

WORKING PAPER

#667 | 2024



Asset liquidity and the welfare costs of business cycles

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October 31, 2024

Work in progress

Abstract

In this paper, we revisit the question of what the welfare costs of business cycles are with new insights. The seminal paper by [Lucas \(1987\)](#) found welfare costs to be negligible at around 1%, but subsequent literature focused on finding mechanisms that could rationalize larger welfare costs. Our study builds on recent research that incorporates incomplete markets, adjustment costs, and marginal propensities to consume to show that welfare costs can be substantial. Our calculations indicate that eliminating business cycle fluctuations would result in a 1.25% increase in welfare, as measured in consumption equivalents. Furthermore, using a 2-asset HANK model, we find a welfare cost of 2.6%. This result arises from considering portfolio adjustment costs, which generate a distribution of marginal propensities to consume along the income dimension that is empirically plausible and produces a share of (rich and poor) hand-to-mouth households that is consistent with recent findings. In periods of recession, these values rise to 11.1%. These results are particularly driven by effects from the price rigidity.

Keywords: Welfare Costs; Business Cycles; Liquidity; Hand-to-mouth

JEL Classification: E32; E21

*Please consider this paper to the Consultaccount Award of the 17th Annual Meeting of the Portuguese Economic Journal. For helpful comments we thank Jorge Soares and Isabel Horta Correia at Annual Meeting of the Portuguese Economic Journal. Pedro Brinca and João Duarte are grateful for funding provided by Fundação para a Ciência e a Tecnologia (UID/ECO/00124/2019, UIDB/00124/2020 and Social Sciences DataLab, PINFRA/22209/2016), POR Lisboa and POR Norte (Social Sciences DataLab, PINFRA/22209/2016) and CEECIND/02747/2018. Ana Melissa Ferreira is grateful for financial support from the Fundação para a Ciência e a Tecnologia, grant number SFRH/BD/144996/2019. Valter Nóbrega is grateful for financial support from the Fundação para a Ciência e a Tecnologia, grant number 2020.09544.BD.

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1 Introduction

Business cycles, which represent the short-term fluctuations in the economy around its long-term trend, are an inherent feature of modern market economies. These fluctuations can result in considerable welfare costs for households, and researchers have been studying the magnitude of these costs and ways to mitigate them for several decades. In this paper, we aim to analyze this issue by making use of new methods in the literature. We focus on the question of how households can smooth consumption over time and how different assumptions about household behavior and economic structures can affect the estimated welfare costs of business cycles.

The welfare cost of business cycles is a measure of the benefits that individuals could obtain in terms of additional consumption if all macroeconomic instability were eliminated in a given economy. When the economy fluctuates from its trend, households evaluate the utility generated in such a stream at a lower rank in comparison with the utility generated when they are able to smooth consumption. It is expected that these fluctuations decrease households' utility severely. However, empirical evidence suggests that the gains from eliminating business cycles are quite weak. In his pioneering work, [Lucas \(1987\)](#) estimated that the welfare gained due to business cycle elimination is merely 0.05%. Lucas's prediction was based on a simple model in which he made several assumptions, including that (i) preferences are time-separable and isoelastic; (ii) the log of annual per capita consumption is serially uncorrelated, and (iii) there is a representative agent. Since Lucas's original work, several researchers have studied the same question, relaxing some of the assumptions made by Lucas. Despite these efforts, a sticking question remains: What is the welfare cost of business cycles when we depart from these assumptions?

The first assumption Lucas made was that preferences are time-separable and isoelastic. Several studies, including [Alvarez and Jermann \(2004\)](#), [Dolmas \(1998\)](#), [Otrok \(2001\)](#) and [Tallarini Jr \(2000\)](#), have addressed this assumption. These authors show that dif-

ferent households react differently to exposures to asset price fluctuations. Even when non-separable preferences matching the business cycle are considered, the welfare costs remain small (Otrok 2001). The second assumption Lucas made was that the log of consumption is serially uncorrelated and normally distributed around a linear trend. Barros et al. (2023), Reis (2009) and Obstfeld (1994) show that the way consumption is modeled is important to determine the welfare cost. They use a representative agent model and show that when persistence is allowed, the cost of business cycles is higher, ranging from 0.5% to 5%. Even if the shock is small, households are not able to smooth consumption so easily, and the welfare costs can be higher than previously estimated. As a matter of fact, even with perfect credit markets, but with a permanent shock, individuals do not want to borrow in order to smooth their consumption, which rises the welfare costs to a value of 7.5% in consumption equivalents (Krebs 2003). ¹

Finally, Beaudry and Pages (2001), Chauvin et al. (2011), Imrohoroglu (1989), Krusell and Smith (1997), Krusell and Smith (1999) and Storesletten et al. (2001) add to the topic the incorporation of models with heterogeneous agents. In these models, agents have different characteristics, preferences, and abilities, which can lead to differences in the welfare effects of business cycles across households. Overall, the inclusion of heterogeneous agents in models of business cycles can provide important insights into the distributional effects of economic fluctuations and the potential trade-offs between macroeconomic stability and equity.

This work is built upon Krusell and Smith (1999) who derive a model that features both uninsurable idiosyncratic shocks and aggregate risk. That is, they use a model where agents differ in terms of employment and preferences, live infinite lives, and have only one risky asset. In this environment, economic cycles are driven by exogenous stochastic shocks in productivity and employment, while the non-cycle economy

¹Storesletten et al. (2001) use a deviation of the Lucas model with countercyclical variation in idiosyncratic risk, which amplifies the welfare cost of aggregate productivity shocks and imposes a cost of its own. Importantly, the magnitude of these effects increases non-linearly in risk aversion.

is calculated using the conditional expectations of aggregate shocks. The authors estimated a welfare cost of up to 1% in the aggregate, measured in consumption equivalents. Nonetheless, they have a striking finding. They found that agents with different wealth are affected distinctively by business cycles. This is, eliminating the welfare costs is more beneficial to poor agents than wealthy ones because when unemployed, the first undergo a higher risk, which makes them more vulnerable to fluctuations, and thus gain almost 30% due to business cycle elimination. We argue that this value reflects the fact that the this model does not consider the fact that agents can have different asset allocations, which creates heterogeneity in terms of their portfolio compositions and, consequently, the way they can insure against a shock. Moreover, the distribution of marginal propensities to consume (MPC) from these one-asset models does not align with the empirical data. These models generate very small average MPCs, with only the agents close to the borrowing constraint having significant responses to income shocks. This could explain why Krusell and Smith’s model shows such a result around the borrowing constraint, and it is one of the mechanisms that we aim to expand.

More recently, [Jeong and Shim \(2022\)](#) use an Aiyagary model with endogenous labor supply and conclude that agents with more wealth would prefer economic fluctuations. They find that the welfare cost gain increases monotonically with wealth level. Similarly, [Cho and Ma \(2023\)](#) use a model proximate to Krusel and Smith, allowing different labor supply elasticities, and also find that welfare effects are heterogeneous across agents, benefiting mostly the rich, due to their less volatile consumption and availability to reallocate savings inter-temporally.² Despite all of this progress, the welfare costs remain small, with values up to 1.5% in [Imrohoroglu \(1989\)](#), 3% in [Ghosh et al. \(2019\)](#), and 4.4% [Beaudry and Pages \(2001\)](#).

Recent literature has highlighted the importance of considering different types of

²[Cho et al. \(2015\)](#) use a representative agent model and conclude that business cycles are welfare-improving when model factors are endogenously determined, and using an RBC model with variable capital utilization, [Lester et al. \(2014\)](#) argue that in a representative agent RBC model, business cycles are always welfare-improving.

assets that households hold. For instance, [Kaplan and Violante \(2014\)](#) examined the differences in marginal propensities to consume of distinct agents using a partial equilibrium model with two assets: (i) one liquid asset with a low return, such as cash or bonds, and (ii) an illiquid asset with a higher return, such as capital. Their findings suggest that agents with different asset types have varying MPCs.

In this study, we investigate the welfare costs of business cycles in an economy where agents can save using two types of assets. We expect that households prefer liquid assets to smooth their consumption under uncertainty, but different agents have different portfolio compositions, which implies a different welfare cost based on their asset holdings and their changes in value.

To address this question, we first developed a model that adds a two-asset dimension to the [Krusell and Smith \(1999\)](#) model. In this new model, agents live infinite lives, experience idiosyncratic shocks, and can hold two types of assets with different returns: a liquid asset with a low return and an illiquid asset with a higher return. Additionally, there is a cost of adjustment when the agent desires to exchange between the two assets. By simulating an MIT shock that generates the welfare costs calculated by the authors in their original model and matches the standard deviation of consumption, we then applied the same shock in our model. Our results show that the cost of adjustment is a key feature of our model, because if it is high, households may not be able to change their portfolio composition even if they prefer to hold more liquid assets, which generates different welfare effects on different households, depending on their portfolio choices. We found that this model reaches a cost of 1.2% in consumption equivalents, which highlights the importance of these features in our model.

Next, we developed a Heterogeneous New Keynesian Model (HANK) with sticky prices and wages, based on [Auclert et al. \(2021b\)](#). Using the same calibration strategy to match the shares of hand-to-mouth agents, our framework reveals that the cost of business cycles in consumption equivalent is 2.6%. This value is higher than the ones

obtained by using different specifications of the [Krusell and Smith \(1999\)](#) model, in which the values range from 1% to 1.25%. Furthermore, we find that in recession periods the welfare cost in consumption equivalents raises to 11.1%.

The remainder of the article is organized as follows: we begin by presenting some stylized facts in Section 2. Then, we explain, in Section 3 the Methodology, followed by the Results in Section 4. And, finally, we present in Section 5 the Conclusion of this article.

2 Stylized facts

The third generation of macroeconomics takes micro data more seriously, which enables current models to create a richer interaction between inequality and the macro-economy. To do so, these models need to focus in things such that: (i) non-convexities and non-homotheticities; (ii) household balance sheets and; (iii) heterogeneous MPC. Recent studies address the importance of the incorporation of plausible empirical MPCs in incomplete markets models ([Kaplan et al. 2014](#), [Bayer et al. 2019](#), [Carroll et al. 2017](#), [Fagereng et al. 2021](#)). This literature defines a household that spends all of its available resources in every pay-period as an Hand-to-mouth (HtM) consumer, and finds that these consumers have a very high MPC out of transitory income shocks, while Non-hand-to-Mouth (NhtM) consumers have lower MPC's. [Kaplan et al. \(2014\)](#) separate HtM agents in two groups, leading to three different categories: (i) Wealthy hand-to-mouth (W-htM), which are households that hold high amounts of wealth in illiquid assets, but do not hold liquid wealth or hold a very low share of these last; (ii) Poor hand-to-mouth (PhTM), who hold little liquid wealth, but no illiquid wealth or a very low share; and (iii) Non hand-to-mouth (NhtM) households, who are not in the two previous groups.

We replicate their results for US from 1989 to 2010 (see Figure 1) using Consumer

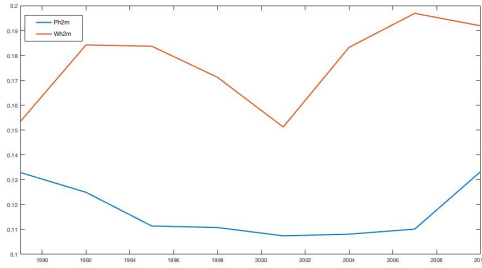


Figure 1: Share of different households

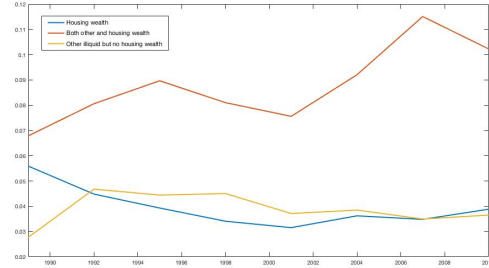


Figure 2: Portfolio composition of W-htM

Survey of Finance (CSF) data³. In 2010, the share of HtM households was above 30%, with almost 20% of agents being WhtM, hence 2/3 of HtM households are WhtM. Nevertheless, the share of these agents increased considerably since 2000, which imply that agents increased the share of illiquid assets in their portfolio, as shown in Figure 2. For European countries they achieve similar results, with countries having a share of HtM agents between 30% to 40%, with Finland being the country that has a lower share of HtM households - only 14%.

The results show that when one analyses the distribution of households without taking the composition of their portfolio into account, one misses an important part of the population that has high MPCs. Note that both, Whtm and PhtM, have high MPC, but they are different in respect to their possibility and/or availability to adjust their asset liquidity to smooth their consumption and insure against shocks. Clearly this shows that we need to look in more detail to specific portfolios of the households, rather than just look to the net worth (Kaplan et al. 2014).

In fact, Carroll et al. (2014) show that the aggregate consumption response is stronger in economies with large wealth inequality and when we consider households only using liquid assets to smooth consumption. In truth, households with a high proportion of liquid assets - specially in periods of high uncertainty - are better insured, because they suffer less from lower return premium gap and, in consequence, their welfare loss may be smaller (Bayer et al. 2019). Hence, it is expected that liquid assets are responsible to

³Note that CSF releases data with gaps of 3 years.

Table 1: Shares of WhtM and PhtM

Year	HtM	WhtM	PhtM	Share of WhtM
1989	0.29	0.15	0.13	0.54
1992	0.31	0.18	0.12	0.60
1995	0.30	0.18	0.11	0.62
1998	0.28	0.17	0.11	0.61
2001	0.26	0.15	0.11	0.58
2004	0.29	0.18	0.11	0.63
2007	0.31	0.20	0.11	0.64
2010	0.33	0.19	0.13	0.59

explain an important fraction of MPCs heterogeneity ⁴ - average annual estimations of MPCs are around 0.5 (Fagereng et al. 2021, Auclert et al. 2021a)

The present article incorporates these features to study the welfare impact of business cycles, taking into consideration that households can hold different types of assets in terms of: (i) liquidity and; (ii) adjustment cost, as in Kaplan and Violante (2014) , in an economy with price and wage rigidities (Auclert et al. 2021b).

3 Methodology

In this section, we develop two standard incomplete markets model that we will later calibrate to resemble the U.S. economy and use to study the welfare costs of business cycles. This model is adaptable in terms of the time preference heterogeneity and saving instruments.

3.1 Krusell-Smith Model

We start our analysis using a model similar to Krusell and Smith (1999). This model serves as the bedrock for our investigation. In this framework, agents have the capacity to save in a single type of asset and are only partially insured against risks.

In order to tailor the model to our specific objectives, we introduce several adjust-

⁴Fagereng et al. (2021) use lottery prizes in Norwegian data and find that only liquid assets and households age correlate with household-level MPCs, and one standard deviation increase in liquidity is associated with an MPC reduction of \$0.08 to the dollar won.

ments. Initially, we incorporate a distinct β parameter, which introduces diversity in discount factors among agents. This modification is crucial as it allows us to align the model with the empirically estimated average quarterly MPC as reported in [Auclert et al. \(2021a\)](#).

Following this, we analyze the impact of incorporating two distinct types of assets, each characterized by differing levels of liquidity. One category encompasses liquid assets, such as bonds, which offer a relatively lower return. In contrast, the second category comprises illiquid assets, like capital, which promise higher returns. Additionally with a representing portfolio adjustment costs, these elements plays a pivotal role in the calibration process, enabling us to match the model to accurately replicate the distributional shares of agents of both poor and wealthy hand-to-mouth.

Finally, we merge these two models to create a Krusell-Smith model with two assets, two assets and distinct discount factors. This combined model possesses the unique capability of aligning with both the observed empirical distributions and MPCs, offering a comprehensive and nuanced representation of the economic.

To describe the models, we start by the shared characteristics between them.

Firms

The economy behaves in perfect competition, with a constant elasticity of substitution (CES) production function in the form of:

$$Y = Z_t K_{t-1}^\alpha L_t^{1-\alpha} \quad (1)$$

where $\alpha \in [0, 1]$, Y is output, K is the aggregate capital input, L is the aggregate labor input, and Z_t is a shock to aggregate productivity. Furthermore, capital evolves as following:

$$K_{t+1} = (1 - \delta)K_t + i \quad (2)$$

where δ is the depreciation rate, K_{t+1} is the next period capital and i is the investment.

Firms maximize their profits in a competitive equilibrium, thus factor prices will be equal to their marginal products:

$$r_t^k = Z_t \alpha \left(\frac{L_t}{K_{t-1}} \right)^{1-\alpha} - \delta \quad (3)$$

$$w_t = Z_t (1 - \alpha) \left(\frac{Z_t \alpha}{r_t^k + \delta} \right)^{\frac{\alpha}{1-\alpha}} \quad (4)$$

Government

This is an aspect of the model that differs from the original model in [Krusell and Smith \(1999\)](#), but we added so savings in liquid assets can be matched by the government bonds outstanding.

The government issues bonds, B^g , and sets a proportional tax on labor income, $\tau_t w_t N_t$, with $\tau > 0$. It faces exogenous government expenses on goods and services, G_t . Each period its budget constraint balances, such that:

$$\tau_t w_t N_t = r_t B^g + G_t \quad (5)$$

Households

In this setting agents face an uninsurable idiosyncratic shock on their wages, as in [Aiya-gari \(1994\)](#), and at each period the agent decides how much to consume and save, and derives utility from consumption. The economy is composed by a large number of ex-ante identical households that desire to maximize their utility function, u :

$$U(c) = \frac{c_{it}^{1-\sigma}}{1-\sigma} \quad (6)$$

where σ is their risk aversion coefficient. This is a standard CRRA utility function in order to be able to produce a balanced growth. There exist n_e idiosyncratic states, and at any period, agents can move across states with an exogenous probability P . The station-

ary distribution of P is denoted by π , and it assumes that the mass of agents in each state e is always equal to $\pi(e)$ ⁵. Borrowing limits are set to zero. Then, we distinguish the models with respect to heterogeneity in discount factors and the inclusion of a portfolio decision between liquid and illiquid assets. The first model, which we call *Benchmark Krusell Smith*, its value function is given by:

$$\begin{aligned} V_t^{KS_{Bench}}(e_t, a_t) &= \max_{c_t, a_{t+1}} \{U(c) + \beta \mathbb{E}_t V_{t+1}(e_{t+1}, a_{t+1})\} \\ \text{s.t.} \\ c_t + a_{t+1} &= w_t e_t + (1 + r_t) a_{it} \end{aligned} \tag{7}$$

One of the key ingredients of this paper is precisely the fact that the original paper from [Krusell and Smith \(1999\)](#) was not able to match the empirical MPCs and they point out that eliminating the welfare costs is more beneficial to poor agents who gain almost 30% due to business cycle elimination. Hence, it is essential to understand if a similar result can be achieved by getting an plausible MPC from the model. To do so, we introduce households that are ex-ante heterogeneous with respect to their discount factor $\beta_i \in \{\beta_1, \beta_2\}$. Thus the value function of this *Krusell-Smith MPC* model is given by:

$$\begin{aligned} V_t^{KS_{MPC}}(\beta, e_t, a_t) &= \max_{c_t, a_{t+1}} \{U(c) + \beta \mathbb{E}_t V_{t+1}(\beta, e_{t+1}, a_{t+1})\} \\ \text{s.t.} \\ c_t + a_{t+1} &= w_t e_t + (1 + r_t) a_{it} \end{aligned} \tag{8}$$

The next ingredient is the different liquidity regarding the savings instruments for the households. We include 2 types of assets: one liquid asset, which has a low return, such as bonds; and one illiquid asset, that has high return, such as capital. Precautionary and smoothing motives induce households to accumulate a higher amount of liquid assets. In consequence, in a response to a income shock, a given household shortage on liquid

⁵This formulation follows [Auclert et al. \(2021b\)](#), departing from the original [Krusell and Smith \(1997\)](#), where the transition probabilities depend on the aggregate state.

wealth can retrieve funds from his illiquid wealth and transform them in liquid assets by incurring in an adjustment cost. Each household decides how much to consume and save given their state and they have the possibility to save in two different assets: (i) a liquid asset, b_t ; and (ii) an illiquid asset, a_t . In order to change their portfolio allocations, households are subjected to a convex adjustment cost $\Phi_t(a_{t+1}, a_t)$, with $\chi_0, \chi_1 > 0$ and $\chi_2 > 1$:

$$\Phi_t(a_{t+1}, a_t) = \frac{\chi_1}{\chi_2} \left| \frac{a_{t+1} - (1 + r_t^a) a_t}{(1 + r_t^a) a_t + \chi_0} \right|^{\chi_2} [(1 + r_t^a) a_t + \chi_0] \quad (9)$$

r^b and r^a are the returns of each asset which captures the liquidity difference between both. The liquid asset, b_t , has a return of r_t^b , and the illiquid asset has a return of r_t^a , such that r_t^b is lower than r_t^a , since each asset provides different risks.

In this manner, there is a trade-off between the two assets. The illiquid asset has a higher return in capital gain and consumption flow, however the adjustment of this asset is subjected to a transaction cost and, in consequence, it can be the case that some households cannot convert their illiquid asset into the liquid asset, if the transaction cost is too high. This implies that wealthy households might prefer to adjust their consumption pattern with fluctuating earnings, rather than smooth consumption, as they will be better by bearing the welfare loss, since the presence of the transaction cost will reduce their capacity to adjust their asset position (Kaplan et al. 2018).

The value function for this *Krusell-Smith 2 Asset* is given by:

$$\begin{aligned} V_t^{KS_{2A}}(e_t, a_t, b_t) &= \max_{c_t, a_{t+1}, b_{t+1}} \{U(c) + \beta \mathbb{E}_t V_{t+1}(e_{t+1}, a_{t+1}, b_{t+1})\} \\ \text{s.t.} & \\ c_t + a_{t+1} + b_{t+1} &= w_t e_t + (1 + r_t^a) a_{it} + (1 + r_t^b) b_{it} - \Phi_t(a_t, a_{t+1}) \end{aligned} \quad (10)$$

To sum up, we add all this ingredients into a final model:

$$\begin{aligned}
V_t^{KS_{2A},MPC}(\beta, e_t, a_t, b_t) &= \max_{c_t, a_{t+1}, b_{t+1}} \{U(c) + \beta \mathbb{E}_t V_{t+1}(\beta, e_{t+1}, a_{t+1}, b_{t+1})\} \\
\text{s.t.} & \\
c_t + a_{t+1} + b_{t+1} &= w_t e_t + (1 + r_t^a) a_{it} + (1 + r_t^b) b_{it} - \Phi_t(a_t, a_{t+1})
\end{aligned} \tag{11}$$

Equilibrium

Given a distribution of agents D , the competitive equilibrium can be summarized as follows:

- Taking factor prices and initial conditions as given, households maximization problem is solved using the value function and the respective policy functions.
- Firms optimize.
- Fiscal authorities follow their rules.
- Asset markets clear::

$$K + B^g = \int a_i di$$

or

$$K + B^g = \int a_i + b_i di$$

- Goods market clears when the final good is used for private and public consumption, investment, price adjustment costs, and liquidity transformation:

$$Y_t = \int c_{it} di + G_t + I_t$$

or

$$Y_t = \int c_{it} di + G_t + I_t + \Phi_t$$

3.2 HANK Model

In this section we describe the development and analysis of the HANK model, following [Auclert et al. \(2021b\)](#). In this model agents have infinite lives and face uninsurable idiosyncratic income risk, which they can insure using two assets with different levels of liquidity, this implies that each asset offers different degrees of return.

The model features sticky prices and wages, where the number of hours worked, n , is defined by a union labor demand, that takes as given household consumption-savings decisions. Finally, the monetary policy has targets for inflation and output, following a standard Taylor rule, and the government has a balanced budget. In the remaining subsections we develop each block in more detail.

Households

The economy is populated by a mass of heterogeneous agents that face idiosyncratic uncertainty and are ex-ante heterogeneous with respect to their discount factor $\beta_i \in \{\beta_1, \beta_2\}$. At state s the household has a fixed transition matrix Π , and the mass of households in state s is equal to π_s , such that $\sum_s \pi_s e(s) = 1$.

Each household decides how much to consume and how much to save in liquid and illiquid assets given their state. In order to change their allocations, households are subjected to a convex portfolio adjustment cost as in Equation 9. Households work the same number of hours and as a compensation of their work, they receive an individual after-tax wage. Households utility is then a function of consumption, c , and work time, n :

$$U(c, N) = \frac{c_{it}^{1-\sigma}}{1-\sigma} - \varphi \frac{N_t^{1+\eta}}{1+\eta} \quad (12)$$

where φ is the notation for disutility if work, and η denotes the Frisch labor elasticity.

In this manner, the household problem is the following:

$$V_t(\beta, e_t, b_t, a_t) = \max_{c_t, b_{t+1}, a_{t+1}} \{U(c, N) + \beta \mathbb{E}_t V_{t+1}(\beta, e_{t+1}, b_{t+1}, a_{t+1})\}$$

s.t.

$$c_t + a_{t+1} + b_{t+1} = (1 - \tau_t)w_t N_t e_t + (1 + r_t^a)a_t + (1 + r_t^b)b_t - \Phi_t(a_t a_{t+1}) \quad (13)$$

$$a_t \geq 0, \quad b_t \geq 0$$

Financial intermediary

A financial intermediary is responsible to issue liquid and illiquid assets. They take both of assets from the households and invest in government bonds, B_t^g , and firm equity, p_t . In order to perform liquidity transformation it incurs in a cost of $\omega \int b_{it} di$.

The main goal of the financial intermediary is to maximize the expected return on illiquid liabilities, $\mathbb{E}_t [1 + r_{t+1}^a]$, which will require the non-arbitrage condition. This implies that at the equilibrium the economy ex-ante return, $\mathbb{E}_t [1 + r_{t+1}]$, equals the expected returns on nominal government bonds and equity. The return pass on to households, taking into consideration the intermediation costs:

$$\mathbb{E}_t [1 + r_{t+1}] = \frac{1 + i_t}{\mathbb{E}_t [1 + \pi_{t+1}]} = \frac{\mathbb{E}_t [d_{t+1} + p_{t+1}]}{p_t} = \mathbb{E}_t [1 + r_{t+1}^a] = \mathbb{E}_t [1 + r_{t+1}^b] + \omega \quad (14)$$

where r_t , r_t^a and r_t^b denote the ex-post returns, subjected to inflation and capital gains. As [Auclert et al. \(2021b\)](#) we assume that capital gains are inserted into the illiquid account, which lead us to the following Fisher Equation:

$$1 + r_t = \frac{1 + i_{t-1}}{1 + \pi_{t-1}} = 1 + r_{t-1}^b + \omega \quad (15)$$

and

$$1 + r_t^a = \Theta_p \left(\frac{d_t + p_t}{p_{t-1}} \right) + (1 - \Theta_p) (1 + r_t) \quad (16)$$

where Θ_p denotes the share of equity in the illiquid portfolio. Equation 16 shows that the return on the illiquid asset is an average from firm equity and dividends, and the return on capital.

Firms

The economy is composed in two segments: a competitive final goods firm, and monopolistically competitive firms that produce a continuum of intermediate goods, j . Intermediate firms have a standard Cobb Douglas production function:

$$Y_{jt} = AK_{jt-1}^\alpha N_{jt}^{1-\alpha} \quad (17)$$

with α denoting the capital share. Firms want to maximize profits choosing their capital stock, subjected to a quadratic adjustment cost $\zeta(\frac{K_{jt}}{K_{jt-1}})K_{jt-1}$, with $\zeta(x) \equiv x - (1 - \delta) + \frac{1}{2\delta\epsilon_I}(x - 1)^2$, where δ defines the depreciation, and $\delta > 0$ and $\epsilon_I > 0$. Each firm sets the price of its product, p_{jt} , subject to a adjustment cost of:

$$\psi_t^p(p_{jt}, p_{jt-1}) = \left(\frac{\mu_p}{\mu_p - 1}\right) \left(\frac{1}{2\kappa_p}\right) [\log(p_{jt}/p_{jt-1})]^2 Y_t \quad (18)$$

where μ_p is the steady-state markup and κ_p is the slope of the Phillips curve. A fraction of firms do not adjust their price index to the previous period inflation, hence for those firms the price is:

$$P_{jt} = \Pi_{t-1} P_{j,t-1}$$

with $\Pi_{t-1} \equiv \frac{P_{t-1}}{P_t}$. Thus, the optimal price-setting of firms generates an indexed Phillips curve, given by Equation 19:

$$\log(1 + \pi_t) = \kappa_p \left(\frac{w_t}{F'_N(K_{t-1}, N_t)} - \frac{1}{\mu_p} \right) + \frac{1}{1 + r_{t+1}} \frac{Y_{t+1}}{Y_t} \log(1 + \pi_{t+1}) \quad (19)$$

noting that $w_t/F'_N(K_{t-1}, N_t)$ denotes the marginal cost, mc_t . The Phillips curve slope is $\kappa_p = \frac{(1-\beta\lambda_p)(1-\lambda_p)}{\lambda_p}$, where λ_p denotes the Calvo price parameter. When prices are fully flexible, this is, $\lambda_p = 0$, all firms set the same price, a constant mark-up over the marginal costs, $\frac{\mu_p}{\mu_p - 1}$.

Given that aggregate investment can be summarized as $I_t = K_t - (1 - \delta)K_{t-1} + \zeta(\frac{K_{jt}}{K_{jt-1}})K_{jt-1}$

and dividends as $d_t = Y_t - \omega_t N_t - I_t - \psi_t$, we will finally achieve the capital stock accumulation equation:

$$(1 + r_{t+1}) Q_t = \alpha \frac{Y_{t+1}}{K_t} mc_{t+1} - \left[\frac{K_{t+1}}{K_t} - (1 - \delta) + \frac{1}{2\delta\epsilon_I} \left(\frac{K_{t+1} - K_t}{K_t} \right)^2 \right] + \frac{K_{t+1}}{K_t} Q_{t+1} \quad (20)$$

where Q_t denotes the Tobin's Q ratio, $Q_t = 1 + \frac{1}{\delta\epsilon_I} \frac{K_t - K_{t-1}}{K_{t-1}}$.

Labor Unions

As in a standard New Keynesian model with sticky-wages, household labor hours, n_{it} , are determined by union labor demand. This procedure is widely used in HANK models, and allows a plausible distribution of MPLs (Auclert et al. 2021a). It assumes a continuum of unions, k , where each labor type wage is settled by a different labor union. This is, each union, k , aggregates efficient units of work into a union-specific task. At a given time asks to the members to supply hours according to, $n_{ikt} = N_{ikt}$, and sets wages to maximize the average utility of households, taking as given their consumption-savings decisions. By setting a nominal wage, W_{kt} , the union suffers a quadratic adjustment cost similar with the price adjustment cost incurred by the firm:

$$\psi_t^w(W_{kt}, W_{kt-1}) = \left(\frac{\mu_w}{\mu_w - 1} \right) \left(\frac{1}{2\kappa_w} \right) [\log(W_{kt}/W_{kt-1})]^2$$

where μ_w is the wage markup, and κ_w is the slope of wage Phillips curve. The union maximization problem leads to a Phillips curve for wage inflation:

$$\log(1 + \pi_t^w) = \kappa_w \left(\varphi N_t^{1+v} - \frac{(1 - \tau_t) w_t N_t}{\mu_w} \int e_{it} c_{it}^{-\sigma} di \right) + \beta \log(1 + \pi_{t+1}^w) \quad (21)$$

the Slope of the Phillips curve is $\kappa_w = \frac{(1-\beta\lambda_w)(1-\lambda_w)}{\lambda_w}$, where λ_w is the Calvo wage parameter. For instance, it will imply that when wages are fully flexible $\lambda_w = 0$, all unions would set the inverse wage markup to $\frac{\mu_w - 1}{\mu_w}$.

Fiscal and Monetary Policies

The government issues bonds, B^g , and sets a proportional tax on labor income, $\tau_t w_t N_t$, with $\tau > 0$. It faces exogenous government expenses on goods and services, G_t . Each period its budget constraint balances, such that:

$$\tau_t w_t N_t = r_t B^g + G_t \quad (22)$$

Furthermore, the monetary authority follows a standard Taylor rule to set the nominal interest rate:

$$i_t = r_t^* + \phi_\pi \pi_t \quad (23)$$

where r_t^* is the optimal real interest rate and ϕ_π is the inflation Taylor rule coefficient. Given inflation and nominal interest rate, the return is given by the Fisher Equation:

$$r_t = \frac{(1+i_t)}{(1+\pi_{t-1})}.$$

Equilibrium

Given a distribution of agents D , the competitive equilibrium can be summarized as follows:

- Taking factor prices and initial conditions as given, households maximization problem is solved using the value function $V_t(\beta, e_t, b_t, a_t)$ and the respective policy functions, $c(\beta, e_t, b_t, a_t)$, $b'(\beta, e_t, b_t, a_t)$ and $a'(\beta, e_t, b_t, a_t)$.
- Financial intermediary, firms and labor unions optimize.
- Fiscal and monetary authorities follow their rules.
- Asset markets clear, this is, total saving by households equals the value of firm equity and government bonds:

$$p_t + B^g = \int a_{it} + \int b_{it} di$$

- Goods market clears when the final good is used for private and public consumption, investment, price adjustment costs, and liquidity transformation:

$$Y_t = \int c_{it} di + G_t + I_t + \psi_t + \omega \int b_{it} di$$

3.3 Calibration

We calibrate all the models to match the US economy. We initially calibrate the HANK Model and we use the endogenous calibrated parameters for all Krusell-Smith models. The model is calibrated for a quarterly frequency.

Preferences

Both models are calibrated in the same way with respect to preferences. We set the Frisch elasticity of labor supply to 1, as in [Trabandt and Uhlig \(2011\)](#), similar to what is used in the literature. The disutility of work and the discount factor are among the parameters calibrated to match key moments in the data. The coefficient of risk aversion is set to be equal to 2 as in [Auclert et al. \(2020\)](#).

Government and Monetary Policy

When calibrating the HANK model, we set government spending, $G = 0.20$ to match the labor tax from [Auclert and Rognlie \(2018\)](#) and Government bonds such that $B^g/Y = 0.42$, as in [Auclert et al. \(2020\)](#). For monetary policy, we use again the same parameters as in [Auclert et al. \(2020\)](#).

Parameters Calibrated Endogenously

For the steady state equilibrium, the set of parameters which do not have any empirical counterpart were endogenously calibrated. Our purpose is to calibrate the model to match the shares of HtM agents in the US economy as in [Kaplan et al. \(2018\)](#). Thus, we have 5 moments to match, which means that we need 5 parameters that do not have any empirical counterpart to have an exactly identified system. Table 2 presents the

Data moment	Data Value	Model Value	Parameters	Value	Description
A/Y	14.36	14.36	β_1	0.977	Discount Factor 1
B/Y	0.92	0.92	ω	0.006	Liquidity premium
Poor HtM	0.10	0.10	χ_0	6.394	Portfolio adj. cost pivot
Wealthy HtM	0.20	0.20	χ_1	35.98	Portfolio adj. cost scale
MPC	0.25	0.25	β_2	0.935	Discount Factor 2

Table 2: Calibration for the 2-Asset HANK model

calibrated parameters and fit. The data values for Assets and Bonds are the same as in [Auclert et al. \(2020\)](#) and match the average in the data of aggregate household wealth to GDP of 382%. The other parameters used in the model are on Table XX of the Appendix.

3.4 Computational Strategy

For solving the model we use the approach developed by [Auclert et al. \(2021b\)](#) that creates a rapid computation of Sequence-space Jacobians, taking the derivatives of perfect-foresight equilibrium mappings between aggregate sequences around the steady state. These Jacobians summarize every aspect of the model that is relevant for the General Equilibrium. The algorithm takes all relevant Sequence-space Jacobians, and then composes and inverts these matrices to obtain the model's full set of impulse responses.

We depart from the model of [Krusell and Smith \(1999\)](#) in which they estimate, at maximum, that the average welfare gains from eliminating business cycles would be around 1%. We use a MIT shock on the TFP that generates impulse response functions (IRF) for all the aggregates, including the aggregate utility of the economy. Then we make use of the same methodology as in [Boppart et al. \(2018\)](#), *i.e.*, we assume that the model is linear and use Wold Decomposition which implies that aggregate variables can be expressed as linear combination of past shocks γ , the IRF coefficients:

$$U_t = e_{z,t}\gamma_0 + e_{z,t-1}\gamma_1 + \dots$$

Hence, given one IRF, we are able to simulate all aggregates of the economy. Namely, we simulate the aggregate of utility and get the average for that period. The achieved

value will be the stochastic utility.

3.5 Business Cycle

The main purpose of this paper is to measure what would be the effects on welfare of eliminating business cycles. We know that when agents face a choice between a risky consumption series $\{c_t^d\}$ and a consumption series that is stable $\{c_t^s\}$, agents prefer the last. In this manner, one can quantify the preference for stability, and measure the costs of fluctuations by the fraction of annual consumption that agents will be willing to pay in order to eliminate these fluctuations. Taking the utility function which assumes that agents are risk averse, *i.e.*, $u''(c) < 0$, we will try to find is the cost of business cycles, λ , such that:

$$E\left[u(\{c_t^d\}_0^T(1+\lambda))\right] = u(\{c_t^s\}_0^T) \quad (24)$$

this means that λ can be seen as the value that represents how much extra consumption we would need to give to an agent in an environment with stochastic consumption to make him indifferent between the stochastic and deterministic consumption schedules.

4 Results

In this section, we will show our primary findings while employing various specifications. Our analysis commences with the replication of the outcomes derived from [Krusell and Smith \(1999\)](#), as demonstrated in Equation 7. This model is carefully tailored to align with US-specific data. To attain the same level of welfare costs as the authors - calculated as in Equation 24 - we conducted a calibration exercise that adjusts the standard deviation of the normal distribution of the shock, ensuring it corresponds to the welfare cost achieved in [Krusell and Smith \(1999\)](#).

To estimate the standard deviation of consumption, we have used quarterly data from the Federal Reserve Bank of St. Louis of real personal consumption expenditure

per capita for non-durable goods. Our dataset spans from the year 1947 up to 2023. Our findings indicate that the standard deviation of consumption shocks is approximately 0.027. This value closely aligns with the estimates previously obtained by [Reis \(2009\)](#) in his research. We also calculate the standard deviation of consumption for periods of recession. To do so, we use NBER quarterly recession indicator for that same time span, and we found that during these periods the standard deviation is 0.131.

4.1 *KS with MPC*

Having successfully calibrated our benchmark model and adjusted the shock parameters accordingly, we can now delve into the examination of welfare costs associated with business cycles for our second specification. The goal is to align the model with a plausible MPC. To accomplish this, we introduce two distinct discount factors: one to clear the asset market and the other to align with the empirical MPC value. Subsequently, we apply the shock magnitude that we derived by replicating the welfare cost and the standard deviation of consumption observed in the KS model.

As anticipated, the primary driver of differentiation between the two models lies in the response of consumption to the TFP shock. [Figure 3](#) illustrates that the model with an empirically calibrated MPC exhibits a more pronounced response in consumption with a positive TFP. This implies that during economic downturns within a business cycle, the fluctuations in consumption are amplified, consequently leading to higher associated welfare costs.

It is important to note that while the calibrated discount factor is designed to match the average MPC, it may not capture the empirical distribution of MPC. Nevertheless, this exercise highlights the pivotal role of MPC in driving the results. In this configuration we attain a welfare cost in consumption equivalent of 1.23%.

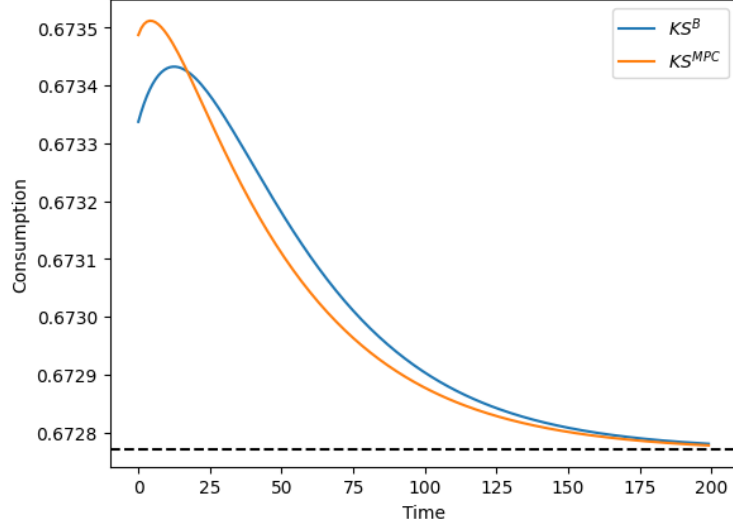


Figure 3: IRF of Consumption for a MIT Shock of 0.1% on TFP

4.2 KS with liquid and illiquid assets

Another noteworthy enhancement to the KS benchmark model involves the inclusion of two distinct asset categories. As detailed in section 3.1, we introduce a liquid asset, denoted as b_t , alongside an illiquid asset, represented by a_t . The key distinction here is that the return on the liquid asset is inferior to that of the illiquid asset, with $r_t^b < r_t^a$.

Following a TFP shock, we witness an increase in the accumulation of both asset types, indicating that households choose to save more in either the liquid or illiquid assets. This shift occurs as a result of the increased returns on both asset categories. Despite the fact that the return on the illiquid asset remains superior to that of the liquid asset, some agents are deterred by the high adjustment costs associated with the illiquid asset. Consequently, these agents exhibit a greater inclination to save in liquid assets rather than illiquid ones.

It's worth mentioning that, even though we didn't specifically aim to match the MPC, our model is capable of generating a MPC of 0.23, a value that closely approximates the empirical estimations. Consequently, with this configuration, we are able to achieve a consumption response that closely mirrors the one observed in section 4.1.

A key feature that we can analyze in this model with two assets is the response of

the different type of hand-to-mouth agents after the shock. Figure 4 illustrates the alterations in the proportions of HtM agents, distinguishing between the poor and wealthy, in response to the shock. Even though both the shares of poor and wealthy HtM agents decline following the shock in a similar way, the return to the steady-state occurs at a swifter pace for the latter. This shift in the agent distribution has ramifications for the

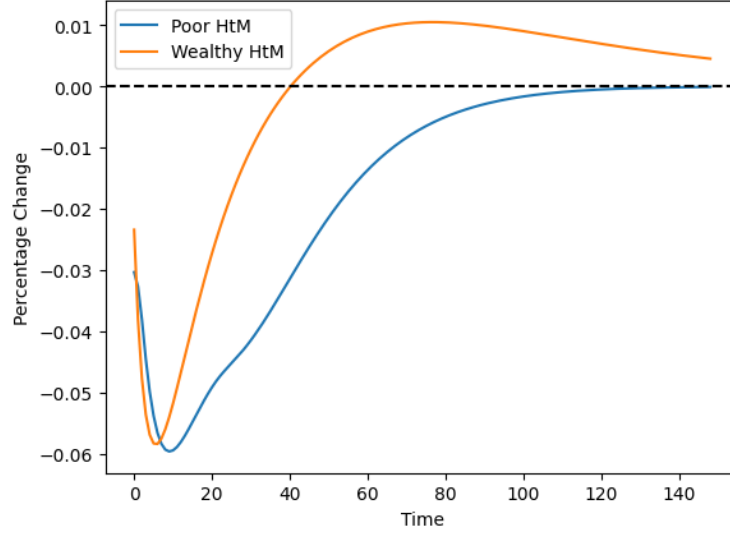


Figure 4: Percentage Change of shares of HtM agent for a MIT Shock of 0.1% on TFP

overall welfare cost of the economy, given the diminishing shares of HtM agents. When we compute the welfare cost in consumption equivalent in this particular scenario, it amounts to 1.2%. It's noteworthy that this value is slightly lower than that observed in the case of KS with MPC, but higher than the benchmark case.

4.3 *KS complete*

In conclusion, we incorporate both elements – an MPC alignment and the inclusion of two assets – into the KS model, as exemplified in equation 10. In this instance, all the previously described mechanisms are applicable. We discern identical patterns in the behaviors of both liquid and illiquid assets, along with their respective prices. Likewise, the shifts in the proportions of poor and wealthy HtM agents mirror those observed earlier.

This scenario yields a welfare cost associated with business cycle fluctuations in consumption equivalent to 1.25%.

4.4 *HANK model*

In this section, we complete our analysis by evaluating the welfare costs in a HANK model. These models represent the cutting edge of research and offer a more precise depiction of reality. As detailed in Section 3, the base calibration was conducted within the HANK model, enabling us to closely align with both the empirical distributions of HtM agents and the quarterly average MPC. Subsequently, we took the innovation parameters from the Normal distribution as found in the KS model but adjusted the magnitude of the shock to match the estimated standard deviation of consumption in the simulated business cycle.

A crucial component of this model lies in how central banks respond to inflation, given that the savings in liquid assets are directly influenced by the interest rates set by monetary authorities. In this model, unlike the previous KS models, aggregate savings in both asset categories initially react inversely. Specifically, a positive TFP shock prompts agents to increase their demand for illiquid assets while decreasing their demand for liquid assets. This dynamic arises because the model demands that the central bank commits to achieve inflation stability, as demonstrated in Equation 23. In order to respond to a decrease in inflation, the central bank must lower the returns on these saving instruments. Consequently, when bad periods in the business cycle occur, consumption is less adversely affected because there is an increasing demand for bonds, which helps absorb the decline in consumption. Analyzing how the proportions of poor and wealthy HtM agents respond, we observe a departure from the patterns observed in the KS model. With a positive TFP shock, agents tend to reduce their holdings of bonds, causing both shares to initially increase before adjusting to smaller values in comparison to the steady state.

All of these mechanisms bring out the essential role that price rigidity plays in shap-

ing the dynamics of business cycles. In this model, using the same shock as the benchmark KS model results in a 2.6% welfare cost associated with business cycle fluctuations in consumption equivalents.

4.4.1 Price and Wage Rigidities

As explained earlier, the role of nominal rigidities in this model is crucial in elucidating how agents respond in the face of a stochastic economy. Figure 5 demonstrates how various parameters of the Phillips Curve, pertaining to price rigidity, impact the welfare costs associated with business cycles. As anticipated, the price rigidity parameter exerts a substantial influence on these costs. This is primarily due to how agents readjust their portfolios following a TFP shock: the greater the rigidity in the economy, the more pronounced the inflation response, prompting a stronger reaction from the central bank. Consequently, this alters the demand for liquid assets, hence affecting the responses of both Poor and Wealthy HtM shares post-shock.

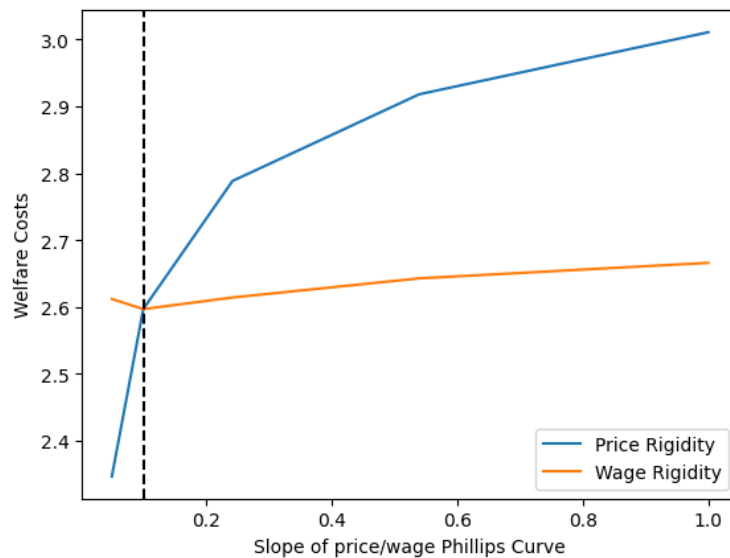


Figure 5: Welfare Costs and Nominal Rigidities

Figure 6 illustrates the distinct responses of the shares held by Poor and Wealthy HtM agents to a positive TFP shock in scenarios with different degrees of price sticki-

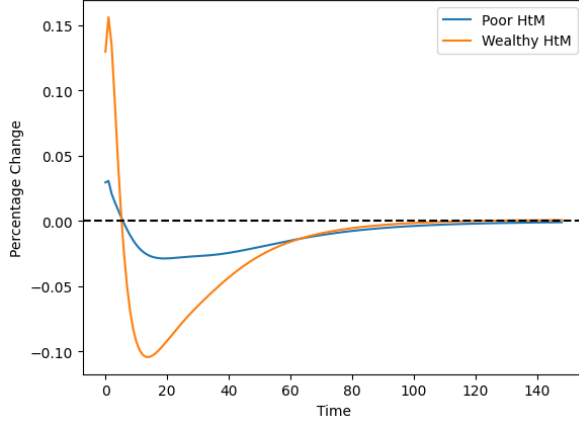


Figure 6: $k_p = 0.1$

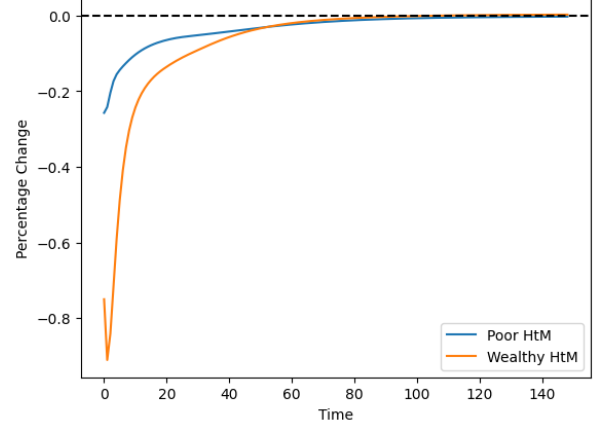


Figure 7: $k_p = 1$

ness. Initially, we observe a sharp increase in the share of wealthy HtM agents, followed by a steep decline—a trend not observed so strong among poor HtM agents. Conversely, Figure 7 depicts the response of these agents when prices exhibit slightly more flexibility. In this case, the share held by both Wealthy and Poor HtM agents decreases. Consequently, we can infer that when the slope of the price Phillips curve is smaller (indicating a more rigid economy), both shares initially increase, as explained earlier. However, when we reduce the degree of price rigidity, the behavior of the agents aligns more closely with that observed in Figure 4. Consequently, welfare costs increase since, during economic downturns, agents are unable to offset the decrease in consumption through a rebalancing of their portfolios towards more liquid assets.

This exercise emphasizes the critical role of the central bank in facilitating agents' consumption patterns throughout the business cycle. Monetary policy significantly influences the incentives for portfolio rebalancing, and consequently, the decision-making process regarding consumption and savings.

4.5 "Murphy's law: anything that can go wrong will go wrong"

A crucial aspect of the rebalancing mechanism hinges on how agents incur costs when adjusting their illiquid asset. In this framework, the rebalancing cost function is defined in Equation 9, exhibiting convexity. Although the welfare costs in normal times are not

significantly higher compared to estimations by [Krusell and Smith \(1999\)](#), the convex nature of the cost function renders these costs substantially higher during recessionary periods. This is because even agents endowed with a substantial quantity of illiquid assets may find themselves forced to make substantial adjustments to their consumption, thereby elevating the overall MPC of the economy.

As such, we examine these consequences during distinct economic cycles, meaning that we aim to solely on understanding the welfare costs of business cycles during recessionary periods. To accomplish this, we conducted empirical estimations of the consumption standard deviation during recessionary periods and calibrated the shock to align with that specific value.

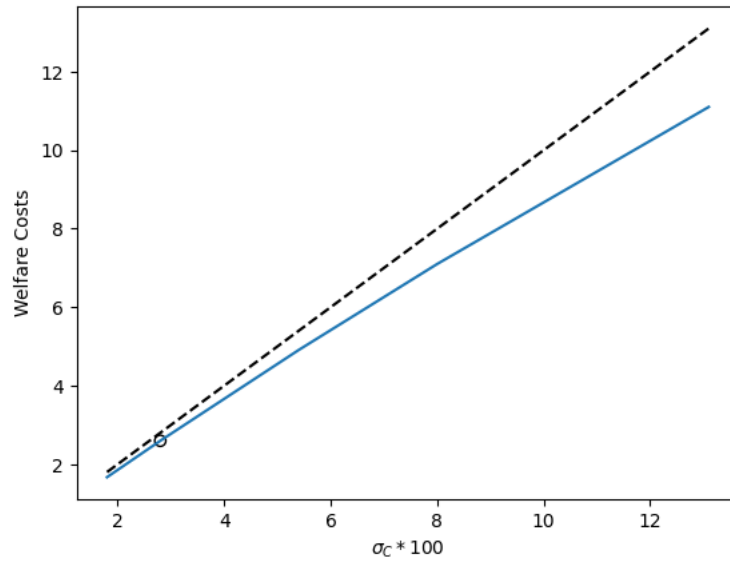


Figure 8: Welfare Costs and Standard Deviation of Consumption

The mechanisms described earlier are equally pertinent in this context. During recessions, there is an amplified necessity for active monetary and fiscal policies need to be more active to avoid the permanent scars of a downturn. Consequently, the monetary policy authority will be compelled to respond with greater severity, leading to more pronounced alterations in household consumption and savings patterns.

This exercise shows the crucial role of adjustment costs, as evidenced in [Figure 8](#), as

we anticipated. For estimates within an economy experiencing a recession, the welfare costs of business cycles escalate to 11.1% for the entire economy.

5 Conclusion

We have shown that the welfare costs of business cycles are higher than those reported by [Lucas \(1987\)](#). Departing from his representative-agent model, we introduce an economy with heterogeneous agents, uninsurable idiosyncratic productivity shocks, and aggregate risk as in [Krusell and Smith \(1999\)](#). Agents in our model hold two different assets: a liquid asset, such as bonds with a low return, and an illiquid asset, such as capital, with a higher return and risk. If agents want to adjust their asset holdings, they incur a transaction cost given by a quadratic cost function. The introduction of adjustment costs allows the model to produce a distribution of marginal propensities to consume that is empirically consistent with previous findings. We find that in this setting, the welfare costs of business cycles reach a maximum value of 1.25% in consumption equivalents. This effect is driven mostly by hand-to-mouth households, which incur high welfare losses when they need to adjust their portfolios in response to aggregate fluctuations.

We then focus on an economy with two assets, with sticky prices and wages, using a HANK model as in ([Auclert et al. 2021b](#)). Again, we use the same shock as the one that we use in the [Krusell and Smith \(1999\)](#) model, and we find that the welfare costs of business cycles in consumption equivalent rises to 2.6%. The value reaches a maximum of 11.1% if we only consider periods of recession. The rise in the welfare cost is not solely attributable to changes in the proportions of poor and wealthy HtM agents, it is also significantly influenced by the presence of wage and price rigidity, with the latter exerting a more pronounced impact.

Future research should consider integrating aggregate uncertainty into the analysis of such shocks. While this paper focuses on MIT shocks to investigate the welfare costs of

business cycles, it is important to note that the existing literature, when searching into the effects of aggregate risk and uncertainty, tends to narrow its focus to one-time, aggregate MIT shocks. This limitation prevents a comprehensive exploration of business cycle fluctuations. An essential augmentation to our model involves adopting a methodology similar to that employed in the work of [Gorodnichenko et al. \(2021\)](#), which will enable a more thorough examination of the impact of aggregate risk and uncertainty on business cycles.

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