consumption

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

demand for real balances,

$$M_t^d \equiv \sum_{k=1}^{N_z}\left[\iint m_t\left(q, d, z_k\right)\psi_t\left(\partial q, \partial d, z_k\right)\right]\bar{p}_k,$$

durables,

$$D_t \equiv \sum_{k=1}^{N_z} \left[\iint d_t\left(q, d, z_k\right) \psi_t\left(\partial q, \partial d, z_k\right) \right] \bar{p}_k,$$

and aggregate savings,

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

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, $R_t^{\tilde{L}}$, and nominal borrowing, $\tilde{B}_t$, and provides a perfectly elastic supply of money, $\tilde{M}_t$, 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 $\tilde{M}_{-1}$ and $\tilde{B}_{-1}$, and an inflation target Π^*, a *fiscal and monetary policy* is a sequence for $t \geq 0$ of labor income taxes, $\{\tilde{\tau}_t\}$, nominal interest rates, $\{R_t^{\tilde{L}}\}$, and nominal government debt, $\{\tilde{B}_t\}$. In each period, for a given realization of the price level, P_t, the nominal money stock, $\tilde{M}_t$, is determined endogenously by demand for real balances,

$$\tilde{M}_t = P_t M_t^d, \tag{13}$$

and nominal government expenditures, $P_t G_t$, are determined endogenously by the government's budget constraint,

$$P_t G_t = \tilde{M}_t - \tilde{M}_{t-1} + \tilde{B}_t - R_t^{\tilde{L}} \tilde{B}_{t-1} + \int \tau_t z_{ti} P_t W_t di, \tag{14}$$

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:

$$\frac{\tilde{B}}{P_t} = S_t - K_t. \tag{15}$$

In the long run, the government can ensure it implements its inflation target, Π^*, by choosing a

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

[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, to adjust instead.

path of nominal bonds that grows at the same rate as desired inflation.

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, $R^{\tilde{L}}$, nominal debt, $\tilde{B}_{t+1} = \Pi^H \tilde{B}_t$, growing at the target rate of inflation, and constant labor income tax, τ, a stationary high-inflation equilibrium is:

1. Prices $P_t, P_t^{\tilde{L}}, P_t^{\tilde{e}}$ 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 $\mathcal{V}(q,d,z)$ 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 ψ^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 Π^H and makes a credible commitment to a lower inflation target $\Pi^L < \Pi^H$ achieved through a sequence of nominal interest rates $\{R_t^{\tilde{L}}\}$ 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 Π_1 from its previously anticipated value Π^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 $P_1^{\tilde{L}}$ 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:

$$q_1 = \begin{cases} \frac{m_0 + a_0(1+P_1^{\tilde{L}}\rho)}{\Pi_1} + \left(1-\delta^D\right) d_0 & \text{if} \quad a_0 < 0 \\ \frac{m_0 + \left((1-\phi_0)\frac{\Pi_1}{\Pi^H} + \phi_0(1+P_1^{\tilde{L}}\rho)\right)a_0}{\Pi_1} + \left(1-\delta^D\right) d_0 & \text{if} \quad a_0 \geq 0 \end{cases}. \tag{16}$$

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 $R_0^{\tilde{L}}/\Pi^H$ and find instead the realized borrowing cost between period 0 and 1 is $(1 + \rho P_1^{\tilde{L}})/(P_0^{\tilde{L}}\Pi_1)$. For households with savings, $a_0 \geq 0$, the redistribution increases the real value of their mutual fund equity, but only for the nominal share of mutual fund assets, ϕ_0. The surprise disinflation has no effect on the real value of the fraction

$1-\phi_0$ of the fund's assets invested in the capital stock. The expression $\left((1-\phi_0)\frac{\Pi_1}{\Pi^H}+\phi_0(1+P_1^{\tilde{L}}\rho)\right)$ adjusts the face value of the household's claim on fund equity to reflect the gain in the real value of the fund's nominal assets. Rather than the expected real return $1+V_1-\delta$ on equity, the household instead earns the realized real return of $\phi_0\frac{(1+P_1^{\tilde{L}}\rho)}{P_0^{\tilde{L}}\Pi_1}+(1-\phi_0)(1+V_1-\delta)$.

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 ψ^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 Π^L consisting of a sequence of nominal interest rates $\{R_t^{\tilde{L}}\}$, nominal government debt $\{\tilde{B}_t\}$, and constant labor income tax, τ, *a disinflation transition equilibrium* is for $t\geq 1$

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

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

3. A sequences of prices $P_t^{\tilde{L}}$, $P_t^{\tilde{e}}$, W_t, V_t, and inflation Π_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 policy 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.[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 ρ. If ρ 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 σ over a CES aggregate of consumption, real balances and durables so that:

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

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

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

[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.[19] 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 η 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, σ, 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 β 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:

$$\Psi\left(d_t, d_{t-1}\right) = \frac{\kappa}{2}\left(\frac{d_t - (1-\delta_d)d_{t-1}}{d_{t-1}}\right)^2 d_{t-1} \tag{19}$$

The parameter κ represents the cost of adjusting durable holdings. Like Hintermaier and Koeniger (2010), we set κ 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, μ, to be .8 as in Kaplan et al. (2020).

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

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

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 τ 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

[19] See Hoffman et al. (1995), Holman (1998), Lucas (2000) and citations therein.

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.

	Lowest by net worth		Highest by net Worth		
Percent of total	10%	50%	10%	5%	1%
Net worth					
data	−0.1	3.8	66.7	54.6	31.2
model	0.4	1.7	69.6	58.4	34.7
Nominal wealth					
data	−4.8	−34.8	121.4	95.4	43.1
model	−10.7	−43.0	107.2	91.0	54.1
Real wealth					
data	0.2	6.3	63.1	51.9	30.5
model	1.6	6.2	65.8	55.2	32.8

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 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 56.2 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

To quantify its welfare costs, we treat the Volcker disinflation as a perfect foresight shock. 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.[21] Then, 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 $\{R_t^{\tilde{L}}\}$ and nominal debt $\{\tilde{B}_t\}$ 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). While we match the series in Figure 1 by construction, Appendix Figure E.1 shows the dynamics of other (non targeted) aggregate variables over the disinflation are broadly consistent with the data.[22]

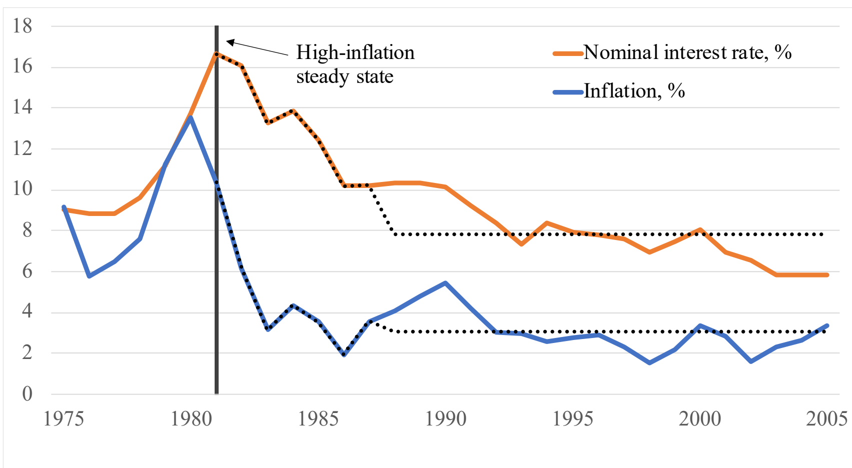

Figure 1: Interest rates and inflation during the Volcker disinflation

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.

The short- and long-run effects of this policy across the distribution of households are mixed. All things equal, everyone benefits from a lower inflation tax, but the unexpected change in the

[21]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).

[22]See discussion in Appendix E.

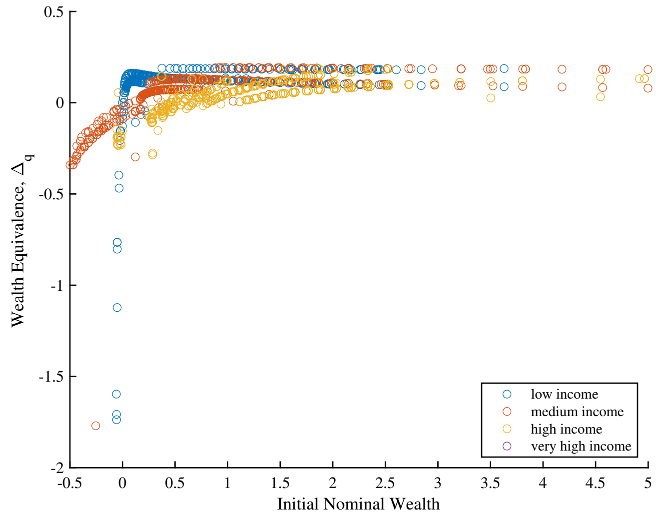

Figure 2: Permanent wealth equivalent of Volcker disinflation as percent

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 a fraction Δ_q of their initial wealth to avoid the disinflation.

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 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 $\mathcal{V}_1^L(q_1, d_0, z_1)$ as the value of a household in period $t = 1$ with real resources q_1 already reflecting redistribution from the unexpected change in Π_1 according to equation (16). The value $\mathcal{V}_1^L$ can be written as a function of sequences of consumption, real money balances and durables determined along the disinflation equilibrium path

$$\mathcal{V}_1^L(q_1, d_0, z_1) = E\left[\sum_{k=0}^{\infty} \beta^k u\left(c_{t+k}^L, m_{t+k}^L, d_{t+k-1}^L\right) | t = 1, z_1\right].$$

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 $\mathcal{V}_1^H(q_1', d_0, z_1)$ 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 $\mathcal{V}_1^H$ can be written as a function of sequences of consumption, real money balances, and durables in the economy where inflation remains high:

$$\mathcal{V}_1^H(q_1', d_0, e_1) = E\left[\sum_{k=0}^{\infty} \beta^k u\left(c_{t+k}^H, m_{t+k}^H, d_{t+k-1}^H\right) | t = 1, z_1\right].$$

Because the initial high inflation environment is stationary $\mathcal{V}_0^H = \mathcal{V}_1^H$.

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

$$\mathcal{V}_1^H\left((1+\Delta_q)\, q_1', d_0, e_1\right) = V_1^L(q_1, d_0, z_1)\ . \tag{20}$$

When $\Delta_q < 0$, this implies that they would be willing to sacrifice fraction Δ_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 Δ_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 percent of their wealth for the poorest households.

Overall, 57.8 percent of households prefer to remain in the high-inflation steady state rather than undergo the disinflation. In Table 2 we tally who would vote for the Volcker disinflation. Since 56.2 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.

At first glance, the prevalence of households who prefer to avoid the disinflation may appear at odds with contemporaneous news coverage that indicated inflation was a major concern (Goodfriend and King, 2005). However, the perceived harms from high inflation do not imply that households would unanimously prefer to accept the costs of a disinflation. In Appendix C, we use the Michigan Survey of Consumers to assess consumer sentiments during this historical period. While we cannot directly observe welfare costs, we do find evidence supportive of the model's predictions, namely that the benefits of the Volcker disinflation are concentrated among higher-income households. As we discuss in in Appendix C, over the disinflation period, the share of high-income households who report being *better* off from prices rises significantly, whereas the share of low-income and middle-income households who report the same is little changed. Reciprocally, the decline in the share who report being *worse* off from prices during the disinflation is significantly larger for high-income than for low- and middle-income households.

	Percent that prefer high inflation		Percent borrowers	Percent of Population
	Short run	Long run		
Total economy	57.8	13.5	56.2	100.0
Borrowers	99.3	0.0	100.0	56.2
Low income	17.8	63.1	18.1	11.8
Middle income	78.0	4.3	78.5	68.3
High income	12.9	13.7	2.4	19.6
Very high income	0.0	99.4	0.0	0.4

Table 2: Preference for Disinflation Policy

Incorporating more realism. Our welfare results are similar when we relax the model's more stringent assumptions. In Appendix D we extend the model to incorporate more realism along three dimensions. First, we relax the assumption of perfect credibility. We apply the method of Evans and McGough (2020) to incorporate adaptive expectations in which households are slow to adjust their expectations of future inflation in response to the disinflation shock. Second, we allow both firms and households to borrow in nominal contracts. This introduces the possibility of a costly firm default in the event of an unanticipated disinflation. Third, we allow some households to refinance their long-term nominal debt. This creates heterogeneity in the duration of nominal borrowing that better aligns with refinancing observed in the mortgage market as in Wong (2015). Appendix Table D.1 summarizes the welfare results under these extensions. As we discuss in Appendix D, the welfare results are similar to the baseline, with roughly 60 percent of households preferring to avoid the disinflation, predominately driven by nominal borrowers.

Finally, our results only allow households to differ by their assets and income. Whereas 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 13.5 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 13.5 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 or mitigating each of these channels. We also apply the quantitative framework to a different setting and use it to 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 ω.

When $\omega = 1$, households hold no money and are unaffected by the inflation tax.[23] 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 ρ. When $\rho = 0$ households borrow in one-period contracts. The effect of increasing ρ 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 Π_t. When $\rho > 0$ they are also affected by the unexpected change in the price of nominal lending $P_t^{\tilde{L}}$. As nominal interest rates fall during the disinflation, the price $P_t^{\tilde{L}}$ will increase. For borrowers, the increase in $P_t^{\tilde{L}}$ 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 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 adjusts the path of 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.

[23] Since the price level is determined independently of money market clearing, this need not be the cashless limit, $\omega \to 1$.

[24] We 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).

	Percent that prefer high inflation			
	baseline	no inflation tax	1-period loans	constant r
Total economy	57.8	61.2	57.9	55.1
Borrowers	99.3	100.0	98.6	98.0
Low income	17.8	19.2	17.5	17.4
Middle income	78.0	79.6	77.5	77.2
High income	12.9	23.1	15.3	1.7
Very high income	0.0	10.7	0.1	0.0

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 loss in the redistribution and the short-run increase in borrowing costs, as a result, 61.2 percent of households would prefer to remain in the high inflation steady state versus 57.8 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. On the other hand, the share of high income households who vote for high inflation increases as they receive a smaller windfall from the redistribution. Consistent with this, the share of households that vote to remain in the high-inflation steady state remains about the same. Amongst borrowers, a substantial amount, 98.6 percent, still prefer to remain in the high inflation steady state driven by the short-run increase in the real interest rate, though the number falls slightly from the baseline calibration.

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 1.7 percent of them would vote for the high-inflation steady state had real rates remained constant. Borrowers, on the other hand, see a small decline in the share voting for high inflation (98.0 percent versus 99.3 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 amount of wealth each household would need to be compensated in order to make them indifferent between the high inflation steady state and the redistribution 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.

	p10	p25	p50	p75	p90	mean
Baseline	0.1	0.1	−1.5	−2.6	−2.7	−1.3
No inflation tax	0.1	0.1	−2.7	−6.1	−6.1	−3.0
1-period loans	0.1	0.1	−1.0	−1.5	−1.5	−0.7
constant r	0.1	0.1	−1.1	−1.9	−2.0	−1.0

Table 4: Alternative Experiments: Distribution of welfare costs

Note: Table shows the distributions of wealth equivalents needed to make households indifferent between the disinflation and the high inflation steady state (see equation 20).

In the baseline model, at the 90th percentile of welfare costs, households would sacrifice 2.7 times times their initial net worth to stay in the high inflation economy. Whereas at the 10th percentile households benefit from the disinflation and would need to be compensated 10 percent of their net worth to stay in the high inflation steady state. On average, the welfare cost is equivalent to 1.3 times a household's 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 3.0 times net worth. However, because the incidence of the inflation tax is largest for low income households the change in welfare is not uniform; at the 90th percentile, the costs are more than double the baseline model while the benefits for those at the 10th percentile remain the same.

By moving to only one-period debt, the average welfare cost falls to 70 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 Π_1 *and* $P_1^{\tilde{L}}$ 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 $P_1^{\tilde{L}}$, the realized borrowing cost is reduced to 9.8 percent. This is reflected in the reduction of costs for the median households. 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 100 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 Π_1 and unexpected change in the price of loans to $P_1^{\tilde{L}}$. 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.

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.[25] 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.[26]

Table 5 shows the results from an up or down vote on whether or not to increase the inflation target. 30.2 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 0.1 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

[25] 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.

[26] 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.

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.

	Percent that prefer low inflation		Percent borrowers	Percent of population
	Short run	Long run		
Total economy	30.2	100.0	69.8	100.0
Borrowers	0.1	100.0	100.0	69.8
Low income	58.9	100.0	40.7	18.5
Middle income	19.6	100.0	80.5	39.0
High income	20.5	100.0	79.7	38.9
Very high income	100.0	100.0	0.0	3.7

Table 5: Vote on increasing the inflation target

As in our baseline experiment, the welfare costs and benefits are distributed unequally across the distribution; 58.9 percent of low-income households prefer to remain in the low-inflation steady state while only 19.6 percent of middle-income and 20.5 percent of high-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 100 percent of their wealth.

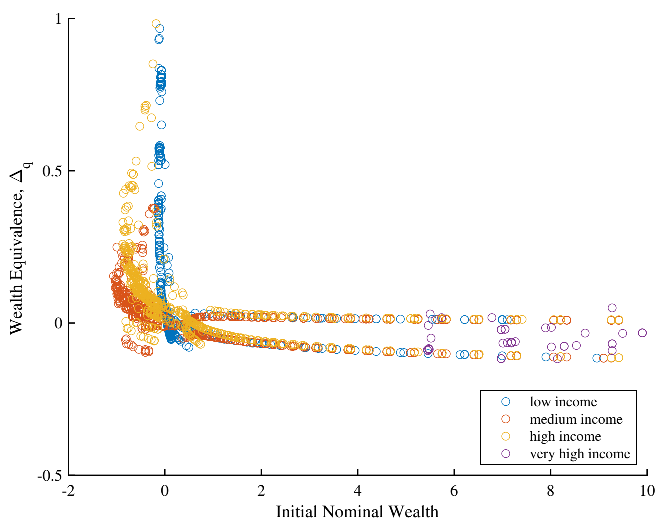

Figure 3: An Inflationary period

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 change in the inflation rate redistributes wealth from nominal borrowers towards savers, but it also lowers the burden of the inflation tax 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 quantify the welfare effects stemming from each of these channels.

Our analysis relies on a Bewley-Imrohoroglu-Huggett-Aiyagari model extended to include a consumer portfolio choice between nominal savings or debt, real durable goods, and money. 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, 56.2 percent of the population, 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 (78.0 percent of middle income households) 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 ($\sim 55\%$) in the experiments with a constant real interest rate and a one-period nominal debt. This is because borrowers, who make up 56.2 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 the their losses during the disinflation and 61.2 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.

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A Data appendix

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

Assets	Liabilities
A. Nominal assets and liabilities	
Liquid:	**Secured borrowing:**
Cash in checking accounts	Home mortgages
Cash in savings or share accounts	Amount owed against land contract notes
Money market and call accounts	Amount outstanding on other property mortgages
IRA or Keogh accounts	
Certificates of Desposit	
U.S. Savings Bonds	
Non liquid:	**Unsecured borrowing:**
Face value of bonds	Amount outstanding on loans other than mortgages[1]
Loans owed to household and gas leases	Credit card debt
Aggregate gross value of land contracts and notes	Amount owed on lines of credit
Thrift type pension account assets	
B. Real assets	
Durables:	
Home	
Other properties	
Vehicles	
Financial:	
Stocks and mutual funds	
Trust accounts	
Business:	
Net value of business with management interests	

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:

$$\min_{\mathbb{P}} \left(X_{model} - X_{data}\right)\left(X_{model} - X_{data}\right) \tag{B.1}$$

where $\mathbb{P}$ is the set of parameters 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 .0381.

$$z \in [0.0381; 0.5801; 2.227; 49.917] \tag{B.2}$$

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

$$\begin{array}{ccccc} & z_1 & z_2 & z_3 & z_4 \\ z_1 & .9765 & .0052 & .0182 & 0 \\ z_2 & .0002 & .9905 & .0092 & 0 \\ z_3 & .0133 & .0198 & .9646 & .0022 \\ z_4 & .0005 & .0002 & .1088 & .8905 \end{array} \tag{B.3}$$

Given the transition matrix, in steady state, 11.8 percent of the population will be low income, 68.3 percent will be middle income, 19.6 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.

	A. Wealth distribution				
	Lowest*		Highest*		
Percent of total	10%	50%	10%	5%	1%
Net worth					
data	-0.55	1.49	76.46	64.92	37.21
model	0.09	3.89	83.34	61.50	16.16
Nominal wealth					
data	-10.51	-26.91	117.82	87.87	36.95
model	-0.76	-15.66	105.47	77.54	19.95
Real wealth					
data	0.73	5.16	71.22	62.19	37.5
model	0.13	4.82	82.29	60.74	15.98

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

*Ordered by net worth. We keep the ordering constant for all asset classes Note: Data on the wealth distribution and the share of households with negative net 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:

$$z \in [0.0381; 0.6270; 0.8410; 36.3057], \tag{B.4}$$

$$\begin{array}{c|cccc} & z_1 & z_2 & z_3 & z_4 \\ z_1 & .955 & .025 & .020 & 0 \\ z_2 & .005 & .019 & .969 & .006 \\ z_3 & .016 & .974 & .010 & 0 \\ z_4 & .00032 & .063 & .003 & .933 \end{array} \tag{B.5}$$

B.3 Model Solution

B.3.1 Household Decision Rules

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

$$m_t \geq m_0 \geq 0 \quad \text{and} \quad d_t \geq d_0 \geq 0 \tag{B.6}$$

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

To simplify notation we define the discounted expected continuation value

$$f_t\left(q', d_{t,} z_t\right) \equiv \beta E\left[\mathcal{V}_{t+1}\left(q'_{,}, d_t, z_{t+1}\right) | z_t, t\right] \ . \tag{B.7}$$

Let ν_t be the multiplier on the secured borrowing constraint, and let κ_t and χ_t be the multipliers on the non negativity constraints for money and durables respectively. Then the KKT conditions (omitting the budget constraint and multiplier λ_t) are

$$\frac{f_{qt} + \nu_t}{\Pi_{t+1}} = \frac{u_{ct}}{1 + i_t} \tag{B.8}$$

$$u_{mt} + \frac{f_{qt}}{\Pi_{t+1}} + \kappa_t = u_{ct} \tag{B.9}$$

$$f_{qt}(1 - \delta_D) + f_{dt} + \nu_t \mu (1 - \delta_D) + \chi_t = u_{ct}(1 + \Psi_{1t}) \tag{B.10}$$

$$\begin{aligned} \nu_t\left(\frac{a_t}{\Pi_{t+1}} + b + \mu(1 - \delta_D) d_t\right) &= 0 \qquad \nu_t \geq 0 \\ \kappa_t(m_t - m_0) &= 0 \qquad \kappa_t \geq 0 \\ \chi_t(d_t - d_0) &= 0 \qquad \chi_t \geq 0 \ . \end{aligned}$$

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

$$\begin{aligned} f_{qt}(1 - \delta_D) + f_{dt} + \nu_t \mu (1 - \delta_D) + \chi_t &= (1 + i_t) \frac{f_{qt} + \nu_t}{\Pi_{t+1}} (1 + \Psi_{1t}) \\ \nu_t \left(\frac{1 + i_t}{\Pi_{t+1}}(1 + \Psi_{1t}) - \mu(1 - \delta_D)\right) - \chi_t &= -f_{qt}\left(\frac{1 + i_t}{\Pi_{t+1}}(1 + \Psi_{1t}) - (1 - \delta_D)\right) + f_{dt} \end{aligned} \tag{B.11}$$

We can determine f_{qt} and f_{dt} from envelope conditions

$$f_{qt}\left(q_{t+1}, d_t, z_t\right) = \beta E_t\left[u_{ct+1}\right] \tag{B.12}$$
$$f_{dt}\left(q_{t+1}, d_t z_t\right) = \beta E_t\left[u_{dt+1} - u_{ct+1}\Psi_{2t+1}\left(d_{t+1}, d_t\right)\right] \tag{B.13}$$

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

$$\Upsilon_t \equiv \omega c_t^{\frac{\eta-1}{\eta}} + (1-\omega)\, m_t^{\frac{\eta-1}{\eta}}$$

so

$$\begin{aligned}
u_{ct} &\equiv \Upsilon_t^{\frac{1-\eta(1-\theta)-\sigma\eta\theta}{\eta-1}} d_{t-1}^{(1-\sigma)(1-\theta)}\theta\omega c_t^{\frac{-1}{\eta}} \\
u_{mt} &\equiv \Upsilon_t^{\frac{1-\eta(1-\theta)-\sigma\eta\theta}{\eta-1}} d_{t-1}^{(1-\sigma)(1-\theta)}\theta\,(1-\omega)\, m_t^{\frac{-1}{\eta}} \\
u_{dt} &\equiv \Upsilon_t^{\frac{\eta\theta-\eta\theta\sigma}{\eta-1}} d_{t-1}^{-\theta-\sigma(1-\theta)}\,(1-\theta)
\end{aligned}$$

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

$$\frac{f_{qt}+\nu_t}{\Pi_{t+1}} = \frac{\Upsilon_t^{\frac{1-\eta(1-\theta)-\sigma\eta\theta}{\eta-1}} d_{t-1}^{(1-\sigma)(1-\theta)}\theta\omega c_t^{\frac{-1}{\eta}}}{1+i_t} \tag{B.14}$$
$$\frac{f_{qt}}{\Pi_{t+1}} + \kappa_t = \Upsilon_t^{\frac{1-\eta(1-\theta)-\sigma\eta\theta}{\eta-1}} d_{t-1}^{(1-\sigma)(1-\theta)}\theta\left(\omega c_t^{\frac{-1}{\eta}} - (1-\omega)\, m_t^{\frac{-1}{\eta}}\right). \tag{B.15}$$

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

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

and

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

so that with $\nu_t = 0$ then

$$\frac{1+i_t}{\Pi_{t+1}}\frac{\rho}{d_{t-1}} = \frac{-f_{qt}\left(\frac{1+i_t}{\Pi_{t+1}}\left(1-\rho\left(1-\delta_D\right)\right) - \left(1-\delta_D\right)\right) + f_{dt}}{f_{qt} d_t},$$

with $\nu_t \geq 0$ then

$$\frac{1+i_t}{\Pi_{t+1}}\frac{\rho}{d_{t-1}} = \frac{f_{dt} - \frac{1+i_t}{\Pi_{t+1}}\left(1-\rho\left(1-\delta_D\right)\right)\left(f_{qt}+\nu_t\right) + \left(1-\delta_D\right)\left(f_{qt}+\mu\nu_t\right)}{d_t\left(\nu_t + f_{qt}\right)}.$$

B.3.2 Interior Solution

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

$$f_{dt} \quad = \quad f_{qt}\left(\frac{1+i_t}{\Pi_{t+1}}\left(1+\Psi_{1t}\right)-\left(1-\delta_D\right)\right)$$

so that given q_{t+1}, z_t, d_{t-1}, and functions $f_{qt}\left(q_{t+1}, d_t, z_t\right)$ and $f_{dt}\left(q_{t+1}, d_t, z_t\right)$, 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

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

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

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

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

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

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

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

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

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

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 $\nu_t>0$.[27] 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 ν_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

[27]Since $\chi_t \geq 0$ and $\nu_t>0$ when the collateral constraint binds, this requires of course that $\mu<\frac{1+i_t}{\Pi_{t+1}}\frac{1+\Psi_{1t}}{1-\delta_D}$, 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.

and thus f_q. From (B.14) with $\nu_t > 0$, and (B.9) with $\kappa_t = 0$ we have

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

and substituting back into the first order condition we get an equation for m_t in terms of d_t and ν_t

$$\begin{aligned} m &= \left(\frac{\left(\omega\Omega_t^{\eta-1} + (1-\omega)\right)^{\frac{1-\eta(1-\theta)-\sigma\eta\theta}{\eta-1}} d_{t-1}^{(1-\sigma)(1-\theta)}\theta\omega}{\frac{1+i_t}{\Pi_{t+1}}\left(f_{qt}+\nu_t\right)\Omega_t}\right)^{\frac{1}{(1-\theta)+\theta\sigma}} \\ &= \left(\frac{\left(\omega\Omega_t^{\eta-1} + (1-\omega)\right)^{\frac{1-\eta(1-\theta)-\sigma\eta\theta}{\eta-1}} d_{t-1}^{(1-\sigma)(1-\theta)}\theta\omega}{\frac{\omega}{1-\omega}\left(\frac{1+i_t}{\Pi_{t+1}}\left(f_{qt}+\nu_t\right) - \frac{f_{qt}}{\Pi_{t+1}}\right)}\right)^{\frac{1}{(1-\theta)+\theta\sigma}} \end{aligned}$$

where

$$\Omega_t \equiv \frac{\omega}{1-\omega}\left(1 - \frac{1}{1+i_t}\frac{f_{qt}}{f_{qt}+\nu_t}\right) .$$

Then one can iterate on the secured borrowing constraint (5) to determine ν_t.

Binding non negativity conditions 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 $\chi =\geq 0$ (constraint on d is just binding).[28] In this event $d_t = d_0$ and $m_t = m_0$ and

$$\nu_t(m) = \frac{-f_q\left(q_t, d_t(m), z_t\right)\left(\frac{1+i_t}{\Pi_{t+1}}\left(1+\Psi_1\left(d_t(m), d_{t-1}\right)\right) - (1-\delta_D)\right) + f_d\left(q_t, d_t(m), z_t\right)}{\left(\frac{1+i_t}{\Pi_{t+1}}\left(1+\Psi_1\left(d_t(m), d_{t-1}\right)\right) - \mu(1-\delta_D)\right)} \tag{B.20}$$

determines ν. Then, we use (B.14) to find a fixed point equation for c_t

$$c_t = \left(\left(\omega c_t^{\frac{\eta-1}{\eta}} + (1-\omega)\, m_0^{\frac{\eta-1}{\eta}}\right)^{\frac{1-\eta+\eta\theta-\eta\theta\sigma}{\eta-1}} d_{t-1}^{(1-\theta)(1-\sigma)}\frac{\theta\omega}{\left(f_{qt}+\nu_t\right)\frac{1+i_t}{\Pi_{t+1}}}\right)^{\eta} .$$

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).

[28] In practice it could be the opposite, but we verify that the candidate solution does not violate any of the KKT conditions.

B.3.4 Cashless Economy

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

CES Preferences We use the parametric specification

$$u\left(c_t, d_{t-1}\right) \equiv \frac{1}{1-\sigma}\left({c_t}^{\theta} d_{t-1}^{1-\theta}\right)^{(1-\sigma)}$$

so

$$\begin{aligned} u_{ct} &\equiv \left({c_t}^{\theta} d_{t-1}^{1-\theta}\right)^{-\sigma} c_t^{\theta-1} d_{t-1}^{1-\theta} \theta \\ u_{dt} &\equiv \left({c_t}^{\theta} d_{t-1}^{1-\theta}\right)^{-\sigma} c_t^{\theta} d_{t-1}^{-\theta}\left(1-\theta\right) \ . \end{aligned}$$

Now we can write equation (B.8) as

$$\frac{f_{qt}+\nu_t}{\Pi_{t+1}} = \frac{\left({c_t}^{\theta} d_{t-1}^{1-\theta}\right)^{-\sigma} c_t^{\theta-1} d_{t-1}^{1-\theta} \theta}{1+i_t} \tag{B.21}$$

Interior solution With $\nu_t = 0$ then given f_{qt}

$$c_t = \left(\frac{\theta d_t^{(1-\sigma)(1-\theta)}}{f_{qt}\frac{1+i_t}{\Pi_{t+1}}}\right)^{\frac{1}{1-\theta(1-\sigma)}}$$

Binding collateral constraint We know d_t is within

$$d_t \in \left[d_0, \frac{q_{t+1}+b}{\left(1-\delta\right)\left(1-\mu\right)}\right]$$

so if d_t exceeds the upper bound then we set $d_t = \bar{d}_t$ and determine $\nu_t \geq 0$ as before.

B.3.5 Numerical Solution

First, define an exogenous grid $D = \{d_1, \ldots, d_{N_d}\}$ (which will be the lagged values of d) and then define an exogenous grid $Q = \left\{q_1, \ldots q_{N_q}\right\}$, where $q_1 = -b + d_0\left(1-\mu\right)\left(1-\delta_D\right) + \frac{m_0}{\Pi^*}$. The policy functions will be defined over an $Q \times D \times Z$ 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 $f_{qt}\left(q_{t+1}, d_t, z_t\right)$ and $f_{dt}\left(q_{t+1}, d_t, z_t\right)$, we start with an initial guess for $m_{t+1}\left(q_{t+1}, d_t, z_{t+1}\right)$ and $c_{t+1}\left(q_{t+1}, d_t, z_{t+1}\right)$, and then use the envelope conditions (B.12) and (B.13) and the transition matrix P_z for z to compute $f_{qt}\left(q_{t+1}, d_t, z_t\right)$ and $f_{dt}\left(q_{t+1}, d_t, z_t\right)$ over the exogenous grid. Then for every $q \times z$, we solve (B.11) for $d_t^N\left(q_{t+1}, z_t\right)$. Next, we solve for the adjustment costs

$$\Psi(d_t^N\left(q_{t+1}, z_t\right), d_{t-1}) = \frac{\rho}{2}\left(\frac{d_t^N - (1-\delta_d)d_{t-1}}{d_{t-1}}\right)^2 d_{t-1} \text{ and } \Psi_1\left(d_t^N\left(q_{t+1}, z_t\right), d_{t-1}\right) = \rho\left(\frac{d_t^N}{d_{t-1}} - \left(1-\delta_d\right)\right)$$

Next using $f_{qt}\left(q_{t+1}, d_t^N, z_t\right)$ and $d_t^N\left(q_{t+1}, z_t\right)$, we look for an interior solution for $c_t^N\left(q_{t+1}, d_{t-1}, z_t\right)$

using (B.17) and

$$
\begin{aligned}
m_t^N\left(q_{t+1},d_{t-1},z_t\right) &= \left(\frac{1+i_t}{i_t}\frac{1-\omega}{\omega}\right)^{\eta} c^N \\
a_t^N\left(q_{t+1},d_{t-1},z_t\right) &= \Pi_{t+1}\left(q_{t+1}-d_t^N\left(1-\delta_D\right)\right)-m_t^N \\
q_t^N\left(q_{t+1},d_{t-1},z_t\right) &= c_t^N+\frac{a_t^N}{1+i_t}+d_t^N\left(q_t,e_t\right)+\Psi\left(d_t^N\left(q_t,z_t\right),d_{t-1}\right) \\
&\quad +m_t^N-w_t z_t\left(1-\tau_t\right)-T_t
\end{aligned}
$$

Check the borrowing constraint Next, we check whether the interior solution for a^N would violate the collateral constraint (or check d^N). If

$$
\frac{a_t^N\left(q_{t+1},d_{t-1},z_t\right)}{\Pi_{t+1}} < -\mu\left(1-\delta_D\right)d^N\left(q_{t+1},z_t\right)
$$

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 where 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, Ψ_t, and the multiplier on the borrowing constraint, ν_t, will also need to be updated

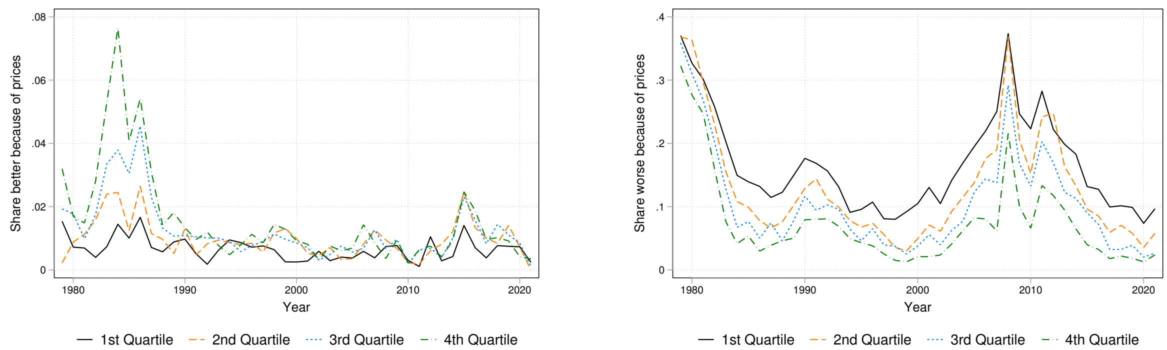
Interpolating over the exogenous grid Finally, using the policy functions defined over the endogenous grid, we interpolate over the exogenous Q gridpoints, and correct for any $q < q^N\left(q_1,d,z\right)$, which requires that the collateral, money, and durable constraints all bind (the Inada conditions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

C Consumer Sentiments during the Volcker Disinflation

In this section, we compare data from the Michigan Survey of Consumers with the welfare costs measured within the model. While the data cannot measure the actual welfare costs of a disinflation, we find evidence supportive of the model's predictions.

For this analysis, we focus on the responses to two specific questions. The survey asks respondents about whether they are better or worse off than a year ago and the reason they are better or worse off. Amongst the answers, respondents can say they are worse off due to "higher prices", or inflation. We tabulate for each calendar quarter the fraction of households who report being better or worse off by income quartile. Figure C.1 plots these shares of respondents who say they are better or worse off because of prices by income over time.

First, in accordance with the presence of a substantial inflation tax in the model, very few if any households in the Michigan Survey say they are better off because of prices before the Volcker Disinflation, and roughly one-third say they are worse off due to prices. Moreover, as in the model, a consistently larger share of low- and middle-income households report being worse off from prices than of high-income households. In the model, these households pay the inflation tax on a larger share of their assets.



(a) Better (b) Worse

Figure C.1: Share of households better or worse because of prices by income quartile

However, disliking inflation in steady state is *not* the same as being willing to go through the disinflation. While we do not have data on how households viewed the disinflation directly, we examine the share who say they are better or worse off due to price changes over time. After the Volcker Disinflation begins in 1982, there is a significant increase in the share of high-income households who say they are better off due to inflation, while the share of low- and middle-income households who say they are better off remains negligible.

Turning to the shares who report being worse off, the declines during the Volcker disinflation were uneven across the income distribution. By 1987, the share of high-income households who say they are hurt by inflation falls almost to zero, while for low-income households it only falls by two-thirds. Together, these patterns align with the model's predictions that the benefits of the disinflation policy are concentrated among the higher income households who are net nominal savers, while low- and middle-income households bear the costs.

D Robustness Exercises

D.1 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, in place of rational expectations, where expected inflation in period $t+1$ must equal the inflation rate announced by the central bank, $\mathbb{E}_t[\Pi_{t+1}] = \Pi^a_{t+1}$, we assume expected inflation is formed as an average of this period's realized inflation and the rate of inflation announced by the central bank, $\mathbb{E}_t[\Pi_{t+1}] = (\Pi_t + \Pi^a_{t+1})$, as in Evans and McGough (2020). Realized inflation will still be equal to the target rate announced by the central bank, Π^a_{t+1}, but households will use $\mathbb{E}_t[\Pi_{t+1}]$ 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, Π^a_{t+1}, will be used in calculating the law of motion of the households wealth, equation (9), and the law of motion for the distribution, (12).

Column two of Table D.1 show the results from a vote of whether households would prefer to remain in the high-inflation steady state in the environment with adaptive expectations versus the baseline model in column one. 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.

	Percent that prefer high inflation			
	baseline	adaptive expectations	corporate debt	refinancing
Total economy	57.8	60.8	66.4	57.9
Borrowers	99.3	99.6	100.0	99.3
Low income	17.8	18.0	19.4	17.8
Middle income	78.0	78.2	80.9	78.0
High income	12.9	26.5	44.3	13.1
Very high income	0.0	36.2	52.8	0.0

Table D.1: Alternative Experiments: Preference for Disinflation Policy

D.2 Nominal Corporate Liabilities

In the baseline model, we assume that the disinflation has no effects on the corporate sector. However, in practice, corporate debt is also held in long-term nominal contracts. After the disinflation, firms are subject to the same surprise increase in the real value of their liabilities as households (Bhamra et al., 2011), and firms without sufficient equity become insolvent and are forced to default on their nominal debt.

To examine this channel we extend the model to introduce nominal corporate borrowing. We assume the representative firm rather than the mutual fund owns the capital stock, and the firm finances its purchases using nominal long-term corporate debt issued by the mutual fund. We use the same duration parameter for long-term corporate borrowing as we do for government and household borrowing from the mutual fund.

Since the firm now borrows in nominal debt to purchase real capital, an unexpected disinflation, which increases the real value of its liabilities, makes the firm insolvent. In this event, we assume the firm declares bankruptcy and reorganizes with a default on the fraction of its nominal debt it cannot repay. We further assume the bankruptcy involves paying additional resource costs, cK_{t-1}, that are proportional to its capital stock.[29] We set this proportional resource cost parameter c following Hennessy and Whited (2007) who estimate that the cost of default is equal to 8.4 percent of a firm's capital stock. To pay these bankruptcy resource costs, we assume the firm reneges on its promised wage, w_1, and temporarily cuts wages below labor's marginal product to w_1' so that:

$$w_1' N = w_1 N - cK_0$$

Because of these additional effects on household's real wage income, the recession generated by the disinflation is costlier than in the baseline model.

Column 3 of Table D.1 shows the share of households who prefer to avoid the disinflation increases significantly when we account for corporate default. Overall the share increases from

[29] In the absence of these resource costs (and with identical duration), the effects of the disinflation (vis-a-vis the corporate default) on the mutual fund's return on equity would be equivalent to our baseline model where the mutual fund owns the capital stock.

58 to 66 percent, and because the bankruptcy costs depress real wage income proportionally, the increase draws especially from high and very high income households who otherwise benefited from the disinflation. Overall, the presence of nominal corporate borrowing and allowing for the resource costs of corporate bankruptcies worsens the recessionary effects of the disinflation. In this sense our baseline results are a lower bound on the welfare costs of the disinflation.

D.3 Refinancing

Our baseline model uses geometrically decaying lending contracts to capture the long duration of household liabilities observed in the data, which consist primarily of fixed rate mortgage debt. In practice, a decline in mortgage rates makes it profitable for some households to refinance their debt at a lower nominal borrowing rate, which in the model, would decrease the effective duration of their debt and lower the cost of the redistribution.

We examine the quantitative importance of refinancing by extending the model to allow some fraction of households to refinance their nominal debt. Empirically, not all households refinance their debt, so using estimates from Wong (2015), we calibrate the model so that 15 percent of households refinance their debt every year. This introduces heterogeneous durations, with 15 percent of households hold one period nominal debt contracts, $\rho = 0$, and the remaining 85 percent of households holding long-term nominal debt with an average duration of 4.5 years as originally calibrated, $\rho = 0.89$. We assume these shares are independent of wealth, durables and productivity.

Column 4 of Table D.1 shows in the extended model the share of households who would vote for the disinflation. Allowing for refinancing reduces the realized borrowing costs for the share allowed to refinance at the expense of harming savers who receive a smaller windfall from the redistribution. Because only 15 percent of household refinance their debt, the effects on the main welfare results are quantitatively small. To one decimal place, only the high-income group (whose windfall is reduced) is affected.

The magnitude of these effects is increasing in the share of households allowed to refinance. In Section 5, we consider the extreme case where everyone is allowed to costlessly refinance. Table 3 shows the more pronounced effects on low- and middle-income households who are more likely to be borrowers relative to high- and very high-income households.

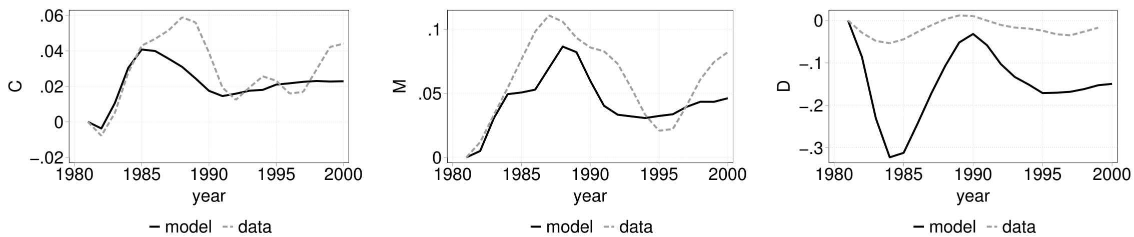
E Dynamics of Aggregate Variables over Disinflation Period

As an additional check on our model, we compare its implied dynamics for key aggregate variables against their data counterparts over the Volcker disinflation. In this exercise, we focus on the dynamics of nondurable consumption, real balances, and durable consumption, due to their importance at the disaggregated household level in determining welfare. In the absence of high quality household-level time series to compare with the model's household-level predictions, we compare the observed aggregate data from this period with the model's aggregates. This exercise is especially useful since these aggregates are not used in any way as calibration targets.[30]

In Figure E.1 we compare the dynamics of nondurable consumption, real balances, and durable consumption when aggregated in the model (solid black line) versus the data (gray broken line) over the Volcker disinflation period. In the model this corresponds to the transition path starting from the high inflation steady state to the low inflation steady state following the 1982 perfect foresight disinflation shock (See Figure 1). For the data series we measure consumption as real personal

[30]Inflation and the nominal interest rate, for example, are matched by construction when we define the disinflation shock.

consumption expenditures, real balances as the M2 Money Stock deflated by the implicit PCE price deflator, and durable consumption using the real consumption of private residential capital (See notes to Figure E.1). Because the model is not designed to capture high-frequency aggregate fluctuations, nor long-run trends, in our comparison we apply a Christiano and Fitzgerald (2003) two-sided band-pass filter to both data and model aggregates to isolate medium-run fluctuations. We keep fluctuations with periodicities between 4 and 16 years, but the results are very similar if we also include shorter-run fluctuations by including periodicities between 2 and 16 years.



(a) Consumption (b) Real Balances (c) Durables

Figure E.1: Path of aggregate variables

Note: Figure shows time series path of consumption, money and durables in the data and the model. For consumption we use Personal Consumption Expenditures (PCE), money is the M2 Money Stock (M2SL), and durables is "Accumulation of produced assets: Consumption of fixed capital: Private: Residential" (K160231A027NBEA). The FRED series IDs are given in parentheses. PCE and M2 are deflated by the PCE Price Index (PCEPI) and Consumption of Fixed Capital is deflated by the PCE Durables Price Index (DDURRG3M086SBEA). Series are passed through a Christiano and Fitzgerald two-sided band-pass filter to remove periodicities under 4 years and greater than 16 years.

Examining Figure E.1, the model is very successful in matching the qualitative movements of the data. For consumption and real balances the quantitative fit is also good. In both the data and the model, consumption declines by about 0.5 percentage points before increasing above its long-run steady state value during the rest of the transition. Real balances increase on impact as consumption rises and inflation falls, which lowers the cost of holding money. The good fit for the model's dynamics of aggregate consumption and real balances relative to the data is reassuring since at the household level, changes in consumption and real balances are key determinants of welfare.

The model is less successful in matching the quantitative movements of durables. In the model, as the real interest rate rises during the transition and inflation falls, households want to borrow less, hold more money, and decrease their durable stock. While the predictions match the qualitative decline in durables, the model over-predicts the actual fall in durable consumption. Fortunately, this overshooting in aggregate durable consumption has relatively little effect on our welfare results. To examine this closely, we compute each household's counterfactual value if it obtained identical sequences of consumption and real balances over the transition, but if its durable stock were held fixed at its value in the high inflation steady-state. The effects on our main results are relatively small; the share of households who prefer high-inflation decreases by 8 percentage points and the average welfare increases by approximately 2 percent. Despite overestimating the decline in durables relative to the data, the large decline in durable consumption has little impact on our main conclusions.