The Geographic Effects of Monetary Policy Shocks *

Juan Herreño
UC San Diego

Mathieu Pedemonte
Federal Reserve Bank of Cleveland†

October 31, 2022

Abstract

We estimate the differential regional effects of monetary policy shocks by exploiting geographical heterogeneity in income across metropolitan areas in the United States. We find that prices and employment in poorer areas react by more to monetary policy shocks. The results for prices hold for headline CPI and a wide range of narrower consumer expenditure categories within the CPI. The results are consistent with New Keynesian models that allow for a different share of hand-to-mouth consumers across regions or different elasticities of intertemporal substitution, but not with models in which regions have different slopes of the Phillips curve or different elasticities of labor supply. An increase in heterogeneity across metropolitan areas amplifies the effect of monetary policy on prices and employment.

Keywords: Heterogeneous Effects of Monetary Policy, Monetary Union, TANK

JEL: E31, E24, E52, E58, F45

*We thank Mark Bils, Corina Boar, Olivier Coibion, Yuriy Gorodnichenko, Joe Hazell, Nir Jaimovich, Ed Knotek, Emi Nakamura, Christina Patterson, David Romer, Sanjay Singh, Jón Steinsson, Nicolas Vincent (discussant), Michael Weber, Johannes Wieland, Ines Xavier, and seminar participants at various institutions for useful comments and discussions. We thank Michael McMain for excellent research assistance.

†The views expressed here are solely those of the authors and do not necessarily reflect the views of the Federal Reserve Bank of Cleveland or the Federal Reserve System.

1 Introduction

In textbook New Keynesian models of a monetary union, regions are equally affected by exogenous shifts in monetary policy, so a rising tide lifts all boats. However, micro-level evidence shows that individuals in the economy are differently affected by national policies as a function of their earnings, balance-sheet positions, or ability to access financial instruments.[1] On top of being differentially affected by shocks, important markets clear at the local level, such as local labor markets or markets for non-tradable goods, potentially amplifying or dampening differences in exposure to aggregate shocks.

This paper estimates the extent to which the transmission of monetary policy shocks to prices and employment is different across US metropolitan areas and evaluates plausible drivers of economic heterogeneity that can explain our findings. As an illustration of the issues we aim to tackle in this paper, Figure 1 compares the change in inflation and employment in two US cities, New York City and Baltimore, and shows that inflation and employment are more cyclical in Baltimore than in New York City.

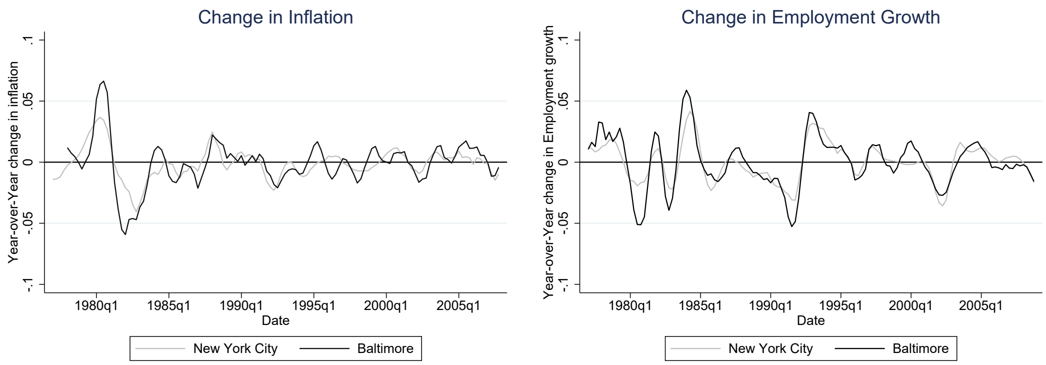
The patterns in Figure 1 could in principle be explained by a combination of differential volatility of regional shocks, differential exposure to aggregate shocks, or differential transmission of macroeconomic policy. We use exogenous variation in the stance of monetary policy since 1969, effectively fixing the shocks affecting these economies, focusing our attention to differential sensitivity to the same set of aggregate shifters.

After a contractionary monetary policy shock, inflation in richer areas in the US declines by less than in poorer ones. We use the Consumer Price Index (CPI) data for 28 metropolitan areas in the US at a quarterly frequency to estimate the effects of a monetary policy shock using local projections and a decomposition into an average effect and a heterogeneous effect by metropolitan area real income, in line with Cloyne, Jorda, and Taylor (2020). Our measure of monetary policy shocks is that originally created by Romer and Romer (2004) and extended to 2007 by Wieland and Yang (2020).

We use more disaggregated data by goods and service expenditure categories and find consistent results. We find that the prices of goods and services of a wide range of narrow cat-

[1] In the case of monetary policy, see Coibion et al. (2017) for differences in income inequality; Beraja et al. (2019) and Wong (2021) provide evidence related to balance-sheet positions. See also Doepke and Schneider (2006).

Figure 1: Inflation and Employment across Space and Time



Note: The figure shows the year-over-year change in smoothed quarterly overall CPI inflation and private employment percentage change for New York City and Baltimore. The smoothing is the four-quarter (backward-looking) moving average of the overall variable.

egories react less in rich areas compared to poor ones. The differential effects are larger for expenditure categories that are priced locally, like food away from home, and we estimate positive, although statistically insignificant differential effects even for highly traded, homogeneous goods, like gasoline when we use conservative standard errors.

We also estimate the effects of monetary policy shifts on employment, on average, and across the geographical income distribution, finding that after a monetary contraction, employment in poorer metro areas falls by more. Using quarterly data on employment from the Quarterly Census of Employment and Wages (QCEW), we generate private employment counts for the same geographical areas as in the price data. We estimate that after a contractionary monetary policy shock of 1 percent, average metro area employment goes down by 1 percent after two years. Beyond these average effects, we show that contractionary monetary policy shocks reduce employment by more in poorer regions. A metropolitan area in the bottom 10th percentile of the geographical income distribution faces a peak employment loss of 2.0 percent, while one in the richest 10th percentile suffers negligible effects. The effects on employment are persistent and occur faster than for prices. Employment declines after the first year of the shock and stays depressed for four years after its occurrence.

A model with variation in the fraction of hand-to-mouth households, or heterogeneity in the slope of the Euler equation across regions can rationalize our results. We build a New

Keynesian model of a monetary union where regions are heterogeneous in their share of hand-to-mouth households, a monetary union extension of the two-agent New Keynesian (TANK) model in Bilbiie (2008). In regions with higher shares of hand-to-mouth households, a larger share of the population is outside their Euler equation and may only smooth consumption via their labor supply decisions. The share of hand-to-mouth households then changes the "effective" sensitivity of regional consumption to real interest rates.

This simple model is able to reproduce the qualitative regional patterns we estimate in the data. Hand-to-mouth households exacerbate the effects of monetary policy shocks, as households cannot smooth consumption after aggregate shocks, affecting local demand. Movements along the labor supply curve affect marginal costs and pass-through the price of local goods, creating differences in regional CPI inflation rates whenever there is home bias or non-tradable goods.

In the model, monetary policy has relevant distributional effects in the short run. Contractionary monetary policy shocks induce larger price decreases in poorer regions. However, it also induces larger declines in employment, driven by the reduced labor supply of Ricardian households in regions with higher shares of hand-to-mouth households. In our calibration, after a contractionary monetary policy shock, hand-to-mouth households increase their labor supply. The empirical reaction of local employment rates we estimate comes from larger cross-regional employment responses between Ricardian agents across regions, not from the employment differences across hand-to-mouth consumers.

We then evaluate whether other sources of heterogeneity in a standard New Keynesian model without hand-to-mouth consumers can induce regional differences in the response to monetary policy shocks in line with our empirical findings. We allow for regional variation in nominal rigidities, elasticities of labor supply, and the inter-temporal elasticity of substitution, the three key parameters in New Keynesian models.

Variation in the intertemporal elasticity of substitution could account for our findings, but heterogeneity in labor supply elasticities or the slope of the Phillips curve cannot, on their own, explain the effects we estimate. Introducing variation in the frequency of price changes and the labor supply elasticity would imply that regions with higher price responses would exhibit lower employment responses. This result is driven by a lower degree of monetary nonneutrality in regions with more flexible prices. A model with reduced-form geographic variation in the elasticity of intertemporal substitution can also rationalize our results by changing the sensitivity of consumption to real interest rates, as the TANK model does via heterogeneity in the share of hand to mouth consumers.

Finally, we use the TANK model to evaluate the aggregate effects of having regions with different shares of hand-to-mouth households. We find that heterogeneity in hand-to-mouth households exacerbates the effects of monetary policy shocks. This effect is explained by the accelerator effect of hand-to-mouth share explained in Bilbiie (2020). This result implies that an increase in the polarization of inequality across space in the US makes the impact of monetary policy on both prices and employment larger.

This paper is part of a growing literature that attempts to understand the distributional effects of monetary policy and its implications. Auclert (2019) and Kaplan, Moll, and Violante (2018) focus on how heterogeneity may change the average effects of monetary policy. Bilbiie (2008) presents a two-agent New-Keynesian model in which hand-to-mouth consumers introduce frictions in the determination of aggregate quantities. We use a framework similar to that in Bilbiie (2008), extending it to a monetary union with heterogeneity in the presence of hand-to-mouth consumers, and we show that this class of models can rationalize the cross-regional heterogeneous responses of monetary policy shocks in the US.

On the empirical front, Coibion et al. (2017) show that monetary policy affects nominal income distribution in the US, Furceri, Loungani, and Zdzienicka (2018) find similar effects for a panel of countries. Cloyne, Ferreira, and Surico (2020) find heterogeneous results depending on the financial position of households. Cravino, Lan, and Levchenko (2018) focus on the heterogeneity of price adjustment. Andersen et al. (2021) document the effects of monetary policy on several sub-components of income triggered by monetary policy shocks that induce increases in inequality after expansionary shocks. While they explore differences in the price stickiness of goods consumed by rich and poor households, we focus on a different mechanism, highlighting that even for the same degree of price rigidity, heterogeneity in real rigidities will induce different inflation dynamics across regions.

Along those lines, Bergman, Matsa, and Weber (2022) look at different demographics affected by a monetary policy shock. They find that groups with lower labor market attachment have higher employment growth after expansionary monetary policy shocks when the market is tighter. Using a New Keynesian model with heterogeneous workers, they show that this effect is plausible when there are differences in workers' productivity. In this paper, we focus on the spatial income heterogeneity of the US. This heterogeneity allows us to evaluate not only the effect on employment but also on price indexes. Having employment and prices allows us to have a complete picture of the effects in terms of real income.

The rest of the paper is organized in the following way: Section 2 presents the data. Section 3 shows the empirical results. Section 4 discusses the distributional effect with different versions of a monetary union New Keynesian model. Section 5 shows the implications of monetary policy for geographic inequality according to the model. Finally, Section 6 concludes.

2 Data

To estimate the effects of monetary policy shocks across space, we estimate impulse response functions of inflation and employment at the regional level via local projections after a monetary policy shock. We construct a balanced panel for 28 metropolitan areas containing 12-month inflation rates and indicators of real economic activity. Our dataset starts in 1969 and ends in 2007, a restriction of using the Romer and Romer (2004) monetary policy shocks.[2] We use headline CPI inflation as our benchmark and present results for various sub-indexes, including CPI for food, food at home, food away from home, gas, and housing.

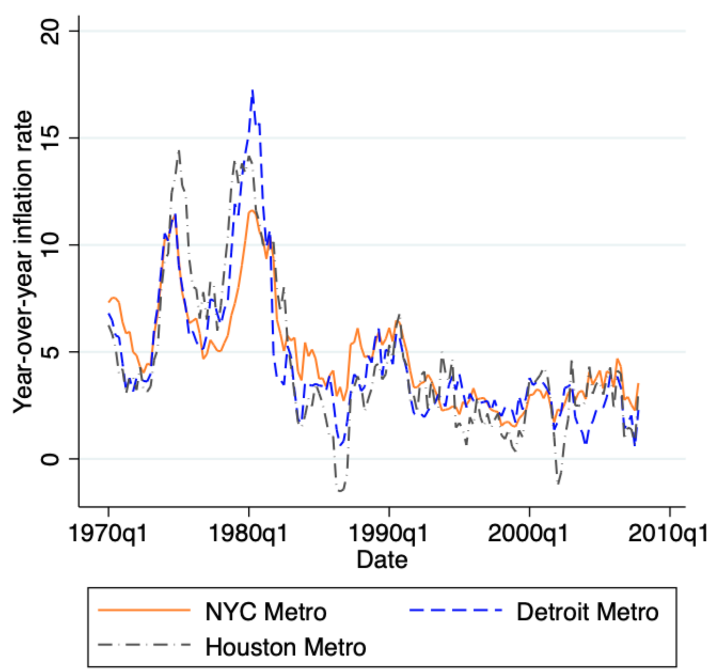
Price index data come directly from the Bureau of Labor Statistics (BLS). For our study, the dispersion of income across space is essential. For that reason, we choose to use city-wide indexes instead of state-wide indexes, such as those produced by Hazell et al. (2022) in order to have more variation in average economic conditions across units of observation. In addition, we will use price indexes for specific consumer categories to illustrate whether our results are driven by changes in degrees of tradeability, product differentiation, or the degree of nominal

[2] The metropolitan areas we consider are Boston-Cambridge-Newton (MA-NH), New York-Newark-Jersey City (NY-NJ-PA), Philadelphia-Camden-Wilmington (PA-NJ-DE-MD), Chicago-Naperville-Elgin (IL-IN-WI), Detroit-Warren-Dearborn (MI), Minneapolis-St.Paul-Bloomington (MN-WI), St. Louis (MO-IL), Washington-Arlington-Alexandria (DC-MD-VA-WV), Baltimore-Columbia-Towson (MD), Miami-Fort Lauderdale-West Palm Beach (FL), Atlanta-Sandy Springs-Roswell (GA), Tampa-St. Petersburg-Clearwater (FL), Dallas-Fort Worth-Arlington (TX), Houston-The Woodlands-Sugar Land (TX), Phoenix-Mesa-Scottsdale (AZ), Denver-Aurora-Lakewood (CO), Los Angeles-Long Beach-Anaheim (CA), San Francisco-Oakland-Hayward (CA), Seattle-Tacoma-Bellevue (WA), San Diego-Carlsbad (CA), Urban Hawaii, Urban Alaska, Pittsburgh (PA), Cincinnati-Hamilton (OH-KY-IN), Cleveland-Akron (OH), Milwaukee-Racine (WI), Portland-Salem (OR-WA) and Kansas City (MO-KS).

rigidities.

In our main specification we will difference away the behavior of prices that is common to every metropolitan area in our dataset. To highlight the variation that we will use, we plot the headline CPI inflation for three selected metropolitan areas in the United States, New York-Newark-Jersey City, NY-NJ-PA (area code S12A in the CPI data), the Detroit-Warren-Dearborn, MI (area code S23B), and Houston-The Woodlands-Sugar Land, TX (area code S37B). Figure 3 presents the data. The main source of variation we will use is the differential inflation rates that metropolitan areas experienced throughout US business cycles. For example, the Houston metro area experienced a higher inflation rate during the Great Inflation of 1974, the Detroit metro area experienced a higher inflation rate during the 1979 inflation, and both had more pronounced changes in inflation during the 2001 recession, compared to New York City.

Figure 2: Inflation Across Metropolitan Areas



Note: In this figure we plot the behavior of 12-month headline CPI inflation at a quarterly frequency for three metropolitan areas: New York-Newark-Jersey City, NY-NJ-PA; Detroit-Warren-Dearborn, MI; Houston-The Woodlands-Sugar Land, TX.

The employment data come from the Quarterly Census of Employment and Wages (QCEW) which has good geographical coverage. We use county-level data at the quarterly frequency covering private employment since 1975. Since the unit of observation for the employment data is the county and for prices is the metropolitan area, we create a correspondence between counties in the QCEW and the statistical sampling units created for the CPI, called Primary Sampling Units (PSUs).[3]

In a similar way than with prices, our main specifications will soak in any effects on employment triggered by the shock that are symmetric across the metropolitan areas in our sample. The figure illustrates the differential local area business cycles of three metropolitan areas as a matter of an example. Houston experienced an employment boom during the early 2000s, an a differential employment loss during the late 1980s. Similarly, the Volcker disinflation hit Detroit by more than New York.

We use the Romer and Romer (2004) shocks, extended to 2007 by Wieland and Yang (2020), as our measure of monetary policy shocks. We aggregate monthly shocks at the quarterly frequency. These shocks capture monetary policy changes that are free of the anticipatory movements of prices and economic activity inherent to monetary policy decisions. Figure 4 shows the shock over the sample time. Most of the variation in the Romer and Romer (2004) measure of monetary policy shocks comes from the Volcker disinflation, as pointed out by Coibion (2012). The variation after the Volcker desinflation is small compared with the experience before the 1980s. Since the Great Recession, the US policy rule has been often limited by the zero lower bound; so we stopped our analysis in 2008. In order to rank regions according to their income, we use data on personal income per capita from the BEA. The empirical estimation and results are presented in the next section.

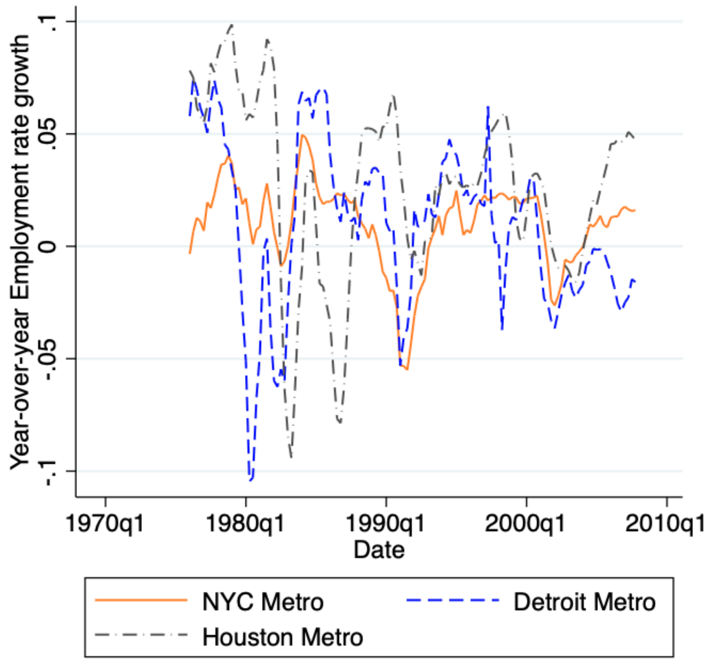
3 Empirical Strategy and Results

In this section, we present our empirical strategy to estimate the causal effect on prices and employment of a monetary policy shock across US metropolitan areas and our estimation results.

For a given price index in location i we compute the cumulative inflation rate between a reference period t and h periods in the future as

[3] Table A.1 in Appendix A.2 shows the correspondence between PSUs in the Price data and the FIPS codes in the QCEW data.

Figure 3: Employment Growth Across Metropolitan Areas



Note: In this figure we plot the behavior of 12-month employment growth at a quarterly frequency coming from the QCEW for three metropolitan areas: New York-Newark-Jersey City, NY-NJ-PA; Detroit-Warren-Dearborn, MI; Houston-The Woodlands-Sugar Land, TX.

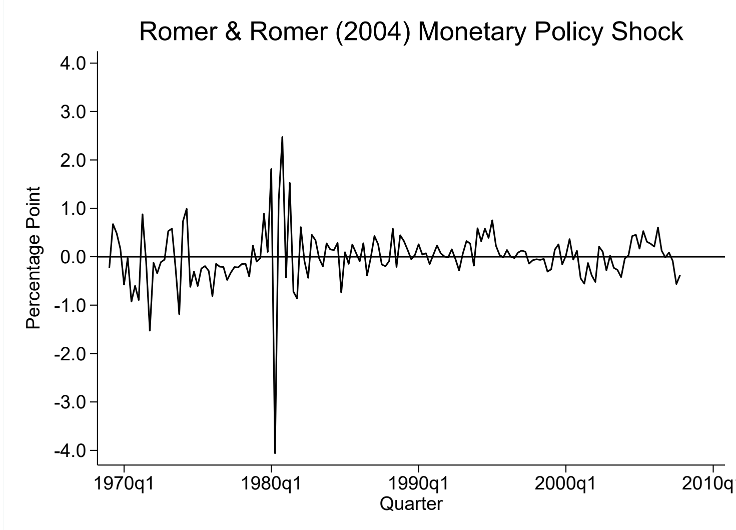
$$\pi_{i,t+h,t} = \frac{P_{i,t+h} - P_{i,t}}{P_{i,t}}.$$

To estimate the effect of a monetary policy shock on prices in the average city, we use a panel version of the Jorda (2005) local projection method with city fixed effects,

$$\pi_{i,t+h,t} = \alpha_i^h + \sum_{j=0}^{J} \beta^{h,j} RR_{t-j} + \sum_{k=0}^{K} \gamma^{h,k} \pi_{i,t,t-k} + \varepsilon_{i,t+h}^h \;\; \forall h \in [0, H], \tag{1}$$

where i is a city, t is the current period, and h denotes the number of quarters after the shock. The coefficient $\beta^{h,j}$ accounts for the cumulative effect of a monetary policy shock j periods ago RR_{t-j}, on inflation $\pi_{i,t+h}$ h periods in the future. α_i^h is a city fixed effect and $\varepsilon_{i,t+h}^h$ is the error

Figure 4: Romer and Romer (2004) Monetary Policy Shock



Note: The figure shows the Romer and Romer (2004) monetary policy shock added at the quarterly level.

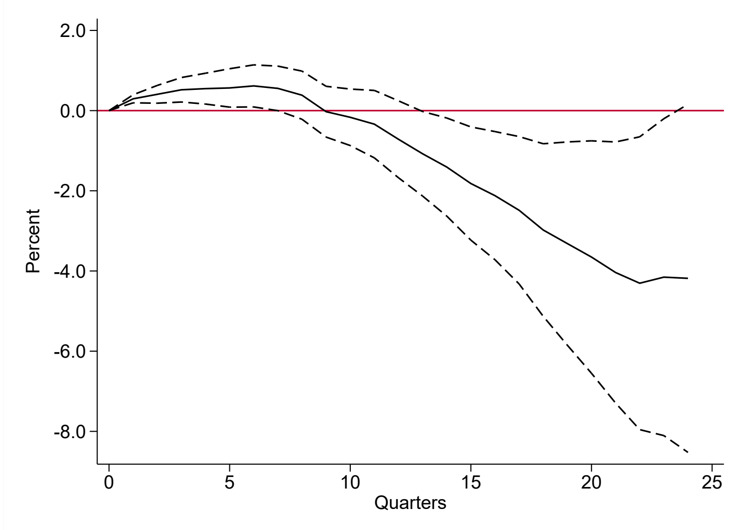
term. We cluster standard errors at the metro area and time level. This specification is a panel version of the lag-augmented local projections as in Montiel Olea and Plagborg-Møller (2021).

The terms $\beta^{h,0}$ trace the cumulative impulse response function on prices at horizon h after a monetary policy shock, controlling for city-specific inflation trends, past shocks, and the inflation dynamics prior to the shock. Figure 5 shows the estimated cumulative impulse response function of overall CPI inflation or, equivalently, the impulse response of prices, after a monetary policy shock that tightens rates by 1 percentage point, after estimating equation 1.

Our results are similar to the original Romer and Romer (2004) results obtained by running a regression of national CPI inflation on the monetary policy shock and controls at the aggregate level. The effect of a monetary policy shock on prices is positive and close to zero for the first two years, followed by a sharp decline, reaching a value of -6 percentage points after 20 quarters. Both the point estimate and the standard errors are similar to those obtained using aggregate data.

We turn our attention to the heterogeneous effects of monetary policy shocks across local economic areas in the United States. Our first approach is to run local projections for each individual location, computing the cumulative effect on prices of monetary policy shocks 8, 12,

Figure 5: Effect of Monetary Policy Shock on Prices - CPI



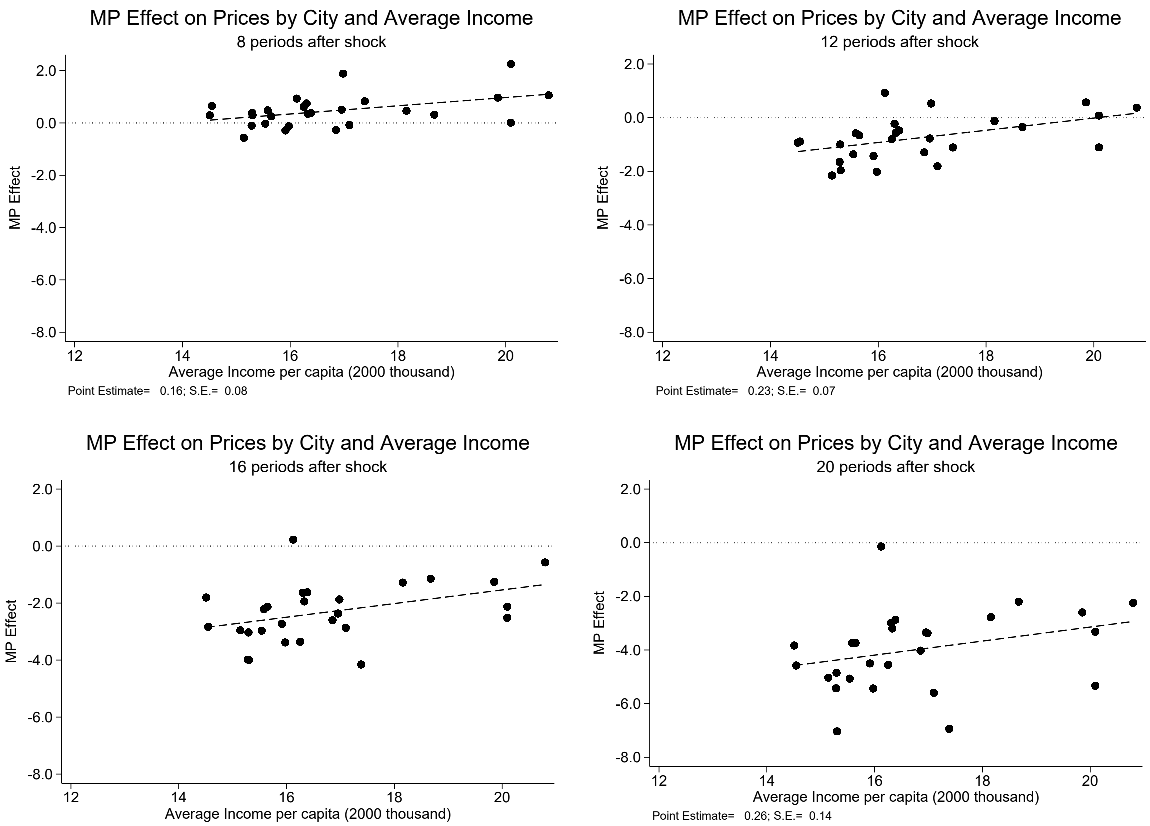
Note: The figure shows the results of equation (1) for the panel of cities. We use $H = 24$, $J = 8$, and $K = 8$. The dashed lines show 90 percent intervals. Standard errors are clustered at the city and time level.

16, and 20 quarters after the onset of the shock. To show our results systematically we plot our estimated effects in Figure , as a function of the income of each city expressed in thousands of dollars of the year 2000.

There is substantial heterogeneity across space and time in Figure (6). Two years after the shock (left top panel), the effects on prices of monetary policy shocks are small, and are increasing, a manifestation of the price puzzle. Three years after the shock (top right panel), poorer cities have accumulated a 2 percent drop in prices, while cities with higher income levels have experienced none. Four and five years after the shock, peak effects of the shocks materialize, with cumulative declines in prices of 2.5 percentage points after 4 years, and meaningful heterogeneity that correlates with city-average income levels.

In order to rank local areas, we use a transformed measure of real personal income per capita. We deflate nominal income per capita using the national CPI to avoid a mechanical correlation between regional real income per capita and regional inflation. Then, we regress real personal income per capita on time fixed effects and use the residual as our normalized measure of income. The interpretation of this residual is the difference in income between a

Figure 6: Effect of Monetary Policy Shock on Prices - CPI by Cities



Note: The figure shows the results of equation (1) for each individual metropolitan area. We use $J = 8$, and $K = 8$. The upper-left panel plots cumulative effects over 8 quarters, the upper-right panel 12 quarters, the lower-left panel 16 quarters and the lower-right panel 20 quarters.

specific city with respect to the average income across cities in our sample for a given year.[4]

Figure (6) presents the heterogeneity of the estimates across local regional areas, but fails to give a sense of the economic meaning, or the statistical differences across locations. Intuitively, each point in the scatter points above does not transmit information about the standard errors associated with the estimation of each local projections. However, it is reassuring that at each horizon, there is a positive relation between income and the size of price responses after monetary policy shock, which dictates our specification choices going forward.

[4]The decision to deflate income by the CPI avoids introducing additional heteroskedasticity in the data as the dispersion measured in current values increases along the time dimension. Our results are robust to not deflating nominal income by aggregate prices but still using the residuals of a regression of nominal income on time fixed effects.

We extend equation 1 to account for regional heterogeneity in terms of real income per capita, which we estimate by running a regression of local inflation rates on the monetary policy shocks, interactions between the monetary policy shock and real relative income per capita, and local area controls that are included in the information set at time t. Our specification uses the Blinder-Oaxaca decomposition on local projections as in Cloyne, Jorda, and Taylor (2020), applied to a panel setting. Formally, we estimate,

$$\pi_{i,t+h,t} = \alpha_i^h + \sum_{j=0}^{J} \beta^{h,j} RR_{t-j} + \sum_{j=0}^{J} \gamma^{h,j} RR_{t-j} \times RPIPC_{i,t-j-1} + \sum_{j=0}^{J} X'_{t-j}\theta^{h,j} + \varepsilon^h_{i,t+h} \;\; \forall h \in [0, H], \quad (2)$$

with

$$X_{t-j} = [RPIPC_{i,t-j-1} \;\; \pi_{i,t,t-j}],$$

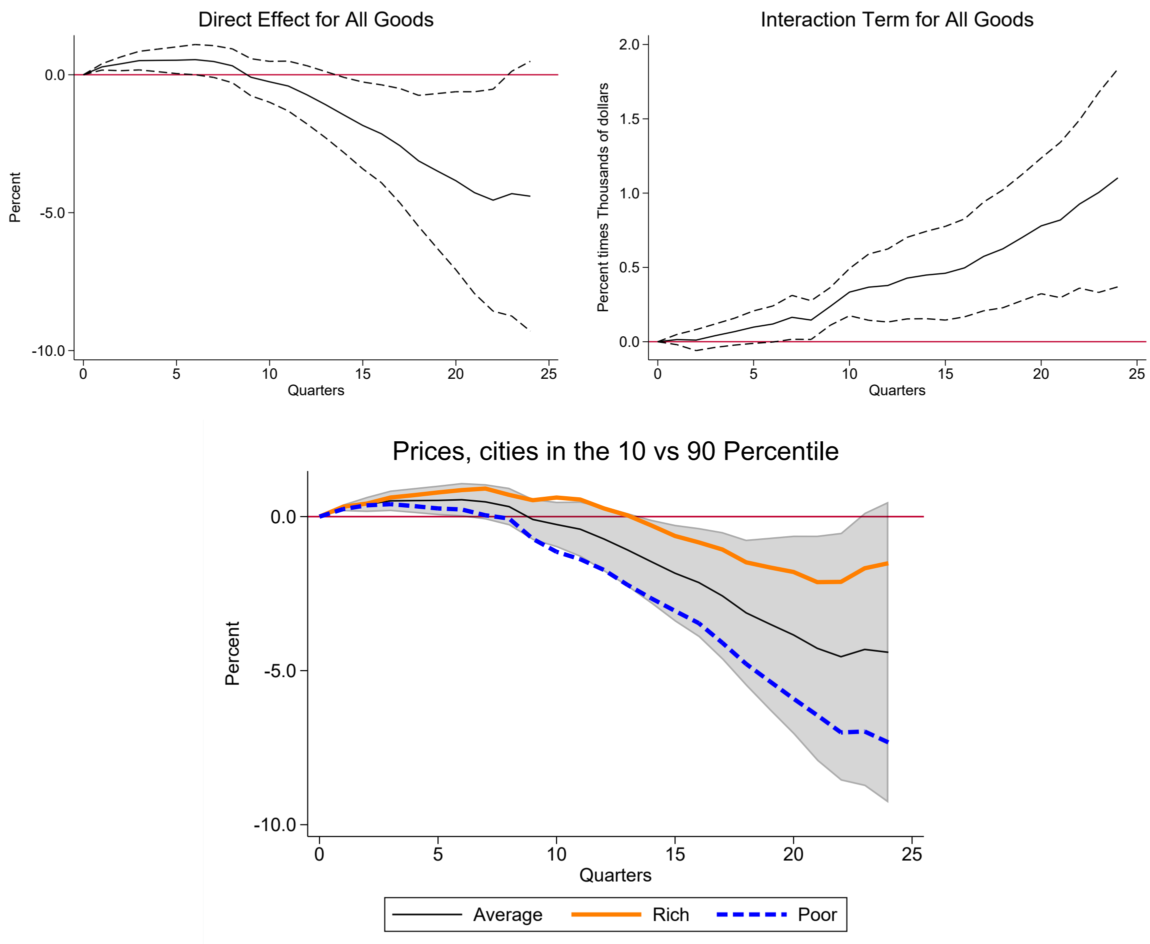
where $RPIPC_{i,t}$ is the relative personal income per capita in city i at time t, and π and RR represent the same objects as before.

The marginal effect of a monetary policy shock that occurs in period t on inflation in city i, h periods after the shock is given by $\beta^{h,0} + \gamma^{h,0} PIPC_{i,t-1}$. Since our income control does not vary with h, we do not use any variation in real income per capita caused by the monetary policy shock. Instead, we use pre-existing differences across metropolitan areas at the onset of the shock.

The top left panel of Figure 7 shows the impulse response of prices for a city of average income. Due to the normalization of real income per capita, the identity of the average city may change at different points in time. The interpretation of the top interaction term in the right panel is the additional effect on prices experienced by a city with real income that is $1000 (in the year 2000) higher than average, after a monetary policy shock of 1 percentage point. The main takeaway of the right panel is that a contractionary monetary policy shock causes a smaller decline in prices in richer cities compared to that in poorer areas. The differential effects are economically sizable; a city with an income per capita that is $1000 higher than the average gets 1.0 percentage point less cumulative inflation after a monetary policy shock of 1 percent after 20 quarters.

To illustrate further the economic relevance of our estimated heterogeneous effects, the bot-

Figure 7: Effect of Monetary Policy and Income Heterogeneity



Note: The top left and right panel of the figure shows the estimated coefficient $\hat{\beta}^h$ and $\hat{\gamma}^h$ from equation 2, respectively. We use $H = 24$, $J = 8$, and $K = 8$. The relative income per capita numbers are year 2000 dollars. The dashed lines show 90 percent intervals. Standard errors are clustered at the metropolitan area and time level. The bottom panel shows the point estimates of the impulse response for notional metropolitan areas in the 10th and 90th percentiles of the income distribution together with the average response coming from the top left panel. The 90th percentile of the distribution is USD 3,060 higher than the average annual income and the 10th percentile is USD 2,105 lower than the average annual income.

tom panel of Figure 7 shows the effect for cities in the 10th percentile of the income distribution versus cities in the 90th percentile, giving a sense of the quantitative importance of our result throughout the geographical distribution of income. A monetary policy shock of the same size causes an effect on prices almost 50 percent larger for cities in the 10th percentile of the distribution compared to the average, and 50 percent milder in the richer 90th percentile compared to the average. Among cities as rich as those in the 90th percentile of the income distribution, we fail to detect negative effects of monetary policy shocks on prices.

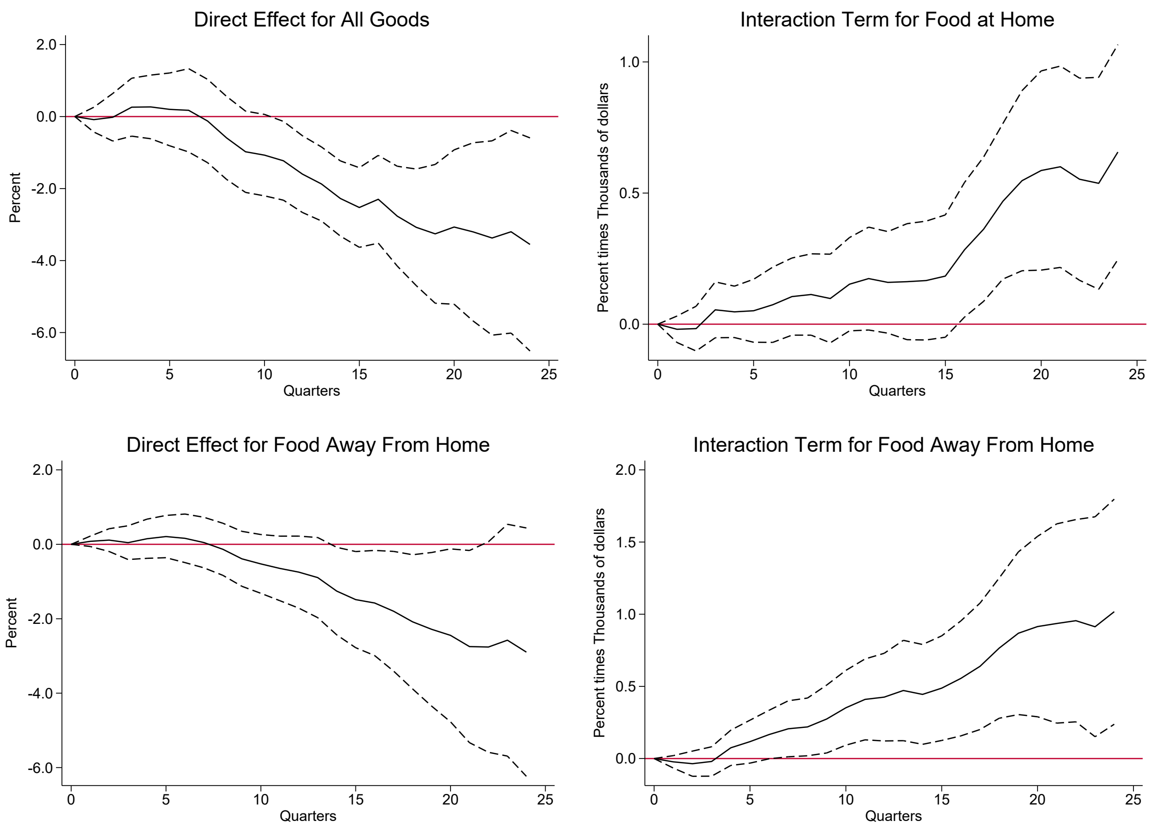
Although the effects for headline CPI are appealing, headline prices are not free of shortcomings. Since regions can vary in their expenditure weights, it could be the case that our results emerge from differences in weights rather than differences in the prices of different categories. The comparison of the sub-components of the CPI allows us to dig deeper into the mechanism behind our main results.

Our results hold across goods with a differential degree of tradeability, with larger differential effects for consumer categories that are closer to being non-traded. Figure 8 shows our estimated impulse responses for "food at home,", a category with a substantial tradeable component, and "food away from home," a category with a large non-tradeable component. In Appendix A.1, Figure A.1 shows similar results for "housing," which also has a large non-tradeable component due to the relevance of shelter in that consumption category. Figure 8 is in line with the intuition that the relative effects in the right panel should be larger for consumption categories that have a larger non-tradeable component to them, since intuitively, consumption and pricing of those goods depends more on local economic conditions.

We provide results for gasoline, a highly tradeable, homogeneous, flexible-price good, which we show in Figure 9. Gasoline has very flexible prices (see Nakamura and Steinsson (2008)), with a frequency of price change of once every month, and its price change behavior is dominated by national and world events, implying that our heterogeneous results as a share of the average results must be smaller. This is in fact what we find, although qualitatively prices react by less in regions with higher average income. We take these results as indicative that our findings are not driven by particular regional differences in technology, quality of goods, or the extent of nominal rigidities in a subset of goods.

As a robustness exercise we control for the sectoral composition of economic activity at the metropolitan area level. One alternative explanation could be that the difference across geographical areas arises because some sectors are more affected by monetary policy shocks than others, and there is sorting between income and sectoral composition. Figure A.2 in Appendix A.1 show the results. The effects are smaller, but still present even when we control for a vari-

Figure 8: Monetary Policy Shocks and Income Heterogeneity - By Tradeability



Note: The left panel shows the β^h coefficient and the right panel shows the γ^h coefficient of equation (2) for Food Away From Home. We use $H = 24$, $J = 8$, and $K = 8$. The dashed lines show 90 percent intervals. Standard errors are clustered at the city level.

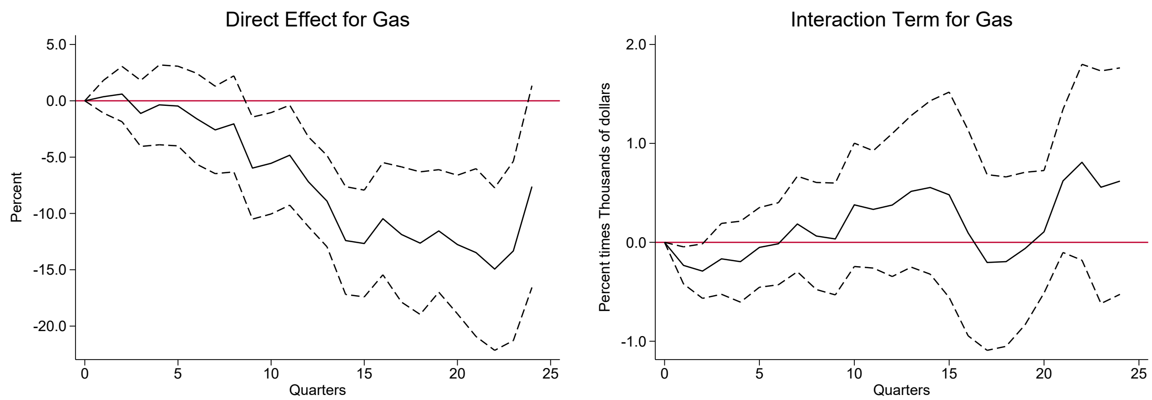
able that may be an outcome of differences of income levels across areas.

3.1 Economic Activity

Although the effects on prices are interesting on their own, to connect the evidence with economic mechanisms, it is important to discuss the differential effects of monetary policy on quantities. For example, a model in which regions are characterized by Phillips curves with slopes that are decreasing with income would create differential price responses in line with those we discussed in the previous section. However, that model would predict that quantities in rich regions would react by more, contrary to the evidence we will show in this section.

We estimate the effect of the Romer and Romer (2004) monetary policy shock on private

Figure 9: Effect of Monetary Policy Shock and Income Heterogeneity for Gas



Note: The left panel shows the β^h coefficient and the right panel shows the γ^h coefficient of equation (2) for gasoline (regular).We use $H = 24$, $J = 8$, and $K = 8$. The dashed lines show 90 percent intervals. Standard errors are clustered at the city level.

employment. We run a specification similar to equation (1), but with the percentage change of private employment as the dependent variable, given by

$$g^e_{i,t+h,t} = \alpha^h_i + \sum_{j=0}^{J} \beta^{h,j} RR_{t-j} + \sum_{k=0}^{K} \gamma^{h,k} g^e_{i,t,t-k} + \varepsilon^h_{i,t+h} \;\; \forall h \in [0, H], \tag{3}$$

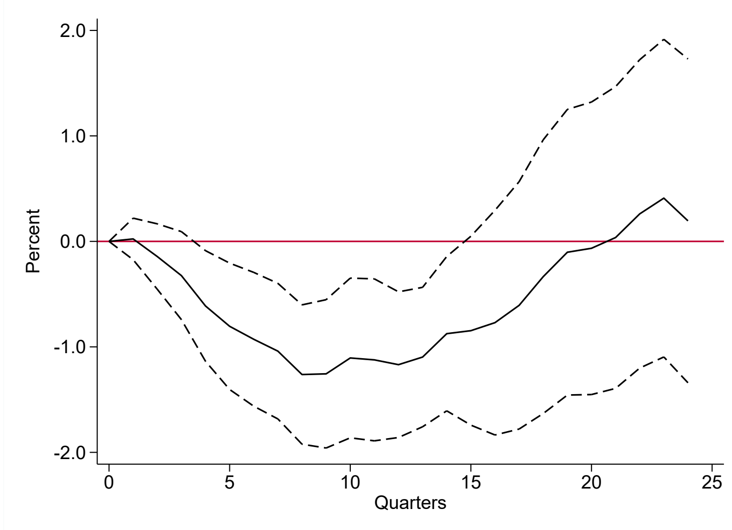
where $g^e_{i,t+h,t}$ is the cumulative employment growth in metropolitan area i between time t and $t + h$.

By estimating $\beta^{h,0}$ in equation 3 we trace the average cumulative impulse response function of private city employment at different horizons after a monetary policy shock that tightens rates by 1 percent.

The figure shows that there is a negative effect on employment after a contractionary monetary policy shock. This effect occurs faster than the effect on prices: After five quarters, there is a decrease in employment that lasts 10 quarters. This effect is significant; the maximum cumulative effect reaches a 1 percent decrease in private employment.

In a fashion similar to what we did for prices, we estimate relative effects by income by interacting the Romer and Romer (2004) shock with our measure of pre-existing city-level real

Figure 10: Effect of Monetary Policy Shock on Employment



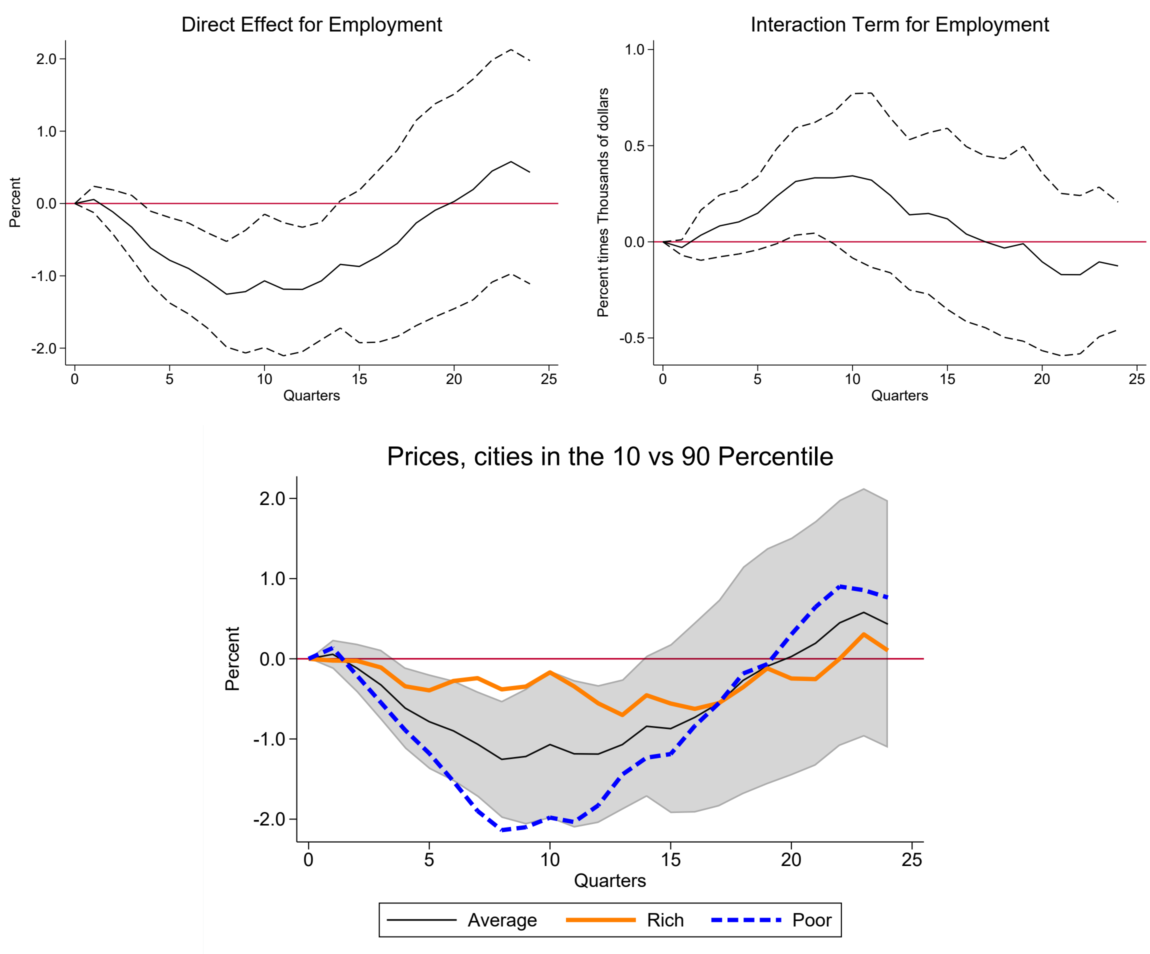
Note: The figure shows the results of equation (3) for the panel of cities. We use $H = 24$, $J = 8$ and $K = 8$. The dashed lines show 90 percent intervals. Standard errors are clustered at the city level.

personal income per capita. The upper panel of Figure 11 presents the direct and interaction effects. We estimate a significant effect of the interaction term that dampens the negative effects for richer cities. The interaction term goes in the opposite direction of the direct effect; richer cities have smaller relative employment declines when the direct effect is negative. When employment starts to recover on average, richer cities experience smaller improvements. These results imply slight variation in rich cities' employment compared with the effect in poor cities.

In order to illustrate the economic relevance of this result, the lower panel of Figure 11 shows the effect for a city in the 10th percentile of real relative income versus a city in the 90th percentile. Our results indicate that poor cities shape the national profile of employment effects. In fact, we are unable to find significant employment effects for cities as rich as those in the 90th percentile of the geographic income distribution. On the other side, cities as poor as those in the 10th percentile of the distribution have employment losses that are two times as large as those observed on average.

The figure shows that the richer city is not affected by the monetary policy shock during the first 15 quarters after the shock, while the poorer city has an effect of almost 2 percent at the

Figure 11: Effect of Monetary Policy Shock and Income Heterogeneity for Employment



Note: The top left and right panel show the estimated coefficients $b\hat{eta}^h$ $ga\hat{m}ma^h$, respectively when the left-hand side variable in equation (2) for private employment. We use $H = 24$, $J = 8$ and $K = 8$. The dashed lines show 90 percent intervals. Standard errors are clustered at the city and time level. The lower panel shows the point estimates $\beta^h + \gamma^h PIPC_{i,t+h}$ of equation (2) for metropolitan areas in the 90th and 10th percentiles of the geographic income distribution along with the average effects from the top left panel. The 90th percentile of the employment distribution is 4,755 USD (in 2000 dollars) higher than the average annual income, while the 10th is 3,596 USD (in 2000) lower than the average annual income.

peak, which is then compensated by an increase in employment after 15 quarters. In the first year, we see an effect in terms of employment, while the effect of a monetary policy shock on prices is small at that horizon. After three years, employment starts to recover. Poor cities drive national effects, as the effects of metropolitan areas with higher income is small throughout the horizon.

4 Discussion

Our results show that poorer cities see larger declines in prices after a contractionary monetary policy shock and larger declines in employment. This section discusses explanations behind these results and insights for the distributive effects within and across regions using our model.

4.1 Inequality Within and Across Borders

We first present a model of a monetary union in which monetary policy shocks induce differential regional responses. The model we will present has a large tradition in macroeconomics and is an extension of TANK models as in Bilbiie (2008) in a monetary union.

The model has two regions: Home and Foreign. Each region has two types of households: Ricardian and hand-to-mouth households Hand-to-mouth households are over-represented in regions with lower income per capita, as they have on average less income compared with Ricardian agents (Kaplan, Violante, and Weidner (2014); Aguiar, Bils, and Boar (2020)).

In this class of models, differential effects across regions after a monetary policy shock is induced via differences in the intertemporal IS curve; therefore, regional consumption has differential sensitivity to changes in real interest rates.

On the other side, the Phillips curve with real marginal costs as the driving variable has the same slope across regions. This is because every region faces the same degree of nominal rigidities, so there will not be any action coming directly from prices being more or less sticky. However, marginal costs will differ across firms due to assumptions of labor immobility across regions, home bias in consumer preferences, and variation in the share of hand-to-mouth households.

Home and Foreign regions are equal in population. A unit mass of Ricardian households populates the Foreign region. The Home region (H) is populated by both Ricardian (HR) and hand-to-mouth households (HH). The share of hand-to-mouth agents is denoted by λ and will be a key parameter in the model. Ricardian and hand-to-mouth households have the same preferences and supply homogeneous labor. Ricardian households save and own firms, and hand-to-mouth households consume their labor income at every point in time. Thus, labor markets are perfectly integrated within a region, and there is no labor mobility across regions.

Households have separable preferences for consumption and leisure that take a standard form,

$$U(C_{j,t}, L_{j,t}) = \frac{C_{j,t}^{1-\gamma}}{1-\gamma} - \psi \frac{L_{j,t}^{1+\alpha}}{1+\alpha},$$

with $j = \{HH, HR, F\}$.

Home Ricardian households maximize their discounted sum of expected utility

$$\max \sum_{t=0}^{\infty} E_0 \beta^t U(C_{HR,t}, L_{HR,t}),$$

subject to a sequence of budget constraints, given by

$$B_{HR,t+1}(1+i_t) + P_{H,t}C_{HR,t} \leq W_{H,t}L_{HR,t} + B_{HR,t} + \Pi_{H,t},$$

where $B_{HR,t}$ are the holdings of nominal bonds. i_t is the national nominal interest rate, common to Home and Foreign regions, and set by the monetary authority. $P_{H,t}$ is the consumer price index in the Home region, $C_{HR,t}$ is the consumption of the Ricardian agent, and $W_{H,t}$ is the nominal wage of the H region. $L_{HR,t}$ is the labor supply of the Ricardian agent. $\Pi_{H,t}$ are the profits of the firms in region H.

Hand-to-mouth households maximize the same utility function, but they do so subject to a static budget constraint that relates labor income to consumption expenditures,

$$P_{H,t}C_{HH,t} \leq W_{H,t}L_{HH,t}.$$

Regional consumption in the home region $C_{H,t}$ is the average of the consumption of both types of households, weighted by their population shares.

$$C_{H,t} = \lambda C_{HH,t} + (1-\lambda)C_{HR,t}.$$

Households have CES preferences over varieties produced in the Home and Foreign region with elasticity of substitution ν and potential home bias $\phi \geq 1/2$. Specifically

$$C_{j,t} = \left[\phi^{\frac{1}{\nu}} C_{j,H,t}^{\frac{\nu-1}{\nu}} + (1-\phi)^{\frac{1}{\nu}} C_{j,F,t}^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}},$$

with $j = \{HH, HR\}$ and,

$$C_{F,t} = \left[\phi^{\frac{1}{\nu}} C_{F,F,t}^{\frac{\nu-1}{\nu}} + (1-\phi)^{\frac{1}{\nu}} C_{F,H,t}^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}}.$$

In the last expression $C_{i,k,t}$ is the consumption of agent i of goods produced in region k, which is a CES aggregate of a continuum of varieties with an elasticity of substitution η,

$$C_{i,k,t} = \left(\int_0^1 C_{i,k,t}(z)^{\frac{\eta-1}{\eta}} dz \right)^{\frac{\eta}{\eta-1}}.$$

There is a continuum of firms in each region producing tradable varieties. Each firm faces demand coming from the three types of consumers,

$$Y_{j,t}(z) = \lambda C_{HH,j,t}(z) + (1-\lambda) C_{HR,j,t}(z) + C_{F,j,t}(z),$$

with $j = \{H, F\}$.

Firms produce using a linear production function in labor and are subject to regional productivity shocks, $Y_t(z) = A_t L_t(z)$. Real marginal costs, denoted MC, expressed in terms of domestic prices are common across firms within a region, and equal to $MC_t = \frac{W_t}{P_{Ht}} \frac{1}{A_t}$.

The price-setting problem of these firms is very standard. Firms can set their prices freely with probability $(1-\theta)$, and must keep their prices unchanged with probability θ, as in Calvo (1983). Firms set prices equal to a markup over the weighted discounted sum of nominal marginal costs. Up to first-order approximation, the optimal price-setting rule, consists of a price $\bar{p}_{Ht}$ that depends on regional prices, real marginal costs, the discount factor β, and the probability that firms may not adjust their prices θ, according to

$$\bar{p}_{Ht} = (1-\beta\theta) \sum_{k=0}^{\infty} (\beta\theta)^k \, \mathbb{E}_t \left[mc_{t+k} + p_{H,t+k} \right]. \tag{4}$$

The Phillips curve in Home and Foreign regions has the same slope, κ,

$$\pi_{Ht} = \beta \mathbb{E}_t \pi_{H,t+1} + \kappa mc_{Ht} \quad (5)$$

$$\pi_{Ft} = \beta \mathbb{E}_t \pi_{F,t+1} + \kappa mc_{Ft} \quad (6)$$

with $j = \{H, F\}$, where $mc_{j,t}$ is the average marginal cost in region j and $\kappa = \frac{(1-\theta\beta)(1-\theta)}{\theta}$ is a coefficient that captures the extent of nominal rigidities.

The risk-sharing condition states that consumption of the Ricardian household in the Home region and consumption of households in the Foreign region obey the following relationship,

$$\left(\frac{C_{HR,t}}{C_{F,t}}\right)^{\gamma} \vartheta_0 = \frac{P_{F,t}}{P_{H,t}}$$

where ϑ_0 is constant and equal to 1 when Home and Foreign regions have the same productivity in the long run. ϑ_0 captures the current expectations of price and quantity differentials in the infinite future.

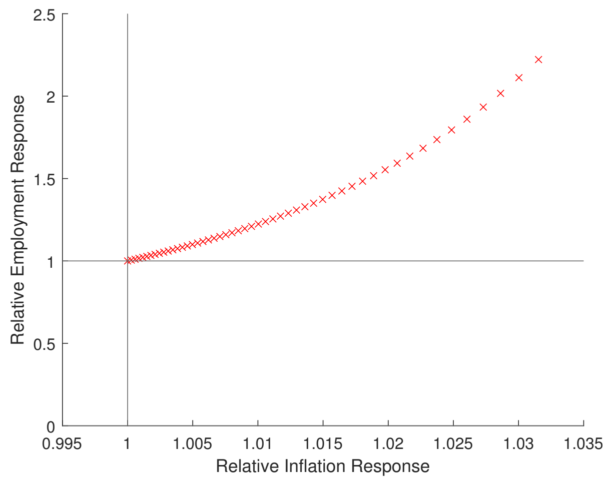
There is a single monetary authority for the monetary union that sets an interest rate i_t according to a monetary policy rule that takes into account national inflation and output in both economies, and a monetary policy shock ε_t,

$$i_t = \phi_\pi(\pi_{Ht} + \pi_{Ft}) + \phi_y(y_{Ht} + y_{Ft}) + \varepsilon_t.$$

This model generates heterogeneous regional responses after a monetary policy innovation. Regions with a higher proportion of hand-to-mouth consumers will suffer a higher drop in employment and prices after a contractionary monetary policy shock, in line with our estimated responses in US data.

Figure 12 shows the relative effect of a monetary policy shock on prices and employment between the Home and Foreign regions. We will present the result of these alternative models using a series of scatterplots. The x-axis of each scatterplot will show the present value of the impulse response function of prices in the Home region relative to the present value of the impulse response of prices in the Foreign region. The y-axis will be analogous but for the employment responses rather than for prices. Each point in the scatterplot will correspond to a model with a different value for the parameter of interest in the Home region. The calibration for the Foreign region is kept fixed.

Figure 12: Relative Price and Employment Responses - Fraction of Hand-to-Mouth Consumers



Note: This figure shows the relative behavior of regional prices, on the x-axis, and employment, on the y-axis, after a national monetary policy shock. The source of regional heterogeneity is the share of hand-to-mouth households (λ). Relative inflation and employment are computed as the ratio between the discounted cumulative impulse response functions of each variable in the Home region divided by the analogous object in the Foreign region. A value of 1 means that the Home and Foreign regions have responses of the same magnitude in present value. Each point of the scatterplot represents the solution of a model with a different value of λ. The calibrations that underlie the figure are presented in Appendix A.3.

Our results do not arise due to lower labor supply after a monetary policy shock from hand-to-mouth households. The labor supply decisions in the Home region are given by

$$\psi L^{\alpha}_{Hj,t} C^{\gamma}_{Hj,t} = \frac{W_{Ht}}{P_{Ht}}, \text{ for } j \in [H, R]. \tag{7}$$

For the case of hand-to-mouth households, plugging in the budget constraint, and solving for the labor supply yields

$$L_{HHt} = \left(\frac{1}{\psi}\right)^{\frac{1}{\gamma+\alpha}} \left(\frac{W_{Ht}}{P_{Ht}}\right)^{\frac{1-\gamma}{\gamma+\alpha}}. \tag{8}$$

Equation 8 makes clear that the co-movement of labor supply decisions of hand-to-mouth households and the real wage depends on whether the intertemporal elasticity of substitution is smaller, equal, or greater than 1. For the case of log-utility, hand-to-mouth households' labor supply is acyclical. However, for the standard case where $\gamma > 1$ the amount of labor supplied by hand-to-mouth households is countercyclical. In this case, hand-to-mouth households compensate for lower real wages by supplying more hours, the only available means they have to smooth consumption.

Due to labor immobility across regions, monetary policy in the model induces changes in labor supply decisions across household types within regions, not only across regions. This model implies that the differences in employment found in the empirical part are not necessarily due to poor households reducing their employment more. In this case, the drop in employment in the poorer region comes from Ricardian agents. The model predicts that the regional employment differences are even bigger if we compare Ricardian agents across borders.

4.2 Alternative Interpretation of Empirical Results

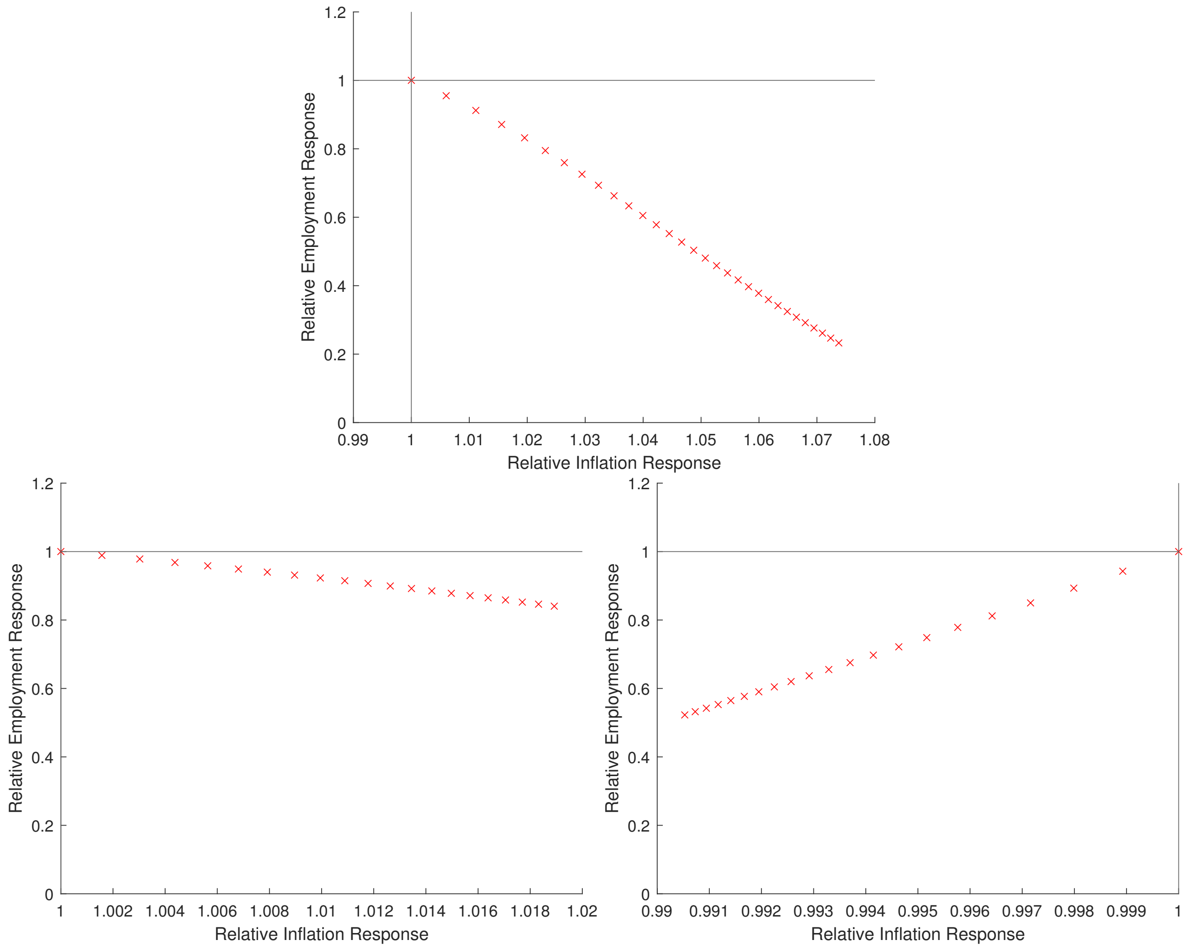
We evaluate whether other margins of variation across regions can produce results like the one found in the empirical section of this paper.

We present results from two-region New Keynesian models of an open economy in which geographical heterogeneity arises from different alternative mechanisms, the extent of nominal rigidities, the elasticity of labor supply, and the intertemporal elasticity of substitution. We set the fraction of hand-to-mouth households λ to zero. We will present the main takeaways of these exercises in this section. The details on the calibration of the models are in Appendix A.4.

The exercise we will perform will be analogous to our main exercise in the previous section. For each economic mechanism highlighted above, we will compare the impulse response of inflation and employment of Home and Foreign economies to a monetary policy shock. Home and Foreign economies are symmetric except for the one particular dimension (nominal rigidities, elasticity of labor supply, elasticity of intertemporal substitution) that we will vary. Each of these margins of heterogeneity will induce differential impulse responses across regions.

The first alternative explanation for our facts is that high-income local economies have a flatter Phillips curve than low-income ones. This alternative explanation is unsatisfactory. Intuitively, if all the action was coming from heterogeneity in the sensitivity of inflation to marginal costs, regions with larger price responses would be closer to monetary neutrality. This finding is the opposite of what we find in the empirical section; regions with larger price responses have larger real responses as well.

Figure 13: Relative Price and Employment Responses



Note: These figures show the relative behavior of regional prices, on the x-axis, and employment, on the y-axis, after a national monetary policy shock. The source of regional heterogeneity is variation in the extent of nominal rigidities (upper panel), elasticity of labor supply (lower left panel) and the intertemporal elasticity of substitution (lower right panel). Relative inflation and employment are computed as the ratio between the discounted cumulative impulse response functions of each variable in the Home region divided by the analogous object in the Foreign region. A value of 1 means that Home and Foreign regions have responses of the same magnitude in present value. Each point of the scatterplot represents the solution of a model with different variations in the extent of nominal rigidities, labor supply or intertemporal elasticity of substitution. The calibrations that underlie the figure are in Appendix A.4.

The equilibrium response of the model confirms this intuition. Figure 13, upper panel shows the relative behavior of inflation versus the relative behavior of employment. The scatterplot traces a downward sloping curve, and every point is in the second and fourth quadrant of the figure. The interpretation is that when regional heterogeneity is induced by variation in nominal rigidities, regions with relatively high inflation responses have relatively low employment responses. This result is the opposite of what we document empirically; regions with relatively high inflation responses have relatively high employment responses.

The second alternative we consider is that the driver of heterogeneity is differences in labor supply elasticity. Variation in the elasticity of labor supply across regions induces changes in marginal costs. So although the sensitivity of inflation to real marginal costs is the same across regions with different elasticities of labor supply, the reaction of inflation to demand shifts will be different across regions.

This intuition explains why Figure 13, upper panel, is qualitatively similar to the lower left panel. The frequency of price changes and the elasticity of labor supply affect the slope of the Phillips curve. So models in which these margins drive regional heterogeneity imply that economies in which inflation is more sensitive to monetary policy shocks should be closer to monetary neutrality.

A final alternative is that regional heterogeneity is driven by differences in the intertemporal elasticity of substitution. The case of the intertemporal elasticity of substitution is a priori less evident, since variation in this margin will introduce cross-sectional changes in the intertemporal IS curve and in the Phillips curve via changes in the behavior of real marginal costs.

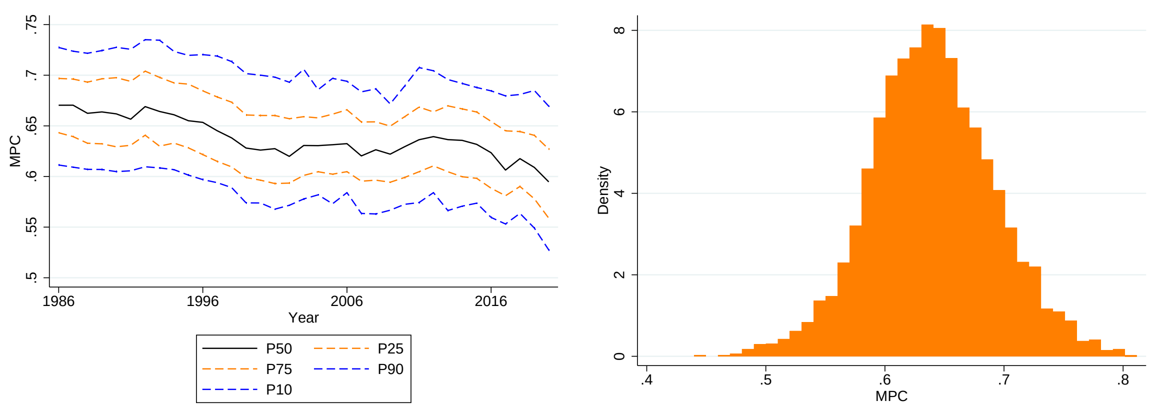
Figure 13, lower right panel, shows that cross-sectional variation in the intertemporal elasticity of substitution creates a pattern counter to the ones we have presented before and in line with those in the data. In fact, the monetary union TANK model we presented before aims to introduce the same variation as reduced-form heterogeneity in intertemporal elasticity of substitution across regions. By placing a fraction of the population out of their Euler equation, the TANK model changes the effective intertemporal elasticity of substitution.

5 Aggregate Implications

In Section 3, we showed that the average relative income of a city is a relevant margin of heterogeneity for the local effects of monetary policy shocks on employment and prices. We showed our results are consistent with a model of a monetary union where regions differ in their share of hand-to-mouth (HtM) households. Aguiar, Bils, and Boar (2020) and Patterson (2019) show a large negative correlation of HtM (or high MPC consumers) with income at the individual level.

We use estimates of the relationship between income and MPCs produced by Patterson (2019) to characterize the average MPCs across cities in the US. Figure 14 shows the evolution of MPCs for US cities since 1986 and their distribution.

Figure 14: Distribution of MPCs in the US over Time



Note: These figures show the distribution of the marginal propensity to consume across US metropolitan areas and over time. We use the estimates from Patterson (2019) and compute them for each metropolitan area at every period of time. The left panel shows the evolution over time for the mean (solid black), 25th and 75th percentile (orange dashed) and 10th and 90th percentile (blue dashed) between 1986 and 2020. The right panel is a histogram that shows the complete distribution of values and their density for all periods of time and year.

The median of the distribution has been relatively stable over time, with a slight decrease in recent years, but there is substantial heterogeneity across US cities. This section explores whether the heterogeneity of regional MPCs and the different shares of hand-to-mouth consumers that heterogeneity implies affect the aggregate effect of monetary policy shocks. We will run counterfactuals that vary the dispersion in the share of HtM households across locations keeping the national share of HtM households constant. We will use the model presented in Section 4.1 to back out the relevance of geographical heterogeneity in determining aggregate outcomes.

We impute the relationship between MPCs and income to individual earnings data from the CPS using estimates by Patterson (2019). We have a panel of MPCs for 177 metropolitan areas from 1986 to 2020.[5] We use our model to obtain the share of hand-to-mouth households in each metropolitan area (λ_i), and compute the 90th and 10th percentiles of the distribution, using that the MPC out of transitory income from HtM consumers is equal to 1 and that of Ricardians consumers is $(1-\beta)$, effectively backing out the value for λ.

We use a labor supply elasticity α equal to 0.5, close to micro estimates, summarized by Chetty et al. (2011), a home bias parameter (ϕ) of 0.8, an intertemporal elasticity of substitution γ of 1, a Calvo parameter θ of 0.75, a discount factor β of 0.995, an elasticity of substitution between goods produced locally and in the other region ν of 1.5, and policy parameters for the Taylor rule of $\phi_y = 0.5$ and $\phi_\pi = 1.5$.

We simulate the model using two regions keeping the national average λ constant, but varying its geographical dispersion. Table 1 shows the results of the simulations.

Table 1: Simulation of Heterogeneous and Homogeneous Monetary Union

	Heterogeneity			Homogeneity		
	Region 1	Region 2	Aggregate	Region 1	Region 2	Aggregate
Share of HtM	0.702	0.579	0.640	0.640	0.640	0.640
Employment	-0.898	-0.554	-0.726	-0.671	-0.671	-0.671
Inflation	-0.105	-0.078	-0.091	-0.085	-0.085	-0.085

Note: This table shows the effect on impact (first period, in percentages) on employment and prices of a 1 percent monetary policy shock. Both simulations have an average share of HtM of 0.64. Columns 2 to 4 (heterogeneity) show the effect of the shock in an economy with heterogeneous values of HtM across regions. Results are shown for each individual region (columns 2 and 3) and the aggregate effect (column 4). Columns 5 to 7 show the same effects, but for an economy where regions have the same share of HtM.

The main message of Table 1 is that heterogeneity amplifies the effect of monetary policy shocks. Amplification arises due to the non-linear effects of the share of hand-to-mouth consumers described in Bilbiie (2020). After a contractionary monetary policy shock, Ricardian

[5]The start date is determined by changes in the geographical sampling of the CPS and our intention to have a balanced panel of metropolitan areas.

agents reduce consumption and labor supply, reducing real wages in the local region. The effect on real wages makes hand-to-mouth (HtM) consumers reduce their spending as they consume exclusively from their labor income. The reduction in local wages, common for a given region by our assumption of integrated local labor markets, produces an additional decrease in demand in the local economy that depends on the share of hand-to-mouth households. This additional effect reduces marginal costs, increasing profits and producing an income effect.[6]

This effect depends critically on the labor supply elasticity (α in our model), and it is non-linear in the share of hand-to-mouth. The higher the share of HtM, the higher the effect in absolute value and at an increasing rate. Because of this non-linearity, the average effect is also larger in absolute value when there is a region with a higher share of HtM compared to the average. Therefore, the higher the dispersion of HtM, the higher the effect will be. Heterogeneity across regions amplifies the effect of monetary policy on both employment and prices.

6 Conclusions

This paper documents the differential regional effects on real and nominal variables of monetary policy shocks in the US. We estimate that monetary policy shocks induce larger effects on both prices and employment in poorer cities. The results for prices hold for overall prices and for a wide range of inflation categories.

We evaluate which economic mechanisms driving regional heterogeneity can rationalize our results. We propose a model in which regions are characterized by a different fraction of hand-to-mouth consumers. By affecting the sensitivity of consumption to real interest rates, the model rationalizes the larger employment and price responses we estimate in the data. On the contrary, models in which regions are characterized by differential slopes of the Phillips curve fail to rationalize our findings, since they would imply lower employment responses in regions with higher price responses.

The effects we estimate are economically large and suggest an important challenge for the monetary authority, since the power of its main tool varies across regions. This challenge is compounded for the case in which regions have differential exposure to the underlying shocks, as in trade shocks (Autor, Dorn, and Hanson (2016)), or government spending shocks (Naka-

[6] See Bilbiie (2008) for details on the conditions for this equilibrium.

mura and Steinsson (2014)).

Our results highlight the potential role of fiscal policy in generating the same aggregate effects as those induced by monetary policy, but with different local effects, as studied in the literature of equivalence results between monetary and fiscal policies (Wolf (2021)). Along that same line, the results of this paper highlight the potential complementary role of fiscal policy in correcting undesirable distributional effects of monetary policy.

References

Aguiar, Mark A., Mark Bils, and Corina Boar. 2020. "Who are the Hand-to-Mouth?" Working paper 26643, National Bureau of Economic Research. DOI https://doi.org/10.3386/w26643.

Andersen, Asger Lau, Niels Johannesen, Mia Jorgensen, and Jose-Luos Peydro. 2021. "Monetary Policy and Inequality." Working Paper 1761, Department of Economics and Business, Universitat Pompeu Fabra. DOI https://ideas.repec.org/p/upf/upfgen/1761.html.

Auclert, Adrien. 2019. "Monetary Policy and the Redistribution Channel." *American Economic Review* 109 (6):2333–67. DOI https://doi.org/10.1257/aer.20160137.

Autor, David H., David Dorn, and Gordon H. Hanson. 2016. "The China Shock: Learning from Labor-Market Adjustment to Large Changes in Trade." *Annual Review of Economics* 8:205–240. DOI https://doi.org/10.1146/annurev-economics-080315-015041.

Beraja, Martin, Andreas Fuster, Erik Hurst, and Joseph Vavra. 2019. "Regional Heterogeneity and the Refinancing Channel of Monetary Policy." *The Quarterly Journal of Economics* 134 (1):109–183. DOI https://doi.org/10.1093/qje/qjy021.

Bergman, Nittai, David A. Matsa, and Michael Weber. 2022. "Inclusive Monetary Policy: How Tight Labor Markets Facilitate Broad-Based Employment Growth." Working Paper 29651, National Bureau of Economic Research.

Bilbiie, Florin O. 2008. "Limited asset markets participation, monetary policy and (inverted) aggregate demand logic." *Journal of Economic Theory* 140 (1):162–196. DOI https://doi.org/10.1016/j.jet.2007.07.008.

———. 2020. "The New Keynesian cross." *Journal of Monetary Economics* 114:90–108. DOI https://doi.org/10.1016/j.jmoneco.2019.03.003.

Calvo, Guillermo A. 1983. "Staggered prices in a utility-maximizing framework." *Journal of Monetary Economics* 12 (3):383–398. DOI https://doi.org/10.1016/0304-3932(83)90060-0.

Chetty, Raj, Adam Guren, Day Manoli, and Andrea Weber. 2011. "Are Micro and Macro Labor

Supply Elasticities Consistent? A Review of Evidence on the Intensive and Extensive Margins." *American Economic Review* 101 (3):471–75. DOI https://doi.org/10.1257/aer.101.3.471.

Cloyne, James, Clodomiro Ferreira, and Paolo Surico. 2020. "Monetary Policy when Households have Debt: New Evidence on the Transmission Mechanism." *The Review of Economic Studies* 87 (1):102–129. DOI https://doi.org/10.1093/restud/rdy074.

Cloyne, James, Oscar Jorda, and Alan Taylor. 2020. "Decomposing the Fiscal Multiplier." *Federal Reserve Bank of San Francisco Working Paper, 2020-12* DOI https://doi.org/10.24148/wp2020-12.

Coibion, Olivier. 2012. "Are the Effects of Monetary Policy Shocks Big or Small?" *American Economic Journal: Macroeconomics* 4 (2):1–32. DOI https://www.aeaweb.org/articles?id=10.1257/mac.4.2.1.

Coibion, Olivier, Yuriy Gorodnichenko, Lorenz Kueng, and John Silvia. 2017. "Innocent Bystanders? Monetary policy and inequality." *Journal of Monetary Economics* 88:70–89. DOI https://doi.org/10.1016/j.jmoneco.2017.05.005.

Cravino, Javier, Ting Lan, and Andrei A. Levchenko. 2018. "Price stickiness along the income distribution and the effects of monetary policy." *Journal of Monetary Economics* 110:19–32. DOI https://doi.org/10.1016/j.jmoneco.2018.12.001.

Doepke, Matthias and Martin Schneider. 2006. "Inflation and the Redistribution of Nominal Wealth." *Journal of Political Economy* 114 (6):1069–1097. DOI https://doi.org/10.1086/508379.

Furceri, Davide, Prakash Loungani, and Aleksandra Zdzienicka. 2018. "The effects of monetary policy shocks on inequality." *Journal of International Money and Finance* 85:168–186. DOI https://doi.org/10.1016/j.jimonfin.2017.11.004.

Hazell, Jonathon, Juan Herreño, Emi Nakamura, and Jón Steinsson. 2022. "The Slope of the Phillips Curve: Evidence from US States." *The Quarterly Journal of Economics* DOI https://doi.org/10.1093/qje/qjac010.

Jorda, Oscar. 2005. "Estimation and Inference of Impulse Responses by Local Projections."

American Economic Review 95 (1):161–182. DOI http://www.aeaweb.org/articles?id=10.1257/0002828053828518.

Kaplan, Greg, Benjamin Moll, and Giovanni L. Violante. 2018. "Monetary Policy According to HANK." *American Economic Review* 108 (3):697–743. DOI https://doi.org/110.1257/aer.20160042.

Kaplan, Greg, Giovanni L. Violante, and Justin Weidner. 2014. "The Wealthy Hand-to-Mouth." Working Paper 20073, National Bureau of Economic Research. DOI https://doi.org/10.3386/w20073.

Montiel Olea, José Luis and Mikkel Plagborg-Møller. 2021. "Local projection inference is simpler and more robust than you think." *Econometrica* 89 (4):1789–1823. DOI https://doi.org/10.3982/ECTA18756.

Nakamura, Emi and Jón Steinsson. 2008. "Five Facts about Prices: A Reevaluation of Menu Cost Models." *The Quarterly Journal of Economics* 123 (4):1415–1464. DOI https://doi.org/10.1162/qjec.2008.123.4.1415.

———. 2014. "Fiscal stimulus in a monetary union: Evidence from U.S. regions." *American Economic Review* 104 (3):753–92. DOI https://10.1257/aer.104.3.753.

Patterson, Christina. 2019. "The Matching Multiplier and the Amplification of Recessions." Unpublished Manuscript, Northwestern University.

Romer, Christina D. and David H. Romer. 2004. "A New Measure of Monetary Shocks: Derivation and Implications." *American Economic Review* 94 (4):1055–1084. DOI http://www.aeaweb.org/articles?id=10.1257/0002828042002651.

Wieland, Johannes F and Mu-Jeung Yang. 2020. "Financial Dampening." *Journal of Money, Credit and Banking* 52 (1):79–113.

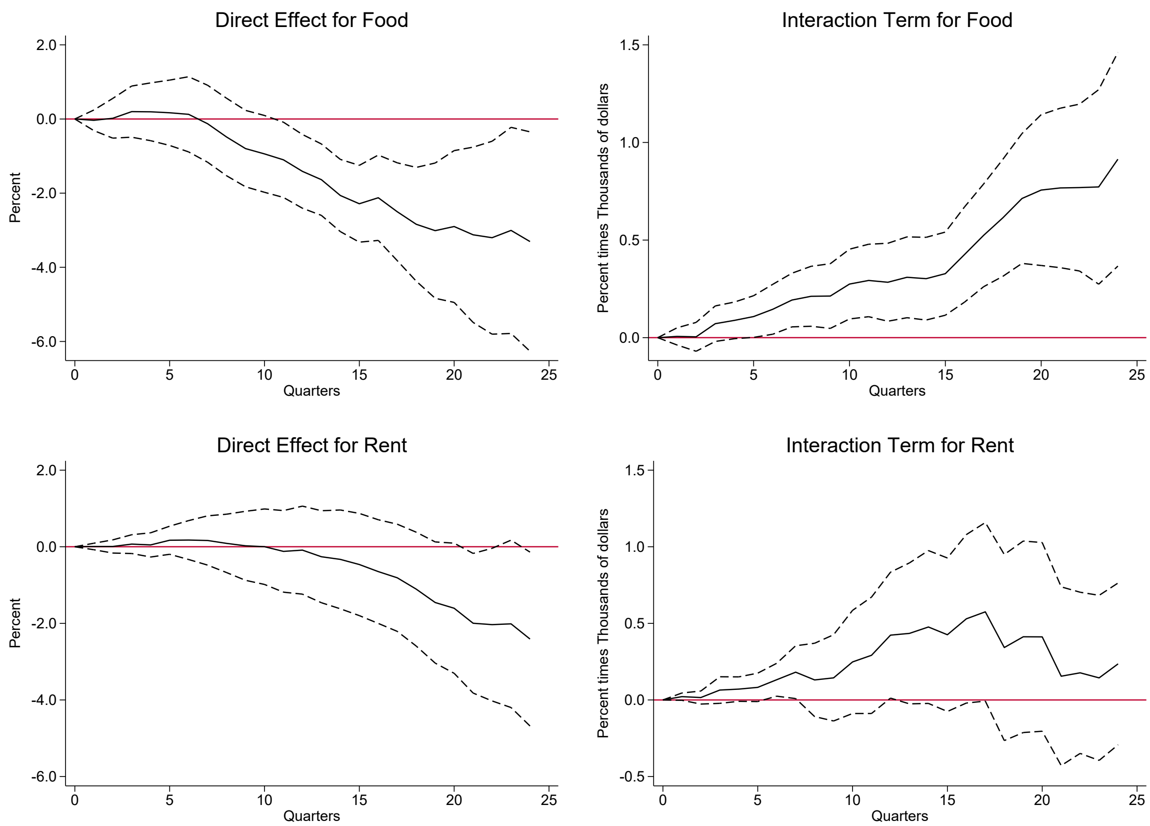
Wolf, Christian. 2021. "Interest rate cuts vs. stimulus payments: An equivalence result." Working paper 29193, National Bureau of Economic Research. DOI https://doi.org/10.3386/w29193.

Wong, Arlene. 2021. "Refinancing and the Transmission of Monetary Policy to Consumption." Working paper 2021-57, Princeton University. DOI https://ideas.repec.org/p/pri/econom/2021-57.html.

A Appendix

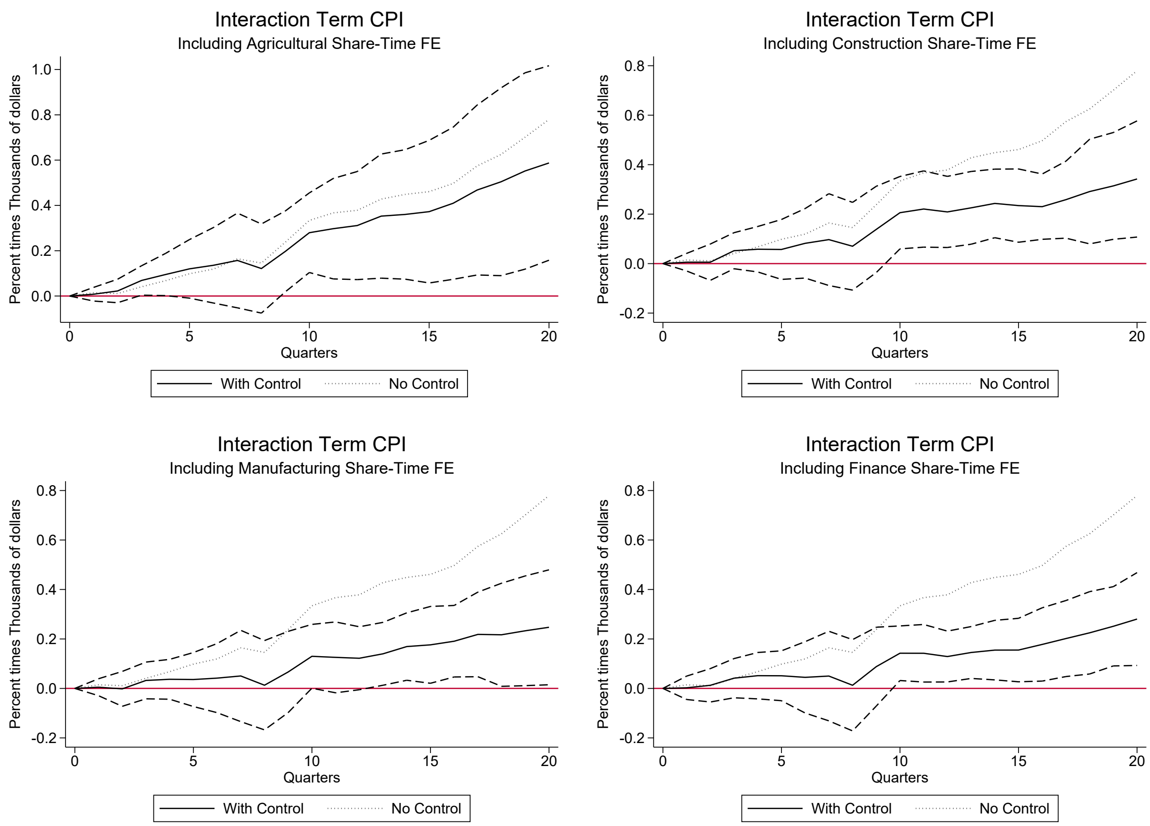
A.1 Additional Figures

Figure A.1: Effect on Narrow Price Indexes



Note: The left panel shows the β^h coefficient and the right panel shows the γ^h coefficient of equation (2) for different price indexes. We use $H = 20$, $J = 8$ and $K = 8$. The dashed lines show 90 percent intervals. Standard errors are clustered at the city level.

Figure A.2: Effect on Narrow Price Indexes



Note: Each figure shows the baseline regression for CPI inflation, controlling by a time fixed effect interacted by the share of employment in the sector indicated in each graph for each city. Agriculture is sector SIC A. Construction is sector SIC C. Manufacturing is sector SIC D and Finance is sector SIC H. We use $H = 20$, $J = 8$ and $K = 8$. The dashed lines show 90 percent intervals. Standard errors are clustered at the city and time level. The dot line shows the baseline regression result.

A.2 Correspondence CPI and QCEW

To merge the CPI and employment data, we get the counties according to the FIPS code that match the PSU zones. The PSU zones have changed over time, so we take the larger set of counties, as adding or removing counties would change employment as well. We keep the numbers of counties constant over the sample. Table A.1 shows the correspondence, with the PSU codes and name and FIPS codes.

Table A.1: Commuting zone and equivalent FIPS codes

PSU 18	PSU 98	Name	FIPS			
S11A	A103	Boston-Cambridge-Newton (MA-NH)	25009	25025	25013	23031
			25017	33015	25027	9015
			25021	33017	33011	
			25023	25005	33013	
S12A	A101	New York-Newark-Jersey City (NY-NJ-PA)	34003	34031	36061	42103
			34013	34035	36071	34021
			34017	34037	36079	34041
			34019	34039	36081	9001
			34023	36005	36085	9005
			34025	36027	36087	9007
			34027	36047	36103	9009
			34029	36059	36119	
S12B	A102	Philadelphia-Camden-Wilmington(PA-NJ-DE-MD)	10003	34015	42045	34009
			24015	34033	42091	34011
			34005	42017	42101	
			34007	42029	34001	
S23A	A207	Chicago-Naperville-Elgin (IL-IN-WI)	17031	17089	17197	18127
			17037	17093	18073	55059
			17043	17097	18089	17091
			17063	17111	18111	
S23B	A208	Detroit-Warren-Dearborn, (MI)	26087	26125	26049	26161
			26093	26147	26091	
			26099	26163	26115	
S24A	A211	Minneapolis-St. Paul-Bloomington (MN-WI)	27003	27053	27123	27163
			27019	27059	27139	27171
			27025	27079	27141	55093
			27037	27095	27143	55109
S24B	A209	St. Louis (MO-IL)	17005	17117	29071	29189
			17013	17119	29099	29510
			17027	17133	29113	28149
			17083	17163	29183	29055
S35A		Washington-Arlington-Alexandria (DC-MD-VA-WV)	11000	51510	51061	51179
			24009	51013	51630	51187
			24017	51043	51107	51685
			24021	51047	51153	54037
			24031	51600	51157	
			24033	51610	51177	
S35E		Baltimore-Columbia-Towson (MD)	24003	24510	24025	24035
			24005	24013	24027	

Table A.2: Commuting zone and equivalent FIPS codes (cont)

PSU 18	PSU 98	Name	FIPS			
S35B	A320	Miami-Fort Lauderdale-West Palm Beach (FL)	12011	12025	12086	
S35C	A319	Atlanta-Sandy Springs-Roswell (GA)	13013	13085	13149	13227
			13015	13089	13151	13231
			13035	13097	13159	13247
			13045	13113	13171	13255
			13057	13117	13199	13297
			13063	13121	13211	
			13067	13135	13217	
			13077	13143	13223	
S35D	A321	Tampa-St. Petersburg-Clearwater (FL)	12053	12057	12101	12103
S37A	A316	Dallas-Fort Worth-Arlington (TX)	48085	48221	48367	48497
			48113	48231	48397	
			48121	48251	48425	
			48139	48257	48439	
S37B	A318	Houston-The Woodlands-Sugar Land (TX)	48015	48157	48291	
			48039	48167	48339	
			48071	48201	48473	
S48A	A429	Phoenix-Mesa-Scottsdale (AZ)	4013	4021		
S48B	A433	Denver-Aurora-Lakewood (CO)	8001	8019	8039	8093
			8005	8031	8047	8013
			8014	8035	8059	8123
S49A		Los Angeles-Long Beach-Anaheim (CA)	6037	6059		
S49C		Riverside-San Bernardino-Ontario(CA)	6065	6071		
S49B	A422	San Francisco-Oakland-Hayward (CA)	6001	6075	6085	6097
			6013	6081	6087	
			6041	6055	6095	
S49D	A423	Seattle-Tacoma-Bellevue (WA)	53033	53061	53035	
			53053	53029	53067	
S49E	A424	San Diego-Carlsbad (CA)	6073			
S49F	A426	Urban Hawaii	15003			
S49G	A427	Urban Alaska	2020	2170		
	A104	Pittsburgh (PA)	42003	42019	42125	
			42007	42051	42129	
	A213	Cincinnati-Hamilton (OH-KY-IN)	18029	21077	39015	39165
			18115	21081	39017	
			21015	21117	39025	
			21037	21191	39061	
	A210	Cleveland-Akron (OH)	39007	39055	39093	39133
			39035	39085	39103	39153
	A212	Milwaukee-Racine (WI)	55079	55101	55133	
			55089	55131		
	A425	Portland-Salem (OR-WA)	41005	41047	41053	41071
			41009	41051	41067	53011
	A214	Kansas City (MO-KS)	20091	20209	29049	29165
			20103	29037	29095	29177
			20121	29047	29107	

A.3 TANK Monetary Union

In this appendix we present the log-linearized equations that characterize the model explained in Section 4.1. In the following equations, lower case represents deviation from the steady state, other than for the case of the price index $P_{j,t}$ and the inflation of the price index $\Pi_{j,t}$, to differentiate it from the price of the good produced in j, $p_{j,t}$ and the price inflation $\pi_{j,t}$.

$$\pi_{H,t} = \kappa mc_{H,t} + \beta \pi_{H,t+1}$$

$$\pi_{F,t} = \kappa mc_{F,t} + \beta \pi_{F,t+1}$$

$$c_{HR,t} = -\frac{1}{\gamma}(i_t - \Pi_{H,t+1}) + c_{HR,t}$$

$$c_{HH,t} = w_{H,t} - P_{H,t} + l_{HH,t}$$

$$-\gamma c_{HR,t} + \gamma c_{F,t} = P_{H,t} - P_{F,t}$$

$$i_t = \phi_\pi(\Pi_{H,t} + \Pi_{F,t}) + \phi_y(y_{H,t} + y_{F,t}) + e_t$$

$$P_{H,t} = \phi p_{H,t} + (1-\phi)p_{F,t}$$

$$P_{F,t} = \phi p_{F,t} + (1-\phi)p_{H,t}$$

$$\Pi_{H,t} = P_{H,t} - P_{H,t-1}$$

$$\Pi_{F,t} = P_{F,t} - P_{F,t-1}$$

$$\pi_{H,t} = p_{H,t} - p_{H,t-1}$$

$$\pi_{F,t} = p_{F,t} - p_{F,t-1}$$

$$mc_{H,t} = \alpha y_{H,t} + (\gamma - (1/\nu))c_{H,t} + (1/\nu)(\lambda c_{HH,H,t} + (1-\lambda)c_{HR,H})$$

$$mc_{F,t} = \alpha y_{F,t} + (\gamma - (1/\nu))c_{F,t} + (1/\nu)c_{FF,t}$$

$$y_{H,t} = \lambda l_{HH,t} + (1-\lambda)l_{HR,t}$$

$$\gamma c_{HR,t} + \alpha l_{HR,t} = w_{H,t} - P_{H,t}$$

$$\gamma c_{HH,t} + \alpha l_{HH,t} = w_{H,t} - P_{H,t}$$

$$-c_{FF,t} + c_{FH,t} = \nu(p_{F,t} - p_{H,t})$$

$$-c_{HH,H,t} + c_{HH,F,t} = \nu(p_{H,t} - p_{F,t})$$

$$-c_{HR,H,t} + c_{HR,F,t} = \nu(p_{H,t} - p_{F,t})$$

$$c_{H,t} = \lambda c_{HH,t} + (1-\lambda) c_{HR,t}$$

$$c_{HH,t} = \phi c_{HH,H,t} + (1-\phi) c_{HH,F,t}$$

$$c_{HR,t} = \phi c_{HR,H,t} + (1-\phi) c_{HR,F,t}$$

$$c_{F,t} = \phi c_{FF,t} + (1-\phi) c_{FH,t}$$

$$y_{H,t} = \lambda \phi c_{HH,H,t} + (1-\lambda)\phi c_{HR,H,t} + (1-\phi) c_{FH,t}$$

$$y_{F,t} = \phi c_{FF,t} + \lambda(1-\phi) c_{HH,F,t} + (1-\lambda)(1-\phi) c_{HR,F,t}$$

$$\varepsilon_t = \rho \varepsilon_{t-1} + e_t$$

We consider values of $\beta = 0.99$, $\alpha = 1.0$, $\eta = 4$, $\rho = 0$, $\gamma = 1$, $\theta = 0.9$, $\phi_\pi = 1.5$, $\phi_y = 0.5$ and $\nu = 3$, $\phi = 0.85$. The values of λ go between 0 and 0.5.

A.4 Alternative New Keynesian Models

We simplify the model used in Section 4. In this case, we assume $\lambda = 0$, but we allow for regional heterogeneity in the parameters of the model. The model is characterized by the following equations:

$$\pi_{Ht} = \beta \mathbb{E}_t \pi_{H,t+1} + \kappa_H mc_{Ht} \tag{9}$$

$$\pi_{Ft} = \beta \mathbb{E}_t \pi_{F,t+1} + \kappa_F mc_{Ft} \tag{10}$$

with

$$mc_{Ht} = \alpha_H y_{H,t} + \left(\gamma_H - \frac{1}{\nu}\right) C_{H,t} + \left(\frac{1}{\nu}\right) C_{H,H,t} \tag{11}$$

$$mc_{Ft} = \alpha_F y_{F,t} + \left(\gamma_F - \frac{1}{\nu}\right) C_{F,t} + \left(\frac{1}{\nu}\right) C_{F,F,t} \tag{12}$$

where $C_{k,j,t}$ is the consumption of region k on region j good in time t. Since here $\lambda = 0$, there are only Ricardian agents; then the IS curve is characterized by:

$$C_{H,t} = -\frac{1}{\gamma_H} \left(i_t - E_t \Pi_{H,t+1}\right) + E_t C_{H,t+1} \tag{13}$$

For region F, we replace that condition with the risk-sharing condition (does not really matter which one we replace).

$$\gamma_H C_{H,t} - \gamma_F C_{F,t} = P_{F,t} - P_{H,t} \tag{14}$$

Finally, we have a national monetary policy rule that symmetrically weights both regions:

$$i_t = \phi_\pi(\pi_{Ht} + \pi_{Ft}) + \phi_y(y_{Ht} + y_{Ft}) + \varepsilon_t.$$

In Section 4, we allow for differences in the intertemporal elasticity of substitution γ_i, extent of nominal rigidities κ_i and the elasticity of labor supply α_i.

The values for α and γ we consider are values between 1 and 3. The values for θ that we consider are between 0.6 and 0.9. The benchmark values for these parameters for the Foreign region, which we keep fixed, are $\alpha = 1$, $\gamma = 1$, and $\theta = 0.75$.