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# The Labor Earnings Gap, Heterogeneous Wage Phillips Curves, and Monetary Policy

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**Abstract**

We study the role of household heterogeneity in skills over the business cycle in the U.S. We document that the ratio of labor income of skilled to unskilled workers (the earnings gap) is coun-tercyclical and increases in response to contractionary monetary policy. This result is due to the higher rigidity in unskilled workers' wages and gross substitution between skills in production. We find that in a calibrated New Keynesian model, when the earnings gap is countercyclical and un-skilled workers are more financially constrained, the impact of monetary policy shocks can be twice as strong as with homogeneous wage rigidities.

**Resumen**

Estudiamos el rol de la heterogeneidad en cualificaciones de los hogares en el ciclo económico para EE.UU. Documentamos que la relación entre los ingresos laborales de los trabajadores calificados y los no calificados (el earnings gap) es contracíclica y aumenta en respuesta a un shock de política monetaria contractivo. Este resultado se debe a la mayor rigidez de los salarios de los trabajadores no calificados y a la sustitución bruta de calificaciones en la producción. Encontramos que, en un modelo neo-keynesiano calibrado, cuando el earnings gap es contracíclico y los trabajadores no calificados están más restringidos financieramente, el impacto de los shocks de política monetaria puede ser dos veces más fuerte que con rigideces salariales homogéneas.

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# 1 Introduction

A recent literature has emphasized the importance of taking into account household heterogeneity to understand aggregate economic fluctuations, and the transmission of monetary policies (see e.g. Kaplan et al. (2018) and Auclert (2019)). Most studies in that literature have considered economic environments with ex-ante identical households, and where heterogeneity is the consequence of uninsurable idiosyncratic income shocks.

In this paper, we show that another dimension of heterogeneity, and namely ex-ante differences in skills/education across the population, might have important implications for the transmission of monetary policies. As we argue below, over the business cycle, "unskilled" workers –i.e. people without a college degree– face more rigid wages, and experience larger fluctuations in their labor income, relatively to "skilled" workers–people with college or higher degrees. Also, unskilled workers typically hold low levels of wealth, so that their consumption essentially mirrors the fluctuations in their labor income–i.e. they have a high marginal propensity to consume (MPC). Within a two-agent New-Keynesian model, we show that the combination of these features –higher wage rigidity and higher MPC of unskilled workers– leads to an amplification of the effects of monetary policy shocks. Under the baseline calibration, the (cumulative) effects of monetary shocks on GDP are twice as large as an economy with no heterogeneity.

We begin our analysis by looking at US data on wages, employment and wealth over the 1980-2018 period, and document three main facts. First, the share of unskilled workers with zero liquid assets is 47% while this share for skilled workers is 18%.[1] This observation suggests that a large share of unskilled workers, if affected by income shocks, cannot rely on buffer savings to avoid consumption fluctuations, and behave effectively as "hand-to-mouth" (HtM) agents. Second, the *earnings gap* (which is the ratio of skilled to unskilled labor income), is countercyclical. This result holds both when looking at unconditional correlations, or when focusing exclusively on the effects on monetary shocks, through an IV-SVAR analysis (following Miranda-Agrippino and Ricco (2017)). The wage Phillips curve is much steeper for unskilled workers than for skilled workers. This suggests that skilled workers have more flexible wages than unskilled workers.[2]

To rationalize these facts, we build a New Keynesian model with incomplete financial markets and heterogeneity in wage stickiness. We assume there are two different groups of workers, skilled and unskilled. Labor markets differ in several ways, but most importantly, they differ in their degree of

[1] According to the Survey of Consumer Finances 2016.

[2] This analysis is similar to Doniger (2019) who also finds that wages of the skilled workers are more flexible than those of the unskilled workers.

wage stickiness. Firms employ these different groups of workers and aggregate them with a constant elasticity of substitution (CES) production function. Workers share bond and equity markets, and hence every agent faces the same rates of return on their assets. We assume that unskilled workers are more financially constrained. Finally, we include all the standard features of New Keynesian literature: price rigidities, monopolistic competition in intermediate goods, and a Taylor rule.

We study analytically how the interaction of labor income inequality and incomplete markets affects aggregate demand. We follow Bilbiie (2008) and Debortoli and Galí (2017) by deriving an Euler equation with incomplete markets and heterogeneity in labor income. As in the latter study, we show that the aggregate Euler equation depends on heterogeneity wedges; in particular, it depends on a *consumption gap* that summarizes how financially constrained and financially unconstrained consumption differ. We show that the consumption gap depends on the earnings gap. In turn, the earnings gap may vary in response to aggregate fluctuations, given that workers belong to different labor markets. Therefore, we show that in a model with different labor markets and financial constraints, if the earnings gap is countercyclical, there is an amplification of monetary policy shocks. This amplification effect appears because those whose income fluctuates the most in response to a monetary policy shock are the workers with higher marginal propensities to consume–the unskilled workers– who are more financially constrained.

Then, we study the specifications of technology and labor markets that give rise to a countercyclical earnings gap in our model. For the labor market arrangement, we follow Galí (2013), which is a model where a union representing each class of workers sets wages. This union has market power regarding the demand for workers and hence charges a markup over the marginal rate of substitution. We also assume nominal wages are sticky, which delivers fluctuating and countercyclical wage markups. Additionally, as we show that labor income shares vary over time, we consider a production technology with imperfect substitutability between workers' groups. We show that the reason why the earnings gap fluctuates in our model is the heterogeneity in labor markets. However, a necessary condition for the earnings gap to vary is gross substitution between groups of the aggregate level. And given that condition, the wages of the skilled workers must be more flexible than those of the unskilled to generate the countercyclicality of the earnings gap.

The intuition of this result is the following. In response to a contractionary monetary policy shock, wages of all groups must fall. When the wages of the unskilled are more sticky, skilled workers become relatively cheaper than unskilled workers. In those conditions, if it is easy to substitute types of workers in the production process, there is a shift in demand from unskilled to skilled workers. These effects generate a more than proportional fall in unskilled workers' labor income that produces the earnings gap to increase.

We then consider a calibrated version of our model to assess quantitatively the effects of monetary shocks. We find that in the presence of labor market heterogeneity, the effects are 20% larger than in a representative agent counterpart (with no heterogeneity) in the model with profits, while the effect of monetary policy doubles in the model without profits. This amplification is obtained because unskilled workers have more procyclical labor income and are more financially constrained than the skilled workers, making their consumption respond more strongly. We also show that the previous mechanism is the most relevant amplification channel in our model.

All these findings suggest that to understand the effects of inequality on the business cycle and for the transmission of monetary policy, we must study the heterogeneity in the responses of income for different groups of workers; i.e., we must also consider the cyclicalities of the indirect effects that impact consumers and workers.

The contributions of this paper can be summarized as follows. We first contribute to the literature on labor income inequality by showing a simple measure of inequality that has aggregate effects, is countercyclical and responds to monetary policy shocks: the earnings gap. Second, we contribute to the literature on wage rigidities by showing empirically that a particular group of agents (the skilled workers) have substantially more flexible wages. Third, we contribute to the theoretical literature on the transmission of monetary policy by highlighting the importance of heterogeneity in wage rigidities for the transmission of shocks. We show that heterogeneous wage rigidities have a crucial role in the transmission of monetary policy through aggregate demand. These results, to the best of our knowledge, have not been reported in previous literature.

**Related Literature.** We follow closely the Two-Agent New Keynesian (TANK) literature. We consider the models by Bilbiie (2008) and Debortoli and Galí (2017), who analyze the consequences of assuming hand-to-mouth consumers for the transmission of monetary policy. Previous papers similar to ours are Broer et al. (2019), Ascari et al. (2017), Colciago (2011), and Furlanetto and Seneca (2012) who combine wage rigidities and limited asset markets participation to study how these features interact and affect the transmission of monetary and technology shocks. All these papers follow the earlier analysis in TANK models by Galí et al. (2007), who study the amplification of government spending shocks in the presence of a share of HtM agents. This paper also relates to the Heterogeneous-Agent New Keynesian (HANK) literature, which highlights the effect of inequality over the business cycle by assuming there is a full distribution of wealth, that they derive from idyosincratic uncertainty. There are several works that include Kaplan et al. (2018), Auclert et al. (2018), Luetticke (2019), and Cui and

Sterk (2018). We abstract from the distribution of assets and idyosincratic uncertainty by assuming fixed shares of HtM agents following the analysis made by Kaplan et al. (2014). Our contribution with respect of the previously mentioned studies is the recognition that there are different classes of workers with their own labor markets which have different dynamics to study how labor markets interact with incomplete access to financial markets.

A paper that is similar to ours is Patterson (2019) who finds a positive correlation between MPCs and labor income cyclicality in the U.S. However, we provide an explanation (different wage rigidities) and a theoretical mechanism that explains why different workers have different labor income cyclicalities (both unconditionally and conditional on a monetary policy shock) and study the implications for consumption of eliminating these differences. Also, our work is related to Dolado et al. (2019). These authors study to what extent capital-skill complementarities explain the different cyclicalities of labor income between skilled and unskilled workers. We build on this work in two respects: (i) we analyze how differences in access to financial markets affect consumption dynamics; and (ii) we show that the heterogeneity in wage rigidities itself generates the countercyclicality of the earnings gap, without assumming an additional mechanism, like capital-skill complementarities.[3]

We are also related to the literature on wage and labor income cyclicality. Taylor (2016) and Basu and House (2016), argue the existence wage rigidities in the U.S., stressing the possibility of heterogeneity in labor market outcomes between different groups of workers.[4] Our work extends Cairó and Cajner (2018) and Doniger (2019). The former shows that unskilled workers' unemployment is more volatile than for skilled workers and concludes that this is due to more volatile job finding rates of unskilled workers. The latter shows that skilled workers face more flexible wages than unskilled workers. This result is similar to ours but with different data and econometric approaches. We extend these results by studying the cyclicality of labor income inequality, because what matters for consumption is the total wage bill and not employment or wages separately. We argue that the heterogeneity in wage rigidities drives the cyclicality of the earnings gap and that it is important for aggregate fluctuations.

**Organization of the Paper.** The remaining of the paper is organized as follows: section 2 shows empirical evidence on the heterogeneity of labor income in the cycle and on how assets are distributed across skill groups. Section 3 show the effects of monetary policy on labor markets dynamics and the heterogeneity in wage Phillips curves by skill levels. Section 4 presents the model. Section 5 studies

[3]Adding capital-skill complemetarities generates a further effect on the rise of the earnings gap in response to a contractionary monetary policy shock.

[4]Le Bihan et al. (2012) and Barattieri et al. (2014) study wage rigidities by using microdata for France and the U.S., respectively. They find nominal wages are staggered while do not study possible heterogeneities between types of workers.

analytically how labor income inequality affects the aggregate demand and why labor income inequality fluctuates in our model. Section 6 studies the quantitative implications of the heterogeneity in wage rigidities. And finally, section 7 concludes.

## 2 Motivating Facts

In the present section, we provide evidence on the heterogeneity of labor markets and the distribution of assets of the different groups of workers. We first show that labor income inequality (the ratio of skilled to unskilled labor income) is countercyclical. And then, we show that skilled workers are richer and have broader access to financial markets than unskilled workers.

### 2.1 The Earnings Gap is Countercyclical

We first show that the labor earnings gap is countercyclical, which means that inequality falls in a boom and rises in a recession. We denote the earnings gap by $\eta_t$, which formally is given by the ratio of skilled to unskilled labor income

$$\eta_t = \frac{\text{Skilled labor income}}{\text{Unskilled labor income}}.$$

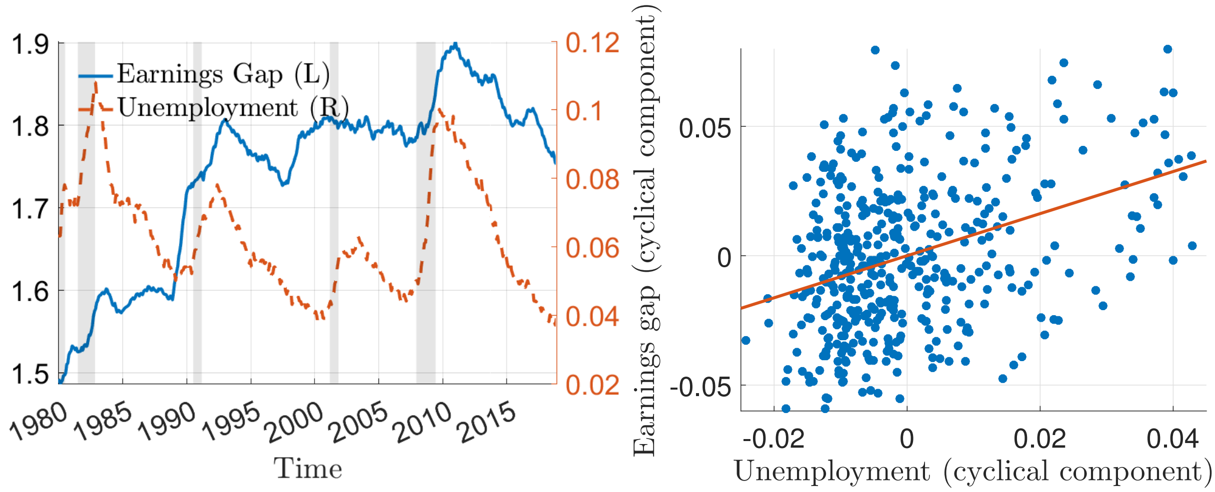
For this paper, we divide the population into these two groups, skilled and unskilled. We consider in the former group workers with a completed bachelor degree or higher while an uncompleted bachelor degree or less in the latter. We are interested in the inequality of total labor income because it is total income and not just wages or labor what determines consumption an it corresponds to the greatest part of total income in the US economy.

To build $\eta_t$, we take the *Current Population Survey* (CPS) that has individual earnings and demographic data. We consider the full sample, which is the period from 1979M1 to 2018M12. We use a uniformed version of the CPS built by the *Center of Economic and Policy Research* (CEPR).[5] The CEPR computes uniformed hourly wage and labor earnings for each period, which are comparable between panels. They also complete the sample by imputing weekly earnings from hourly wages and vice-versa if the respondent lacks one of the variables. We use the CEPR measure of total weekly labor earnings in what follows. Hence, we calculate labor income by group as its cross-sectional weighted average.

Figure 1 depicts the series of the earnings gap. On the left hand side, we plot the twelve-month moving average of the earnings gap together with unemployment. On the right hand side, we plot the

[5] See http://ceprdata.org/ for more information.

**Figure 1:** Labor earnings gap and unemployment.




*Notes: This figure shows the earnings gap in the business cycle. The left-hand panel depicts the level of the earnings gap (twelve-month moving average) compared with the unemployment rate. The gray vertical lines correspond to the NBER recessions. The right-hand panel shows the scatter of the relation between the cyclical component of the earnings gap and of the unemployment rate.*

cyclical component of the earnings gap against the cyclical component of unemployment.[6]

Left panel of Figure 1 shows some interesting facts. First, since the 2000's, the earnings gap is high, and around 1.8. Second, our earnings gap reflects the increase on labor income inequality between skilled and unskilled workers documented in previous studies. At the beginning of the 1980's the earnings gap was about 1.5; i.e, skilled workers earned 50% more than the unskilled. During the 1980's the gap increased substantially and rose to about 1.8, to stay around that level until the Great Recession.[7] Third, the earnings gap increases in recessions and falls in expansions. In all the recessions except for 2001 (which seems to be a very particular one), the earnings gap has increased significantly. There are also several periods in which the gap increases even in expansions like the period prior to 1990. However, in long periods of expansion, like 1992-1997 or from 2011 to 2018, the earnings gap fell, but the fall was less pronounced than that of the unemployment rate, suggesting that the earnings gap has even more persistence than the unemployment rate. Fourth, and related to the previous point, the earnings gap seems to behave assymetrically; i.e, the earnings gap increases sharply in recessions but seems to stay at high levels for a long period, often until the next recession takes place and pushes inequality further up.

[6] We use the Hamilton (2018) filter extract the trend component of both series.

[7] This is consistent with the evidence on the increase of the skill premium. In general the skill premium literature only looks at the widening of the wage gap. But as we are interested in what determines consumption, we study total labor income.

Right panel on Figure 1 shows the relation between the cyclical component of unemployment and the earnings gap. Hence, not only is the medium- to long-run relation between unemployment and the earnings gap positive but their cyclical components correlate positively as well. Therefore, labor income inequality increases in recessions and falls in booms. To confirm that this is the case, we run the following regression

$$\log(\eta_t) = c + \chi u_t + \sum_{m=1}^{12} \gamma_m \mathbb{I}_m + e_t, \tag{1}$$

where $\eta_t$ is the earnings gap, $u_t$ is unemployment that we use as an indicator of aggregate economic conditions, controlling for monthly dummies $\mathbb{I}_m$.

Table 1 shows the results from regressing of the earnings gap on unemployment for three different specifications: (i) we regress the cyclical component of unemployment on the cyclical component of the earnings gap computed using the Hamilton (2018) filter; (ii) the previous excercise but using the Hodrick-Prescott filter; and (iii) detrending the series with a linear and a quadratic trend as controls.

**Table 1:** The relation between the earnings gap and unemployment.

| | Dep. var: $\log(\eta_t)$ | | |
|---|---|---|---|
| | Cycle, Hamilton | Cycle, HP | Cycle, Qtrend |
| $u_t$ | 0.808*** | 1.028*** | 0.780*** |
| | (0.0985) | (0.344) | (0.121) |
| Adj. $R$-sq | 0.137 | 0.225 | 0.279 |
| $N$ | 445 | 480 | 480 |

Standard errors in parentheses

*p<0.10, ** p<0.05, *** p<0.01

*Notes: This table shows the regressions of Equation (1). We run three specification, depending on the treatment of the data. We show the data filtered with Hamilton (2018) filter, the HP-filter, and substracting a linear and a quadratic trend.*

Table 1 confirms the observations on Figure 1; i.e, there is a positive relation between the earnings gap and the unemployment rate. In all the specifications, a rise in unemployment implies a rise in the earnings gap, that is always statistically significant. The specification shown in the right panel of Figure 1 is the one represented in the first column of Table 1, which shows that the earnings gap increases by 0.8% after a 1 percentage point increase in the unemployment rate.

These figures are economically significant. For example, during the Great Recession unemployment rose by about five percentage points, which meant that the earnings gap increased by about 4%.[8]

The aim of this exercise is to understand what kind of model fits the data best. On the one hand, these results suggest that the labor income shares of different groups shift over time. This shift means that we must consider the economy as one in which the elasticity of substitution is different from one. Also, we must take into account that different groups of workers have their own labor market dynamics which account for a different jointly movement of hourly wages and hours.[9]

## 2.2 Skilled Workers are Richer and Have More Access to Financial Markets

Finally, we show that skilled workers own most of the assets in the U.S. economy and that unskilled workers are out of the financial markets in a higher proportion.

Table 2 shows the shares of zero assets individuals by skill level. We build these indicators based on Kaplan et al. (2014), using the *Survey of Consumer Finances* 2016. Kaplan et al. (2014) separate between liquid and illiquid assets. The former is composed of checking accounts, cash in hand and similar accounts, private and government bond holdings, minus revolving, and consumer credit. The latter is composed of net housing (housing value minus mortgage-backed debt), net private businesses, direct and indirect equity holdings, and durables. Like them, we consider as zero-asset holders, individuals that hold ≤US$1000 of net worth in absolute value (in 2004 US$). We adjust this threshold by inflating US$1000 to 2016 prices. Additionally, we report the share of debtors that each group has.

If we compare these figures with the ones reported by Kaplan et al. (2018), we can observe that they are very similar in the full sample. They show that on the SCF 2004, the share of hand-to-mouth (this is, individuals with zero liquid assets) is 0.28, while we find a slightly higher percentage of those individuals, 0.33. However, our estimates may be biased upwards since we do not conduct the imputation of cash they do.

[8] In Appendix A we run these estimations using the Survey of Income and Program Participation, which deliver similar results. We also consider there unemployment benefits and show that they do not affect the results significantly.

[9] In Appendix C we decompose the earnings gap into a wage and an hours gap to show that both components are countercyclical.

**Table 2:** Shares of Hand-to-Mouth and debtors by educational level.

| | Shares of zero assets | | Debtors |
|---|---|---|---|
| | Illiq | Liq | Liq |
| Full sample | .17 | .33 | .15 |
| $\leq$ Some College | .24 | .47 | .14 |
| $\geq$ College grad | .09 | .18 | .16 |

Source: SCF 2016.

*Notes: This table shows the shares of zero assets by educational level. We show the decomposition presented by Kaplan et al. (2014) by using the Survey of Consumer Finances 2016. We separate liquid from illiquid assets by educational attainment. Additionally, we show the share of debtors (in liquid assets) of each group.*

However, our focus is on the difference between skill levels. As Table 2 shows, the difference between skilled and unskilled individuals is considerable. 24% of unskilled individuals hold zero illiquid assets, with this figure rising to 47% for liquid assets. Those figures imply that almost half of the uneducated-high volatility of labor income people have no means of consumption smoothing in the short run. For skilled workers, these numbers fall considerably. Only 9% of educated individuals hold zero illiquid assets, while 18% hold zero liquid. The previous facts imply that unskilled people not only earn a lower labor income, but they have more limited access to financial markets than skilled workers. This result matters because there is a relationship between labor income responses and the marginal propensities to consume which generates an amplifying effect of monetary policy shocks.

## 3 Monetary policy and the Earnings Gap: an Empirical Assesment

In this section, we study the cyclicality of the earnings gap *conditional* on a shock. This allows us to answer two questions regarding the earnings gap. First, if the earnings gap continues to be countercyclical conditional on an identified shock. And second, explain why the earnings gap is countercyclical. For the former question we study the response of the earnings gap to an identified monetary policy shock, while for the latter we study the dynamic multiplier of wage inflation with respect to unemployment, which allows us to approximate the slope of the wage Phillips curve of each of the two skill levels. We do that exercise to get an approximation of the differences in wage rigidities between groups. For both exercises we estimate Bayesian Local Projection with instrumental variables following Miranda-Agrippino and Ricco (2017).

### 3.1 Monetary Policy Shocks Raise the Earnings Gap

Next, we show that a contractionary monetary policy shock increases the earnings gap. In this exercise, we are interested in the cyclicality of the earnings gap conditional on a monetary policy shock. We take a vector of monthly observed variables for the U.S., given by

$$X_t = \{IP_t, UNEM_t, \eta_t, C_t, P_t, PCOM_t, EBP_t; R_t\}, \tag{2}$$

where $IP_t$ is the log of industrial production index, $UNEM_t$ is unemployment, $\eta_t$ is the log of the earnings gap, $C_t$ is the log of consumption of nondurables, $P_t$ is the log of the price index, $PCOM_t$ is the log of a commodity price index, $EBP_t$ is the excess bond premium by Gilchrist and Zakrajšek (2012), and $R_t$ is the one-year Treasury Bond.[10]

We estimate the model following Miranda-Agrippino and Ricco (2017) (MAR), who use an informationally robust instrument for a monetary policy shock and compare the responses of different estimation methods.[11] They argue that the high-frequency shocks identified by Gertler and Karadi (2015) (GK) are biased, and show that these shocks are autocorrelated and depend on the central bank's private information. MAR point out that these biases can lead to "puzzling" responses, at least with Local Projections, as Stock and Watson (2018) and Ramey (2016) also stress. Then, the authors remove informational bias from the Fourth Federal Funds Futures (FF4) high-frequency surprise to obtain a valid instrument.[12] In the same way as the GK shocks, MAR shocks are computed for the periods from 1990M1 to 2012M12. We make the identification using this subsample while we use the whole sample to estimate the LPs and VARs.[13]

We compare three methods: (i) a Bayesian VAR (BVAR); (ii) a Local Projection (LP); and (iii) a Bayesian Local Projection (BLP). We follow their procedure because it accounts for the bias and estimation variance trade-off that VARs and LPs have. The Bayesian VAR produces more efficient

[10]We build the earnings gap as we exposed before. We obtain the data from the database presented by McCracken and Ng (2016). All variables are drawn from FRED. We consider INDPRO for Industrial Production, UNRATE for unemployment, PCND for consumption, CPIAUCSL for the price index, CRBPI for the index of commodity prices, and GS1 for the interest rate. We include the excess bond premium as a proxy of financial conditions and also because it has been used as a proxy of a demand shock.

[11]For more details on the procedure, see Appendix B.

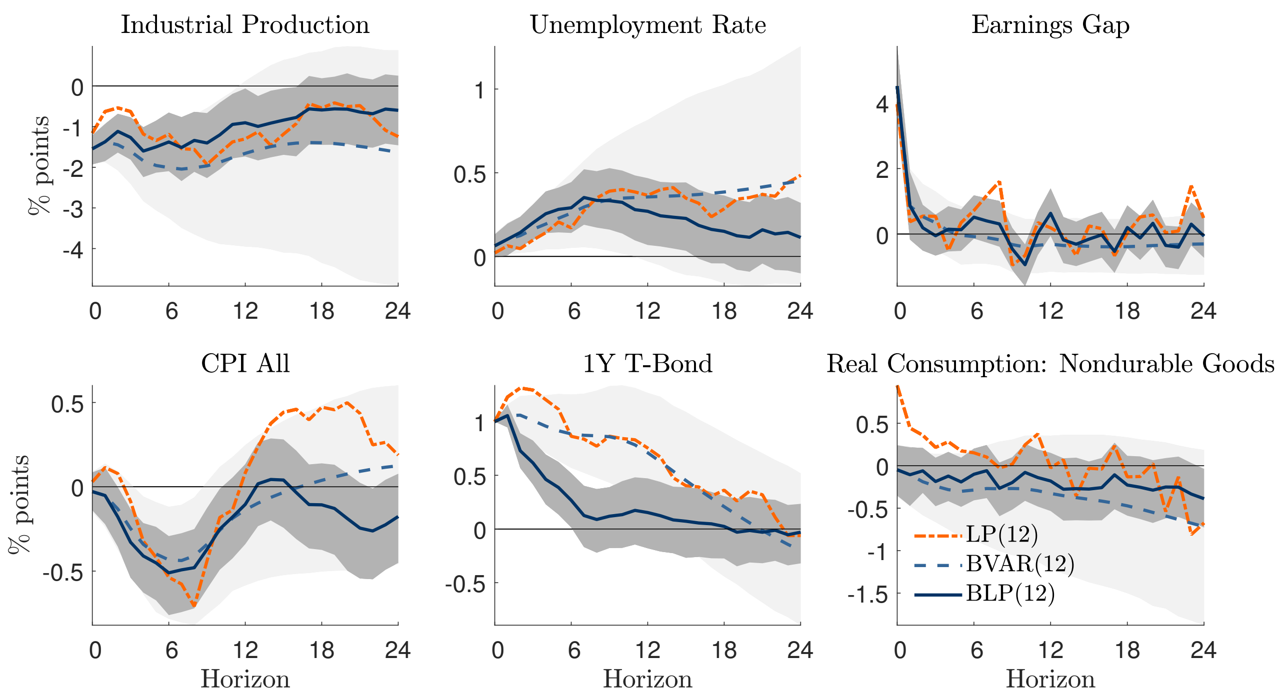
[12]They regress Greenbook forecasts and revision of the forecasts for several variables (GDP growth, inflation, and the unemployment rate) on the GK FF4 shocks. They obtain the informationally robust shock as the residual of that regression.

[13]Jarociński and Karadi (2020) also tackle this problem by decomposing the GK shock into expansionary and contractionary monetary policy shocks, to show that effectively, the high-frequency identification also includes the information that the central bank is releasing when the monetary policy is decided.

parameters than the simple VAR and LP, but it is more prone to bias if the model is misspecified. That is why VAR and LP, if they are misspecified, produce highly inaccurate estimates. According to MAR, these issues can be the reason for "puzzling" responses and lack of robustness.

We study the effect of a shock that produces a one-percent rise in the interest rate. The sample period is 1979M1-2014M12. As we explained before, we conduct three exercises, two of them using a Bayesian approach. We set as the training sample the first eight years of data and on all the estimations we consider twelve-month lagged specifications.

**Figure 2:** Impulse-responses to an identified monetary policy shock.




*Notes: This figure presents the responses of macroeconomic variables to an identified monetary policy shock for the variables in Equation (2). We depict three alternative estimates, a Local Projection (short orange dashes), a Bayesian VAR (longl light blue dashes), and a Bayesian Local Projection (solid blue). We report confidence bands at the 90% significance for both BVAR (light gray) and BLP (dark gray).*

Figure 2 shows the responses of IP, unemployment, the earnings gap, CPI, the interest rate, and consumption to a contractionary monetary policy shock for the three methods: (i) Local Projection (short orange dashes); (ii) Bayesian VAR (long light blue dashes); and (iii) Bayesian Local Projection (solid blue). We report the 90% confidence bands for the BVAR (light gray) and for the BLP (gray). The monetary policy identification is normalized such that the impulse is equivalent to a one-percent increase in the one-year Treasury Bond on impact.

The responses of the variables are similar for all the methods. Notice that the BLP helps to smooth out the responses of the Local Projection. Even though, in levels BLP is not an average of BVAR and

LP, the volatility of the IRF's are in between these two methods. Finally, and more importantly, the BLP estimation is successful in improving the efficiency of the estimators, by obtaining more precise estimates with respect to both LP and BVAR. (We do not show LP confidence bands as they go off the charts.)

From the responses of the variables we see neither product nor price puzzles. After a contractionary monetary policy shock, the industrial production index falls by about 1.5 percentage points and the CPI falls with a trough in the second quarter. Unemployment is also affected, increasing by about 0.4 percentage points at the peak. This result is important because we will take advantage of this demand shock in the preceding section.

We find that the earnings gap increases after the contractionary monetary policy shock. The earnings gap increases significantly by about 4% on impact. The effect in the first quarter is about 5% which is economically important. The effect is not very persistent and fades away three months after the shock. Finally, in our estimates, consumption does not fall significantly at least for the horizon we take into account.

These results suggest that monetary policy shocks generate labor income inequality between skilled and unskilled workers, and that the earnings gap is countercyclical after an identified monetary policy shock. In the next section, we study a reason why the earnings gap is countercyclical, and then we show, with the help of a model, why these inequalities matter for the business cycle.

### 3.2 The Wage Phillips Curve: Steeper for Skilled Workers

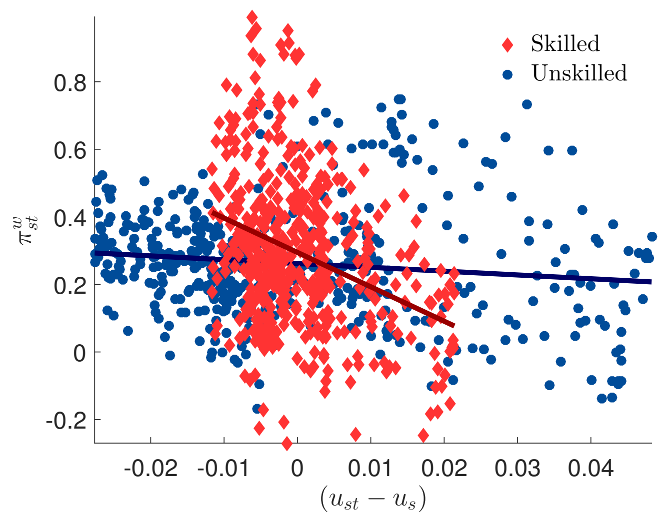
Now, we are interested in explaining why the earnings gap is countercyclical. One possible reason is that the slopes of the wage Phillips curves differ between skills. Let us define the wage Phillips curve of workers' group $s$ as

$$\pi_{wt}^{s} = -\kappa_s(u_t^s - u) + \beta \mathbb{E}_t \pi_{wt+1}^{s} \tag{3}$$

where $\kappa_s \geq 0$, $\pi_{wt}^{s}$ is wage inflation of group $s$, $u_t^s$ is group $s$ unemployment (with $u$ being the natural unemployment rate), and $\beta$ is a time discount factor. Equation (3) is the usual negative relation between wage inflation and unemployment as first proposed by Phillips (1958). This version, which is forward looking, is the one introduced by Galí (2011) who extends the approach by Erceg et al. (2000). This equation can be derived from microfoundations (monopolistic competition in the labor market and nominal wage rigidities) as we explain in the next section. Then, the focus of the following exercise is on finding differences in the $\kappa_s$'s for the different groups of workers.

Figure 3 shows a scatter for unemployment and wage inflation for both groups. The first to note is the significant difference on the intervals spanned by both groups. While the skilled workers have a more volatile wage inflation, the unskilled workers have a more volatile unemployment rate. Additionally, the relationship between wage inflation and unemployment differs significantly. The slope for skilled workers is about -0.1 while it is -0.01 for unskilled workers.

**Figure 3:** Wage inflation and unemployment by skill level.




*Notes: This figure shows the relation between wage inflation $\pi^w_{st}$ and unemployment $u_{st}$ for skilled and unskilled workers. We also show the linear fit for both groups of workers. The slopes of the fitted lines are -0.1 and -0.01 for skilled and unskilled, respectively. Both estimates are significant at the 95 percent level.*

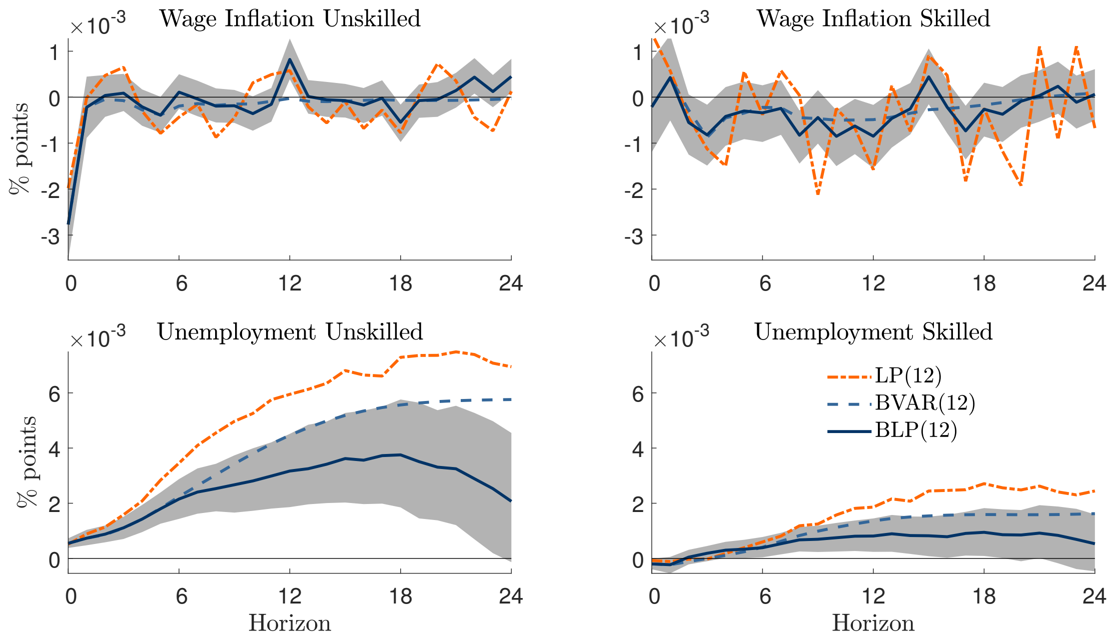
However, the evidence presented in Figure 3 is not conclusive as the OLS estimates of these wage Phillips curves have several shortcomings. First of all, the OLS estimation of Equation (3) does not constitute a structural relation, as it is an ad-hoc relationship. Second, for that reason, the OLS estimate has endogeneity bias as we are omitting variables that will likely correlate with the residual, like the natural unemployment rate. For these reasons, we must switch towards a more structural relationship, which we will obtain by estimating the slopes by taking advantage of the exogenous aggregate demand shock we presented above.

To estimate a proxy for $\kappa_s$ in a semi-structural way, we augment the IV-BLP estimation of the previous section with the series of unemployment and wage inflation rates for unskilled and skilled workers, but we exclude the earnings gap and consumption.[14] Then, to infer the slope of the wage Phillips curves, we compare the responses of wage inflation and unemployment with the identified demand shock in the spirit of Barnichon and Mesters (2019) and Barnichon and Mesters (2020). To do so, we follow Galí and Gambetti (2018) and Del Negro et al. (2020) who study the slopes of the

[14]We exclude the earnings gap because the unemployment rate and wages are collinear with the earnings gap.

Phillips curve by analyzing the relative response of wage inflation and unemployment to an identified demand shock.[15] Intuitively, the procedure takes advantage of the exogeneity of the shock, which in our case, as it is a monetary policy shock, represents a demand shifter. Therefore, the resulting relative response of wage inflation and unemployment is how the demand shifts along the wage Phillips curve, which gives us a proxy of its slope (the $\kappa_s$'s).

**Figure 4:** Response of wage inflation and unemployment to a monetary policy shock at the skill level.




*Notes: This figure presents the responses of labor market variables at the skill level to an identified monetary policy shock where we augmented the VAR on 2 with wage inflation and unemployment intead of including the earnings gap. We depict three alternative estimates, a Local Projection (short orange dashes), a Bayesian VAR (long light blue dashes), and a Bayesian Local Projection (solid blue). We report confidence bands at the 90% significance for both BVAR (light gray) and BLP (dark gray).*

Figure 4 shows the responses of wage inflation and unemployment for the two skill groups in response to an identified contractionary monetary policy shock. The response of wage inflation differs for both groups. For unskilled workers wage inflation responds negatively on impact, with the effects disappearing almost immediately. Wage inflation for skilled workers takes about three months to respond, with the effect remaining negative up to 12 periods. On the other hand, unemployment for unskilled workers goes up immediately and is much higher than for skilled workers. The peak of unemployment for unskilled workers is about four times that of the skilled workers.

To study to what extent the underlying wage Phillips curves are different, we compute the Dynamic

[15]See additionally, Gilchrist and Zakrajsek (2018) who study the slope of the Phillips curve at a sectoral level.

Multipliers, as defined in Galí and Gambetti (2018)

$$\Phi_w(h) = \frac{\sum_{k=0}^{h} \frac{\partial \pi_{wt+k}}{\partial \varepsilon_t}}{\sum_{k=0}^{h} \partial \frac{u_{t+k}}{\partial \varepsilon_t}},$$

which is the relative response of wage inflation to the response of unemployment. The interpretation of this statistic is that if unemployment responds minimally and wage inflation responds substantially, the wage Phillips Curve is steep. Table 3 shows the dynamic multipliers at different horizons for the BLP and LP estimates.

**Table 3:** Dynamic Multipliers

| | BLP | | | | LP | | | |
|---|---|---|---|---|---|---|---|---|
| Horizon | Full | Unskilled | Skilled | S/U | Full | Unskilled | Skilled | S/U |
| 6 | -0.26 | -0.53 | -4.21 | 7.90 | -0.11 | -0.22 | -1.60 | 7.38 |
| 12 | -0.16 | -0.20 | -1.21 | 6.23 | -0.07 | -0.08 | -0.44 | 5.34 |
| 18 | -0.10 | -0.09 | -0.78 | 8.82 | -0.07 | -0.06 | -0.28 | 4.88 |
| 24 | -0.07 | -0.05 | -0.52 | 10.1 | -0.03 | -0.03 | -0.22 | 5.64 |

*Notes: This figure presents the empirical Dynamic multipliers estimated from augmenting 2 with unemployment and wage inflation at the skill level. The table reports the Dynamic Multipliers from the BLP and LP estimations at six, twelve, 18, and 24 month horizon. We also report the dynamic multiplier from aggregate wage inflation and unemployment and the ratio between the dynamic multipliers of skilled and unskilled.*

As Table 3 shows, the dynamic multiplier for skilled workers is much larger than for unskilled. That result means that for the same response of unemployment, the reaction of wages is larger for skilled workers than for unskilled. The differences are large, with the dynamic multiplier being about nine times larger for skilled than for unskilled.[16] The differences in the dynamic multipliers are significant at the 68% level for the 12- and 18-month horizon (see Appendix D for details on the test).[17]

**Discussion.** The results above point towards significant differences between the slopes of the skilled and unskilled wage Phillips curves implied by our BLP analysis. Before continuing the study of the impact of these features of the labor markets on the overall economy, we must emphasize that, unlike Barnichon and Mesters (2020), we abstract from the endogeneity and bias that arises from estimating

[16]These results are in line with the results stressed by Doniger (2019) in which the wages of unskilled are more rigid than those of skilled.

[17]Appendix E shows the projections implied by our estimates given the shocks. We show that, *conditional on a monetary policy shock* the slope of the Phillips curve of skilled workers is much steeper than the slope of unskilled workers. Moreover, the latter is completely flat in this case.

Phillips curves without taking into account expected inflation. As we are interested in studying the differences in the slope of the Phillips curves, we can abstract from the expectational term in Equation (3). Thus, if we assume that the discount factors are the same for both groups of workers, we can correctly estimate the differences in $\kappa_s$.[18]

Also, showing wages of the unskilled responding more strongly to the monetary policy shock may seem contradictory with finding that wages of the unskilled are more sticky. However, our concept of rigidity is not an unconditional variation in wage inflation but it is a *relative* concept. For us, a group of workers have more flexible wages if their wage inflation responds more strongly *given* the response of their unemployment. Therefore, even though the unskilled workers receive the shock in a stronger way (both their wage inflation and unemployment respond more strongly), this group of workers have more sticky wages. This argument differentiates us from Dolado et al. (2019) who show a similar analysis focusing on the stronger effect that aggregate shocks have on the labor market variables of the unskilled workers. In the theoretical analysis we show that heterogeneity in wage rigidities and gross substitution between skills in production is enough to generate a countercyclical earnings gap, without resorting to a device that make unskilled workers more exposed to shocks. It follows from this that capital-skill complementarities (or any mechanism which exposes unskilled workers more to a shock) further amplifies the response of the earnings gap and would work in our favor.

# 4 Model

Our model is a Two-Agent New Keynesian (TANK) model with wage rigidities as Furlanetto and Seneca (2012), following Bilbiie (2008). We extend these works by assuming there are two labor markets (for unskilled $u$ and skilled $s$), in which wages are set by a union that is also group-specific and is subject to nominal wage adjustment costs. A measure one households populates each skill group (which we denote by $h$). In each group, there is a share $\lambda_h$ of financially constrained agents, that can not save, borrow, or hold equity. There are two types of firms, a continuum of monopolistically competitive intermediate goods producers and a final goods producer that aggregates these intermediate goods through a CES production function. These intermediate firms demand all types of labor. We embed these features into a New Keynesian model with price rigidities and monetary policy. Time is discrete.

[18] We would like to estimate these equations by including expected wage inflation for each group but, unfortunately, we do not have access to expected wages at the individual level. A promising source is the *Survey of Consumer Expectations* released by the New York Fed, which contains these kinds of data; however, the series is still short.

### 4.1 Households

We assume there are two groups of workers. Each household belongs to a given class $h \in \{u, s\}$ with $\mu_h$ denoting the mass of the class, where $\mu_l + \mu_h = 1$. We assume that a share $\lambda_h$ of households in skill group $h$ have no access to financial markets (cannot borrow or lend and cannot own shares), while the remaining $(1 - \lambda_h)$ are unconstrained. We call the former group *constrained* and the latter *unconstrained*. We index with $i$ the access to financial markets; i.e., $i \in \{k, r\}$, with $r$ denoting unconstrained ($r$ for "Ricardian") and $k$ denoting constrained ($k$ for "Keynesian"). Hence, household features are given by a pair of indices $(i, h)$.

Households derive utility from consumption and disutility from labor. We assume there is a continuum of $j \in (0, 1)$ tasks each household $(i, s)$ can execute. Hence, household $(i, s)$ maximizes its lifetime utility, time-discounted at a factor $0 < \beta < 1$, given by

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \mathcal{U}\left(c^i_{ht}, \{n^{ij}_{ht}\}^1_{j=0}\right), \tag{4}$$

where $c^i_{ht}$ is consumption and $n^{ij}_{ht}$ is hours supplied by workers from household $(i, h)$ to the task $j$. In particular, following Galí (2011), we assume a separable utility function of the form

$$\mathcal{U}(c^i_{ht}\{n^{ij}_{ht}\}^1_{j=0}) = \frac{(c^i_{ht})^{1-\gamma}}{1-\gamma} - \chi \frac{\int_0^1 (n^{ij}_{ht})^{1+\varphi} dj}{1+\varphi},$$

where $\gamma$ is the inverse of the intertemporal elasticity of substitution, $\chi$ is the parameter of disutility of labor, and $\varphi$ is the inverse of the Frisch elasticity of the labor supply.

**The Problem of Unconstrained Households.** Unconstrained consumers can accumulate risk-free bonds and their borrowing constraint is given by

$$q_t b^r_{ht+1} = b^r_{ht} + \int_0^1 w^{rj}_{ht} n^{rj}_{ht} dj + D^r_{ht} - c^r_{ht}, \tag{5}$$

where $w^{rj}_{ht} = W^{rj}_{ht}/P_t$ is the real wage per unit of labor, $n^{rj}_{ht}$, where due to labor market frictions $n^{rj}_{ht}$ is taken as given by the household as we explain below; $q_t = Q_t/P_t$ is the price of real bonds (which in equilibrium is $q_t = 1/(1 + r_t)$ with $r_t$ the real return on bonds); and $D^r_{ht}$ are dividends delivered by firms. Hence, these workers maximize function (4) subject to constraint (5). The maximization problem of these households gives as a result the following Euler equation

$$1 = \beta(1 + r_t) E_t \left(\frac{c^r_{ht}}{c^r_{ht+1}}\right)^{-\gamma}. \tag{6}$$

**The Problem of Constrained Households.** Constrained households consume their flow of income every period. Hence, constrained consumption is given by

$$c_{ht}^{k} = \int_{0}^{1} w_{ht}^{kj} n_{ht}^{kj} dj, \tag{7}$$

where, as they are outside of the financial system, they receive only labor income.

The difference between constrained and unconstrained consumers is critical in our model because it implies different $\mathcal{MPC}$s out of total income among households, because it generates an aggregate demand effect from the earnings gap's fluctuations. From the permanent income hypothesis, we know that the $\mathcal{MPC}$ of unconstrained consumers is approximately $r/(1+r)$ (as in the permanent income hypothesis), while that of the constrained worker is equal to one, as Equation (7) shows. Those differences generate departing consumption dynamics between groups of workers as long as the shares of hand-to-mouth $\lambda_h$'s are distinct and labor income fluctuates differently. The group with higher $\lambda_h$ has a higher average $\mathcal{MPC}$; hence, their consumption responds much more to income shocks than the other groups. We exploit a similar argument as Bilbiie (2020) in which is the income cyclicality of the high-$\mathcal{MPC}$ consumer.

## 4.2 Distribution of Monopoly Profits

We assume the distribution of profits is according to the data. In particular, we set the distribution of profits to unconstrained consumers to be equal to a share of total profits in the economy. This share is denoted by $\vartheta_h$. We calibrate $\vartheta_h$ according to the *Survey of Consumer Finances 2016*. That survey shows that skilled workers own about 83% of the equity in the U.S. economy. Accordingly, we assume the dividends that are delivered to group $h$ unconstrained consumers are given by

$$D_t^h = \frac{\vartheta_h}{\mu_h(1-\lambda_h)} D_t. \tag{8}$$

## 4.3 Workers' Unions

Following Erceg et al. (2000), we assume that for each task-group $(j, h)$, there is a union that decides wages $w_{ht}^{j}$. In this setting, unions have market power as workers' tasks are in monopolistic competition. The union aggregates individual labor such that $n_{ht}^{j} = \lambda_h n_{ht}^{kj} + (1-\lambda_h) n_{ht}^{rj}$. Then, we assume there is a Dixit-Stiglitz aggregator that determines aggregate labor for each labor group $s$, given by

$$N_{ht} = \left( \int_0^1 \left( n_{ht}^{j} \right)^{\frac{\varepsilon_h - 1}{\varepsilon_h}} dj \right)^{\frac{\varepsilon_h}{\varepsilon_h - 1}},$$

where $\varepsilon_h$ is the elasticity of the demand for labor tasks in workers' group $h$, which is also a measure of the market power of the union. The Dixit-Stiglitz aggregator gives rise to the following demand for each task $(j, h)$:

$$n_{ht}^j = \left(\frac{w_{ht}^j}{w_{ht}}\right)^{-\varepsilon_h} N_{ht}. \tag{9}$$

We assume nominal wages are sticky and their changes are subject to the following Rotemberg adjustment costs that are measured in utility units:

$$\Gamma^h\left(\frac{W_{ht}^j}{W_{ht-1}^j} - 1\right) = \frac{\theta_h}{2}\left(\frac{W_{ht}^j}{W_{ht-1}^j} - 1\right)^2, \tag{10}$$

where $\theta_h$ is the nominal wage adjustment cost parameter, assumed to be skill-group specific. Then, the problem of the union is to choose the optimal labor, the nominal wage and the wage inflation rate by solving

$$\max_{n_{ht}^{ij}, W_{ht}^j, \pi_{wt}^{jh}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\lambda_h U\left(c_{ht}^k\right) + (1-\lambda_h) U\left(c_{ht}^r\right) - v\left(n_{ht}^{ij}\right) - \Gamma^s\left(\frac{W_{ht}^j}{W_{ht-1}^j} - 1\right)\right], \tag{11}$$

subject to Equation (9), and given that wage inflation is defined as $\pi_{wt}^{jh} = \frac{W_{ht}^j - W_{ht-1}^j}{W_{ht-1}^j}$. We denote with $U(c_{ht}^i) = \frac{(c_{ht}^i)^{1-\gamma}}{1-\gamma}$ and $v\left(n_{ht}^j\right) = \chi\frac{(n_{ht}^{ij})^{1+\varphi}}{1+\varphi}$. This maximization problem leads to[19]:

$$\left(\pi_{wt}^h + 1\right)\pi_{wt}^h = \frac{\varepsilon_h}{\theta_h} N_{ht}\left\{v'(N_{ht}) - \frac{\varepsilon_h - 1}{\varepsilon_h}\overline{mgu}_{ht} w_{ht}\right\} + \beta E_t\left(\pi_{wt+1}^h + 1\right)\pi_{wt+1}^h \tag{12}$$

where $\overline{mgu}_{ht} = \lambda_h U'(c_{ht}^k) + (1-\lambda_h)U'(c_{ht}^r)$ is the average marginal utility of consumption of group $h$. Equation (12) is the New Keynesian Wage Phillips Curve (NKWPC) for group $h$.

Equation (12) relates the nominal wage inflation with hours worked and the aggregate group $h$ worker's preferences; it is a version of the wage Phillips curve described by Erceg et al. (2000) adapted to heterogeneity and Rotemberg adjustment costs. Due to these labor market frictions, all workers in skill group $h$ supply $N_{ht}$ hours at a real wage $w_{ht}$. This equation allows us to calibrate the model to generate different dynamics for the two labor markets.

We can rewrite the NKWPC in a way that will be useful in the analysis below as

$$\left(\pi_{wt}^h + 1\right)\pi_{wt}^h = \kappa_{ht}\left(\frac{1}{\mathcal{M}_{wt}^h} - \frac{1}{\mathcal{M}_w^h}\right) + \beta E_t\left(\pi_{wt+1}^h + 1\right)\pi_{wt+1}^h. \tag{13}$$

where $\kappa_{ht} = \frac{\varepsilon_h}{\theta_h}\left(w_{ht} N_{ht}\overline{mgu}_{ht}\right) = \frac{\varepsilon_h}{\theta_h}\aleph_{ht}$ which depends on three terms: i) the elasticity of substitution between tasks $\varepsilon_h$ within group $h$; ii) the wage adjustment cost parameter $\theta_h$; and iii) $\aleph_{ht}$, which we

[19] See Appendix F for a detailed derivation.

call the *dynamic income effect*. The latter term, for our calibration, has little impact on the aggregate outcomes.

The wage markup $\mathcal{M}^h_{wt}$ is the ratio of the marginal rate of substitution to the real wage

$$\frac{1}{\mathcal{M}^h_{wt}} = \frac{v'(N_{ht})}{w_{ht}\overline{mgu}_{ht}}, \tag{14}$$

where the wage markup is equal to $\frac{\varepsilon_h}{\varepsilon_h - 1}$ in the steady state (also called the *desired* markup). Notice that the more rigid wages are, the stronger the fluctuations on the wage markups, as can be seen in Equation (13). That implies that for two groups $h$ and $h'$, if $\kappa_{h't} > \kappa_{ht}$ wage markups of group $h$ are more volatile than those of group $h'$.

Finally, as Galí (2011) shows, Equation (13) can be written as the relation between wage inflation and unemployment. Let us define unemployment as the deviation of hours worked $N_{ht}$ and labor market participation $L_{ht}$. We define labor market participation as the hours that the worker is willing to provide at the current labor market conditions (at the prevailing wage), in the absence of labor market frictions. Labor market participation is, then, determined by[20]

$$w_{ht} = \frac{v'(L_{ht})}{\overline{mgu}_{ht}}. \tag{15}$$

By combining Equation (15) with Equation (14) and using $v'(N) = \chi N^{\varphi}$, we find a mapping between markups and unemployment, with the latter defined as $U_{ht} = \frac{L_{ht}}{N_{ht}}$

$$\mathcal{M}^h_{wt} = \left(\frac{L_{ht}}{N_{ht}}\right)^{\varphi} = U^{\varphi}_{ht}.$$

Then, Equation (13) can be written as

$$\left(\pi^h_{wt} + 1\right)\pi^h_{wt} = \kappa_{ht}\left(\frac{1}{U^{h\varphi}_t} - \frac{1}{U^{\varphi}}\right) + \beta E_t\left(\pi^h_{wt+1} + 1\right)\pi^h_{wt+1}, \tag{16}$$

which writes the NKWPC as the relation between wage inflation and unemployment like Equation (3).

## 4.4 Firms

**Final Goods Producers.** A competitive representative firm produces a final good by aggregating a continuum of intermediate inputs with the following production function

$$Y_t = \left(\int_0^1 y_{ft}^{\frac{\varepsilon-1}{\varepsilon}} df\right)^{\frac{\varepsilon}{\varepsilon-1}}.$$

[20]See Galí (2015) Ch. 7 for a detailed explanation.

This composite is an aggregate of a continuum of intermediate goods with measure one. In this setting, the final firm decides how to allocate its demand among the different intermediate goods. After cost minimization, the demand for each intermediate good $f$, and the aggregate price index writes

$$y_{ft} = \left(\frac{p_{ft}}{P_t}\right)^{-\varepsilon} Y_t, \quad \text{and} \quad P_t = \left(\int_0^1 p_{ft}^{1-\varepsilon} df\right)^{\frac{1}{1-\varepsilon}}. \tag{17}$$

**Intermediate Goods Producers: Labor Demand.** Each intermediate good $f$ is produced by a monopolistically competitive producer using labor $n_{fst}$ of both skill groups according to the production function

$$y_{ft} = \left[\omega_u n_{fut}^{\frac{\sigma-1}{\sigma}} + \omega_s n_{fst}^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}},$$

which is a CES aggregator of the skill groups. Skill groups are imperfect substitutes of each other. The elasticity of substitution between skill groups is given by $\sigma$. If $\sigma > 1$ skill groups are gross substitutes while if $\sigma < 1$ they are gross complements. As explained before, the value of $\omega_h$ represents the labor income share of the group of workers $h$. Each intermediate producer hires workers from each skill group $h$ at a real wage $w_{ht}$. Therefore, the demand for each class $h$ is

$$w_{ht} = \frac{1}{\mathcal{M}_t^p} \frac{\omega_h}{\mu_h} \left(\frac{Y_t}{N_{ht}}\right)^{\frac{1}{\sigma}},$$

which corresponds to the real wage in per-capita terms. Then, $N_{ht}$ is the class $h$ aggregate hours worked.[21] This way of expressing the problem of the firm, and then obtaining a per-capita wage is useful for two reasons. First, it allows us to close the model properly; and second, it allows us to split the income share received by each type of worker (given by $\omega_h$) with the size of the group (given by $\mu_h$) which may be different. These two parameters allow us to calibrate the earnings gap in steady state.

The index of aggregate wages is

$$w_t = \left[\omega_u w_{ut}^{1-\sigma} + \omega_s w_{st}^{1-\sigma}\right]^{\frac{1}{1-\sigma}}.$$

Due to intermediate firms' market power, there are profits in this economy. These profits are determined by a wedge $\frac{1}{\mathcal{M}_t^p}$ which is the total marginal cost consistent with equilibrium, or analogously, the inverse of the firms' price mark-up $\mathcal{M}_t^p$.

[21] These optimality conditions arise from minimizing:

$$\max_{n_{fut}, n_{fst}} \mu_u w_{ut} n_{fut} + \mu_h w_{ht} n_{fst} - \frac{1}{\mathcal{M}_t^p}\left(\left[\omega_u n_{fut}^{\frac{\sigma-1}{\sigma}} + \omega_s n_{fst}^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} - y_{ft}\right),$$

where $\frac{1}{\mathcal{M}_t^p}$ corresponds to the real marginal cost in equilibrium, which is equivalent to the Lagrange multiplier of the cost minimization problem.

**Intermediate Goods Producers: Price Setting.** The intermediate producer chooses its price to maximize profits subject to Rotemberg (1982) price adjustment costs, denoted by $\Theta_t$. These costs are quadratic on inflation and expressed as a function of produced output $Y_t$. This is $\Theta_t\left(\frac{p_t}{p_{t-1}}-1\right) = \frac{\theta}{2}\left(\frac{p_t}{p_{t-1}}-1\right)^2 Y_t$, where $\theta$ is the parameter that drives the degree of price rigidity.

Therefore, each intermediate producer chooses $\{p_t\}_{t\geq 0}$ to maximize

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{c^r_{t+1}}{c^r_t}\right)^{\sigma} \left\{\Pi_t(p_t) - \Theta_t\left(\frac{p_t}{p_{t-1}}-1\right)\right\}$$

$$\text{with } \Pi_t(p_t) = \left(\frac{p_t}{P_t} - \frac{1}{\mathcal{M}^p_t}\right)\left(\frac{p_t}{P_t}\right)^{-\varepsilon} Y_t,$$

where $\beta\left(\frac{c^r_{t+1}}{c^r_t}\right)^{\gamma}$ is the stochastic discount factor that corresponds to the pool of unconstrained agents. Given the assumptions above, the inflation rate (after the intermediate firms optimization) is determined by the following New Keynesian Phillips curve:

$$(\pi_t+1)\pi_t = \frac{\varepsilon}{\theta}\left(\frac{1}{\mathcal{M}^p_t} - \frac{1}{\mathcal{M}^p}\right) + \beta\left(\frac{c^r_{t+1}}{c^r_t}\right)^{\gamma}(\pi_{t+1}+1)\pi_{t+1}.$$

Finally, intermediate firms generate an aggregate amount of profits in each period given by

$$D_t = \left(1 - \frac{1}{\mathcal{M}^p_t}\right)Y_t - \frac{\theta}{2}\pi_t^2 Y_t.$$

## 4.5 Monetary Authority

In the presence of nominal rigidities, the real interest rate $r_t$ is determined by monetary policy, which sets the nominal interest rate $i_t$ according to a Taylor rule

$$i_t = i^* + \phi_\pi(\pi_t - \overline{\pi}) + \phi_y \log(Y_t/Y^*) + \varepsilon^{mp}_t.$$

We denote by $\phi_\pi$ and $\phi_y$ the preference parameters for inflation and the output gap, respectively. $\varepsilon^{mp}_t$ is a monetary policy shock that follows an AR(1) process given by:

$$\log(\varepsilon^{mp}_t) = \rho_{mp}\varepsilon^{mp}_{t-1} + u^{mp}_t$$

Monetary authorities seek a nominal interest rate target in steady state given by $i^*$ (where $i^* = r + \overline{\pi}$). Given the inflation level and the nominal interest rate, the real rate is determined by the Fisher equation $r_t = i_t - E_t\pi_{t+1}$.

### 4.6 Equilibrium

An equilibrium in this economy is given by paths of individual variables for households' decisions $\{b_{ht}^i, c_{ht}^i\}_{t\geq 0}$ $\forall$ $(i,h)$; labor market prices and quantities $\left\{\{N_{ht}, w_{ht}, \pi_{wt}^h\}_{h=1}^{\in}\right\}_{t\geq 0}$; prices and returns $\{\pi_t, r_t, i_t\}_{t\geq 0}$, and aggregate quantities such that: (i) households maximize their objective functions taking as given both prices and aggregate quantities; and (ii) all markets clear. In our economy, we have four markets: the goods market, the market for bonds, and two labor markets.

Consumption of a given group $h$ is given by:

$$c_{ht} = \lambda_h c_{ht}^c + (1-\lambda_h) c_{ht}^u,$$

Hence, aggregate consumption writes

$$C_t = \mu_u c_{ut} + \mu_s c_{st}.$$

Finally, goods market clearing holds

$$Y_t = C_t + \Theta_t.$$

where $\Theta_t$ are the price adjustment costs.

## 5 Analytical results

In this section, we obtain two analytical results that guide us in understanding the role of labor income inequality in the business cycle. First, we show how the earnings gap affects the business cycle through an aggregate demand effect. In particular, we study how, due to market incompleteness, the earnings gap influences consumption behavior represented by the aggregate Euler equation. We illustrate that if the earnings gap is countercyclical, monetary policy shocks are amplified through this aggregate demand channel. Second, we show that in the model presented above, the only reason the earnings gap fluctuates is the difference in labor markets between the skill groups. The earnings gap is countercyclical if worker groups are gross substitutes, and wages of the unskilled workers are relatively more sticky than those of the skilled workers.

To study the effect of the earnings gap in a simple way, we make the following assumptions (which we relax in the full model later): (i) the share of hand-to-mouth workers in the unskilled group is equal to one and the share of hand-to-mouth in the skilled group is zero; and (ii), there are no price rigidities nor market power on intermediate goods. This latter assumption allows us to isolate labor income as the only source of inequality since there are no profits to distribute unequally in that setup, while we maintain the aggregate demand activated with the wage rigidities.

### 5.1 Aggregate Demand and the Earnings Gap

We first solve for the IS equation in this economy. As Debortoli and Galí (2017) show, when there is limited access to financial markets, the IS equation (or the aggregate demand) depends on the inequality wedges. Recall $C_t = \mu_u c_{ut} + \mu_s c_{st}$, where each group's consumption is given by $c_{ht} = \lambda_h c^k_{ht} + (1-\lambda_h) c^r_{ht}$. Then, as under assumption (i), $\lambda_u = 1$ and $\lambda_s = 0$, consumption of unskilled workers is $c_{ut} = c^k_{ut}$ and that of skilled workers is $c_{st} = c^r_{st}$. Hence, aggregate consumption writes $C_t = \mu_u c^k_{ut} + \mu_s C^r_{st}$. Notice that in this example the aggregate share of hand-to-mouth is given by $\mu_u$ (and $\mu_s = 1 - \mu_u$).

Next we introduce the *consumption gap*, which is the percentage difference between the skilled and unskilled workers' consumption, as $\nu_t = 1 - \frac{c_{ut}}{c_{st}}$. According to our simplifying assumptions, unskilled and skilled workers' consumption is given by their labor income (as there is no other source of income); this is, $c_{ut} = n_{ut} N_{ut}$ for unskilled workers and $c_{st} = w_{st} N_{st}$ skilled workers. Therefore, the consumption gap is given by

$$\nu_t = 1 - \frac{w_{ut} N_{ut}}{w_{st} N_{st}} = 1 - \frac{1}{\eta_t}. \tag{18}$$

Equation (18) shows that in this setup, the consumption gap depends only on the earnings gap, $\eta_t$. Then, we obtain an expression for the aggregate demand in this economy. Recall that the only agent who can save or borrow is the skilled worker. Hence, there is only one Euler equation, given by

$$\hat{c}_{st} = E_t\{\hat{c}_{st+1}\} - \frac{1}{\gamma}(r_t - \rho),$$

which is the loglinear approximation of Equation (6). Rewriting aggregate consumption as $C_t = c_{st}(1 - \mu_l \nu_t)$, it can be written, in log differences with respect to the steady state, as $\hat{c}_t = \hat{c}_{st} + \hat{h}_t$, with $\hat{h}_t = -\frac{\mu_u}{1-\nu\mu_u}\hat{\nu}_t$ being an inequality index. Thus, the aggregate Euler equation is given by

$$\hat{c}_t - \hat{h}_t = E_t\{\hat{c}_{t+1} - \hat{h}_{t+1}\} - \frac{1}{\gamma}(r_t - \rho). \tag{19}$$

Replacing the consumption gap in the inequality index $\hat{h}_t$ ($\hat{\nu}_t = \hat{\eta}_t$) we have

$$\hat{h}_t = -\frac{\mu_u}{1 - \nu\mu_u}\hat{\eta}_t.$$

Finally, we substitute the inequality index $\hat{h}_t$ in Equation (19), and assuming goods market clearing ($\hat{y}_t = \hat{c}_t$), the IS equation becomes

$$\hat{y}_t = E_t\{\hat{y}_{t+1}\} - \frac{1}{\gamma}(r_t - \rho) + \frac{\mu_l}{1 - \nu\mu_l} E_t\{\Delta\hat{\eta}_{t+1}\}. \tag{20}$$

Equation (20) is the dynamic IS equation of an economy with incomplete markets and inequality in labor markets. As we mentioned before, as a consequence of incomplete markets, the Euler equation depends on any form of inequality between the constrained and the unconstrained consumers. In this case, output depends on $\hat{\eta}_t$ and on how it fluctuates over the business cycle. This relation appears because, as inequality switches, the economy distributes resources between agents. If inequality falls ($\hat{\eta}_t$ goes down), the economy relatively distributes resources from skilled (and unconstrained) to unskilled (and constrained) agents or from low- to high-$\mathcal{MPC}$ agents.

Hence, solving Equation (20) forward, we can show that

$$\hat{y}_t = -\frac{1}{\gamma}\mathbb{E}_t \sum_{s=0}^{\infty} \hat{r}_{t+s} - \frac{\mu_l}{1-\nu\mu_l}\hat{\eta}_t, \tag{21}$$

Equation (21) is the expression for the output gap in our economy. As is common in New Keynesian models, the output gap depends on the path of future interest rates (or its deviations from its steady state level $\rho$). Additionally, in our model, the output gap depends on the contemporaneous deviation of the earnings gap. Whether fluctuations in the earnings gap are amplifying or not depends on the earnings gap's cyclicality. If inequality is countercyclical; i.e., if inequality falls in booms ($\hat{\eta}_t < 0$ as $\hat{y}_t > 0$), incomplete markets amplify monetary policy shocks more strongly. Whereas, if $\eta_t$ is procyclical, labor income inequality stabilizes output fluctuations. Therefore, it is not only inequality in financial access that has an amplifying effect on the economy, but also the unequal fluctuations in labor earnings.

The amplification effect arises from the fact that in a recession, if the earnings gap goes up, the workers with higher MPC suffer a larger proportional drop in their labor earnings. That implies that aggregate consumption responds more strongly.

## 5.2 The Cyclicality of the Earnings Gap

In this section, we show that the countercyclicality of the earnings gap holds for reasonable assumptions consistent with the empirical evidence presented above. To do so, we solve the labor market equilibrium with the assumptions we imposed at the beginning of this section.

To get a closed form expression for the earnings gap we first solve, for a generic group $s$, its labor income $w_{ht}N_{ht}$ by equalizing labor supply and demand

$$\mathcal{M}_{ht}N_{ht}^{\varphi}C_{ht}^{\gamma} = w_{ht} = \frac{\omega_h}{\mu_h}\left(\frac{Y_t}{N_{ht}}\right)^{\frac{1}{\sigma}},$$

which implies that labor income is given by

$$w_{ht}N_{ht} = \mathcal{M}_{ht}^{\frac{1-\sigma}{1+\varphi\sigma}} C_{ht}^{\gamma\frac{1-\sigma}{1+\varphi\sigma}} Y_t^{\frac{1}{\sigma}\frac{(\sigma-1+1+\sigma\varphi)}{1+\varphi\sigma}} \left(\frac{\omega_h}{\mu_h}\right)^{\frac{(\sigma-1+1+\sigma\varphi)}{1+\varphi\sigma}}. \tag{22}$$

Equation (22) is the labor income of workers in group $h$. The first point to notice is that labor income fluctuates with output. That relation depends on the elasticity of substitution between skill groups. With perfect substitutability ($\sigma = 1$), the labor income share $\left(\frac{w_{ht}N_{ht}}{Y_t}\right)$ is equal to $\frac{\omega_h}{\mu_h}$ in our specification, hence the labor income ratio is constant for every group. When that happens, all groups get a fixed labor income share, and hence, there is no effect of labor heterogeneity on the aggregate demand as labor income inequality does not fluctuate. That is the case, for instance, of Cobb-Douglas technology.

Without perfect substitutability, labor income depends on: consumption (through the income effect); the share of income earned per-capita ($\omega_h/\mu_h$); the group's wage markup; and aggregate output. As we are interested in the impact of wage rigidities, let us study the relationship between the labor income of group $h$ and its wage markup. This relationship depends crucially on the value of $\sigma$, the elasticity of substitution between skills in production. With gross substitutability ($\sigma > 1$), the relationship between the wage markup and labor income is negative. The intuition is the following: as markups of a group $h$ go up, the labor supply schedule shifts upward, generating higher wages for a given level of hours supplied. This positive effect on labor income is counteracted by the impact on hours demanded by firms. When the markup of a group $h$ goes up, its labor gets more expensive, thereby lowering the demand for labor. With gross substitution the fall in demand is amplified as firms substitute workers of the group $h$ with workers of other groups that have become relatively cheaper. That generates a disproportionate fall in hours worked by group $h$.[22] In this context, what dominates labor income is the effect of hours, which implies that group $h$ labor income falls when its markup goes up. That means that markups are a crucial source of labor income fluctuations in this economy. Hence, if markups fluctuate differently for the different groups of workers there are distributional effects from aggregate fluctuations.

Next, using Equation (22) we compute the earnings gap by dividing the skilled labor income by the unskilled labor income. The log-deviation with respect to the steady state of the labor earnings gap can be written as

$$\hat{\eta}_t = \underbrace{\hat{\eta}_t^{\mathcal{M}}}_{\text{labor}} + \underbrace{\hat{\eta}_t^{C}}_{\text{financial}} , \tag{23}$$

which depends on two components, *labor market heterogeneity*, $\hat{\eta}_t^{\mathcal{M}} = \frac{1-\sigma}{1+\varphi\sigma}\left(\hat{\mathcal{M}}_{st} - \hat{\mathcal{M}}_{ut}\right)$, and *financial access heterogeneity*, $\hat{\eta}_t^{C} = \gamma\frac{1-\sigma}{1+\varphi\sigma}\left(\hat{c}_{st} - \hat{c}_{ut}\right)$. Equation (23) does not depend on heterogeneity in $\omega_h/\mu_h$ as we assume they are constant.

Two points worth mentioning about Equation (23). First, that the labor earnings gap depends

[22] In other words, the labor demand is more elastic the higher is $\sigma$.

on labor markets heterogeneity $\hat{\eta}_t^{\mathcal{M}}$ as these different workers belong to different labor market that obey their dynamics. This labor market heterogeneity component may arise from diverse labor market frictions, which, in our case, arise from heterogeneous wage rigidities. However, $\hat{\eta}_t^{\mathcal{M}}$ is not specific to our setup. Furthermore, any model that generates a labor supply where wages are not equal to the marginal rate of substitution, fits the relationship shown by Equation (23). For instance, a *search and matching* model would do it as well.

Second, as the labor supply in our model depends on income effects (through the effect of consumption on the labor supply), the labor earnings gap depends on the differential responses of consumption between the different groups of workers, given by $\hat{\eta}_t^C$. This last term depends on financial frictions. Different responses of consumption appear in the presence of different financial frictions. For example, in a model with a Representative Agent, consumption of all workers moves identically, and hence $\hat{\eta}_t^C = 0$. But since there are hand-to-mouth agents within each group and the shares of hand-to-mouth between the different workers differ in our model, the term *financial access heterogeneity* is different from zero as in that case, the consumption response of workers' groups are different.

According to our simplifying assumptions, $\eta_t^C$ depends only on the earnings gap. Then, we can solve the earnings gap simply as a function of labor markets heterogeneity. As $\eta_t = \frac{c_t^s}{c_t^u}$, then the earnings gap is given by

$$\hat{\eta}_t = \frac{1}{1-\chi}\hat{\eta}_t^{\mathcal{M}}, \tag{24}$$

where $\chi = \gamma\frac{1-\sigma}{1+\varphi\sigma}$.

Thus, the only reason why the earnings gap fluctuates in this setting is the difference in labor markets. Additionally, we can obtain the cyclicality of the earnings gap. Let $\frac{\partial \hat{\mathcal{M}}_{ht}}{\partial \hat{y}_t}$ denote the cyclicality of group $h$ wage markup, which we consider a proxy for the degree of wage rigidity faced by the group. Recall that in our model (from Equation 12) when wages of a group $h$ are more rigid, $\mathcal{M}_{ht}$ fluctuates more strongly. Then, the cyclicality of the earnings gap is given by

$$\frac{\partial \hat{\eta}_t}{\partial \hat{y}_t} = \frac{1-\sigma}{1-\gamma+(\gamma+\varphi)\sigma}\left(\frac{\partial \hat{\mathcal{M}}_{st}}{\partial \hat{y}_t} - \frac{\partial \hat{\mathcal{M}}_{ut}}{\partial \hat{y}_t}\right). \tag{25}$$

Equation (25) shows that two terms drive the cyclicality of the earnings gap. On the one hand, the earnings gap depends on a term in which the key parameter is the elasticity of substitution between skills on production. The first requirement to generate a countercyclical $\hat{\eta}_t$ is this elasticity being greater than one; i.e., $\sigma > 1$ (the skill groups are gross substitutes). If skill groups are gross substitutes, then $\frac{1-\sigma}{1-\gamma+(\gamma+\varphi)\sigma} < 0$. On the other hand, the earnings gap's cyclicality depends on endogenous variables related to differences in labor markets. This second term depends on the differential response of labor market markups in our model with heterogeneity in wage rigidities. Recall that these markups are countercyclical, this is $\frac{\partial \hat{\mathcal{M}}_{ht}}{\partial \hat{y}_t} < 0$ for $h = u, s$. Hence, to generate a countercyclical earnings gap we require that $\left|\frac{\partial \hat{\mathcal{M}}_{st}}{\partial \hat{y}_t}\right| < \left|\frac{\partial \hat{\mathcal{M}}_{ut}}{\partial \hat{y}_t}\right|$. That case occurs when unskilled worker wages are more sticky than those of the skilled workers. Under these two conditions, the earnings gap is countercyclical.

The intuition of this result is as follows. In response to a contractionary monetary policy shock, all wages should fall. If the wages of the unskilled workers are more sticky, the unskilled workers become more expensive relative to skilled workers. With gross substitution, there is a shift in demand from unskilled to skilled workers. Then, for these reasons, the labor income of the unskilled falls by more than the labor income of the skilled, thereby increasing the earnings gap.

These two requirements are supported by the evidence presented above, as well as by previous literature. On the one hand, many studies estimate the elasticity of substitution between skilled and unskilled workers. In particular, Ciccone and Peri (2005) show that for many specifications and instrumenting by demand and supply factors, the elasticity of substitution between skilled and unskilled workers is about 1.5. They compare their estimates with other estimates in the literature, which range between 1.3 and 2. Also, Acemoglu (2002) studies the elasticity of substitution between skills in the context of Directed Technical Change. He obtains an elasticity of substitution between skilled and unskilled of about 1.4.

On the other hand, Section 3 above shows that in the data, the wage Phillips curve is steeper for skilled workers. That is consistent with skilled workers having less responsive markups in absolute values as Equation (13) describes, which implies that the second requirement also holds in the data. Next, we study to what extent these facts generate the comovement of the earnings gap and output in the full-blown calibrated model and we study the quantitative impact of these facts.

## 6 Quantitative Analysis

In this section, we show quantitative results for the calibrated model. We do two experiments. First, we show the effects of the heterogeneity in wage rigidities without profits, in which the only inequality between workers is the different adjustment of wages in the cycle. Second, we show the results for the full model, with profits. We start by describing the calibration.

### 6.1 Calibration

**Household Problem Parameters.** We set the inverse of the intertemporal elasticity of substitution $\gamma$, the inverse of the Frisch elasticity of labor supply $1/\varphi$, and the disutility of labor $\chi$, equal to one. The discount factor $\beta$ is set such that the interest rate is one-percent quarterly. We assume that there are two groups of workers, unskilled and skilled, denoted by $u$ and $s$, respectively. We set the shares of the groups to be $\mu_u = 0.65$ and $\mu_s = 0.35$ according to the average 2000-2018 obtained from CPS. The shares of hand-to-mouth in each group are set according to Table 2; i.e., $\lambda_u = 0.47$ and $\lambda_s = 0.18$. Additionally, we observe that skilled workers hold 83% of the total equity in the economy, so we set $\vartheta_u = 0.17$ and $\vartheta_s = 0.83$.

**Production and Nominal Rigidities.** We set the elasticity of substitution between varieties $\varepsilon$ at 10, implying a share of profits equal to 10% of GDP in steady state. We set the cost of adjusting prices at $\theta = 100$, which implies a slope of the Phillips curve as in a model with sticky prices a la Calvo with an average price duration of one-year. We assume the elasticity of substitution between skills to be $\sigma = 1.5$, a value consistent with the literature on skill complementarity (see Ciccone and Peri (2005) or Acemoglu (2002)). We set $\omega_u = \omega_s = 0.5$, which implies that both workers' groups receive half of the total labor income (which is consistent with CPS estimates). This calibration, in addition to the $\mu_h$'s generate a an earnings gap equal to 1.85 in steady state, which is in consistent with what we show in Figure 1. Finally, we set $\varepsilon_h$ uniformly for both workers at 10.

**Government and monetary policy.** Monetary policy follows a Taylor rule with $\phi_y = 0$, $\phi_\pi = 1.15$ in the baseline calibration. We set that low parameter to avoid unintended effects from the response of monetary policy to consumption behavior. The persistence parameter of the exogenous monetary policy shock is set to $\rho_{mp} = 0.75$, while we scale the size of the shock $\sigma_{mp}$ to generate a one-percent increase in the real interest rate in all the exercises below.

**Wage rigidities.** Finally, we set the wage adjustment cost parameters to match the empirical ratio of the dynamic multipliers. We calibrate these parameters separately in our two experiments, with and without firms' profits. We target the ratio of the dynamic multipliers to be close to eight as shown in Table 3.

The results for the calibration in both scenarios are described in Table 4. The calibration implies that when we assume fully flexible prices (and no profits), the duration of unskilled workers' wages is of about a year and a half (18 months)[23] , while for skilled workers' wages it is about half a year (six months). These figures imply that the average duration of wages in the economy is about a year (in line with Le Bihan et al. (2012)). We compare two scenarios, one in which the wage rigidities differ, which we call *baseline* and other in which the wage rigidities are the same, which we call *alternative.*

[23] According with the equivalence between Calvo and Rotemberg proposed by Born and Pfeiffer (2018), see Appendix G.

In the alternative scenario we set both rigidities equal to the average of the baseline. Both cases are reported in Table 4.

We calibrate another version of the model in which we assume that prices are sticky and there are profits. In this case, the total stickiness in the economy is shared between wages and prices, and hence, the wage rigidities that match the ratio of dynamic multipliers fall. The duration of unskilled workers' wages is about 14 months while for skilled workers' wages it is about four months. We also study this baseline in contrast to the alternative calibration with the average wage rigidity. The calibration is exposed in Table 4 as well.

**Table 4:** Dynamic multipliers implied by the model. With and without firms' profits.

**Without profits**

| | Dynamic Multipliers | | |
|---|---|---|---|
| | Unskilled | Skilled | S/U |
| $\theta_u = \theta_s$ | -0.126 | -0.126 | 1 |
| $\theta_u > \theta_s$ | -0.088 | -0.77 | 8.8 |
| | Calibration | | |
| $\theta_h$ | 242 | 9.31 | |
| Duration | 6.12 | 1.69 | |

**With profits**

| | Dynamic Multipliers | | |
|---|---|---|---|
| | Unskilled | Skilled | S/U |
| $\theta_u = \theta_s$ | -0.143 | -0.147 | 1.03 |
| $\theta_u > \theta_s$ | -0.088 | -0.77 | 8.8 |
| | Calibration | | |
| $\theta_h$ | 141 | 5.03 | |
| Duration | 4.78 | 1.43 | |

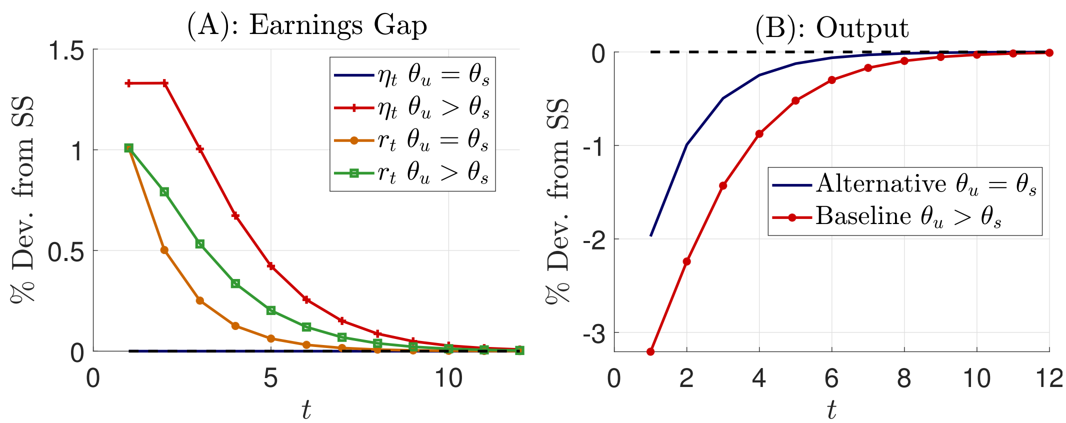
*Notes: This table shows the calibration of the wage rigidities in our model. The left-hand table shows the case without profits and the right-hand the case with profits and price rigidities. We report in both tables the dynamic multiplier as the cummulative response of wage inflation divided by the cummulative response of unemployment. The column S/U corresponds to the ratio of dynamic multipliers. We also show the adjustment cost parameters $\theta_s$ that deliver the dynamic multipliers already described and the average duration of wages implied by the $\theta_s$.*

## 6.2 The Effects of Monetary Policy: No Profits

We first show the effect of having a countercyclical earnings gap in a model without profits. In this subsection, we highlight that the earnings gap's mechanism does not rely on the countercyclical markups, as in the baseline HANK and TANK models, to generate amplification or dampening of monetary policy shocks. Instead, the impact of inequality arises from differences in nominal rigidities faced by the different workers who have different marginal propensities to consume.

Figure 5 shows the response of the economy to a contractionary monetary policy shock which corresponds to an increase of one percent in the real interest rate (on impact) in an economy without profits; i.e., where the differential response of labor income is the source of the redistribution in the cycle.[24] We show the two scenarios: the baseline ($\theta_u > \theta_s$) and the alternative ($\theta_u = \theta_s$). The left-hand panel shows the response of the interest rate and the earnings gap. The right-hand panel depicts the response of output. After a contractionary monetary policy shock, the earnings gap only rises in the case of the baseline calibration, consistent with the analytical results. The baseline calibration delivers a milder response with respect to the empirical evidence, which is close to 2.3 percent in the first quarter. For the case of output, we find significant amplification of monetary policy shocks derived from the aggregate demand effects of the inequality in wage rigidities. We find an amplification effect of about 62 percent on impact, which is more persistent than in the alternative scenario (due to the persistence in $\eta_t$). Moreover, the cumulative response of output in the baseline scenario is 2.2 times larger than in the alternative. Therefore, having a countercyclical earnings gap implies a significant amplification of monetary policy shocks in the absence of countercyclical price markups.[25]

**Figure 5:** IRF's to a monetary policy shock. Left: earnings gap and the real interest rate. Right: output.




*Notes: This figure presents the response of the earnings gap and the real interest rate (left-hand panel) and output (right-hand panel) to a monetary policy shock in the model. In these plots we show our two cases: the baseline ($\theta_u > \theta_s$) and the alternative economies ($\theta_u = \theta_s$). We report the response to a scaled shock that delivers a one-percent increase in the real rate on impact. All the responses correspond to deviations from the steady state. This figure shows the calibration in which we assume there are no profits nor price rigidities.*

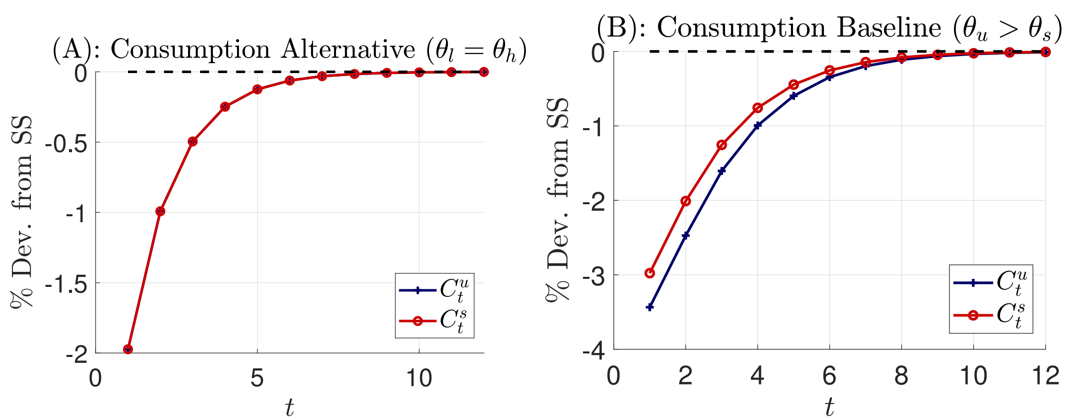
The effects of monetary policy also imply redistribution in the cycle. Figure 6 shows the response of groups' consumption to a monetary policy shock. The left-hand panel shows the response in the alternative scenario. In this case, consumption responses are identical, even though these groups differ in their shares of hand-to-mouth workers. As there are no profits, both workers' income fluctuate

[24] We scale the size of the shock to deliver a one percent increase in the real rate to get the same response as shown in the empirical evidence in both calibrations.

[25] Figure H.1 in Appendix H shows the responses of wage inflation and unemployment for both groups of workers in the different calibrations.

equally, and hence, their consumption reacts identically. The right-hand panel shows the baseline calibration. Two points are worth noting. First, monetary policy affects the unskilled consumers more than the skilled ones. This is a consequence of the higher volatility of labor income of unskilled workers. Second, the amplification effects from the countercyclical $\eta_t$ affect both consumers, even though the skilled labor income is more stable than in the alternative scenario. This is due to a spillover effect from the excessive negative response of consumption of the unskilled workers, which pushes the aggregate demand further down.

**Figure 6:** IRF's of groups consumption to a monetary policy shock. Left: Alternative calibration. Right: Baseline calibration.




*Notes: This figure presents the responses of consumption for the two skill levels in the model without firms' profits. The left-hand panel shows the alternative scenario ($\theta_u = \theta_s$) while the right-hand panel shows the baseline scenario ($\theta_u > \theta_s$).*

One can view the left-hand panel as the direct effect of monetary policy in our full model; hence, the difference between the right and left panels is approximately the indirect effect of monetary policy when we have heterogeneous wage rigidities. Given that both groups of workers have some degree of financial constraint, both groups have some departure from the representative agent, and their indirect effects are significant. Therefore, monetary policy has distributional effects, and the excess volatility from the countercyclical earnings gap affects both consumers through the indirect effect. Naturally, as we mentioned above, the most affected are unskilled workers.

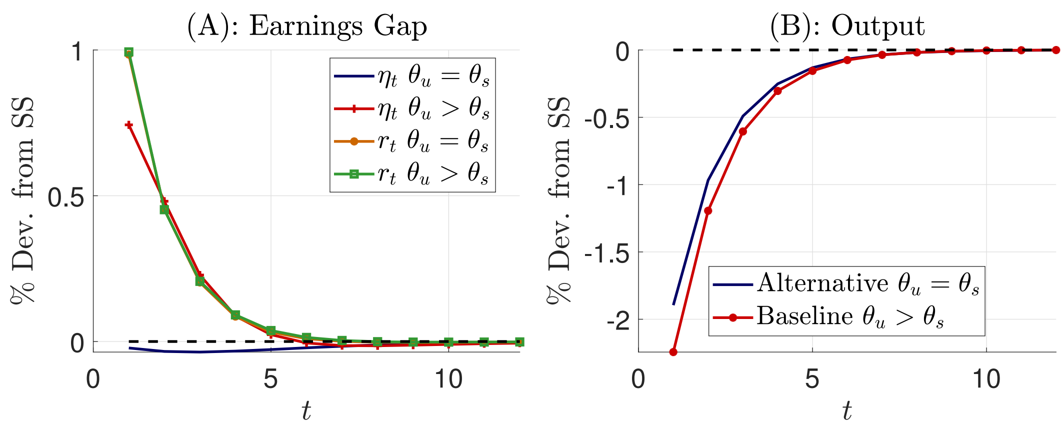
## 6.3 The Effects of Monetary Policy: With Profits

As most of the HANK and TANK literature relies on the existence of countercyclical markups to deliver aggregate effects from inequality and incomplete markets, we compare our results above with a case in which this additional redistributional channel exists. In the case with profits, as they are driven by the countercyclical markups, the effect of wage rigidity heterogeneity weakens as wage and price markups have an inverse relationship.

Figure 7 shows the response of the earnings gap and output to a one-percent increase (on impact) in the interest rate. The response of output to a monetary policy shock is weaker that in the previous case. The earnings gap increases by about 0.8 percent on impact, which is far from both the data and the model without profits. In this case, we also observe amplification derived from this countercyclical earnings gap, but the amplification is much lower, but still significant. The amplification effect of having differences in labor markets is about 18 percent on impact while the cumulative response is about 20 percent larger in the baseline calibration than in the alternative one.

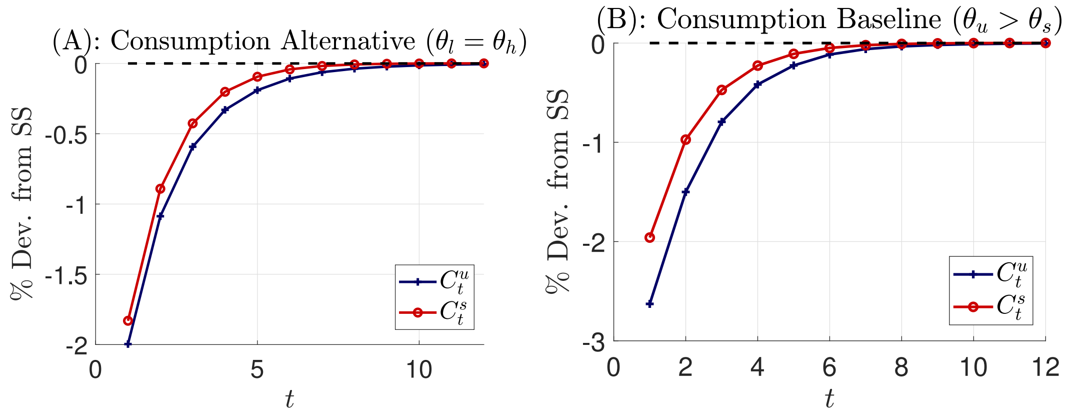
This lower amplification effect is due to the countercyclical price markups. In models with both price and wage rigidities, the total markup (the sum of log markups) is countercyclical, causing the three markups to move in the same direction. Which markup moves more depends on the relative stickiness of the corresponding prices and wages. When prices are fully flexible, all fluctuations are absorbed by the wage markups with their differences being what generate the amplification effects previously described. If prices are sticky, price markups weaken the responsiveness of wage markups. This implies that the amplification triggered by wage stickiness is lower that with flexible prices. For instance, with fully sticky prices, the differences in wage markups have no effect. The intermediate case is what we observe in Figure 7.

**Figure 7:** IRF's to a monetary policy shock. Left: earnings gap and the real interest rate. Right: output.




*Notes: This figure presents the response of the earnings gap and the real interest rate (left-and panel) and output (right-hand panel) to a monetary policy shock in the model. In these plots we show our two cases: the baseline ($\theta_u > \theta_s$) and the alternative economies ($\theta_u = \theta_s$). We report the response to a scaled shock that delivers a one-percent increase in the real rate on impact. All the responses correspond to deviations from the steady state. This figure shows the calibration in which we assume there are profits and price rigidities.*

**Figure 8:** IRF's of groups consumption to a monetary policy shock. Left: Alternative calibration. Right: Baseline calibration.




*Notes: This figure presents the responses of consumption for the two skill levels in the model with firms' profits. The left-hand panel shows the alternative scenario ($\theta_u = \theta_s$) while the right-hand panel shows the baseline scenario ($\theta_u > \theta_s$).*

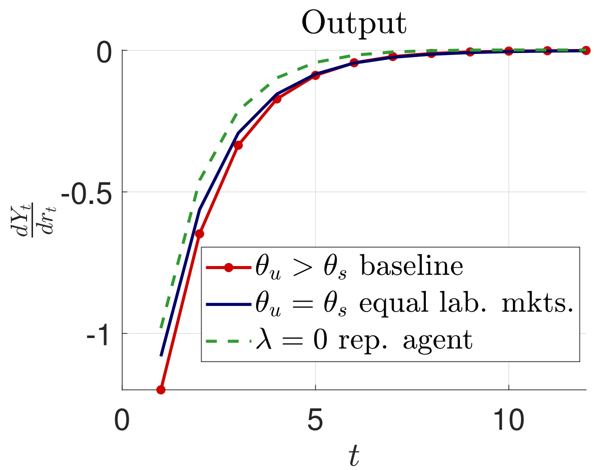
While the effect of amplification gets relatively weakened, there are still significant distributional effects of monetary policy. The response of unskilled workers' consumption is about 30 percent stronger than that of the skilled workers in the baseline calibration, as Figure 8 shows. This implies that unskilled workers are still worse off because of their labor market dynamics.

### 6.4 The Effects of Monetary Policy: Other Benchmarks

Finally, we explore the impact of the different features of our model conditional on a monetary policy shock. Figure 9 shows the response of output to a monetary policy shock for different assumptions in the model with profits. We compare economies with and without incomplete markets and with equal and different labor markets. Now, we report the elasticity of output to the interest rate $\frac{\partial Y_t}{\partial r_t}$, to capture the response of output relative to the response of the real interest rate. The first thing to note is that without financial frictions (with $\lambda_u = \lambda_s = 0$ hence a Representative Agent), the elasticity of output to the real interest rate does not depend on the labor market dynamics; this is because the real interest rate only drives aggregate consumption in a Representative Agent. Second, with limited financial access and equal labor markets, there is amplification, but it is small. We also interpret this as evidence of the effect of wage rigidities. When wages are rigid, profits fluctuate less (as the main component of marginal costs is wages), and the amplification from incomplete markets gets diminished.

However, if we consider that the earnings gap fluctuates as in our benchmark (with $\theta_u > \theta_s$), there is an amplification of shocks far beyond that implied by financial frictions. As we showed before, on

**Figure 9:** Decomposition of the response of output in the model.




*Notes: This figure presents the response of output to a monetary policy shock in the model. We show the dynamic multiplier of output with respect to the interest rate; i.e., the ratio of the response of output to the interest rate. We show three alternative calibrations. The RANK case,* $\lambda_h = 0$*. The baseline and the alternative calibration.*

impact, the effect of having different labor markets is substantial. In our model (with wage rigidities), the consequence of including incomplete markets generates an impact that is only 7% larger than the Representative Agent, while in the full model, the elasticity to the interest rate is 25% stronger than the representative agent ($\lambda = 0$). All this means that the contribution of labor market heterogeneity is about 72% of the total–cumulative– effect of jointly having incomplete markets and labor market heterogeneity. These effects imply that labor income heterogeneity may be an important source of amplification of business cycles.

# 7 Conclusion

In this paper, we study the role of the heterogeneity of indirect effects for the transmission of monetary policy. We first study, empirically, the *earnings gap*, which is the ratio of labor income of skilled to unskilled workers. We show that the earnings gap is countercyclical and increases in response to a contractionary monetary policy shock. To explain these facts, we estimate heterogeneous slopes of the wage Phillips curves for the two skill workers' groups. We find that the slope for skilled workers is about eight times steeper than that for the unskilled workers. This suggests that the wages of skilled workers are significantly more flexible than those of the unskilled.

Then, we propose a model that rationalizes these facts. We show that if there is gross substitution between skills in production and unskilled workers have more sticky wages, the earnings gap is countercyclical and increases in response to a monetary policy shock. We embed these features in a New Keynesian model in which there is limited access to financial markets. We assume there are two types of workers and that within these groups there are financially constrained and unconstrained workers. We assume that the group of unskilled workers has a higher share of constrained agents, which means that they have a higher marginal propensity to consume. We find that there are significant amplification effects from the heterogeneity in wage rigidities interacting with incomplete markets. The effects of monetary policy can be twice as large with respect to the case of equal wage rigidities.

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# Appendix

## A The Earnings Gap with the SIPP

A useful test of the robustness of finding in Section 2.2 is to compare them with a different survey. We take the *Survey of Income and Program Participation* (SIPP) that has data of individual workers. We consider the period from 1990 to 2012. The advantage of this survey is that it provides regularly updated data on wages, income, and educational and demographic characteristics of workers.

The survey is composed of several panels, in which about 10,000 households are followed over four years in a four-month frequency. Each four month window is called a *wave* in which households report their job status, their wage, and the social benefits being received, as well as households' individual characteristics. Each panel lasts for about four years and is constructed to be representative of the U.S. population. We use a uniformed version of the SIPP panels built by the *Center of Economic and Policy Research* (CEPR).[26] The CEPR compute uniformed hourly wage and labor earnings for each period which are comparable between panels. They also complete the sample by imputing monthly earnings from hourly wages and vice-versa if the respondent lacks one of the variables. We use the CEPR measure of total monthly labor earnings in what follows. Hence, we calculate labor income by group as the cross-sectional weighted average.

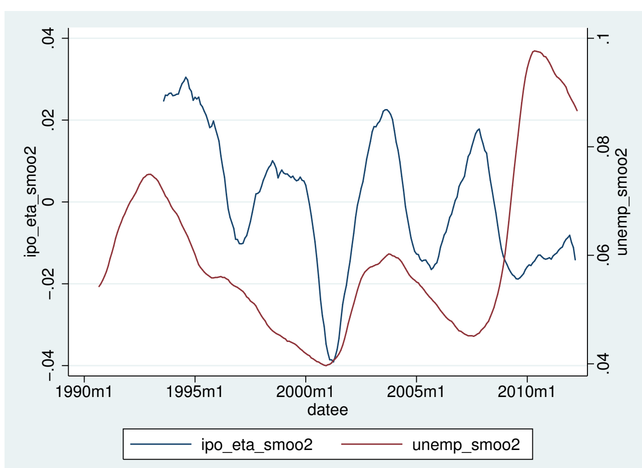



**Figure A.1:** Labor earnings gap and unemployment.

Figure A.1 depicts the series of $\eta_t$.[27] The figure shows some interesting patterns. First, on average,

[26]See http://ceprdata.org/ for more information.

[27]We plot the annual moving average. The SIPP is incomplete in some periods. To get a complete series of $\eta_t$, we interpolate $\eta_t$ in those periods. (this happens in eight months in 2000 and four in 2008, where they did not conduct the survey) In the regressions that follow, we take out these interpolated periods and run the regressions only with the

the labor earnings gap is about two, which means that skilled workers get about twice as much labor income as unskilled workers. Second, labor income inequality is characterized by large fluctuations. Our series shows several peaks and troughs, with the sharpest around the dot-com crisis in 2001. Third, that in recessions, the earnings gap increases. In the 1991 and the 2008 recessions, the earnings gap went up considerably, while in the 2001 recession, the earnings gap was already large prior to the recession.

Next we calculate the unconditional relation of the earnings gap with the cycle. To study this relation, we run the following regression:

$$\eta_t = c + \chi u_t + \beta W_t + \varepsilon_t, \tag{A.1}$$

where we regress our $\eta_t$ with aggregate unemployment as a measure of the business cycle. Hence, we are interested in $\hat{\chi}$. We include some controls $X_t$ that may be time trends and/or monthly dummies depending on the specification used.

These results are shown in Table A.1. We consider both four-month and monthly data. We also consider specifications in levels and filtered. We filter the data using the Hamilton filter.[28] Each regression controls for monthly dummies and the robust standard deviations are shown in parenthesis. Additionally, we consider two definitions for $\eta_t$: without unemployment insurance (panel (A)) and with unemployment insurance $b_t^k$ (panel (B)). We check the results by running the same regression with different treatments of the data. As mentioned before, we consider both monthly data (which is the frequency of the survey) and four-monthly data (which is the frequency of the waves). Additionally, we run the regressions with the data both in levels and filtered, to study the effect of the high persistence of unemployment on labor income inequality.

Several lessons can be taken from Table A.1. First, that for all specifications, the correlation between unemployment and $\eta_t$ is positive. Therefore, inequality *rises* with unemployment. In a recession, unskilled workers receive even lower labor income with respect to skilled workers. In all the specifications where we consider only labor income, the estimated coefficients are significant.

Second, this correlation is economically important. Take, for instance, the second column in panel (A), that is our preferred specification. For every one percentage point increase in unemployment, inequality rises by 0.83 percentage points.

That implies that in a recession which makes unemployment increase by two percentage points, labor income for unskilled workers is almost one and a half points less than for skilled workers. Moreover,

available data.

[28] Hamilton (2018)

| | | | | | | |
|---|---|---|---|---|---|---|
| | | (A) Dep var. $\hat{\eta}_t$(labor income) | | | | |
| $u_t$ | 0.97*** | 0.99*** | 0.79*** | 0.78*** | 1.10*** | 1.25*** |
| | (0.18) | (0.42) | (0.19) | (0.32) | (0.17) | (0.37) |
| | | (B) Dep var. $\hat{\eta}_t$(labor income + unemployment benefits) | | | | |
| $u_t$ | 0.94*** | 0.98** | 0.66*** | 0.65** | 1.02*** | 1.16*** |
| | (0.18) | (0.41) | (0.17) | (0.32) | (0.15) | (0.33) |
| Frequency | 1m | 4m | 1m | 4m | 1m | 4m |
| Filtered | ✓ | ✓ | ✗ | ✗ | ✗ | ✗ |
| Trend | ✗ | ✗ | ✓ | ✓ | ✗ | ✗ |
| Month dummies | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

Note: Robust standard errors in parentheses.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

**Table A.1:** Cyclicality of labor income inequality, for different specifications.

as panel (B) in Table A.1 shows, unemployment benefits do not "help" to solve this cyclicality, they only help to diminish the coefficients of the relation of labor income inequality with unemployment, but these coefficients remain high.

# B Econometric Strategy

To study the response of the labor market variables to a monetary policy shock, we follow Stock and Watson (2018) and Gertler and Karadi (2015) by estimating instrumental variable Local Projections and instrumental varible VARs with exogenous instruments for monetary policy, based on high-frequency identification.

Let us consider $X_t$, which is a $k \times 1$ vector of observable variables. We assume $X_t$ follows an invertible VAR(p), which has an moving-average representation given by

$$X_t = u_t + \psi_1 u_{t-1} + \psi_2 u_{t-2} + \ldots \quad u_t \sim WN(0, \Sigma_u). \tag{B.1}$$

The process for $X_t$ also admits a structural representation given by

$$X_t = B_0 \varepsilon_t + B_1 \varepsilon_{t-1} + B_2 \varepsilon_{t-2} + \ldots \quad \varepsilon_t \sim N(0, \mathbb{I}_k). \tag{B.2}$$

In line with the VAR literature we recover the structural shocks $\varepsilon_t$ by assuming a structural relation given by $u_t = B_0 \varepsilon_t$. There are two assumptions required if we are to claim that the $\varepsilon_t$'s are proper structural shocks: (i) the econometrician when estimating Equation (B.1) includes all the information required by the structural relation (the observed equation is well specified); and (ii) there is no uncertainty about the assumed matrix $B_0$.

Usually, these two requirements are not met. That is why we claim that the shocks that are obtained with the relation $\varepsilon_t = B_0^{-1} u_t$ are not always well identified. Therefore, as we can not always elude these problems, the best procedure is to instrument the shocks as proposed by Stock and Watson (2012) and implemented by Gertler and Karadi (2015) (GK) and Miranda-Agrippino and Ricco (2017) (MAR).[29]

We implement an external instruments procedure for the estimation of the effect of a monetary policy shock as follows. Let us write the equation that relates structural ($\varepsilon_t^x$) and reduced-form ($u_t^x$) shocks as

$$\begin{pmatrix} u_t^{mp} \\ u_t^{nomp} \end{pmatrix} = \begin{pmatrix} \underset{[k\times 1]}{b_1} & | & \underset{[k\times(k-1)]}{b_2} \end{pmatrix} \begin{pmatrix} \varepsilon_t^{mp} \\ \varepsilon_t^{nomp} \end{pmatrix}$$

where $b_1$ is a $k \times 1$ vector that relates the reduced-form innovation in the interest rate $u_t^{mp}$ with all the structural shocks. The aim is to instrument the structural shock to the interest rate with an external instrument. Before explaining our procedure, let us recap the conditions for a valid instrument $z_t$:

Find $z_t \notin y_t$ such that:

1. Relevance: $\mathbb{E}[z_t \varepsilon_t^{mp'}] = \alpha$.

2. Exogeneity: $\mathbb{E}[z_t \varepsilon_t^{nomp'}] = 0$.

3. Lead-lag exogeneity $\mathbb{E}[z_t \varepsilon_{t+j}^i] = 0 \quad \forall j \neq 0 \;$ and $\; \forall i$.

Furthermore, the system to be identified can be written as:

$$\begin{pmatrix} u_t^{mp} \\ u_t^{nomp} \end{pmatrix} = \begin{pmatrix} \underset{[1\times 1]}{b_{11}} & | & \underset{[k\times(k-1)]}{b_{21}} \\ \underset{[(k-1)\times 1]}{b_{12}} & | & \underset{[k\times(k-1)]}{b_{22}} \end{pmatrix} \begin{pmatrix} \varepsilon_t^{mp} \\ \varepsilon_t^{nomp} \end{pmatrix},$$

then, we multiply that system by the instrument $z_t$ and take expectations,

$$\begin{pmatrix} \mathbb{E}(u_t^{mp} z_t') \\ \mathbb{E}(u_t^{nomp} z_t') \end{pmatrix} = B_0 \begin{pmatrix} \mathbb{E}(\varepsilon_t^{mp} z_t') \\ \mathbb{E}(\varepsilon_t^{nomp} z_t') \end{pmatrix} = \begin{pmatrix} b_1 & b_2 \end{pmatrix} \begin{pmatrix} \alpha' \\ 0 \end{pmatrix} = \begin{pmatrix} b_{11}\alpha' \\ b_{12}, \alpha' \end{pmatrix}$$

which implies

$$\mathbb{E}(u_t^{mp} z_t')^{-1} \mathbb{E}(u_t^{nomp} z_t') = b_{11}^{-1} b_{12} \tag{B.3}$$

[29] Stock and Watson (2018) analyzes the properties of Local Projection- and SVAR-IV.

Equation (B.3) represents the relations used in making an identification through an external instrument. If the instrument is valid, $b_1$ is consistently estimated. In practice, this method is equivalent to regressing $u_t^{nomp}$ against $u_t^{mp}$ using $z_t$ as an external instrument. The procedure we follow involves four steps. First, get an estimate of $u_t$ from a BVAR and a Local Projection. Second, regress $u_t$ against $z_t$. Third, calculate $b_{11}^{-1}b_{12}$ as a ratio of regression coefficients. Finally, choose a normalization, for instance $b_{11} = 1$.

As in MAR, we use their informationally robust instrument and compare the responses of different estimation methods.We compare three methods: (i) a Bayesian VAR (BVAR); (ii) a Local Projection (LP); and (iii) a Bayesian Local Projection (BLP). We follow their procedure because it accounts for the bias and estimation variance trade-off that VARs and LPs have. The Bayesian VAR produces more efficient parameters than the simple VAR and LP, but it is more prone to bias if the model is misspecified. That is why VAR and LP, if they are misspecified, produce highly inaccurate estimates. According to MAR, these issues can be the reason for "puzzling" responses and lack of robustness.

This aforementioned trade-off can be accounted for by Bayesian estimation. We follow these authors and take a Bayesian approach to Local Projection, which optimally spans the model space between VAR and LP impulse-response functions. This procedure helps to unravel the puzzles that may arise from model specification. The BLP procedure requires us to specify a (Normal-Inverse Whishart) prior for the local projection coefficients at each horizon. These priors are centered around the iterated coefficients of a similarly specified VAR estimated over a pre-sample. The posterior mean of BLP responses takes the form

$$B_{BLP}^{(h)} = \left(X'X + \left(\Omega_0^{(h)}\lambda^{(h)}\right)^{-1}\right)^{-1}\left((X'X)B_{LP}^{(h)} + \left(\Omega_0^{(h)}\lambda^{(h)}\right)^{-1}B_{VAR}^{h}\right)$$

where $X \equiv (x_{h+2}, ..., x_T)'$, and $x_t = (1, y'_{t-1}, ..., y'_{t-h})'$. Intuitively, BLP regularises LP responses by using priors centered around an iterated VAR, while allowing the data structure to select the optimal degree of departure from the priors at each horizon ($\lambda^{(h)}$'s). The procedure treats these parameters as endogenous and estimates them as the maximizers of the posterior likelihood. In this way they balance the bias and the estimation variance at all horizons, and solve the trade-off. We follow their procedure closely. A detailed analysis and description of this approach can be found in Miranda-Agrippino and Ricco (2017).

# C Decomposing the Earnings Gap.

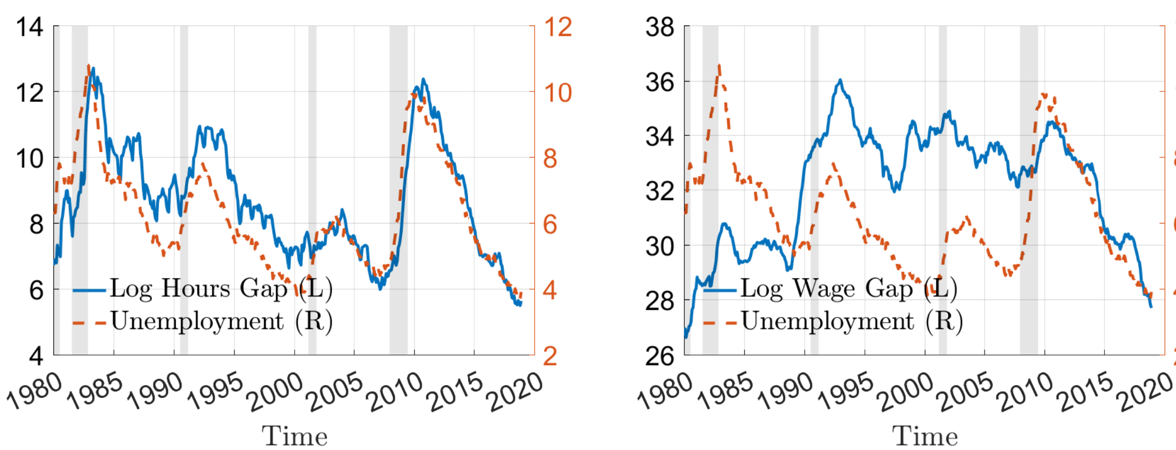
We can further analyze the (log) earnings gap by decomposing it into a wage and an hours gap. Denote with $w_{st}$ and $N_{st}$ the wage and hours of group $s$ at time $t$, the earnings gap is given by $\eta_t = \frac{w_{ht}N_{ht}}{w_{lt}N_{lt}}$

(with $h$ for skilled and $l$ for unskilled). Then, the log of the earnings gap can be decomposed as

$$\begin{aligned}\log(\eta_t) &= \log\left(\frac{\text{Skilled labor income}}{\text{Unskilled labor income}}\right) = \log\left(\frac{w_{st}}{w_{ut}}\right) + \log\left(\frac{N_{st}}{N_{ut}}\right) \\ &= \log\left(\text{Wage Gap}\right) + \log\left(\text{Hours Gap}\right).\end{aligned}$$

Figure C.1 shows the previous decomposition for our data. The left-hand panel depicts the hours gap (in logs) while the right-hand panel shows the wage gap (in logs). Both the hours gap and the wage gap are countercyclical. In recessions, both wage and employment inequality increase. While hours inequality is highly correlated with unemployment, the wage gap also correlates but at a lesser extent. The wage gap suggests that the increase in wage inequality explains the upward trend the earnings gap had between early eighties and mid nineties, and also explains the greater part of the earnings gap, by accounting for about three fourths of earnings inequality. Finally, it is worth to highlight the recent recovery of the US labor market. Inequality went down both for hours and wages, following about the same path of the unemployment rate. This latter fact has not happened in past recoveries.

**Figure C.1:** Wage and hours gap and unemployment.



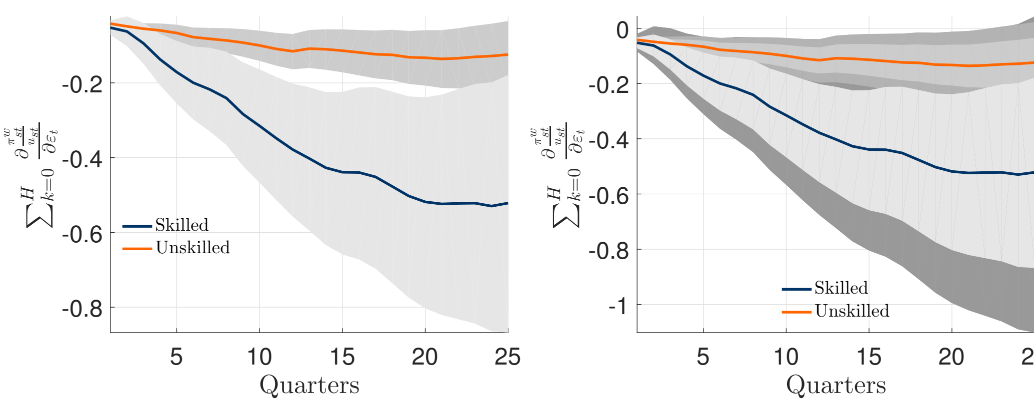

*Notes: This figure shows the decomposition of earnings gap into an hours gap (the left-hand panel) and a wage gap (the right-hand panel). We show the log of each variable with respect to the unemployment rate. The gray vertical lines correspond to the NBER recessions.*

## D Test for the Dynamic Multiplier

To conduct the test of the significance of the difference between the slopes of the Phillips curve, we run the Bayesian BLP by including the ratio $\pi_{st}/u_{st}$ instead of $\pi_{st}$ and $u_{st}$ separately. The reason why we do that is because the distribution of the actual dynamic multipliers get undetermined as the response of unemployment, $\sum_{k=0}^{h} \frac{\partial u_{st}}{\partial \varepsilon_t}$, is zero with a high frequency, and hence the dynamic multiplier gets undefined. Instead, we show $\sum_{k=0}^{h} \frac{\partial \frac{\pi_{st}}{u_{st}}}{\partial \varepsilon_t}$ which can be seen as a more restrictive test for the actual dynamic multiplier. It is more restrictive since it would require that at *every* point of the IRF's, the two dynamic multipliers must differ.

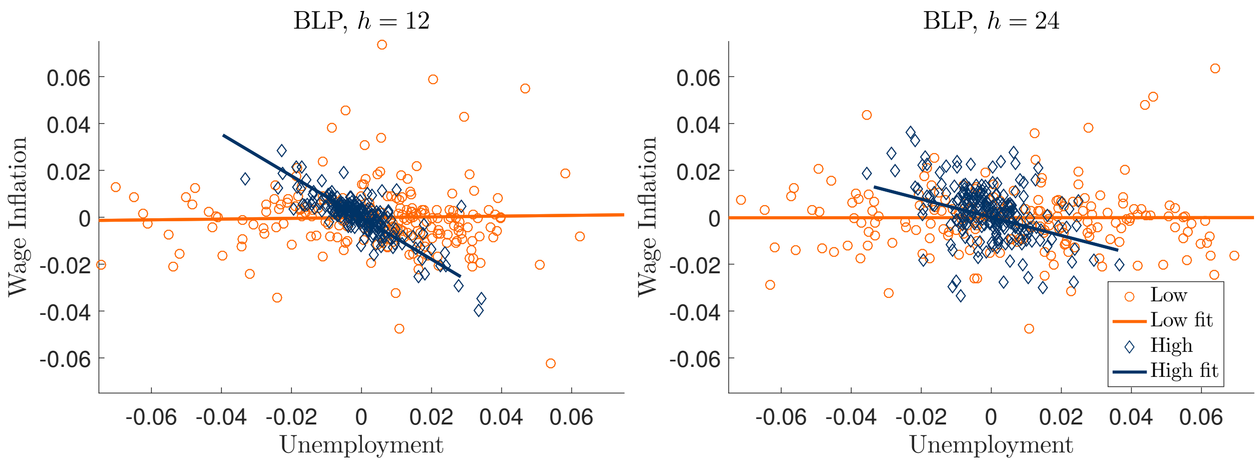
Figure D.1 shows the test for $\sum_{k=0}^{h} \frac{\partial \frac{\pi_{st}}{u_{st}}}{\partial \varepsilon_t}$ for different horizons. We report the median and the 68% confidence interval on the lef-hand panel, while we add the 90% confidence interval in the right hand panel. The test delivers significance at the 68% confidence from month eight. Also, we document "weak" significance at the 90% level. If we consider the Unskilled as the benchmark, the skilled median falls outside the 90% confidence interval of the unskilled, which is still significant with this criteria. Recall that this is a more strict test since it requires the ratio $\pi_{st}/u_{st}$ and not the variables separately to respond in different way.

**Figure D.1:** Test for the Dynamic multiplier.



# E Projected Wage Inflation and Unemployment

**Figure E.1:** Projected wage inflation and unemployment.




*Notes: This figure presents the projections of wage inflation and unemployment rate conditional* only *on the identified monetary policy shock. The left-hand side depicts the projections up to 12-month and the right-hand panel up to 24-month. In both plots, the diamond blue are the projections for skilled workers and the circle orange for unskilled workers.*

Figure E.1 shows a scatter of the projections implied by the BLP. We build the projections by using the estimated parameters to calculate projected series of unemployment and wage inflation rates for skilled and unskilled workers, using the realized shocks in the data. Hence, only we show the series that are conditional on the monetary policy shock. The rounded orange points are the projections for unskilled while the diamond blue are for skilled.[30] The figure deserves some comments. First, conditional on the monetary policy shock, unskilled wages are substantially rigid; both for twelve and 24 month horizon, the implied wage Phillips curve by these estimations are flat. Second, and in line with the previous findings, the projected wage Phillips curve for skilled workers is noticeably steeper than for unskilled wages.

# F Wage Phillips Curve Derivation

To solve for the wage Phillips curves, unions solve

$$\max_{w_{ht}^j, \pi_{ht}^j} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[ \lambda_h U(c_{ht}^k) + (1-\lambda_h) U(c_{ht}^r) - v(n_{ht}^j) - \frac{\theta_h}{2} \left( \frac{w_{ht}^j}{w_{ht-1}^j} - 1 \right)^2 \right] \tag{F.1}$$

[30]These series are different from the sum of the impulse responses since the projection scales down the responses of the variables in accordance with the series of realized shocks.

subject to

$$n_{ht}^{j} = \left(\frac{w_{ht}^{j}}{w_{ht}}\right)^{-\varepsilon_h} n_{ht} \tag{F.2}$$

The FOCs are

$$\lambda_h U'(c_{ht}^{k})\frac{\partial c_{ht}^{k}}{\partial w_{ht}^{j}} + (1-\lambda_h)U'(c_{ht}^{r})\frac{\partial c_{ht}^{r}}{\partial w_{ht}^{j}} - v'(n_{ht}^{j})\frac{\partial n_{ht}^{j}}{\partial w_{ht}^{j}} - \theta_h(\pi_{ht}^{hj}+1)\pi_{ht}^{hj}\frac{1}{w_{ht}^{j}} + \beta\theta_h\mathbb{E}_t(\pi_{ht+1}^{hj}+1)\pi_{wt+1}^{hj}\frac{1}{w_{ht}^{j}} = 0 \tag{F.3}$$

where we used $\pi_{st} = \frac{w_{st}}{w_{st-1}}$. First, notice that

$$\frac{\partial n_{ht}^{j}}{\partial w_{ht}^{j}} = -\varepsilon_h \frac{n_{ht}^{j}}{w_{ht}^{j}}, \quad \text{and} \quad \frac{\partial c_{ht}^{k}}{\partial w_{ht}^{j}} = \frac{\partial c_{ht}^{r}}{\partial w_{ht}^{j}} = (1-\varepsilon_h)n_{ht}^{j} \tag{F.4}$$

$$\Big(\lambda_h U'(c_{ht}^{k}) + (1-\lambda_h)U'(c_{ht}^{r})\Big)(1-\varepsilon_h)n_{ht}^{j} + v'(n_{ht}^{j})\varepsilon_h\frac{n_{ht}^{j}}{w_{ht}^{j}} - \theta_h(\pi_{wt}^{hj}+1)\pi_{wt}^{hj}\frac{1}{w_{ht}^{j}} \tag{F.5}$$

$$+\beta\theta_h\mathbb{E}_t(\pi_{wt+1}^{hj}+1)\pi_{wt+1}^{hj}\frac{1}{w_{ht}^{j}} = 0 \tag{F.6}$$

Define $\overline{mgu}_{ht} = \lambda_h U'(c_{ht}^{k}) + (1-\lambda_h)U'(c_{ht}^{r})$ and after symmetry

$$(\pi_{wt}^{h}+1)\pi_{wt}^{h} = \frac{\varepsilon_h}{\theta_h}N_{ht}\left\{v'(N_{ht}) - \frac{\varepsilon_h - 1}{\varepsilon_h}\overline{mgu}_{ht}w_{ht}\right\} + \beta\theta_h\mathbb{E}_t(\pi_{wt+1}^{h}+1)\pi_{wt+1}^{h} \tag{F.7}$$

# G Rotemberg-Calvo Equivalence

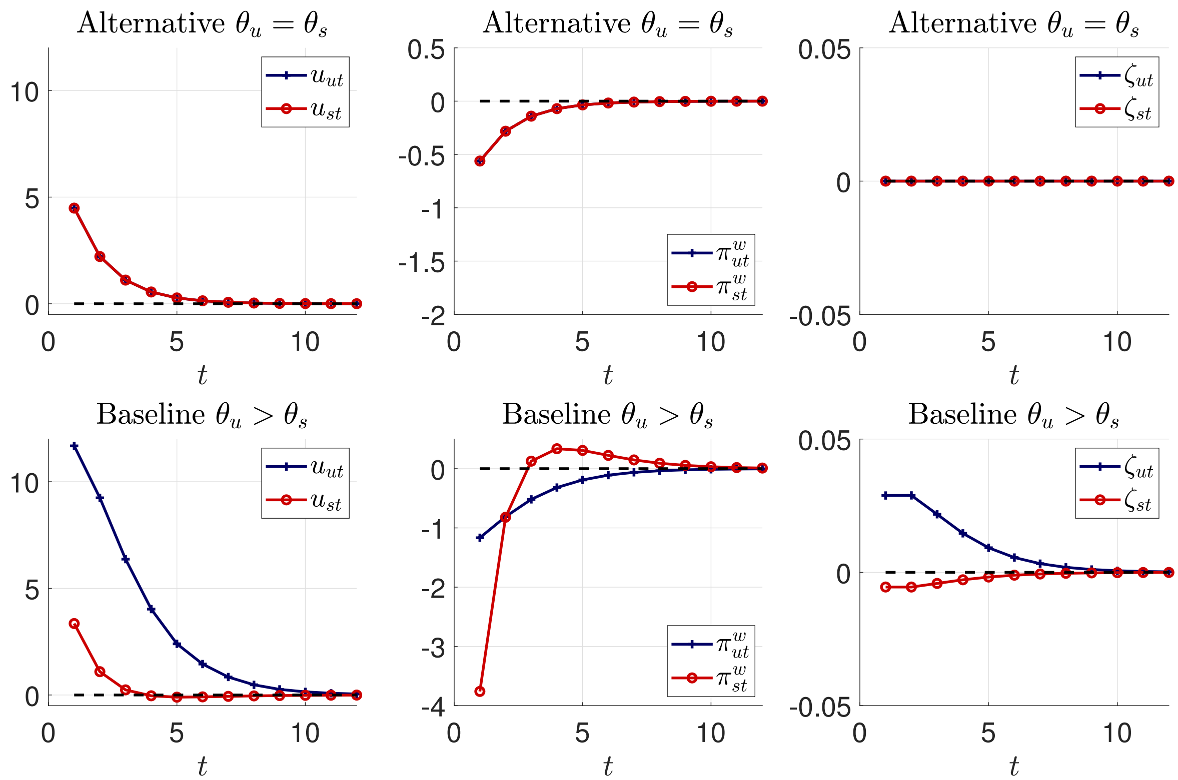
To compute the equivalence between calvo and rotemberg, we follow Born and Pfeiffer (2018). The relation between Calvo and Rotemberg is given by:

$$\frac{(1-\aleph_h)}{\aleph_h}(1-\beta\aleph_h) = (\varepsilon_h - 1)(1-\alpha)\frac{(\varepsilon-1)}{\varepsilon}\frac{1}{\theta_h} \tag{G.1}$$

where $\aleph_h$ is the Calvo probability of not adjusting wages, and $\theta_h$ is the parameter of the wage adjustment cost with Rotemberg.

# H Extra IRFs

**Figure H.1:** IRFs of groups consumption to a monetary policy shock. Left: Alternative calibration. Right: Baseline calibration.



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