The Regional Keynesian Cross[‡]

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Abstract

We study the transmission of monetary policy across space in a heterogeneous agents New Keynesian (HANK) model of a monetary union. Using sequence-space methods, we derive the *regional Keynesian cross*: a characterization of the response of local employment to unexpected changes in interest rates along two dimensions of spatial heterogeneity: (i) openness to national trade and (ii) intertemporal marginal propensities to consume (iMPCs). At the core of our mechanism is an equilibrium complementarity between these two channels, which we validate in the data. We provide an aggregation result and derive the *national Keynesian cross* that summarizes the role of the joint distribution of regional iMPCs and trade openness across space for the nation-wide response to aggregate shocks. We provide empirical support for our theory using detailed county-level data and identified monetary surprises for the United States. Our main result is that the joint regional distribution of county-level openness to national trade and iMPCs is crucial for the amplification of monetary shocks and the potency of fiscal stabilization policies.

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1 Introduction

This paper studies the transmission of monetary policy across space. Empirically, we document that U.S. monetary policy surprises, identified with the high-frequency approach, induce local employment responses that vary substantially across U.S. counties. Two characteristics go a long way in accounting for this observable heterogeneity: local non-tradable to tradable employment ratio and local stock market wealth. We find that counties with either high non-tradable employment or low wealth are more responsive to monetary policy. Crucially, these two channels are jointly significant, both economically and statistically.

Guided by our empirical results, we develop a heterogeneous agents New Keynesian (HANK) model of a monetary union with two layers of regional heterogeneity: household intertemporal marginal propensities to consume (iMPCs) and openness to national trade, defined as the ratio of non-tradable to tradable goods produced in a given county. We derive a general equilibrium regional variant of the canonical Keynesian-cross-like representation, which we label the *regional Keynesian cross*. Our formula shows that the first-order response of local employment to changes in interest rates can be decomposed into three channels: intertemporal substitution, expenditure switching, and a regional multiplier. We express these three channels analytically as a simple function of iMPCs and the non-tradable share of the wage bill using a sequence-space representation (Mankiw and Reis, 2006, Boppart et al., 2018, Auclert et al., 2021a).

Our theoretical result can speak to the *intertemporal* Keynesian cross (Auclert et al., 2018), the *New Keynesian* cross (Bilbiie, 2020), and the *international* Keynesian cross (de Ferra et al., 2020, Auclert et al., 2021b). Crucially, our framework moves beyond the elegant convenience of two agent New Keynesian (TANK) models where a fixed fraction of households are non-Ricardian (Campbell and Mankiw, 1989, Galí et al., 2007, Bilbiie, 2008). Instead, each region in our multi-region economy is populated by a continuum of households, each endogenously featuring different iMPCs like in the standard HANK literature and in line with the powerful finding in Hagedorn et al. (2019) that incomplete markets and a full distribution of households are essential elements to analyze the magnitude of MPCs and of the macroeconomic propagation of shocks.

A key mechanism in our model is a novel complementarity between iMPCs and regional openness to trade, which arises from the equilibrium interactions between the local share of non-tradable employment and the standard demand-side channel of the HANK literature. In particular, within our framework, the extent to which large iMPCs amplify the local response to aggregate shocks is increasing in the share of non-tradable employment, and vice-versa. This complementarity is a testable prediction for which we provide evidence in the data, thus validating a key model mechanism. Extensions to our baseline setup allow for reactions from the fiscal authority and aggregate demand from the rest of the nation.

We move beyond the regional Keynesian cross representation by aggregating the continuum of counties in our economy into an expression that we label the *national Keynesian cross*. We provide an intuitive and tractable decomposition of the response of aggregate employment with respect to monetary shocks into four components: the standard Keynesian cross, heterogeneity in the openness to national trade, heterogeneity in local iMPCs, and the complementarity term that links openness to trade and household wealth. Crucially, a complete characterization of the national macroeconomic response is only possible in a model that captures *both* household and openness to trade heterogeneity. Failure to incorporate either of the two elements leads to model mis-specification because the complementarity term –which is essential both in the data and in our theory– would then be lost. We complete the paper by discussing how our work relates to other recent developments in the literature.

Our theoretical and empirical results are important for at least two reasons. First, in the highly influential optimal currency area (OCA) literature (pioneered by Mundell (1961), McKinnon (1963), and Kenen (1969)) it is often assumed that symmetric demand shocks can be handled by the monetary authority while asymmetric shocks require fiscal stabilization. However, we find that monetary policy itself induces asymmetric responses across different counties within a currency area. Moreover, as we show in our model, the ability of policy to stabilize local economic activity is dampened the more open to national trade a region is, i.e., the lower non-tradable employment is. This is in stark contrast to the seminal idea of McKinnon (1963) that openness to trade alleviates the costs of monetary unions and is, in fact, in line with the powerful insights of Farhi and Werning (2016a, 2017): economic stabilization is more effective if regions are less open to inter-regional trade.

Second, our findings are important for the large and ever-growing literature that bridges together incomplete markets, cross-sectional heterogeneity, and nominal rigidities (Werning, 2015, Auclert, 2019). In particular, the influential HANK literature emphasizes the importance of heterogeneity in households' MPCs, which is closely linked to the cross sections of liquid wealth and disposable income (McKay and Reis, 2016, Kaplan et al., 2018). Our theoretical and empirical results, on the other hand, suggest that in order to rationalize the dynamics which is observed in the data, it is important to account for a second layer of heterogeneity: openness to national trade. As we emphasize throughout the paper, modelling both channels of heterogeneity at the same time leads to multiple novel implications.

Literature Our paper contributes to several different literature strands. First and foremost, we contribute to the literature that embeds incomplete-markets economies (Bewley, 1977, Huggett, 1990, Aiyagari, 1994, Imrohoglu, 1996) into environments with nominal rigidities (see, e.g., Werning (2015) and Auclert (2019) for a general treatment).[1] In particular, we develop a HANK model of a monetary union with two-layered regional heterogeneity and use it to study the regional and aggregate economic effects of demand-driven fluctuations.

Second, our framework and analysis are conceptually related to the optimal currency area (OCA) literature (Mundell, 1961, McKinnon, 1963, Kenen, 1969, Alesina et al., 2002, Kenen and Meade, 2008). Specifically, important ideas that we touch upon in the context of U.S. regional dynamics are openness to trade (McKinnon, 1963), factor mobility across counties (Blanchard and Katz, 1992), and fiscal integration and stabilization policies (Farhi and Werning, 2016a, 2017). In doing so, our modelling approach is heavily inspired by Farhi and Werning (2017)'s treatment of fiscal unions. Our framework presents a tractable nexus between the above two literature strands which in large part emphasize, respectively, the role of cross-sectional heterogeneity in wealth and openness to trade (or, alternatively, home bias). In fact, an absolutely crucial component of our narrative is the interaction between openness to national trade and household wealth –a complementarity that we capture both in the model and in the data.

Third, our paper builds on the new open-economy macroeconomics literature (Obstfeld and Rogoff, 1995, Galí and Monacelli, 2005, Rey, 2013, Miranda-Agrippino and Rey, 2022). Our theoretical framework is, methodologically, essentially a continuum of small open *counties* which are modelled in the spirit of the Galí and Monacelli (2005, 2008) small open economy setup. Our solution characterization is in the sequence space, an approach developed and popularized in the works of Mankiw and Reis (2006), Boppart et al. (2018), and Auclert et al. (2021a). Fourth, our empirical analysis complements studies that elicit macroeconomic and/or partial equilibrium elasticities in response to policy shocks (not

[1] Some prominent studies include Mankiw and Reis (2002, 2006) Bilbiie (2008), Kaplan and Violante (2014), Farhi and Werning (2016b, 2017), Challe et al. (2017), Debortoli and Galí (2018), Kaplan et al. (2018), Auclert (2019), Bilbiie (2020), Auclert et al. (2018, 2020, 2021a), Aguiar et al. (2020), Bayer et al. (2020), Ottonello and Winberry (2020), de Ferra et al. (2020), Lee et al. (2020), Ravn and Sterk (2020), Luetticke (2021), Bilbiie (2021), Guo et al. (2022), Schaab and Tan (2022), Druedahl et al. (2022), Bayer et al. (2022), Bilbiie et al. (2022), Bellifemine et al. (2022), and Acharya et al. (2023) among others. See Krueger et al. (2016) and Kaplan and Violante (2022) for a through analysis and summary of the literature with an emphasis on household heterogeneity.

limited to those by the monetary authority) from regional data, often in combination with structural modelling (Nakamura and Steinsson, 2014, Chodorow-Reich, 2019).[2] Last but not least, our paper contributes to a growing body of work that studies how monetary policy operates across space, building on Carlino and Defina (1998) who, to the best of our knowledge, are the first to provide empirical evidence on differential regional effects of U.S. monetary policy.[3]

2 Empirical Analysis

In this section we first present the data used in our analysis. We then document heterogeneity in the regional responses of employment to monetary shocks across U.S. counties. Next, we show that two characteristics can jointly account for the observed geographical heterogeneity: (i) stock market wealth per capita, which we interpret as a proxy for local *MPCs*, and (ii) *openness to national trade*, which we measure as the local ratio of employment in non-tradable industries to employment in tradable industries.

2.1 Data

Employment Our main data source is the Local Area Unemployment Statistics (LAUS) from the Bureau of Labor Statistics. The LAUS register is a non-survey based dataset which combines multiple data sources to provide monthly employment estimates for different levels of regional disaggregation. These estimates are constructed to match those that would be obtained from surveying a representative sample. In what follows, we focus on county-level employment.[4]

We obtain annual county-level employment for 4-digit North American Industry Classification System (NAICS) sectors from the County Business Patterns (CBP) dataset published by the U.S. Census. Data before 1998 are based on the SIC industry classification. Hence, we link SIC sectors to NAICS according to the SIC-NAICS concordance tables provided by the U.S. Census. We then classify 4 digit-NAICS sectors into tradable and non-tradable industries according to the standard definition proposed by Mian and Sufi

[2] Some relevant examples include Beraja et al. (2019), Guren et al. (2020), Chodorow-Reich et al. (2021), Holm et al. (2021), Wolf (2021a,b), Dupor et al. (2023), Hazell et al. (2022), Beraja and Wolf (2022), Patterson (2022), McCrory (2022), among others. See Chodorow-Reich (2020) for a comprehensive discussion.

[3] Other notable studies include Adam and Zhu (2016), Corsetti et al. (2021), Adam et al. (2022), Almgren et al. (2022), De Ridder and Pfajfar (2017), Fornaro and Romei (2022), Hauptmeier et al. (2020), Bergman et al. (2022), and Herreño and Pedemonte (2022).

[4] As of 2020, there were 3,143 counties across the 50 U.S. states. Our dataset comprises a total of 3,120 counties, 92.50% of which are present in all months of the sample.

(2014).

Next, for each county j and each year t in our dataset we define our baseline trade openness variable as the non-tradable to tradable employment ratio $\rho_{jt} \equiv L_{jt}^{NT}/L_{jt}^{T}$, where L_{jt}^{NT} represents the total number of people working in non-tradable sectors in county j and year t, while L_{jt}^{T} is the total number of people employed in tradable sectors in the same county-year unit. Panel (a) of Figure A.1 in Appendix A.1 ranks U.S. counties according to their non-tradable to tradable employment ratio ρ_{jt}, averaged across all years in our sample.

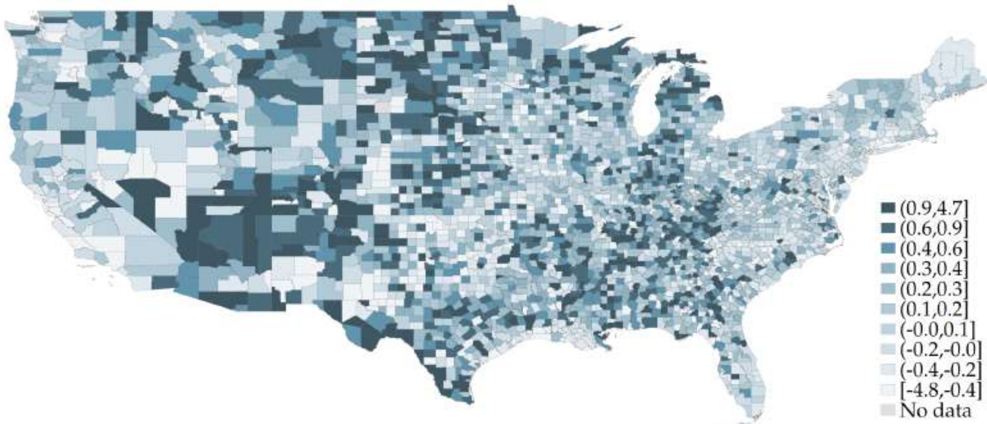
Wealth Our county-level data on stock market wealth come from Chodorow-Reich et al. (2021). This measure of wealth is obtained by applying an improved version of the canonical capitalization method to data on taxable dividend income aggregated at the county level.[5] We construct an annual measure of stock market wealth per capita, spanning the years 1989-2015, by using county population data from the U.S. Census. Panel (b) of Figure A.1 in Appendix A.1 ranks U.S. counties based on their real stock market wealth per capita, averaged over the whole time sample.

Monetary policy In order to capture monetary policy surprises, we follow the high-frequency identification approach.[6] Specifically, following Gurkaynak et al. (2005) and Gertler and Karadi (2015) we use the change in the 3-month ahead Fed Funds futures within a 30 minute window around FOMC announcements as our baseline instrument for monetary shocks. For robustness, we also employ the narrative instrument approach as proposed in Romer and Romer (2000) and updated by Miranda-Agrippino and Rey (2020). Finally, we also consider a measure that is robust to the information content of policy announcements, as constructed by Miranda-Agrippino and Ricco (2021) and Degasperi and Ricco (2021). Throughout the rest of our analysis, we normalize the sign of the measure of monetary shocks ε_t such that positive values are associated with *expansionary* monetary policy. Moreover, we also normalize ε_t to have a standard deviation of unity.

[5]We refer the reader to Chodorow-Reich et al. (2021) for a thorough description of the construction of stock wealth data.

[6]See, among others, Kuttner (2001), Gurkaynak et al. (2005), Bernanke and Kuttner (2005), Campbell et al. (2012), Gertler and Karadi (2015), Gorodnichenko and Weber (2016), Nakamura and Steinsson (2018), Jarocinski and Karadi (2020), Bauer and Swanson (2022).

Figure 1: Regional Heterogeneity in the Effects of U.S. Monetary Policy



Note: This figure plots the 3-year ahead county-specific cumulative employment responses to a 1 standard deviation expansionary monetary policy shock $\beta_{j,36}$, estimated from the panel local projection (1). The coefficients are in percentage points and represent deviations from the (population weighted) average response.

2.2 Regional Responses to Monetary Shocks

Geographic heterogeneity We document substantial heterogeneity in the response of employment to monetary shocks across U.S. counties. To do so, we estimate a panel version of the Jordà (2005) local projection.[7] In particular, for each county j and month t in our sample, and for horizons $h = 0, ..., 36$, we run the following regression:

$$\Delta \log(L_{j,t+h}) = \alpha_{jh} + \delta_{th} + \beta_{jh} \times \varepsilon_t + \sum_{\ell=1}^{12} \gamma_{h\ell} \Delta \log(L_{j,t-\ell}) + u_{jht} \tag{1}$$

Where $\Delta \log(L_{j,t+h}) = \log(L_{j,t+h}) - \log(L_{j,t-1})$ represents the h-month ahead cumulative change in employment in county j, α_{jh} is a county fixed effect, while δ_{th} denotes a time fixed effect. Finally, $\Delta \log(L_{jt-\ell}) = \log(L_{j,t-1}) - \log(L_{j,t-\ell-1})$ denotes past county-level employment growth, while ε_t is the monetary surprise.

Figure 1 shows the county-specific coefficients β_{jh} estimated from (1) for a 3-year ahead horizon, $h = 36$. Because they represent individual deviations from the population-weighted average response, the coefficients are centered around zero. Figure 1 documents a large degree of cross-county heterogeneity in the employment response to monetary shocks. In particular, some counties experience an increase in employment up to 4.7 percentage points larger than the average response, while for others the change in employment is up to 4.8 p.p. smaller than the average county. Furthermore, the heterogeneity uncovered in Figure 1 does not seem to be randomly distributed across regions. On

[7] For consistency with the rest of the analysis, our regression results are weighted by county population in the year 2000.

the contrary, there appears to be some geographical clustering in the distribution of the county-specific response to shocks. For this reason, we next turn to analyzing the potential factors underlying this heterogeneity, and on the implications for economic theory.

Explaining geographic heterogeneity We now explore whether some fundamental county-level economic characteristics are able to account for the observed regional heterogeneity displayed in Figure 1. In particular, we show that local MPCs and industry composition – proxied respectively by stock market wealth per capita and the ratio of employment in non-tradable to tradable industries – are two important drivers of the heterogeneity in the regional response to monetary policy.

Economic theory suggests that MPCs play a crucial role in the transmission of monetary policy.[8] However, MPCs are a challenging object to estimate in the data. First, because identified exogenous variations in household's income are rare. Second, because it is often difficult to get access to household-level expenditure data at a sufficiently high frequency. Moreover, our research question requires a sufficiently accurate proxy for MPCs that varies both in space (across counties) and in time. However, since most estimates of MPCs rely on survey data, the sample size is usually not large enough to construct accurate estimates at the county level. Moreover, studies estimating MPCs usually rely on windfall income (e.g. tax rebates) as an exogenous source of income variation. These kinds of income shocks are rare in the data, so that estimates for MPCs can only be obtained for a very limited number of years. Because of these data limitations, we resort to a proxy for MPCs. In particular, workhorse incomplete market models à la Aiyagari-Bewley-Hugget-İmrohoroğlu predict that an agent's wealth is a crucial determinant of their responsiveness to aggregate shocks. Moreover, a large strand of literature (Kaplan et al., 2014, Kaplan and Violante, 2022) has shown that liquid – as opposed to illiquid – wealth is a much better predictor of MPCs than total wealth. Thus, we resort to stock market wealth per capita as our main proxy for MPCs. A fundamental advantage of this approach is that the data is available at annual frequency. Finally, since Chodorow-Reich et al. (2021) estimate stock market wealth per capita using data on the universe of US households, we avoid any accuracy concerns arising from sample size issues.

Besides MPCs, the seminal work of McKinnon (1963) places at the center stage the role of openness to international trade in a large and burgeoning optimal currency area literature. In our context, this maps to the degree of local openness to countrywide trade. Furthermore, Mian et al. (2013) and Mian and Sufi (2014) emphasize the role of sectoral composition, particularly the tradable vs non-tradable industrial divide, for the transmis-

[8] See Kaplan and Violante (2022) for a detailed discussion.

sion of local and aggregate demand shocks. Finally, several studies have shown how openness to trade is important for the transmission of aggregate shocks in general and for monetary policy in particular (Cugat, 2019, Chodorow-Reich et al., 2021, Auclert et al., 2021b, Fornaro and Romei, 2022). Motivated by the literature, we therefore focus on the role of trade openness as captured by the non-tradable to tradable employment ratio ρ_{jt}, as defined previously.

Guided by economic theory, we have identified MPCs and industry composition as the two main candidates that could account for the unexplained heterogeneity observed in Figure 1. However, the literature has uncovered many other channels for the transmission of monetary policy: some examples include housing and mortgage markets,[9] demographic structure,[10] fiscal response and automatic stabilizers,[11] banking markets,[12] firm age and capital structure,[13] and price and wage rigidities.[14] For this reason, we run an empirical horse race between our two preferred channels and several of the other channels proposed in the literature, to assess what are the best predictors of the observed geographical heterogeneity in the response to monetary shocks. To do so, we focus on the estimated $\beta_{j,24}$ in (1). In particular, we rank the estimated 2-year ahead county-specific responses $\beta_{j,24}$ from the smallest to the largest and group them into 50 bins. We then compute the population-weighted average of $\beta_{j,24}$ within each bin. Next, we collect data on a variety of county specific characteristics that have been showed to be potentially important determinants of the transmission of monetary policy. These include the Herfindahl-Hirschman Index (HHI) for bank deposits, the size distribution of firms, house prices, land availability, race structure, and age structure.[15] For each of these variables, we first compute the county average over the years in our sample, and then take a population-weighted average within each bin. Finally, we regress the within-bin average coefficient on our battery of county specific characteristics.

Because of the big emphasis the literature has placed on the role of MPCs for the transmission of aggregate shocks, we always include average stock market wealth per capita in our regressions. As it turns out, average stock market wealth per capita alone is already able to account for a good chunk of the observed cross-sectional heterogeneity. In fact, the

[9]See, e.g., Di Maggio et al. (2017), Beraja et al. (2018), Cloyne et al. (2019), Berger et al. (2021), Eichenbaum et al. (2022), Wong (2021).

[10]See, e.g., Leahy and Thapar (2022), Bartscher et al. (2022).

[11]See, e.g., McKay and Reis (2016, 2021), Kaplan et al. (2018), Alves et al. (2020).

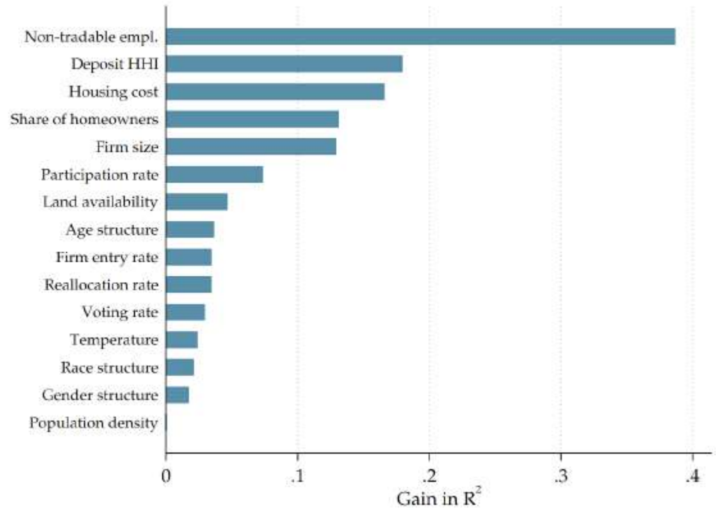
[12]See, among others, Drechsler et al. (2017), **?** and Bellifemine et al. (2022).

[13]See, e.g., Ottonello and Winberry (2020), Bahaj et al. (2022), Cloyne et al. (2022), Jungherr et al. (2022), Jeenas (2019).

[14]See, among others, Olivei and Tenreyro (2007, 2010), De Ridder and Pfajfar (2017), Coglianese et al. (2022)

[15]Appendix A.2 describes the data used for Figure 2 in more detail.

Figure 2: Accounting for Unexplained Heterogeneity



Note: we group county-specific coefficients $\beta_{j,24}$ from (1) into 50 bins. Then, we regress within-bin population weighted averages of coefficients on within-bin population weighted averages of stock market wealth per capita. Each bar represents the gain in R-squared when we add one extra variable to this baseline regression.

R-squared from this binned regression is 50.40%. What we focus on, however, is the gain in R-squared that is obtained by adding each of our potential explanatory variables one at a time. Figure 2 shows the results of this exercise. The striking result from this figure is how the average non-tradable to tradable employment ratio nearly doubles the explanatory power of the regression, increasing the R-squared from 50.40% to 89.08%. On the other hand, while all other characteristics we consider clearly have some non-negligible explanatory power, compared to trade openness their ability to account for the observed heterogeneity in the data is substantially smaller. Figure A.4 in Appendix A.1 further visualizes the strong correlation between the county-specific response and our two proxies for MPCs and openness to trade.

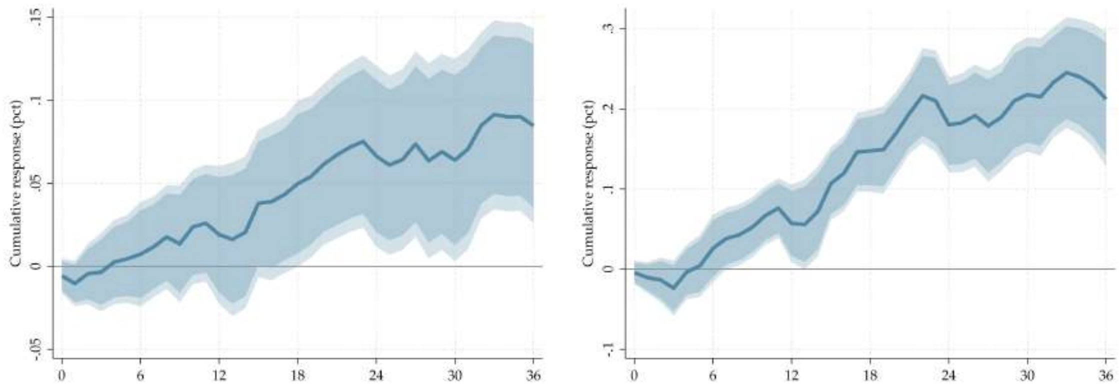
Panel local projections We now turn to decomposing the regional heterogeneity in the response to monetary policy according to the two crucial characteristics suggested by theory as well as data in Figure 2: regional MPCs, as proxied by stock market wealth per capita, and regional industry composition. In order to do so, for each month in our sample we rank counties in quartiles according to our two variables of interest: wealth per capita w_{jt}, and the non-tradable to tradable employment ratio ρ_{jt}. We then construct two indicator variables: D^{NT}_{jt}, which equals one when the ratio of non-tradable to tradable employment ρ_{jt} in county j is in the top quartile of the cross-section of counties in the year before period t; and D^{W}_{jt}, which equals one when stock market wealth per capita in county j is in the bottom quartile of the cross-section of counties in the year before period t. Notice that, to avoid endogeneity concerns, we lag our two indicators D_{jt}^{NT} and D_{jt}^{W} by one year so that they refer to the year before the monetary shock. However, using contemporaneous variables does not materially affect any of our results. Figure A.2 in Appendix A.1 shows the geographical distribution of our indicator variables, by plotting the share of periods in which each county belongs to the top (bottom) 25% of the non-tradable to tradable employment ratio (stock market wealth per capita) distribution. We then run the following lag-augmented panel local projection (Montiel Olea and Plagborg-Møller, 2021), with errors clustered at the county-level:

$$\begin{aligned}\Delta \log(L_{jt+h}) = &\underbrace{\alpha_{jh} + \delta_{th}}_{\text{Fixed effects}} + \underbrace{\beta_h^{NT} \times D_{jt}^{NT} \times \varepsilon_t}_{\text{Industry interaction}} + \underbrace{\beta_h^{W} \times D_{jt}^{W} \times \varepsilon_t}_{\text{Wealth interaction}} \\ &+ \underbrace{\alpha_h^{T} D_{jt}^{NT} + \alpha_h^{W} D_{jt}^{W}}_{\text{Interaction controls}} + \underbrace{\sum_{\ell=1}^{12} \gamma_{h\ell} \Delta \log(L_{jt-\ell})}_{\text{Lagged controls}} + u_{jht} \end{aligned} \tag{2}$$

where the definition of $\Delta \log(L_{jt+h})$, ε_t, and $\Delta \log(L_{jt-\ell})$ is the same as in (1), α_{jh} is a county fixed-effect, δ_{th} represents a time fixed effect, while D_{jt}^{NT} and D_{jt}^{W} are the indicator variables defined above. Notice that, while the time fixed effect δ_{th} will absorb the monetary shock, what we are interested in is the *differential* response to the shock across counties. For this reason, (2) crucially includes interaction terms between the monetary shock and our newly constructed indicator variables. Because we are interacting the shock with binary variables, the interpretation of the coefficients is straightforward: the baseline group is represented by counties which are in the bottom 75% of the non-tradable to tradable employment distribution ($D_{jt}^{NT} = 0$) and in the top 75% of the stock market wealth per capita distribution ($D_{jt}^{W} = 0$). Then, β_h^{NT} simply represents the differential response of high non-tradable employment counties (for which $D_{jt}^{NT} = 1$ and $D_{jt}^{W} = 0$) relative to the baseline group. Similarly, β_h^{W} represents the differential response of low wealth (high MPC), low non-tradable employment counties (for which $D_{jt}^{W} = 1$ and $D_{jt}^{NT} = 0$) relative to the baseline. Finally, the differential response of counties for which both $D_{jt}^{NT} = 1$ and $D_{jt}^{W} = 1$ will be simply given by the sum $\beta_h^{NT} + \beta_h^{W}$.

Figure 3 plots the IRF coefficients from (2) in response to a 1 standard deviation expansionary monetary shock ε_t. Panel (a) shows the estimates for the β_h^{NT} coefficient. Compared to counties for which $D_{jt}^{NT} = 0$ and $D_{jt}^{W} = 0$, counties which are in the top quartile of the non-tradable to tradable employment distribution tend to respond more to monetary shocks. In fact, these regions experience a cumulative increase in employment up to 0.1% larger relative to the baseline group. To put this estimate in perspective, consider

Figure 3: Decomposing the Heterogeneous Response to Monetary Policy



(a) β_h^{NT} (b) β_h^{W}

Note: IRFs to a 1 standard deviation expansionary monetary shock. Errors are clustered at the county level. Lightly shaded areas represent 95% confidence intervals. Darkly shaded areas are 90% confidence intervals. The y-axis represents the cumulative percentage change in employment. The x-axis represents months elapsed since the shock.

that a 1 standard deviation expansionary monetary shock corresponds to roughly a 10 basis points cut in the Fed funds rate. Ramey (2016) finds that the 3-year ahead cumulative response of real activity to a 10 basis points cut estimated in the literature lies in the range 0.03%-1.18%, with a mean of 0.53% and a median of 0.43%. Thus, our estimated *differential* response of 0.1% appears economically sizeable, corresponding to a large share of the average response.

Similarly, panel (b) displays the estimated β_h^W. High MPC counties in the bottom quartile of the stock market wealth per capita distribution experience a larger employment response to monetary shocks, compared to low non-tradable employment, high wealth areas. In particular, the cumulative change in employment is up to 0.2% larger for those counties for which $D_{jt}^W = 1$, relative to the baseline. Again, this magnitude appears economically large when we compare it to the range of estimates on the aggregate output effects of monetary shocks. Notice also that this finding is not in direct contrast with the results in Chodorow-Reich et al. (2021). The authors show how counties with higher stock market wealth per capita tend to experience larger employment fluctuations in response to shocks to *stock market capitalization*. On the other hand, our estimated response is conditional on a monetary policy shock. While this shock may indeed induce revaluation effects on the stock market, its direct effect mainly goes through intertemporal substitution, which is a completely different channel from the one analyzed in Chodorow-Reich et al. (2021).

2.3 Threats to Identification

Our main regressor of interest, the measure of monetary shocks, is relatively immune to standard endogeneity critiques as it is based on a fairly standard methodology that employs high-frequency changes in financial variables.[16] A potential threat to our analysis could however come from omitted variable bias. In particular, it may be the case that we are not controlling for some other determinants of the local response to monetary policy. In so far as these unobserved determinants covary systematically with our two variables of interest – stock market wealth and non-tradable employment – this would invalidate our previous claim that local MPCs and trade openness are some key drivers of the local response to monetary policy.

In Appendix A.1, we try to address these concerns by running a thorough battery of robustness checks. First, our main results do not change if we include an interaction of the monetary shock with the state fixed effect. This is isomorphic to allowing the regional response to change with any time invariant characteristic that varies across states. For example, since most of the fiscal response in the U.S. takes place at the state and federal level, this exercise addresses concerns that our results are not driven by differential local fiscal responses. Second, we show that results are robust to controlling for the interaction between the state fixed effect, the time fixed effect, and the monetary shock. In this specification the slope of the response varies with any characteristic that is constant within a given state in a given month. Hence, this shows that our results are robust, for example, to counties reacting differently to monetary shocks because of the presence of regional business cycles (Beraja et al., 2019).

Taking stock Before proceeding with our theoretical framework, we briefly summarize our main empirical findings. We find that in response to the same identified monetary policy surprise, counties that feature high local non-tradable to tradable employment ratios and/or low stock market wealth per capita experience differentially greater subsequent growth in local employment. The effects are both statistically and economically significant. Moreover, these two channels remain significant when used in the *same* empirical specification. This, importantly, suggests that a robust theory of monetary policy transmission through space should be able to speak to both sources of regional heterogeneity simultaneously. Armed with this empirical understanding, we now present our model.

[16] Recent studies question the exogeneity of monetary policy surprises based on high-frequency identification; see for example Miranda-Agrippino and Ricco (2021) or Bauer and Swanson (2022). In Appendix A.1, we address these concerns by showing that our results are robust to using a narratively identified instrument of monetary shocks – as in Romer and Romer (2000) – as well as measures that control for the information content that is embedded in policy announcements (Miranda-Agrippino and Ricco, 2021).

3 A Model of the Regional Keynesian Cross

In this section we present the general framework of our economy. We build a model of a monetary union composed of small open counties (small open economies as in Galí and Monacelli (2005)). Each small open county is modeled using a HANK framework, featuring Huggett (1990)-type incomplete markets as well as nominal rigidities. We add heterogeneous sectoral composition to this setup and provide a representation of our economy using the Sequence Space Jacobian approach in the spirit of Mankiw and Reis (2006), Boppart et al. (2018), Auclert et al. (2021a). Although our framework does not feature aggregate uncertainty, Boppart et al. (2018), importantly, show that perfect-foresight transitions in response to a zero-probability "MIT" shock - such as what we construct and analyze in our paper - are identical to impulse-response dynamics that one can compute with first-order perturbation from a model with aggregate uncertainty.

3.1 Setup

Time $t \geq 0$ is discrete. There is a continuum of counties indexed by $j \in [0, 1]$. Each county is modeled as a small open economy as in Galí and Monacelli (2005) and is atomistic, with a measure $\lambda(j)$ of population. There is no aggregate uncertainty and we consider perfect-foresight impulse responses to shocks around the steady state ("MIT shocks").

Households In each county j there is a continuum of households with total measure $\lambda(j)$ facing some non-insurable idiosyncratic shocks. We follow the standard incomplete market approach to model household heterogeneity. In particular, agents differ in their idiosyncratic productivity state e, which evolves over time according to some county-specific generic Markovian process. Having different income processes for each county is a reduced-form way of getting different levels of wealth holdings and MPCs accross counties. For each county, the mean productivity e is denoted by $\bar{e}_j$. A household i in county j has preferences defined over an aggregate consumption good c_{jit} as well as labor supply ℓ_{jit}, which imply the following time-0 utility:

$$\mathbb{E}_0 \sum_{t \geq 0} \beta^t \{u(c_{jit}) - v(\ell_{jit})\}$$

Agents pay a proportional tax τ_t on their real labor income and can imperfectly insure themselves by trading in a risk-free bond b_{jit} subject to a borrowing limit $\underline{b} \leq 0$. Their budget constraint then reads:

$$c_{jit} + b_{jit+1} = (1 - \tau_t) z_{jit} e_{jit} + (1 + r_t) b_{jit}, \quad b_{jit+1} \geq \underline{b} \tag{3}$$

In (3) above, we denote by z_{jit} real gross labor income which is given by:

$$z_{jit} = \frac{W_{jt}}{P_{jt}} \ell_{jit} e_{jit}$$

where W_{jt} and P_{jt} are respectively the aggregate wage and price index in county j. These two indices will be defined momentarily.

Demand composition There are two goods in the economy: tradables and non-tradables. The defining feature of non-tradable goods is that they must be consumed in the county in which they are produced. For tradable goods, on the other hand, the location of consumption is completely decoupled from that of production. The aggregate consumption basket is defined as a constant-elasticity-of-substitution (CES) composite c_{jit} of the two goods c_{jit}^{NT} and c_{jit}^{T}:

$$c_{jit} = \left[\omega^{1/\nu} \left(c_{jit}^{NT} \right)^{(\nu-1)/\nu} + (1 - \omega)^{1/\nu} \left(c_{jit}^{T} \right)^{(\nu-1)/\nu} \right]^{\frac{\nu}{\nu-1}} \tag{4}$$

where ω is a parameter governing households' preferences for non-tradables and $\nu > 0$ is the elasticity of substitution between the two types of goods. Both of these parameters are invariant across counties. In turn, households split their spending between the two types of goods as follows:

$$c_{jit}^{NT} = \omega \left(\frac{P_{jt}^{NT}}{P_{jt}} \right)^{-\nu} c_{jit} \quad \text{and} \quad c_{jit}^{T} = (1 - \omega) \left(\frac{P_{jt}^{T}}{P_{jt}} \right)^{-\nu} c_{jit} \tag{5}$$

Where P_{jt}^{NT} and P_{jt}^{T} represent, respectively, county j's price index for non-tradable and tradable goods, while P_{jt} is the aggregate price index in county j. Because in our model preferences are homothetic and do not depend on the household type i, both the price and wage indices as well as the composition of the consumption basket will be identical across household types within one county.[17] Moreover, we assume perfect substitutability

[17] Clearly, the level of consumption can still differ between households within a county.

between tradable goods produced in different counties:

$$c_{jit}^T = \int_0^1 c_{jit}^T(j')dj'$$

Hence, the law of one price holds nationally for the tradable good, i.e., $P_{jt}^T = P_t^T$ for all j.[18] Note that, because tradable goods produced in different counties are perfect substitutes, for a given level of tradable consumption c_{jit}^T, the composition of this consumption $\{c_{jit}^T(j')\}_{j'\in[0,1]}$ will be indeterminate. We solve this indeterminacy by assuming that the share of tradable consumption sourced from county j' is equal to the size $\lambda(j')$ of county j'. This, coupled with the small open county-economy assumption and the absence of home bias, implies that within-county demand for tradable goods produced by the same county will be zero. Finally, the price index corresponding to the preferences represented in (4) is given by:

$$P_{jt} = \left[\omega\left(P_{jt}^{NT}\right)^{1-\nu} + (1-\omega)\left(P_t^T\right)^{1-\nu}\right]^{\frac{1}{1-\nu}}$$

Supply composition Similarly to demand, the supply side of each county is comprised of two sectors: one producing the tradable good and one producing the non-tradable good. We follow Berger et al. (2022) to model the supply of labor to the two sectors: individual households' aggregate labor supply ℓ_{jit} is a composite of a measure of labor supplied to the non-tradable sector ℓ_{jit}^{NT} and a measure ℓ_{jit}^T supplied to the tradable sector. In particular, the labor supply composition is given by the following CES aggregator:

$$\ell_{jit} = \left(\alpha_j^{-\frac{1}{\eta}}(\ell_{it}^{NT})^{\frac{\eta+1}{\eta}} + (1-\alpha_j)^{-\frac{1}{\eta}}(\ell_{it}^T)^{\frac{\eta+1}{\eta}}\right)^{\frac{\eta}{\eta+1}} \tag{6}$$

Where η is the elasticity of substitution between the two sectors and is assumed to be constant across counties. This parameter governs how easy it is to reallocate workers between the two sectors. The parameter α_j, on the other hand, is *county-specific* and captures the propensity of county j to produce non-tradable goods.[19] It is going to play a crucial role in our analysis. Given (6), households split their labor supply in the following fashion:

$$\ell_{jit}^{NT} = \alpha_j\left(\frac{W_{jt}^{NT}}{W_{jt}}\right)^{\eta}\ell_{jit}, \quad \text{and} \quad \ell_{jit}^T = (1-\alpha_j)\left(\frac{W_{jt}^T}{W_{jt}}\right)^{\eta}\ell_{jit} \tag{7}$$

[18]Here we are ruling out home bias in the consumption of tradable goods. This simplifies our analysis and does not affect the substance of any of the results.

[19]The parameter α_j can be equivalently interpreted as governing county j's non-tradable labor endowment.

Finally, the wage index corresponding to this labor supply structure is given by:

$$W_{jt} = \left(\alpha_j (W_{jt}^{NT})^{1+\eta} + (1-\alpha_j)(W_{jt}^{T})^{1+\eta}\right)^{\frac{1}{1+\eta}}$$

Final goods producers Firms in both the tradable and the non-tradable sector produce using a linear production technology: $Y_{jt}^s = L_{jt}^s$, $s \in \{NT, T\}$. Moreover, in both sectors the market for final goods is perfectly competitive. As a result, final prices for the two goods equal the marginal cost, i.e., $P_{jt}^s = W_{jt}^s$, $s \in \{NT, T\}$. Note that because the law of one price holds in the tradable sector, the wage in that sector is going to be equalized across counties, i.e., $W_{jt}^T = W_t^T$ for all $j \in [0, 1]$.

Labor markets The source of nominal rigidities in the economy is given by wage stickiness. In line with the New Keynesian sticky-wage literature (Erceg et al., 2000, Schmitt-Grohé and Uribe, 2005, Auclert et al., 2018), we assume that the amount of hours worked is determined by labor unions. In particular, each county is inhabited by one labor union which sets the aggregate wage index and the aggregate number of hours worked in order to maximize the welfare of the average household in the economy. Moreover, the union follows a uniform allocation rule of labor across households, so that $\ell_{jit} = L_{jt}$. The objective function of the union is defined so to define a standard wage Phillips curve. Given the aggregate wage index W_{jt}, sectoral wages W_{jt}^{NT} and W_{jt}^T, and the aggregate amount of hours worked L_{jt}, households then optimally allocate labor across the two industries following (7).

National Government There is a national Government administrating a tax and transfer scheme on households' real labor income $z_{jit}e_{jit}$. Net tax revenues T_{jt} at the regional level are defined as:

$$\tau_t \int \frac{W_{jt}}{P_{jt}} \ell_{ijt} e_{ijt} di = \tau_t \frac{W_{jt} L_{jt} \bar{e}_j}{P_{jt}} = T_{jt}$$

The Government is the sole issuer of liquid assets in the economy, which are the real bonds B_t. The Government's intertemporal budget constraint is given by:

$$B_{t+1} + \int T_{jt} d\lambda(j) = r_t B_t$$

Monetary policy Monetary policy follows a real interest rate rule:[20]

$$i_t = r_t + \pi_{t+1} + \varepsilon_t,$$

where π_t denotes national inflation, $\pi_t = \int_0^1 \pi_{jt} d\lambda(j)$. This rule is a special case of the standard Taylor Rule, with a coefficient of 1 on inflation. This real interest rate rule assumption guarantees that the wage Philips curve only affects nominal quantities, thus simplifying our derivation of the Keynesian Cross, which will be a function of real variables alone.

Regional equilibrium We are now ready to define the notion of a regional equilibrium, which characterises the response of a given county j while taking the national response exogenously given.[21]

Definition 1 (Regional Equilibrium)**.** *In a county j, given an initial regional distribution $G_{j0}(b, e)$ over bonds b and idiosyncratic states e, and an exogenous sequences of real interest rates $\{r_{jt}\}_{t\geq 0}$, a regional equilibrium is a path for prices $\left\{P_{jt}, P_{jt}^{NT}, P_{jt}^{T}, W_{jt}, W_{jt}^{NT}, W_{jt}^{T}\right\}_{t\geq 0}$ for j, aggregate quantities $\left\{L_{jt}, L_{jt}^{NT}, L_{jt}^{T}, C_{jt}\right\}_{t\geq 0}$ for j, individual allocation rules $\{c_{jt}(b, e), b_{jt+1}(b, e)\}$, and joint distributions over assets and productivity levels $G_{jt}(b, e)$, such that, taking the rest of the nation's response and the fiscal response as exogenous, households, unions, and firms in county j optimize, and the market clearing condition for the non-tradable good holds, i.e.:*

$$L_{jt}^{NT} = C_{jt}^{NT} \quad \forall\, j \tag{8}$$

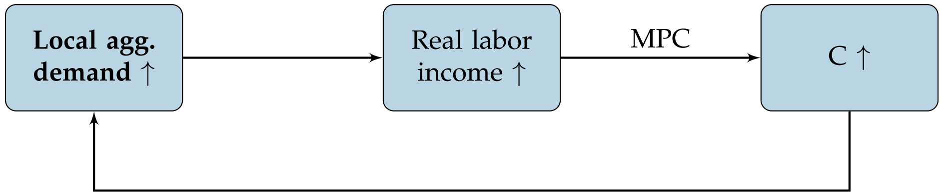
3.2 Revisiting the Keynesian Multiplier

The standard Keynesian multiplier logic We start by briefly revisiting the logic of the Keynesian multiplier in our regional framework. Figure 4 conveys the intuition behind the standard Keynesian multiplier. Following an increase in aggregate demand, real income rises via increased labor demand. This increase in real income in turn translates into an increase in consumption. Finally, the rise in consumption feeds back into a rise in aggregate demand, generating in this way the well-known loop that gives rise to the Keynesian multiplier. In this framework the MPC represents the crucial determinant of the

[20]This type of rule has been used extensively in the literature, see for example Woodford (2011), McKay et al. (2016), Auclert et al. (2018).

[21]Note that in a regional equilibrium we focus on the response of a single county in isolation. Hence, because of the small open economy assumption, we can assume both the response of the fiscal authority, as well as the response of aggregate demand in the rest of the nation, to be exogenously given.

Figure 4: The Standard Keynesian Multiplier



size of the multiplier, as it governs the magnitude of the pass-through from real income to consumption, and back to aggregate demand.

Wage and price elasticities Before turning to the description of our mechanism, it is useful to define two elasticities that will play an important role in our analysis.

Definition 2 (ρ_j and ξ_j)**.** *We denote by ρ_j the steady state elasticity of the wage index W_j with respect to the non-tradable wage W_j^{NT} in county j. Similarly, we denote by ξ_j the elasticity of the price index P_j with respect to the price of non-tradable goods P_j^{NT} in county j:*

$$\rho_j \equiv \frac{\partial \log W_j}{\partial \log W_j^{NT}} \quad \textit{and} \quad \xi_j \equiv \frac{\partial \log P_j}{\partial \log P_j^{NT}}$$

Because of the CES structure that we have imposed on the demand for goods and the supply of labor, ρ_j and ξ_j turn out to have a convenient interpretation. In fact, they respectively represent the non-tradable share of the wage bill and the non-tradable share of consumption expenditure:

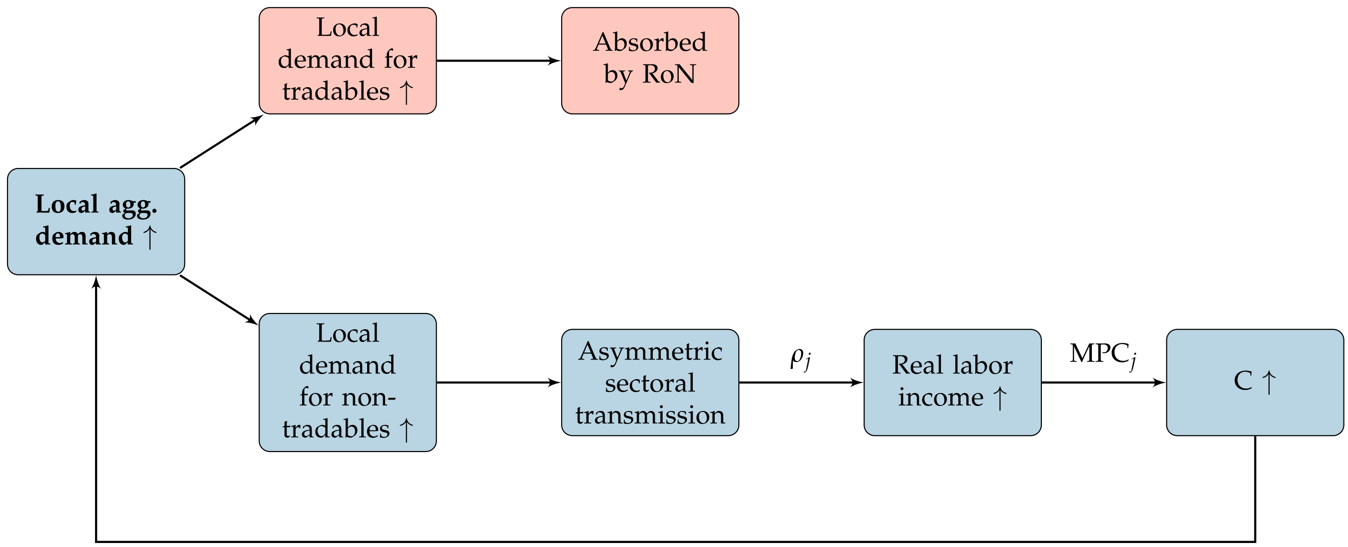
$$\rho_j = \frac{L_j^{NT} W_j^{NT}}{L_j W_j} \quad \text{and} \quad \xi_j = \frac{C_j^{NT} P_j^{NT}}{C_j P_j} \tag{9}$$

From (9), it is clear that ρ_j and ξ_j are bounded between 0 and 1. Moreover, a log-linearization of the expressions for the wage and the price index reveals an additional interpretation for these elasticities: ρ_j and ξ_j respectively represent the exposure of the supply and demand side of county j's economy to fluctuations in the non-tradable sector:

$$d \log W_{jt} = \rho_j d \log W_{jt}^{NT} + (1 - \rho_j) d \log W_t^T \quad \text{and} \quad d \log P_{jt} = \xi_j d \log P_{jt}^{NT} + (1 - \xi_j) d \log P_t^T \tag{10}$$

Recall that, because of perfect competition in the market for final goods, it holds that $P_{jt}^s = W_{jt}^s$, $s \in \{NT, T\}$. From (10), we can derive a log-linearized expression for the real

Figure 5: The Regional Keynesian Cross



labor income in county j, $\frac{W_{jt}}{P_{jt}}$:

$$d\log\left(\frac{W_{jt}}{P_{jt}}L_{jt}\right) = \left(\rho_j - \xi_j\right) d\log W_{jt}^{NT} + (\xi_j - \rho_j) d\log W_t^T + d\log L_{jt} \tag{11}$$

(11) decomposes the variation in real labor income into the change in real wage and the change in hours worked. The relative magnitude of ρ_j and ξ_j pins down the extent to which the real wage varies in response to a change in sectoral wages (and prices). In what follows, we'll assume zero net supply of bonds at the county level in steady state, which implies $\rho_j = \xi_j$. Hence, any change to the real labor income will go through changes in the number of hours worked L_{jt} in the rest of our analysis.

Now, the extent to which total labor responds to demand shocks in the non-tradable sector depends on ρ_j since it can be expressed as the elasticity of total labor supply to changes in labor supply in the non-tradable sector:

$$\frac{d\log L_{jt}}{d\log L_{jt}^{NT}} = \rho_j \tag{12}$$

When ρ_j is low (high), total labor supply has a low (high) exposure to fluctuations in labor supply in the non-tradable sector. Hence, in what follows ρ_j will capture the pass-through of demand shocks to the non-tradable sector to real income via the exposure of total labor supply to the labor supply in the non-tradable sector.

The regional Keynesian multiplier logic We are now ready to extend the logic of the Keynesian multiplier to our regional setting. In order to do so, we focus on an individual county j and consider a rise in *local* aggregate demand only. Figure 5 describes the transmission mechanism of the local demand shock in this setting. First, the local increase in aggregate demand splits into a rise in demand for tradable as well as non-tradable goods. Since the county is atomistic, the increase in tradable demand does not feed back to the local economy, but is instead "lost" to the rest of the nation. On the other hand, since non-tradables can only be produced locally, the rise in demand for non-tradables fully feeds back to the home county. Hence, the initial rise in local aggregate demand has an effect on the domestic demand for non-tradables only, and thus induces an asymmetric sectoral transmission.

As already discussed above, ρ_j is then going to determine county j's exposure to fluctuations in the non-tradable sector. This asymmetric transmission turns out to have crucial implications. When ρ_j is high, the rise in the demand for the non-tradable good induces a rise in non-tradable labor which passes through a rise in total labor in proportion of ρ_j, and hence to real labor income. ρ_j is therefore a central object shaping the pass-through of local demand shocks to regional real labor income. In turn, the pass-through of real labor income to consumption is again governed by MPCs, just like in the standard Keynesian multiplier. As each iteration of the Keynesian multiplier goes through, the asymmetric sectoral transmission we just described takes place, and the strength of this transmission is governed by both ρ_j and the MPCs in j. Our framework therefore nests the standard Keynesian multiplier logic, which is however distorted by the county-specific national trade openness.

3.3 The Regional Keynesian Cross

Throughout this section, we zoom-in on the behavior of a single county, with the small open county/economy assumption allowing us to take the national and fiscal response as given. We assume zero net supply of bonds at the county level in steady state.[22] Since the focus is on a single county j, we normalize its average productivity $\bar{e}_j$ to 1.

Aggregate consumption function Because the labor union allocates labor uniformly across households, we can express idiosyncratic net real income as a function of aggregate

[22] In other words, every county is solving a Huggett (1990) model.

county-level quantities only. In particular we have:

$$(1-\tau_t)z_{ijt}e_{ijt} = \left(\frac{W_{jt}L_{jt}}{P_{jt}} - T_{jt}\right)e_{jit}$$

Substituting the expression above into the household's budget constraint (3), it is easy to see that, given the state (b,e), the path of optimal policy rules $\{c_{jt}(b,e), b_{jt+1}(b,e)\}$ is entirely pinned down by the sequence of aggregate real income $\left\{\frac{W_{jt}}{P_{jt}}L_{jt} - T_{jt}\right\}_{t\geq 0} \equiv \left\{Z_{jt}\right\}_{t\geq 0}$, together with the sequence of real interest rate $\left\{r_{jt}\right\}_{t\geq 0}$. Hence, we can integrate over the states to write aggregate consumption at time t as a function of the sequence of aggregate real income and real interest rate only:

$$\int c_{jt}(b,e)dG_{jt}(b,e) = \mathcal{C}_{jt}\left(\left\{Z_{js}\right\}_{s\geq 0}, \left\{r_{js}\right\}_{s\geq 0}\right) \tag{13}$$

In order to derive our main result, we start by substituting domestic demand for non-tradable goods (5), together with the aggregate consumption function (13), into the market clearing condition (8):

$$L^{NT}_{jt} = \omega\left(\frac{P^{NT}_{jt}}{P_{jt}}\right)^{-\nu}\mathcal{C}_{jt}\left(\left\{Z_{js}\right\}_{s\geq 0}, \left\{r_{js}\right\}_{s\geq 0}\right) \tag{14}$$

We then linearize (14) around the steady state with respect to an unanticipated and exogenous perfect-foresight path of deviations of the real interest rate, which we denote by $d\boldsymbol{r}_j \equiv (dr_0, dr_1, \dots)'$.[23] Following Auclert et al. (2020), we denote the Jacobian of $\mathcal{C}_t(\cdot)$ with respect to aggregate real labor income $\boldsymbol{Z} \equiv (Z_0, Z_1, \dots)'$ by $\boldsymbol{M}$, which is a matrix whose element (t,s) is given by $\frac{\partial \mathcal{C}_t(\cdot)}{\partial Z_s}$. Similarly, we denote by $\boldsymbol{M}^r$ the matrix of elasticities of $\mathcal{C}_t(\cdot)$ with respect to the interest rate sequence $\boldsymbol{r} \equiv (r_0, r_1, \dots)'$, $\boldsymbol{M}^r_{t,s} \equiv \frac{\partial \log \mathcal{C}_t(\cdot)}{\partial r_{js}}$.

The Regional Keynesian Cross We assume that all counties apart from j are inhabited by hand-to-mouth agents. As a result, demand of the rest of the nation is unaffected by the shock $d\boldsymbol{r}_j$. This implies that the demand for domestically produced tradable goods is unchanged.[24] Moreover, it also follows that the price of tradables –and, in turn, the wage paid in the tradable sector– does not move in response to the shock. For the moment, we also assume that there is no response of the fiscal authority, so that $d\boldsymbol{T}_j = 0$. We will relax

[23] Here the prime notation denotes the transpose operator.

[24] Notice that counties are assumed to be atomistic, hence local demand for domestically produced tradables equals zero.

this assumption later on in the text. We can then express the linearized version of (14) as a fixed point equation for $d\boldsymbol{L}_j \equiv (dL_{j0}, dL_{j1}, \dots)'$. We are ready to derive one of the main results of this paper:

Proposition 1 (The Regional Keynesian Cross)**.** *Assuming zero net supply of bonds in county j, the first-order response of employment $d\boldsymbol{L}_j$ to a monetary shock $d\boldsymbol{r}_j$ satisfying a regional equilibrium with no fiscal response and no national response solves the following fixed point equation:*

$$d\boldsymbol{L}_j = \underbrace{\rho_j \boldsymbol{M}_j^r d\boldsymbol{r}_j}_{\textit{Int. substitution}} + \underbrace{\rho_j \boldsymbol{M}_j d\boldsymbol{L}_j}_{\textit{Multiplier}} - \underbrace{\frac{\nu}{\eta}(1-\xi_j) d\boldsymbol{L}_j}_{\textit{Exp. switching channel}} \tag{15}$$

Proof. See Appendix B.3. □

Decomposing the channels Proposition 1 shows that the local response of employment to a monetary policy shock is governed by four elasticities (ρ_j, ξ_j, ν and η), together with the intertemporal MPCs (iMPCs) summarized by the matrix $\boldsymbol{M}_j$, and the intertemporal substitution motive captured by $\boldsymbol{M}_j^r$. (15) also provides a decomposition of the total employment response into three different channels, each of which is governed by a subset of the parameters just outlined above.

Intertemporal substitution channel – Through its effect on real interest rates, monetary policy induces households to substitute consumption intertemporally. This is often referred to as a the "direct effect" of monetary policy (Kaplan et al., 2018). The matrix $\boldsymbol{M}_j^r$ captures the extent to which agents are both willing and able to engage in this intertemporal substitution. In our framework, the intertemporal substitution channel is proportional to $\boldsymbol{M}_j^r \times d\boldsymbol{r}_j$, where the factor of proportionality is given by ρ_j. The intertemporal substitution channel is premultiplied by a factor ρ_j because of the logic depicted in Figure 5 above: any shock to local aggregate demand is only allowed to transmit to the regional economy through the market for non-tradables.

Regional multiplier – The regional Keynesian multiplier channel is represented by the term $\rho_j \times \boldsymbol{M}_j \times d\boldsymbol{L}_j$. This channel captures the indirect (higher order) effects of the transmission of the original shock. Following the intuition in Figure 5, the increase in labor $d\boldsymbol{L}_j$ necessary to satisfy the original change in demand generates a rise in real labor income. In our regional setting, however, local demand shocks can only influence the domestic economy via the non-tradable sector. For this reason, only a share ρ_j of labor income corresponding to the non-tradable wage bill is affected by the shock. Finally, as in the standard case, the iMPC matrix $\boldsymbol{M}_j$ determines the pass-through from labor income onto consumption, and back to local demand.

Expenditure switching channel – There is one final channel arising from the fact that local demand shocks get transmitted asymmetrically to the two sectors: the expenditure switching channel. In particular, this asymmetric sectoral transmission implies that the relative price of tradables to non-tradables will move in response to the shock. Because of this change in the relative price, agents will then substitute demand between the two goods. The magnitude of this channel is intuitively governed by the relative size of the elasticity of substitution in demand and supply, ν and η respectively. Clearly, when the demand elasticity is large (small) relative to the supply one, the relative price will move a lot (little) for a given asymmetric demand shock. The larger the movement in the relative price, the more agents are going to substitute consumption between the two sectors. On top of this, the tradable share of consumption expenditure $1-\xi_j$ also matters in determining the overall size of the expenditure switching channel. The intuition for this is that when households consume a larger fraction of tradable goods, i.e. $1-\xi_j$ is large, the demand for non-tradables that gets substituted for a given change in the relative price will be larger.[25] Finally, when agents substitute away from non-tradables the increase in demand for tradables is absorbed by the rest of the nation. Because of this, the expenditure switching channel enters (15) with a negative sign.

Solving for the fixed point The general solution to the fixed point problem in (15) is given by the following proposition.

Proposition 2. *Assuming $\boldsymbol{M}_j$ is positive semi-definite, the equilibrium employment response $d\boldsymbol{L}_j$ is unique and given by*

$$d\boldsymbol{L}_j = \underbrace{\sum_{k\geq 0} \widetilde{\boldsymbol{M}}_j^k}_{=\left(\boldsymbol{I}-\widetilde{\boldsymbol{M}}_j\right)^{-1}} \rho_j \boldsymbol{M}_j^r d\boldsymbol{r}_j \tag{16}$$

where $\widetilde{\boldsymbol{M}}_j$ is defined as $\widetilde{\boldsymbol{M}}_j \equiv -\frac{\nu}{\eta}(1-\xi_j)\boldsymbol{I} + \rho_j \boldsymbol{M}_j$

(16) provides a direct mapping between the exogenous real interest rate shock $d\boldsymbol{r}_j$ and the endogenous employment response $d\boldsymbol{L}_j$.

3.4 MPC-Trade Openness Complementarity

We now show that our framework predicts a mechanism novel to the HANK literature: complementarities between openness to national trade and household heterogeneity in

[25] Note that with our zero net supply assumption, $\rho_j = \xi_j$.

the transmission of shocks. To shed further light on the mechanism and to simplify the exposition, let's assume that η is large and ν is small so that the expenditure switching channel is negligible.[26] We can then rewrite (16) as follows:

$$d\boldsymbol{L}_j \approx \underbrace{\sum_{k\geq 0} \left(\rho_j \boldsymbol{M}_j\right)^k}_{\text{MPC-trade openness complementarity}} \rho_j \boldsymbol{M}_j^r d\boldsymbol{r}_j \tag{17}$$

Equation (17) highlights a key and novel prediction of our model: There is a complementarity between the demand-side channels at work in the standard HANK literature – captured by the iMPC matrix $\boldsymbol{M}_j$ – and the supply-side channels of our framework – captured by ρ_j. In particular, within our framework, the regional industrial composition governs the extent to which household heterogeneity in general and MPCs in particular matter for the local employment response to monetary policy. Specifically, household heterogeneity and non-tradable employment act as complements: a low value of ρ_j discounts the role played by the iMPC in the transmission of monetary policy, so that the effect of MPCs on the employment response is increasing in ρ_j.

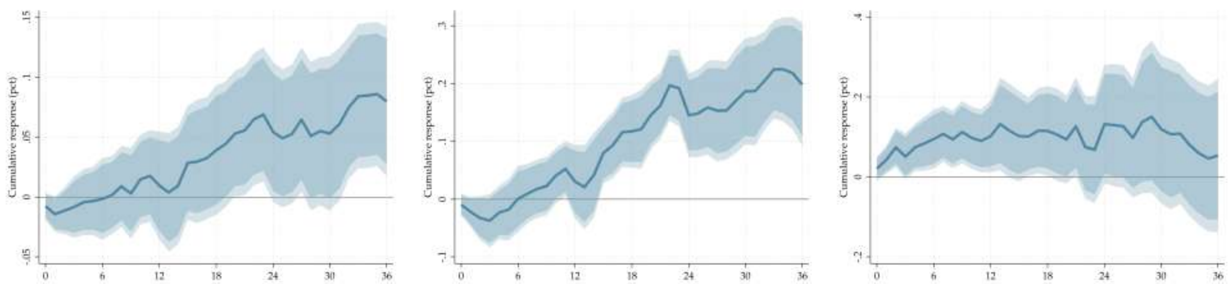
Evidence of Complementarities in the Data We now present evidence that this wealth-openness complementarity is present in the data. To do so, we modify our baseline regression (2) to include a triple interaction between our wealth dummy D_{jt}^{W}, the trade openness dummy D_{jt}^{NT}, and the monetary shock ε_t. The coefficient on this triple interaction term, $\beta_h^{NT,W}$, can be interpreted as a cross-derivative. It captures the complementarity between the demand-side channel related to stock market wealth per capita and the supply-side channel due to the intensity of non-tradable activity. Hence, the regression specification now becomes:

$$\begin{aligned}\Delta \log(L_{jt+h}) = {} & \underbrace{\alpha_{jh} + \delta_{th}}_{\text{Fixed effects}} + \underbrace{\beta_h^{NT} \times D_{jt}^{NT} \times \varepsilon_t}_{\text{Industry interaction}} + \underbrace{\beta_h^{W} \times D_{jt}^{W} \times \varepsilon_t}_{\text{Wealth interaction}} + \underbrace{\beta_h^{NT,W} \times D_{jt}^{NT} \times D_{jt}^{W} \times \varepsilon_t}_{\text{Triple interaction}} \\ & + \underbrace{\alpha_h^{T} D_{jt}^{NT} + \alpha_h^{W} D_{jt}^{W} + \alpha_h^{T,W} D_{jt}^{NT} \times D_{jt}^{W}}_{\text{Interaction controls}} + \underbrace{\sum_{\ell=1}^{12} \gamma_{h\ell} \Delta \log(L_{jt-\ell})}_{\text{Lagged controls}} + u_{jht}\end{aligned} \tag{18}$$

Figure 6 plots the IRFs for the three interaction coefficients. The first two panels show that the more flexible specification (18) delivers results very similar to our baseline re-

[26] Notice that this assumption just simplifies the analytical derivations, but does not materially affect any of the subsequent results.

Figure 6: Wealth-Trade Openness Complementarity in the Data



(a) β_h^{NT} (b) β_h^{W} (c) $\beta_h^{NT,W}$

Note: IRFs to a 1 standard deviation expansionary monetary shock. Errors are clustered at the county level. Lightly shaded areas represent 95% confidence intervals. Darkly shaded areas are 90% confidence intervals. The y-axis represents the cumulative percentage change in employment. The x-axis represents months elapsed since the shock.

gression (2) for the coefficients β_h^{NT} and β_h^{W}. Moreover, the estimated coefficient $\beta_h^{NT,W}$ is positive and statistically significant for nearly all horizons $h = 1, .., 36$. This means that the employment response of counties with both $D^W = 1$ and $D^{NT} = 1$ is greater than the sum of the response of counties with $D^W = 1$ and $D^{NT} = 0$ and the response of counties with $D^W = 0$ and $D^{NT} = 1$. Thus, these results suggest that the two channels - household wealth and openness to trade - reinforce each other, in line with the complementarities predicted by our model and outlined in (17).

4 Model Results

In this section, we illustrate some of the key results of our model. We first show how the different channels highlighted in (15) depend on openness to trade, governed by α_j, as well as on household heterogeneity, summarized by $\boldsymbol{M}_j$ and $\boldsymbol{M}_j^r$. We then analyze the role that the reaction of the fiscal authority plays in shaping the regional response. We also discuss the importance of the rest of the nation's reaction to the monetary shock for the local employment response. Finally, we discuss implications of our two-layered heterogeneity setup for economic stabilization instruments.

4.1 Parameterization

We parameterize our model to quarterly frequency. In what follows our aim is not to perform a fully-fledged quantitative exercise. Rather, we set some realistic parameter values in order to highlight some key features of our framework.

Table 1: Model Parameterization

Parameter	Description	Value	Comment
β	Discount rate	0.9957	Standard
σ	Inverse IES	1	Standard
φ	Frisch Elasticity	1	Chetty et al. (2011)
ψ	Labor disutility	1	Normalization
ω	Preference for non-tradables	0.66	Hazell et al. (2022)
ν	Elasticity of substitution between the two goods	1.5	Hazell et al. (2022)
η	Elasticity of substitution between the two sectors	0.45	Berger et al. (2022)
ρ_e	Persistence of the log-productivity process	0.9	Target MPC = 0.25
σ_e	Cross-sectional std of log-productivity process	0.1	Target MPC = 0.25
$\underline{b}$	Borrowing limit (as pct. of natural borrowing limit)	1.7%	Target MPC = 0.25
P^T	Tradable price index	1	Numeraire
C^T	Rest of nation demand for tradable goods	1	Exogenous

Preferences We set the intertemporal elasticity of substitution $1/\sigma$ to a standard, agnostic value of 1. For the Frisch elasticity of labor supply, we choose $\varphi = 1$, around the ball-park of micro and macro elasticities reviewed in Chetty et al. (2011). We also normalize the labor disutility parameter ψ to 1. Finally, we set the discount rate β to 0.9957.

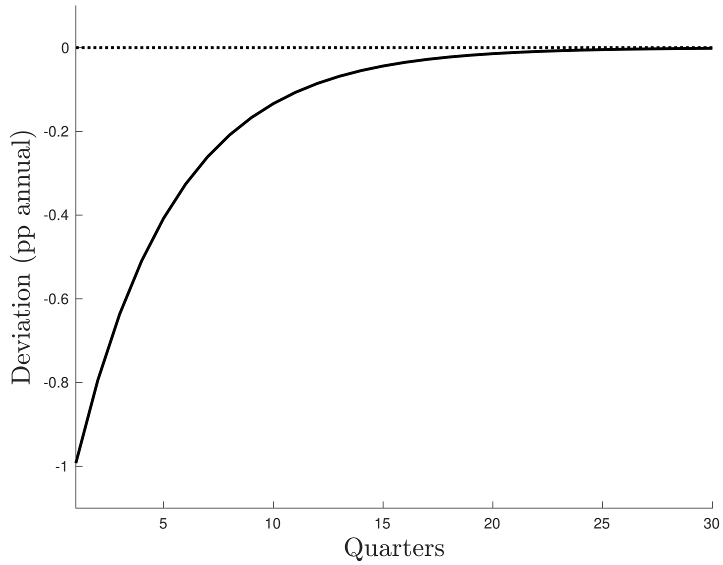
Sectoral supply and demand We follow Hazell et al. (2022) and set the demand elasticity of substitution between tradables and non-tradables ν to 1.5. We also set the parameter governing consumers' preferences for non-tradables ω to 0.66, as in Hazell et al. (2022).[27] Finally, we set the elasticity of substitution of labor supply between the two sectors to 0.45, in line with the across-markets elasticity of labor supply estimated in Berger et al. (2022).

Productivity process and borrowing limit We parametrize the process for log-productivity e and the borrowing limit $\underline{b}$ in order to match a value of 0.25 for the MPC on impact, following Kaplan and Violante (2014). In particular, we model the log-productivity process as an AR(1) with persistence $\rho_e = 0.9$ and cross-sectional standard deviation $\sigma_e = 0.1$. We discretize the AR(1) process into a Markov chain with 5 income states. We also set the borrowing limit $\underline{b}$ to 1.7% of the natural borrowing limit, which, together with our zero net supply condition, implies our regional economy is a low-liquidity environment. This ensures that the iMPCs are sufficiently high, see Figure B.3 in Appendix B.1. Figure B.1 in Appendix B.1 depicts the resulting stationary wealth distribution of our economy.

Other parameters We normalize the price of the tradable good P^T to 1, thus making the tradable good the numeraire. Finally, since demand for domestically produced goods

[27] Notice that our results are qualitatively unaffected if we change the value of ω.

Figure 7: The real interest rate shock



Note: AR(1) shock to the real interest rate r_{jt} (annualized) with quarterly persistence 0.9, and corresponding to an initial annualized impulse of -1%, over a period of 30 quarters.

coming from the rest of the nation is exogenously determined from the perspective of the local county, we normalize C^T to 1.

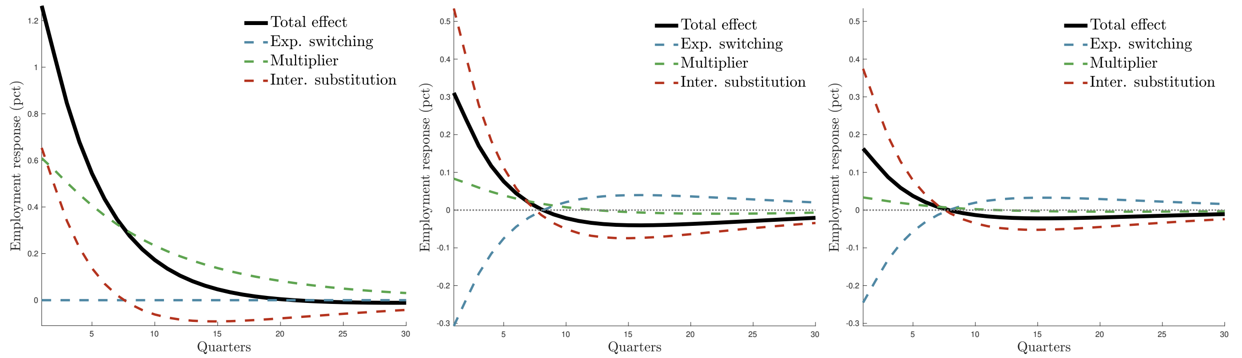
4.2 Impulse Response to a Monetary Shock

We now analyze the local employment response to a one-time unexpected expansionary real interest rate shock. In particular, we consider an experiment where a 1% (annualized) decrease in the annual interest rate takes place at time $t = 1$. The real interest rate then mean-reverts to steady state at a quarterly rate of 0.9. Figure 7 plots the path for the annualized real interest rate, in deviation from its steady state. In what follows, we compute the IRFs in response to this shock and decompose them into the channels described above, using the parametrization outlined in Table 1.

The Role of Openness to Trade Figure 8 plots the IRF decomposition in the benchmark one-region one-industry case ($\alpha_j = \omega = 1$), as well as in the baseline case of a multi-sector economy ($\omega = 0.6$) for different values of the trade openness parameter $\alpha_j \in \{0.4, 0.9\}$. The response for the benchmark one-region economy is reported in Figure 8a.[28] Since there is only one good and one sector, the expenditure switching channel is shut down by construction. Moreover, under our calibration, the on-impact multiplier effect is about

[28] Figure B.4 in Appendix B.2 provides the IRF decomposition for the representative agent case.

Figure 8: Responses to a Monetary Shock: the Role of Openness to National Trade



(a) One-industry benchmark (b) Two-industry, high α (c) Two-industry, low α

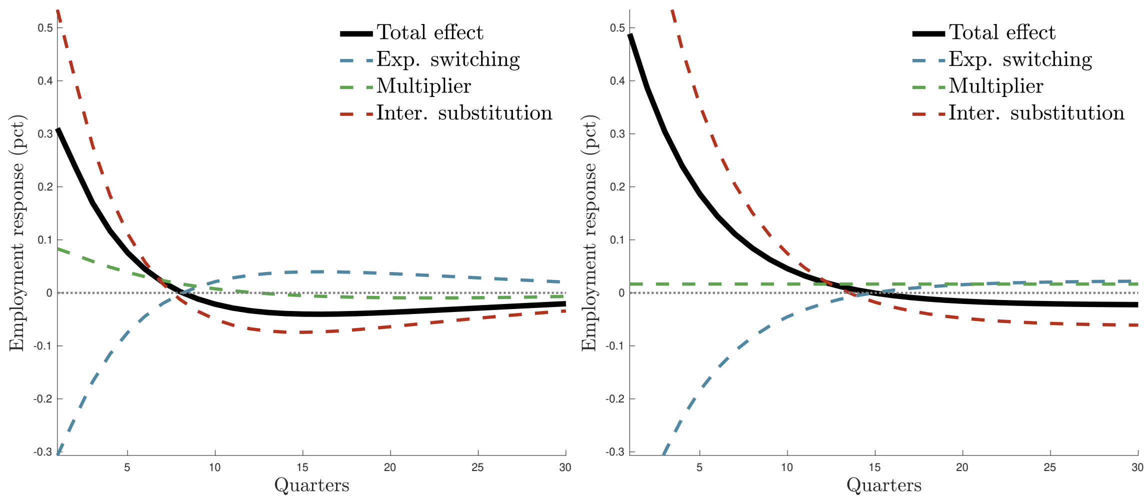
Note: Quarterly impulse responses decomposition for the shock displayed in Figure 7 in a regional equilibrium with no fiscal response and no national aggregate demand response for a one-industry benchmark ($\omega = \alpha = 1$) compared to the multi-industry case with $\omega = 0.6$ and two values of α over 30 quarters.

as large as the intertemporal substitution effect. Figure 8b and 8c illustrate the role of heterogeneous trade openness by plotting the IRF decomposition respectively for a large and a small value of the trade openness parameter α_j. In the regional equilibrium with no national or fiscal reaction, the employment response is always lower in the two-industry case than in the one-industry one, as was already clear from (15). The reason for this is that both the multiplier and the intertemproal substitution channel get dampened by a factor $\rho_j < 1$, since these channels only act through the non-tradable sector, as already emphasized in Figure 5.

From Figure 8 we can also see how, as the non-tradable sector shrinks (α_j decreases), the total employment response shrinks as well. In our framework, this decrease in the employment response is mainly driven by the multiplier channel. In fact, note that moving from the case in which $\alpha_j = 0.9$ to the case in which $\alpha_j = 0.4$ the multiplier channel shrinks by as much as 80%, while the intertemporal substitution channel only decreases by around 25%. The reason for this is that even though in (15) both the multiplier and the intertemporal substitution channel are pre-multiplied by a common factor ρ_j, this has much larger quantitative implications for the multiplier channel. In fact, this channel acts both through direct and indirect effects on the total employment response, as it affects every iteration of our Keynesian Cross mechanism. Finally, note that the model's prediction that counties with a larger tradable sector tend to respond less to monetary policy is in line with our empirical findings in Figure 3.

The Role of Household Heterogeneity We now turn to analysing the role that household heterogeneity plays in shaping the local employment response in a regional equilib-

Figure 9: Responses to a Monetary Shock: the Role of Household Heterogeneity



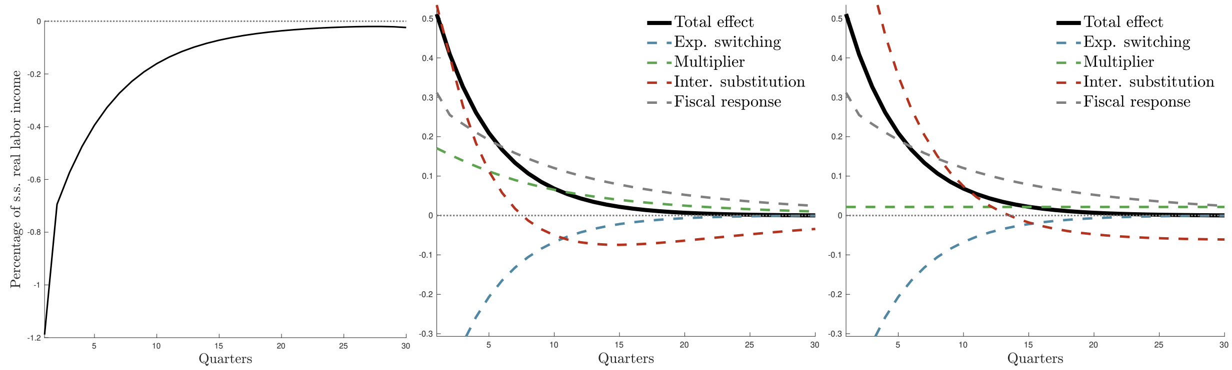
(a) Two-industry, HA

(b) Two-industry, RA

Note: Quarterly impulse responses decomposition for the shock displayed in Figure 7 in a regional equilibrium with no fiscal response and no national aggregate demand response, for the benchmark economy with tradables and non-tradables ($\omega = 0.6, \alpha_j = 0.8$) for the HA and RA cases over 30 quarters.

rium with no national demand or fiscal responses. Figure 9 compares the employment response of the HA economy to that of a RA economy in our multi-industry benchmark with $\omega = 0.6$ and $\alpha_j = 0.9$. Perhaps surprisingly, the response in the HA economy is weaker than that in the RA economy. This is because introducing market incompleteness has two opposing effects on the overall response. On the one hand, the multiplier channel (indirect effect) is magnified because of larger MPCs. On the other hand, the intertemporal substitution channel (direct effect) is weakened because constrained agents cannot fully engage in intertemporal substitution. However, in our framework the presence of the tradable sector generates a dampening which is much greater for the multiplier effect than for the intertemporal substitution effect, as discussed earlier. Because the response to monetary shocks in a HA economy goes primarily through indirect effects, while direct effects are much more important in the RA case, the weakening of the multiplier channel induced by our supply structure generates a larger dampening of the employment response in the HA economy, compared to the RA one. Hence, in a regional equilibrium where the fiscal response and the national aggregate demand response are both zero, heterogeneity leads to a dampening of the employment response to monetary shocks. In the next two paragraphs, we allow both the fiscal authority and national demand to react to the shock, and show that under reasonably small values of such reactions, heterogeneity leads to an amplification of the employment response, as we observe in the data.

Figure 10: Heterogeneity-Neutralizing Path of Income Taxes



(a) Path of aggregate taxes (b) HA with fiscal transfers (c) RA with fiscal transfers

Note: Panel (a) plots the path for the aggregate tax $\frac{dT}{W_j/P_j}$ that equalizes the employment response in the RA economy and the HA economy. Because $d\boldsymbol{T}$ is normalized by the real wage, we can interpret panel (a) as the path of aggregate taxes expressed as a percentage of the aggregate real wage. Panels (b) and (c) respectively plot the decomposition of the employment response given this path for taxes.

Fiscal response The heterogeneous agents literature has emphasized the role that the response of the fiscal authority plays in shaping the effects of monetary policy: the failure of the Ricardian equivalence implies that the fiscal reaction to a monetary shock is an important determinant of the overall size of the employment response (Kaplan et al., 2018, Alves et al., 2020). Fiscal policy has been found to be particularly powerful in delivering a strong employment response when agents are not able to engage in intertemporal substitution, as is the case in the presence of borrowing constraints. Hence, introducing a fiscal response to the monetary shocks can help match the empirical finding that counties with higher liquid wealth per capita (closer to Ricardian households) respond less to monetary shocks.

In order to assess which level of the fiscal transfer would induce a larger response in the HA economy than in the RA one in a regional equilibrium, we compute the path of fiscal transfers that equalizes the employment response in the HA economy with that in the RA economy. To do so, we first add transfers to our Regional Keynesian Cross equation (15). We can rewrite (15) in a regional equilibrium with a non-zero fiscal response $d\boldsymbol{T}_j$, still holding the national demand response fixed as follows:

$$d\boldsymbol{L}_j = \underbrace{\rho_j \boldsymbol{M}_j^r d\boldsymbol{r}_j}_{\text{Int. substitution}} + \underbrace{\rho_j \boldsymbol{M}_j d\boldsymbol{L}_j}_{\text{Multiplier}} - \underbrace{\frac{\nu}{\eta}(1-\xi_j) d\boldsymbol{L}_j}_{\text{Exp. switching channel}} - \boxed{\underbrace{\rho_j \boldsymbol{M}_j d\boldsymbol{T}_j}_{\text{Fiscal response}}} \tag{19}$$

In (19), taxes $d\boldsymbol{T}_j$ enter with a negative sign, since a rise in total taxes decreases net real income $\frac{W_{jt}L_{jt}}{P_{jt}} - T_{jt}$. Figure 10 plots the path of the aggregate income tax equalizing the employment response in the HA and RA economy for the same shock $d\boldsymbol{r}_j$ described in Figure 7. Figure 10b and Figure 10c plot the induced IRFs and their decomposition for the HA and RA economies respectively. We can see how the fiscal response achieves equalization of the total employment response in the two economies by cutting taxes, thus activating a multiplier effect which is much stronger in the HA than in the RA case. Under our particular parametrization, and while still keeping the assumption of no aggregate demand response from the rest of the nation, the on-impact tax break needs to be about 1.2% of the aggregate real labor income for the HA economy to equalize the response of the HA economy to that of the RA one. Note also that the magnitude of the equalizing fiscal response is decreasing in α_j, since the dampening of the multiplier channel gets larger as we decrease α_j. Moreover, for any tax cut larger than the equalizing one, the HA economy will feature a larger response than the RA one.

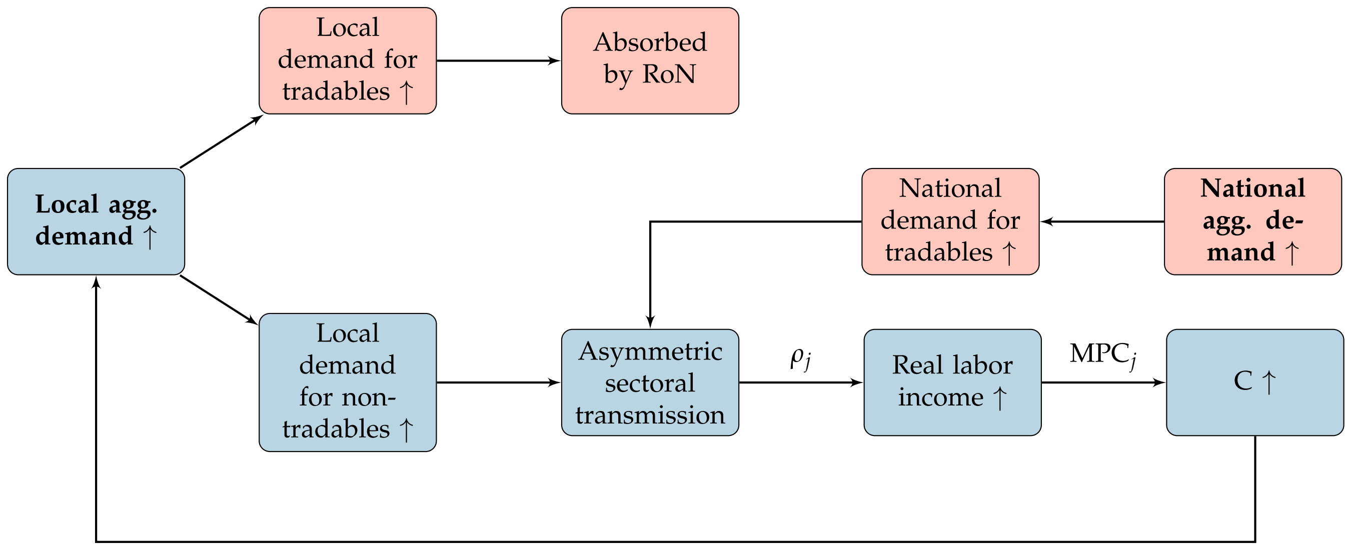
National aggregate demand In order to keep the exposition simple and focus on the regional mechanism, we have so far assumed that the rest of the nation does not respond to the monetary shock. In this section, we relax this unrealistic assumption by allowing for a national response. However, because of our small open county/economy assumption, we can for now treat the response of the rest of the nation as an exogenous object and still focus on shocks to the real interest rate in county j, $d\boldsymbol{r}_j$. We will fully endogeneize the national response later on in the text.

From the perspective of an individual county j, following an expansionary monetary shock, the national response acts as an aggregate shifter, inducing a non-zero measure increase in the demand for locally produced tradable goods and raising the price and the wage in the tradable sector. However, including the national response channel does not affect any of the intuition discussed before. In particular, the regional Keynesian multiplier logic still applies: at the regional level, the multiplier only works through the non-tradable sector. This intuition is visualized in Figure 11: a rise in national aggregate demand only translates into an additional impulse feeding in the Regional Keynesian Cross. Accordingly, because the national response translates into an increased demand for locally produced tradables, we now need to consider the market clearing condition for tradables. In particular, as tradable goods produced in different counties are perfectly substitutable and hence the law of one price holds in the tradable sector, market clearing for tradables produced in county j reads:[29]

$$L_{jt}^T = \int_0^1 C_{it}^T d\lambda(i) \tag{20}$$

[29] Note that here we are making use of our assumption that the share of tradable consumption sourced from county j' to county j is equal to the size $\lambda(j')$ of county j', i.e., $C_{jt}^T(j') = \lambda(j')C_{jt}^T$.

Figure 11: The Regional Keynesian Cross with a National Demand Response



Note that (20) implies that the labor response in the tradable sector should be equalized across counties in every period, i.e., $d\log L^T_{jt} = d\log L^T_{st}$, for all $j, s \in [0,1]$. This model prediction is consistent with the empirical results in, for example, Mian and Sufi (2014) and Chodorow-Reich et al. (2021).

The following proposition expresses the Regional Keynesian Cross in presence of an exogenous national response to the monetary impulse:

Proposition 3 (Regional Keynesian Cross with national response)**.** *The first-order response of employment $d\boldsymbol{L}_j$ to a monetary shock $d\boldsymbol{r}_j$ satisfying a regional equilibrium with no fiscal response and a national response solves the following fixed point equation:*

$$d\boldsymbol{L}_j = \underbrace{\rho_j \boldsymbol{M}^r_j d\boldsymbol{r}_j}_{\text{Int. substitution}} + \underbrace{\rho_j \boldsymbol{M}_j d\boldsymbol{L}_j}_{\text{Multiplier}} - \underbrace{\frac{\nu}{\eta}(1-\xi_j) d\boldsymbol{L}_j}_{\text{Exp. switching channel}} + \boxed{\underbrace{d\boldsymbol{N}}_{\text{National response}}} \tag{21}$$

where $d\boldsymbol{L} = \int_0^1 d\boldsymbol{L}_i d\lambda(i)$ and $d\boldsymbol{N}$ captures the spill-over from the rest of the nation response and satisfies:

$$d\boldsymbol{N} = (1-\rho_j)\left[\frac{\nu}{\eta} d\boldsymbol{L} + \int_0^1 \boldsymbol{M}_i d\boldsymbol{L}_i d\lambda(i) + \int_0^1 \boldsymbol{M}^r_i d\boldsymbol{r}_i d\lambda(i)\right] \tag{22}$$

Proof. See Appendix B.4. □

(21) clarifies the intuition which was already present in Figure 11: from the perspective of an individual county, the national response acts as an aggregate shifter acting through

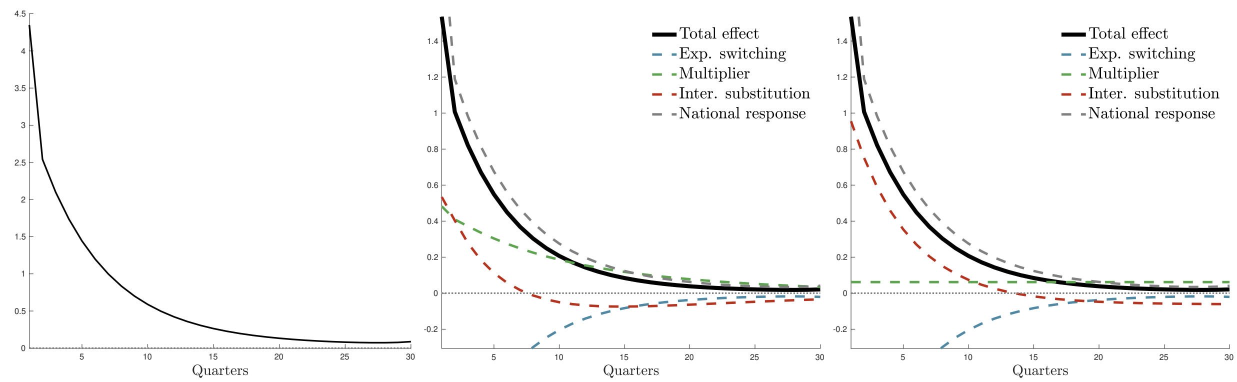
the tradable goods market. Moreover, (22) shows that the national response enters (21) additively with a factor of proportionality $1-\rho_j$. The reason for this is that aggregate demand from the rest of the nation spills-over to county j's local economy only through the market for non-tradables. Note, however, that this does not necessarily imply that counties with a larger share of tradable employment $1-\rho_j$ will respond more to changes in aggregate national demand $d\boldsymbol{N}$. In fact, once the increased demand for tradables coming from the rest of the country transmits to the local economy, the regional multiplier mechanism that we discussed above kicks in. As the magnitude of this multiplier is increasing in the share of non-tradable employment ρ_j, the role that ρ_j plays for the transmission of changes in national demand to the local employment response is ambiguous.

Another interesting implication of Proposition 3 is that the presence of a national response dampens the expenditure switching channel, as can be seen from the first term in (22). This is due to the fact that the price for non-tradables has two countervailing effects: on the one hand, it moves local demand away from non-tradables, on the other hand it crowds-in demand for tradables from the rest of the Nation. In particular, taken together, (21) and (22) imply that in response to an expansionary monetary shock the overall effect of the expenditure switching channel will be negative only for those counties which experience a labor response larger than the national a one, i.e., for which $d\boldsymbol{L}_j > d\boldsymbol{L}$. The opposite will instead be true for those counties for which $d\boldsymbol{L}_j < d\boldsymbol{L}$. Finally, (22) makes clear that the *joint* distribution of employment responses and iMPCs across space (counties) matters for determining the size of national demand spillovers to the local economy. This can be seen more clearly once we rearrange (21) and express it in terms of covariances as follows:

$$d\boldsymbol{L}_j = -\frac{\nu(1-\rho_j)}{\eta}d\boldsymbol{L}_j + \rho_j\boldsymbol{M}_j d\boldsymbol{L}_j - \rho_j\boldsymbol{M}_j d\boldsymbol{T}_j + \rho_j\boldsymbol{M}_j^r d\boldsymbol{r}_j + (1-\rho_j)\left[\frac{\nu}{\eta}d\boldsymbol{L} + \boldsymbol{M}d\boldsymbol{L} - \boldsymbol{M}d\boldsymbol{T} + \boldsymbol{M}^r d\boldsymbol{r}\right]$$
$$+ (1-\rho_j)\Big[\mathrm{Cov}(\boldsymbol{M}_i, d\boldsymbol{L}_i) - \mathrm{Cov}(\boldsymbol{M}_i, d\boldsymbol{T}_i) + \mathrm{Cov}(\boldsymbol{M}_i^r, d\boldsymbol{r}_i)\Big] \tag{23}$$

Where $\boldsymbol{M} = \int_0^1 \boldsymbol{M}_i d\lambda(i)$, $\boldsymbol{M}^r = \int_0^1 \boldsymbol{M}_i^r d\lambda(i)$, $d\boldsymbol{T} = \int_0^1 d\boldsymbol{T}_i d\lambda(i)$, and $d\boldsymbol{r} = \int_0^1 d\boldsymbol{r}_i d\lambda(i)$. (23) shows that the joint distribution of iMPCs, employment responses, fiscal responses, and changes in the real interest rates across the nation matters for the local employment response. However, the distribution of national trade openness across space does not enter the Regional Keynesian Cross (23) directly. Nonetheless, as we will show later on, the joint distribution of trade openness and household heterogeneity across space is going to play a crucial role in determining the country-wide employment response to monetary shocks, and hence will still matter for the local employment response and affect (23).

Figure 12: Heterogeneity-Neutralizing Path of National Response



(a) National response (b) HA with national response (c) RA with national response

Note: Panel (a) plots the path for the percentage change in national demand that equalizes the employment response in the RA economy and the HA economy, in percentage points. Panels (b) and (c) respectively plot the decomposition of the employment response given this tradable sector wage path.

As we already did for the fiscal response, we can now compute the period-by-period change $d\boldsymbol{N}$ that equalizes the total employment response in the HA and RA economy at each horizon. Figure 12 plots this heterogeneity-neutralizing response together with the IRF decomposition in the two economies. Under our parametrization, the on-impact increase in national demand required to equalize the response in the RA and HA economy is around 4.5%. An increase that is larger than this will imply that the response of the HA economy is greater than the RA one, in line with what we find in the data.

4.3 Stabilization Policies

In this section we look at the implications that regional heterogeneity in MPCs and openness to trade have for stabilization policies. To do so, we allow both for the presence of a national demand response and for a fiscal response. In order to simplify the analysis, however, we now focus on a case in which $d\boldsymbol{r}_j = \boldsymbol{0}$, i.e. the real interest remains fixed in the short run. In this context, the Regional Keynesian Cross can be expressed as follows:

$$d\boldsymbol{L}_j = \rho_j \boldsymbol{M}_j d\boldsymbol{L}_j - \frac{\nu}{\eta}(1-\xi_j)d\boldsymbol{L}_j + (1-\rho_j)d\boldsymbol{N} - \rho_j \boldsymbol{M}_j d\boldsymbol{T}_j \tag{24}$$

Suppose county j is hit with an exogenous national demand shock $d\boldsymbol{N}$ inducing a variation in the demand for tradable goods produced in j. What path of transfers $d\boldsymbol{T}_j$ stabilizes employment given the national demand shock, so that $d\boldsymbol{L}_j = \boldsymbol{0}$? From (24), the employment-stabilizing fiscal response for county j following a national demand shock

dN is simply given by:[30]

$$dT_j = \left(\rho_j M_j\right)^{-1} \left(1 - \rho_j\right) dN \tag{25}$$

The first important implication of (25) is that the two dimensions of regional heterogeneity that we are considering shape macro-stabilization policies. Specifically, for a given shock dN, the size of the fiscal response that stabilizes employment will be smaller for counties with high levels of non-tradable employment, meaning high ρ_j. This is due to two factors. First, the shock affects counties with large non-tradable sectors to a lesser extent since national demand propagates through the tradable sector. Second, since the regional multiplier is increasing in ρ_j, regions with high non-tradable employment require smaller changes in taxes to achieve a given change in employment. Because of the same reason, (25) also shows that high-iMPC counties will require smaller fiscal interventions in order for output to be stabilized. Moreover, the iMPC-trade openness complementarity that was discussed in Section 3.4 is also relevant for stabilization policies. In particular, (25) shows how the extent to which iMPCs matter for the employment-stabilizing response depends on industry composition, and viceversa.

If a shock affects all counties symmetrically, the size of the employment-stabilizing fiscal response depends on the unique characteristics of each county.[31] Because of this, within our regional framework fiscal policy can play an important role in macroeconomic stabilization, going back to the "Tinbergen rule" (Tinbergen, 1952): following a symmetric shock, monetary policy has access only to a single instrument –namely, the nominal interest rate– to stabilize employment across regions; fiscal policy, on the other hand, is endowed with a multidimensional tool, since it can set region specific transfers and is therefore better equipped to stabilize activity across space. This suggests, for example, that in response to a symmetric shock monetary policy can guarantee that output is stabilized on average across counties, while fiscal policy will be responsible for stabilizing employment at the county level.

Finally, an interesting implication of these results is that in our model zero-deficit fiscal policy can be expansionary. The fiscal authority can indeed set transfers $\{dT_j\}_{j\in[0,1]}$ such that $\int_0^1 dT_j d\lambda(j) = \mathbf{0}$ while still increasing aggregate employment. This is due to the fact that different counties feature different fiscal multipliers, so that transferring resources from low to high-multiplier counties is going to boost national economic activity.

[30] When markets are incomplete M_j is invertible. More formally, dT_j solves $\rho_j M_j dT_j = \left(1 - \rho_j\right) dN$.

[31] As explained above, the national demand shock dN is symmetric across counties but propagates asymmetrically, because it only acts through the market for tradables. However, the result that the employment-stabilizing response is county-specific does not rely on this asymmetric transmission, and also holds when we keep fixed the size of the effective shock $d\tilde{N} \equiv \left(1 - \rho_j\right) dN$.

5 The National Keynesian Cross

We now turn to aggregating the regional Keynesian crosses for our continuum of counties $j \in [0,1]$ to derive an expression for the National Keynesian Cross, linking the response of aggregate, country-wide employment to a monetary shock. In particular, we show how the joint distribution of iMPCs and trade openness across space (regions) matters in shaping the national response. To do so, we integrate the Regional Keynesian Cross with a national response (21) over the measure of counties $\lambda(j)$. The country-wide change in employment $d\boldsymbol{L} = \int_0^1 d\boldsymbol{L}_j d\lambda(j)$ is then characterized by the following expression:

$$d\boldsymbol{L} = -\frac{\nu}{\eta}\left[\int_0^1 (1-\rho_j) d\boldsymbol{L}_j d\lambda(j) - (1-\rho)\, d\boldsymbol{L}\right] + \int_0^1 \rho_j \boldsymbol{M}_j d\boldsymbol{L}_j d\lambda(j) - \int_0^1 \rho_j \boldsymbol{M}_j d\boldsymbol{T}_j d\lambda(j) + \int_0^1 \rho_j \boldsymbol{M}^r_j d\boldsymbol{r}_j d\lambda(j) + (1-\rho)\left[\int_0^1 \boldsymbol{M}_j d\boldsymbol{L}_j d\lambda(j) - \int_0^1 \boldsymbol{M}_j d\boldsymbol{T}_j d\lambda(j) + \int_0^1 \boldsymbol{M}^r_j d\boldsymbol{r}_j d\lambda(j)\right] \tag{26}$$

Where $d\boldsymbol{L}_j$ is given by (21) and $\rho = \int_0^1 \rho_j d\lambda(j)$. We can rewrite (26) in terms of covariances as follows:

$$\begin{aligned} d\boldsymbol{L} = & \underbrace{\boldsymbol{M}\,(d\boldsymbol{L} - d\boldsymbol{T}) + \boldsymbol{M}^r d\boldsymbol{r}}_{\text{Standard Keynesian cross}} \\ & + \underbrace{\boldsymbol{M}\left[\mathrm{Cov}(\rho_j, d\boldsymbol{L}_j) - \mathrm{Cov}(\rho_j, d\boldsymbol{T}_j)\right] + \boldsymbol{M}^r\,\mathrm{Cov}(\rho_j, d\boldsymbol{r}_j) + \frac{\nu}{\eta}\mathrm{Cov}(\rho_j, d\boldsymbol{L}_j)}_{\text{Trade openness heterogeneity}} \\ & + \underbrace{(1-\rho)\left[\mathrm{Cov}(\boldsymbol{M}_j, d\boldsymbol{L}_j) - \mathrm{Cov}(\boldsymbol{M}_j, d\boldsymbol{T}_j) + \mathrm{Cov}(\boldsymbol{M}^r_j, d\boldsymbol{r}_j)\right]}_{\text{iMPC heterogeneity}} \\ & + \underbrace{\mathrm{Cov}(\boldsymbol{M}_j, \rho_j\,(d\boldsymbol{L}_j - d\boldsymbol{T}_j)) + \mathrm{Cov}(\boldsymbol{M}^r_j, \rho_j d\boldsymbol{r}_j)}_{\text{iMPC-trade openness complementarity}} \end{aligned} \tag{27}$$

Where $\boldsymbol{M} = \int_0^1 \boldsymbol{M}_j d\lambda(j)$, $\boldsymbol{M}^r = \int_0^1 \boldsymbol{M}^r_j d\lambda(j)$, $d\boldsymbol{T} = \int_0^1 d\boldsymbol{T}_j d\lambda(j)$, and $d\boldsymbol{r} = \int_0^1 d\boldsymbol{r}_j d\lambda(j)$. (27) shows that in our regional framework, the country-wide employment response to a monetary shock can be decomposed in four different objects: a monetary version of the standard intertemporal Keynesian cross (Auclert et al., 2018) term, a term capturing the effect of heterogeneous trade openness, one object representing the role of iMPCs heterogeneity across regions, and a term capturing equilibrium interactions.

Shutting down trade openness heterogeneity – If we shut down heterogeneity in regional trade openness, so that it holds that $\rho_j = \rho$ for all $j \in [0,1]$, (27) becomes:

$$d\boldsymbol{L} = \boldsymbol{M}\,(d\boldsymbol{L} - d\boldsymbol{T}) + \boldsymbol{M}^r d\boldsymbol{r} + \mathrm{Cov}(\boldsymbol{M}_j, d\boldsymbol{L}_j) - \mathrm{Cov}(\boldsymbol{M}_j, d\boldsymbol{T}_j) + \mathrm{Cov}(\boldsymbol{M}^r_j, d\boldsymbol{r}_j) \tag{28}$$

(28) shows the effect of iMPC heterogeneity across regions for the national response. We can see that the country-wide employment response is amplified whenever high MPC regions experience large labor responses. In fact, recall that the strength of the regional multiplier is increasing in households' iMPCs, summarized by $\boldsymbol{M}_j$. Thus, when regions with high iMPCs experience large employment responses, a large multiplier effect is going to kick-in at the local level, hence amplifying the national response. Precisely because of this intuition, (28) also shows that the distribution of the fiscal authority's reaction across regions matters for the aggregate employment response. In fact, after an expansionary monetary shock, the aggregate employment response is going to be amplified whenever fiscal policy engages in transfers from low MPC to high MPC regions. Finally, the last term in (28) shows how, quite intuitively, the national response is increasing in the covariance across space between households' intertemporal substitution motives –captured by $\boldsymbol{M}_j^r$– and the change in the county-specific real interest rate. Note how, differently from the Regional Keynesian Cross (15), (28) features no expenditure switching channel. In fact, in the case in which trade openness is homogeneous across regions, the expenditure switching channel cancels out on aggregate, since any substitution of demand from non-tradables to tradables taking place at the local level is still going to be satisfied within the nation.

Shutting down MPC heterogeneity – If we shut down heterogeneity in iMPCs across regions, so that it holds that $\boldsymbol{M}_j = \boldsymbol{M}$ and $\boldsymbol{M}_j^r = \boldsymbol{M}^r$ for all $j \in [0,1]$, (27) becomes:

$$d\boldsymbol{L} = \boldsymbol{M}\left(d\boldsymbol{L} - d\boldsymbol{T}\right) + \boldsymbol{M}^r d\boldsymbol{r} + \boldsymbol{M}\left[\mathrm{Cov}(\rho_j, d\boldsymbol{L}_j) - \mathrm{Cov}(\rho_j, d\boldsymbol{T}_j)\right] + \boldsymbol{M}^r\,\mathrm{Cov}(\rho_j, d\boldsymbol{r}_j) + \frac{\nu}{\eta}\mathrm{Cov}(\rho_j, d\boldsymbol{L}_j) \quad (29)$$

(29) shows the role of heterogeneous trade openness across space for the national response. It can be seen how the aggregate response is amplified whenever high non-tradable intensity regions experience large employment responses. This is because the magnitude of the regional multiplier is increasing in the share of non-tradable employment ρ_j, as discussed above. Thus, when counties with high non-tradable employment experience large employment changes a larger multiplier effect kicks-in, hence amplifying the national response. Analogously to the case of MPC heterogeneity, (29) also shows that the distribution of fiscal transfers across space shapes the national employment response. In particular, following an expansionary monetary policy shock, the national response is going to be amplified whenever the fiscal authority redistributes from low to high non-tradable employment counties.[32] Similarly, the country-wide employment response is also increasing in the covariance between the county-level share of non-tradable employment and the change in the county-specific real interest rate. This is because at

[32]This is once more due to the fact that the regional multiplier is increasing in the share of non-tradable employment.

the local level the magnitude of the intertemporal substitution (direct) channel of monetary policy is increasing in ρ_j. Finally, note that when openness is heterogeneous across regions, it is in general no longer the case that the expenditure switching channel cancels out on aggregate. This fact is captured by the last term in (29). To see this, consider the case of an expansionary monetary policy shock and recall that at the local level the size of the expenditure switching channel is decreasing in the share of non-tradable employment. Hence, whenever the regions that experience the largest employment responses have high non-tradable employment, the expenditure switching is going to be smaller in those counties that also feature a large multiplier channel. In turn, this is going to amplify the national employment response.

MPC-trade openness interactions – The last term in (27) shows how in our framework the *joint* distribution of trade openness and households' MPCs across space matters in shaping the aggregate response to a monetary shock. Moreover, even in the limit case in which there is no sorting of households and industries between regions, i.e., in which $\text{Cov}(\rho_j, \boldsymbol{M}_j) = \text{Cov}(\rho_j, \boldsymbol{M}_j^r) = 0$, the iMPC-industry complementarities term would still be present in (27). In fact, as we have showed in the context of the Regional Keynesian Cross, our setting features a complementarity between household heterogeneity and trade openness. This complementarity is still present at the aggregate level.

6 Discussion

In this section we offer a qualitative discussion of how our framework relates to other prominent and recent advances in the literature. Specifically, an important implication of our key result - Proposition 1 - is that our two-layered heterogeneity structure relates to and sometimes nests several existing models and concepts.

HANK – When both the preference for non-tradables ω and the trade openness parameter α_j go to 1, the model collapses to a standard one-industry, one-region economy, since the only active sector is the non-tradable one. In particular, we have $\rho_j = \xi_j = 1$. Thus, under this parametrization, the Regional Keynesian Cross (15) simplifies to $d\boldsymbol{L}_j = \boldsymbol{M}_j d\boldsymbol{L}_j + \boldsymbol{M}_j^r d\boldsymbol{L}_j$. This representation corresponds to a monetary version of the intertemporal Keynesian cross described in Auclert et al. (2018), with the driver of the response given by monetary – rather than fiscal – shocks.

TANK – Our model can also be generalized to nest the framework of Bilbiie (2020). In particular, we can always rewrite the household problem such that the implied Jacobians $\boldsymbol{M}_j$ and $\boldsymbol{M}_j^r$ correspond to those in the standard Two Agent New Keynesian (TANK) model. Furthermore, if we consider the limiting case of having only tradables ($\omega = \alpha_j =$

0), our framework boils down to a special case of a regional TANK model with no sectoral heterogeneity, such as the one presented in Herreño and Pedemonte (2022).

RANK – Note that the matrices $\boldsymbol{M}_j$ and $\boldsymbol{M}_j^r$ capture all household heterogeneity in the economy. In particular, changes to the borrowing limit or to the parametrization of the income process in the economy are going to result in different iMPCs. Thus, if we relax the borrowing limit to the natural one and shut down income volatility, the Jacobians $\boldsymbol{M}_j$ and $\boldsymbol{M}_j^r$ collapse to the ones for the representative agent, with $\boldsymbol{M}_j \approx 0$ (small iMPCs). If we also set $\omega = \alpha_j = 1$ as above, our model collapses to the standard representative agent New Keynesian model, as in Galí (2008) and Woodford (2003).

International Keynesian Cross – A recent literature has uncovered novel insights when analyzing household heterogeneity in the context of international economics. de Ferra et al. (2020) develop a small open economy HANK framework and show that portfolio composition and foreign currency borrowing determine the degree of amplification of the domestic macroeconomic response to foreign demand shocks. In a recent paper, Auclert et al. (2021b) derive an insightful result in sequence space: the *International* Keynesian Cross (IKC), whose key component is the open-economy multiplier of domestic real interest rate shocks, which is governed by home bias. Generally speaking, a small-open-economy extension of our model would yield a generalized multiplier with two very distinct features. First, the degree of openness to *national* trade, as captured by the regional distribution of non-tradable employment intensity. Second, the extent of openness to *international* trade which, as in de Ferra et al. (2020), is measured on the intensive margin by the exposure of the domestic population to foreign currency and demand shocks. This generalization would enable general equilibrium quantification of asymmetric regional welfare effects of foreign shocks such as, for example, the China syndrome (Autor et al., 2020), which is very well known to have had a highly unequal impact on U.S. counties. More work in this direction is required.

The Matching Multiplier – A growing literature highlights that sorting of workers across sectors can produce powerful amplification effects of demand shocks (Cugat, 2019, Patterson, 2022). In a recent paper, Patterson (2022) uncovers the "matching multiplier" channel: the transmission of aggregate shocks is amplified by high-MPC individuals sorting themselves into highly cyclical jobs. Similarly, Cugat (2019) finds that working in the tradable versus non-tradable sector is an important determinant of the household-level response to aggregate shocks. She then shows that this channel has important consequences for the propagation of aggregate shocks in a small open economy New Keynesian model with household heterogeneity. Our empirical investigation uncovers a complementarity between regional household and industry compositions. Specifically, the response to monetary policy shocks is amplified in counties which simultaneously have a high share of non-tradable employment and high MPCs. This complementarity does *not*, however, necessarily imply that high-MPC individuals are being employed in the non-tradable sector. While our empirical setting cannot rule out the sorting mechanism completely, the fact that we control for the role of regional MPCs and non-tradable employment *jointly* implies that we are able to partially account for it.

7 Conclusion

We build an empirically-motivated general equilibrium model of a monetary union with two layers of regional heterogeneity: intertemporal MPCs and trade openness. We derive a *regional Keynesian cross*: variation of a canonical formula that is characterized in the context of monetary policy transmission across units of space. Essential to our mechanism and derivations is a novel iMPC-trade openness complementarity that arises through equilibrium interactions between our two sources of regional heterogeneity. This complementarity is supported by the data, thus validating our modelling approach. The mechanism survives aggregation and features explicitly in the *national Keynesian cross* and the nationwide macroeconomic response to monetary shocks.

Despite the first-glance complexity of our empirical and theoretical exercises, a simple and unifying theme emerges organically - openness to trade is essential for the magnitude of the multiplier and for the efficacy of macroeconomic stabilization policies. Counties that are more open to national trade feature a dampened response to national monetary impulses and, contrary to the seminal arguments of McKinnon (1963), are generally more vulnerable in terms of fiscal funding that is required to stabilize the local economy following adverse demand shocks. We are thus re-inforcing the general results of Farhi and Werning (2017) from the additional angles of a data-rich empirical analysis and a multi-dimensional HANK model solved in sequence space.

Our paper can help to direct a large class of macroeconomic models that study general equilibrium transmission of shocks through *regions*. The regional Keynesian cross representation can guide new avenues for empirical tests and applications in a wide variety of settings. A promising application of our approach is represented by the Eurozone context, where intra- as well as cross-country heterogeneity in household wealth and trade openness present another laboratory for policy analysis. Another fruitful extension of our framework could be along the international dimension: permitting households in our economy to invest internationally would generate a generalized Keynesian cross that would combine intra- and inter-national multipliers of domestic and foreign shocks.

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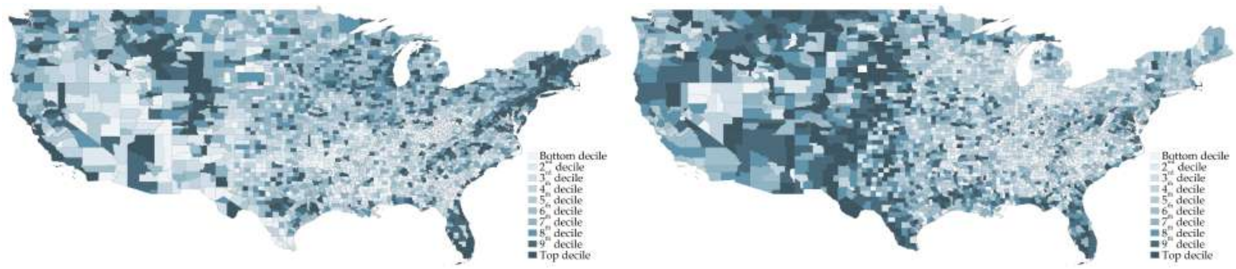
A Empirical Appendix

A.1 Additional Results and Robustness Checks

Figure A.1: County rankings: 1990-2015 average

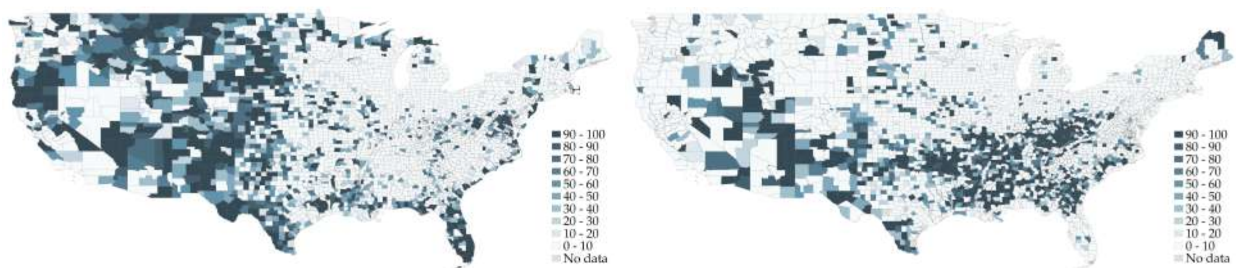


(a) Non-tradable / tradable employment ratio

(b) Real stock market wealth per capita

Note: we rank counties based on their average real stock market wealth per capita and non-tradable to tradable employment ratio over the years 1990 to 2015.

Figure A.2: Geographical Distribution of D^{NT}_{jt} and D^{W}_{jt}

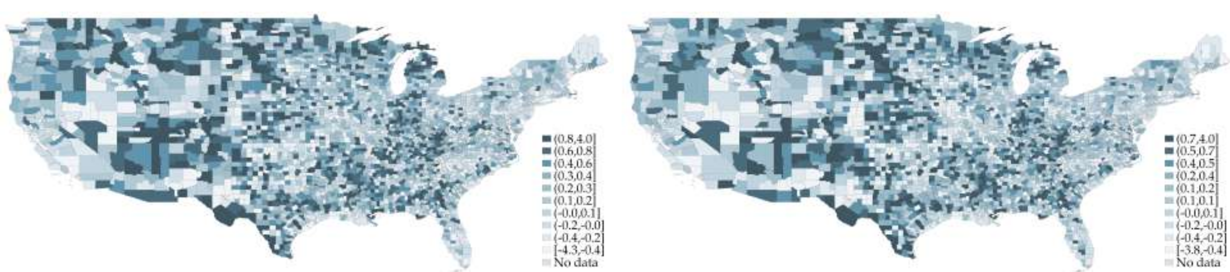


(a) Non-tradable / tradable employment ratio

(b) Real stock market wealth per capita

Note: this figure shows the share of years in which each county has our two indicator variables of interest D^{NT}_{jt} and D^{W}_{jt} turned on.

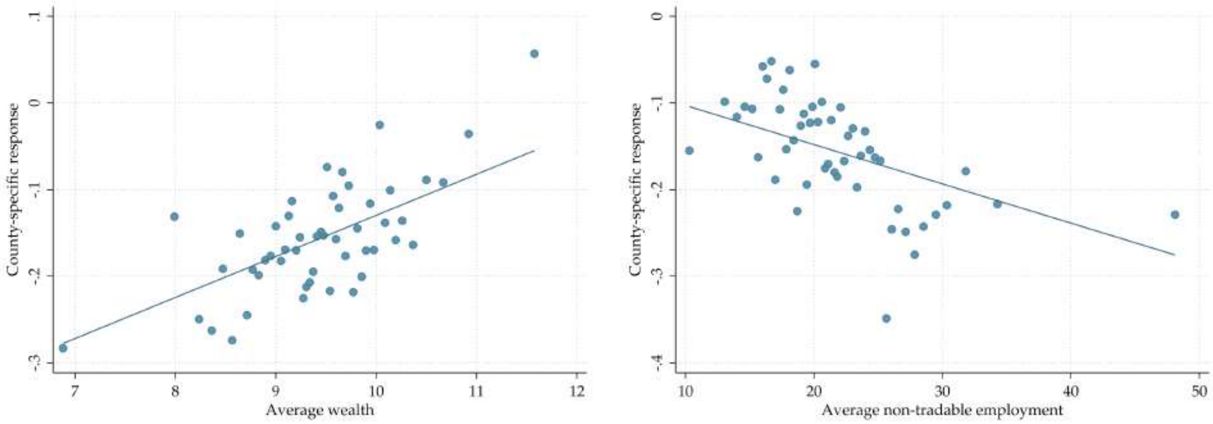
Figure A.3: Regional Responses to Monetary Shocks – Different Horizons



(a) 30-month ahead

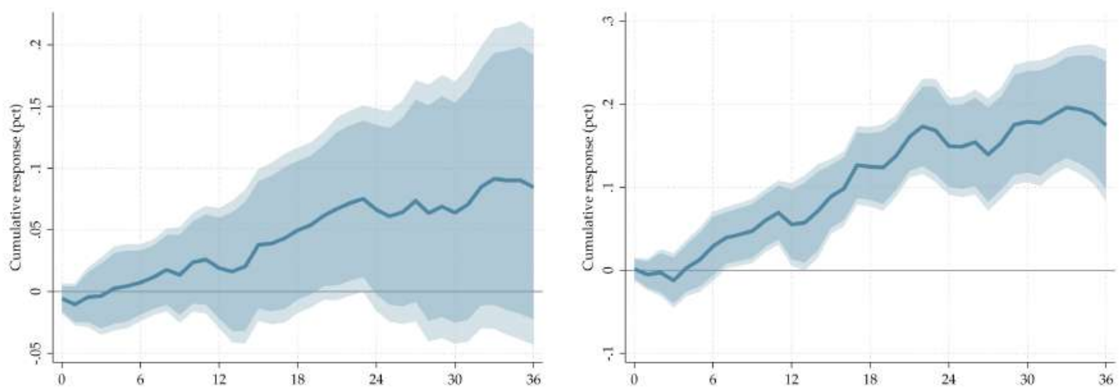
(b) 24-month ahead

Figure A.4: County-specific Response vs Wealth & Non-tradable Employment



Note: this figure plots the relationship between the county-specific response to monetary shock and real stock market wealth per capita as well as non-tradable employment. We group counties in 50 bins and compute population weighte average of both y-axis and x-axis variables.

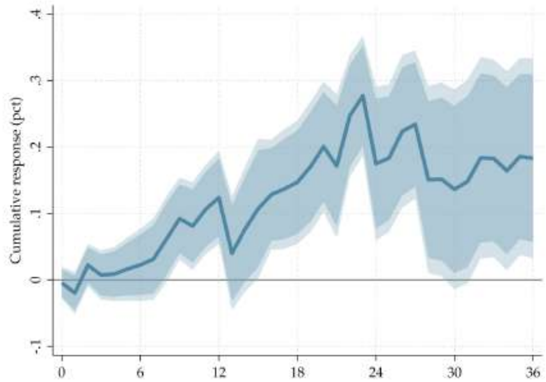
Figure A.5: Robustness – two-way clustering at date and county level



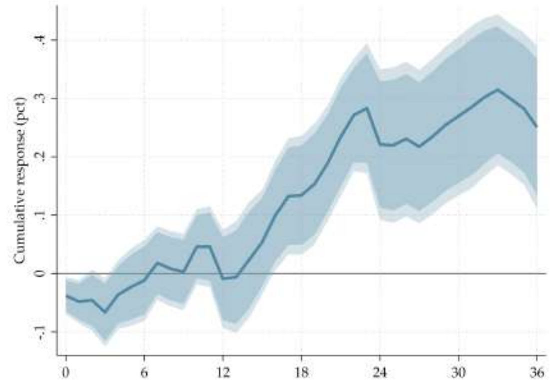
(a) β_h^{NT} (b) β_h^{W}

Note: errors are two-way clustered at the county and time level. Lightly shaded areas represent 95% confidence intervals. Darkly shaded areas are 90% confidence intervals. The y-axis represents the cumulative percentage change in employment. The x-axis represents months elapsed since the shock.

Figure A.6: Robustness – top 5%



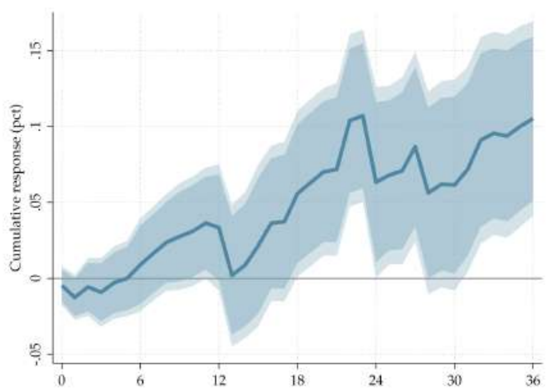
(a) β_h^{NT}



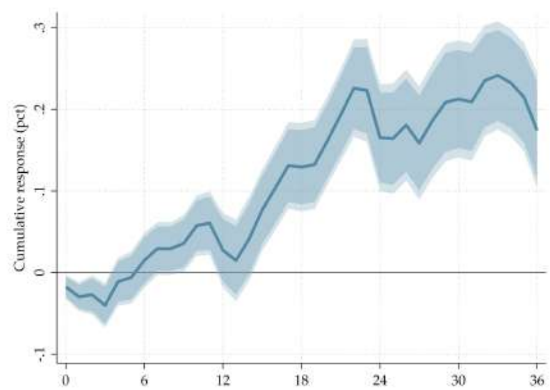
(b) β_h^{W}

Note: errors are clustered at the county level. Lightly shaded areas represent 95% confidence intervals. Darkly shaded areas are 90% confidence intervals. The y-axis represents the cumulative percentage change in employment. The x-axis represents months elapsed since the shock.

Figure A.7: Robustness – top 15%



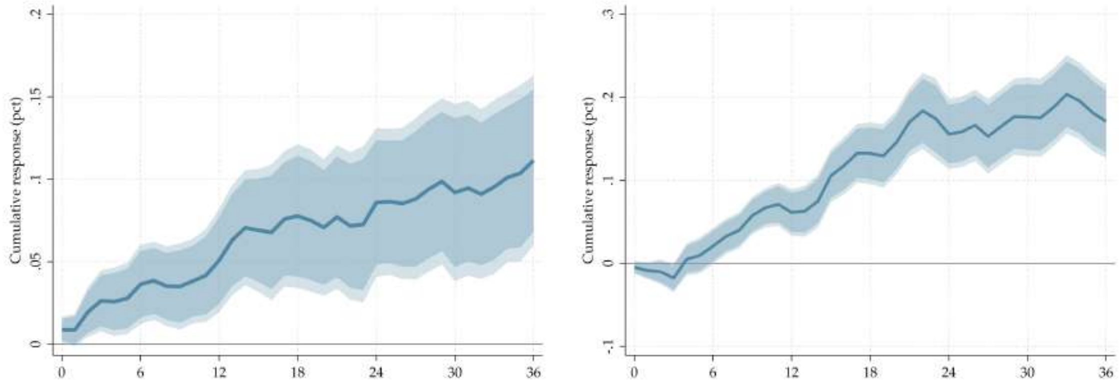
(a) β_h^{NT}



(b) β_h^{W}

Note: errors are clustered at the county level. Lightly shaded areas represent 95% confidence intervals. Darkly shaded areas are 90% confidence intervals. The y-axis represents the cumulative percentage change in employment. The x-axis represents months elapsed since the shock.

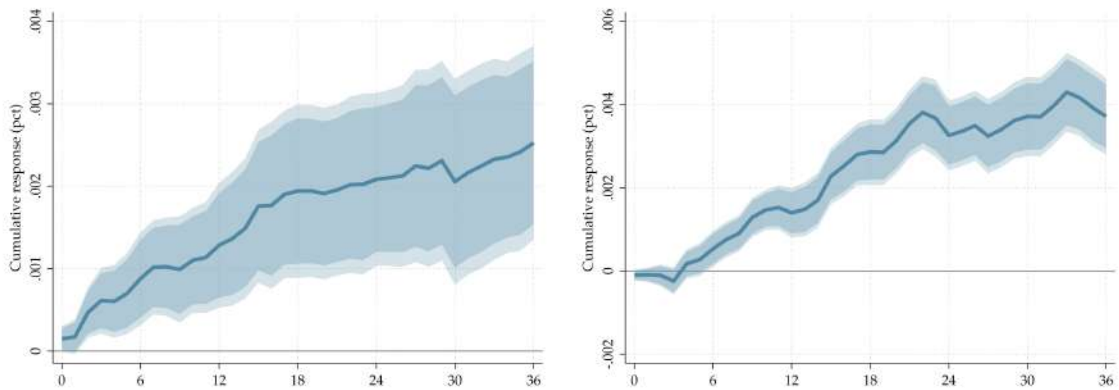
Figure A.8: Robustness – top 50%



(a) β_h^{NT} (b) β_h^{W}

Note: errors are clustered at the county level. Lightly shaded areas represent 95% confidence intervals. Darkly shaded areas are 90% confidence intervals. The y-axis represents the cumulative percentage change in employment. The x-axis represents months elapsed since the shock.

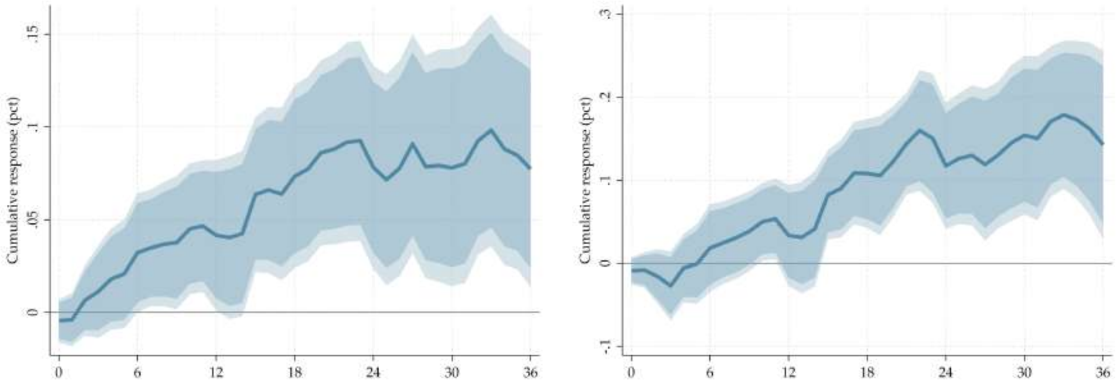
Figure A.9: Robustness – continuous interaction – percentiles



(a) β_h^{NT} (b) β_h^{W}

Note: errors are clustered at the county level. Lightly shaded areas represent 95% confidence intervals. Darkly shaded areas are 90% confidence intervals. The y-axis represents the cumulative percentage change in employment. The x-axis represents months elapsed since the shock.

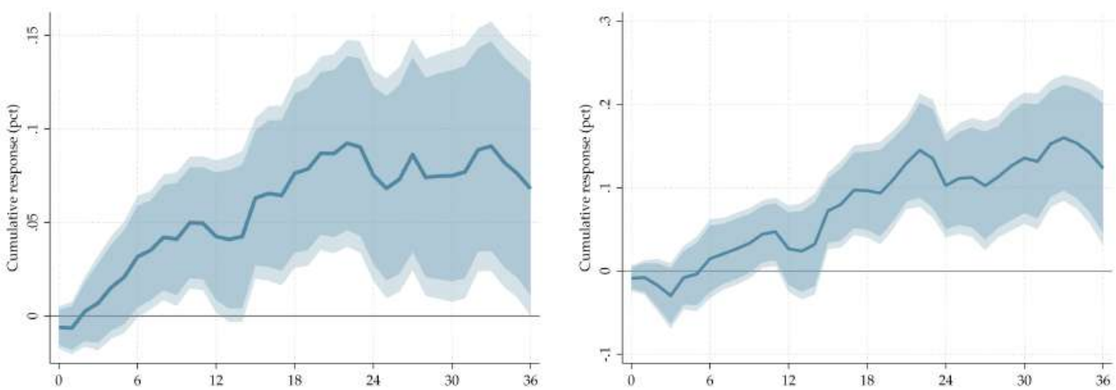
Figure A.10: Robustness – state FE$\times$shock



(a) β_h^{NT} (b) β_h^{W}

Note: errors are clustered at the county level. Lightly shaded areas represent 95% confidence intervals. Darkly shaded areas are 90% confidence intervals. The y-axis represents the cumulative percentage change in employment. The x-axis represents months elapsed since the shock.

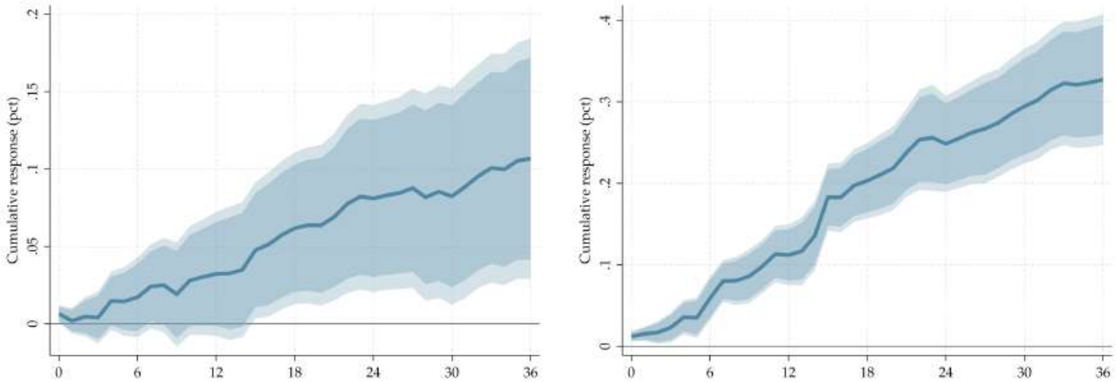
Figure A.11: Robustness – state$\times$date FE$\times$shock



(a) β_h^{NT} (b) β_h^{W}

Note: errors are clustered at the county level. Lightly shaded areas represent 95% confidence intervals. Darkly shaded areas are 90% confidence intervals. The y-axis represents the cumulative percentage change in employment. The x-axis represents months elapsed since the shock.

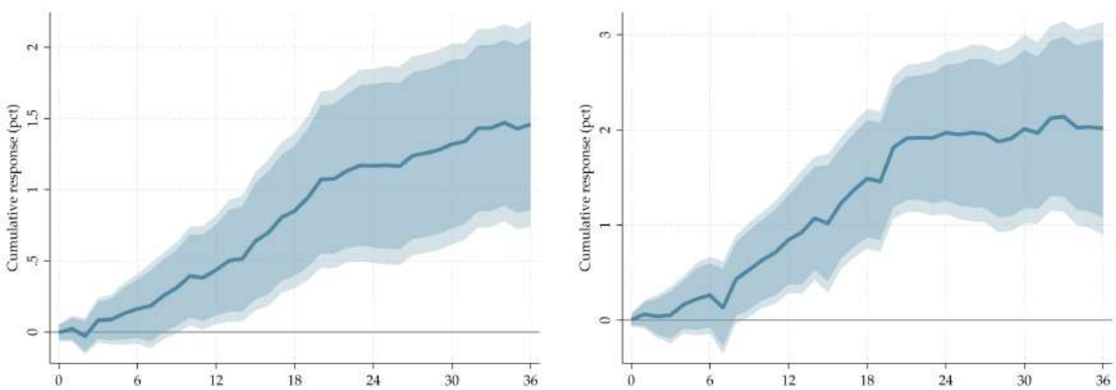
Figure A.12: Robustness – seasonally adjusted employment



(a) β_h^{NT} (b) β_h^{W}

Note: errors are clustered at the county level. Lightly shaded areas represent 95% confidence intervals. Darkly shaded areas are 90% confidence intervals. The y-axis represents the cumulative percentage change in employment. The x-axis represents months elapsed since the shock.

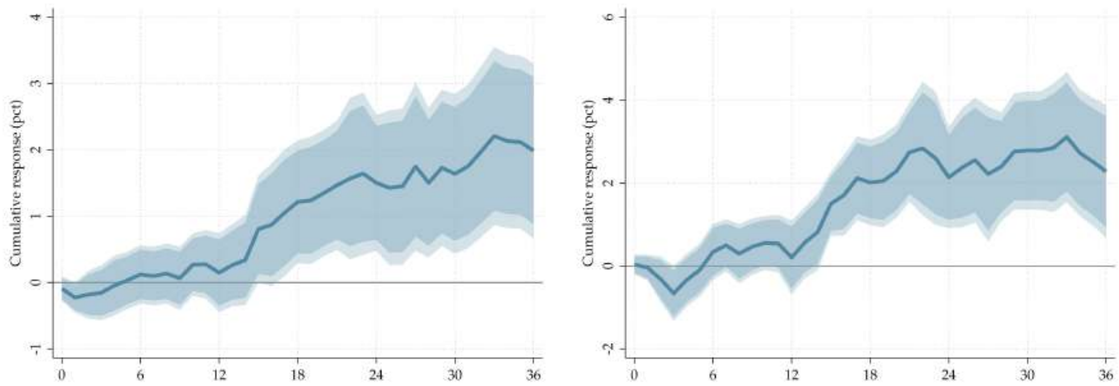
Figure A.13: Robustness – Romer and Romer (2000) shock



(a) β_h^{NT} (b) β_h^{W}

Note: errors are clustered at the county level. Lightly shaded areas represent 95% confidence intervals. Darkly shaded areas are 90% confidence intervals. The y-axis represents the cumulative percentage change in employment. The x-axis represents months elapsed since the shock.

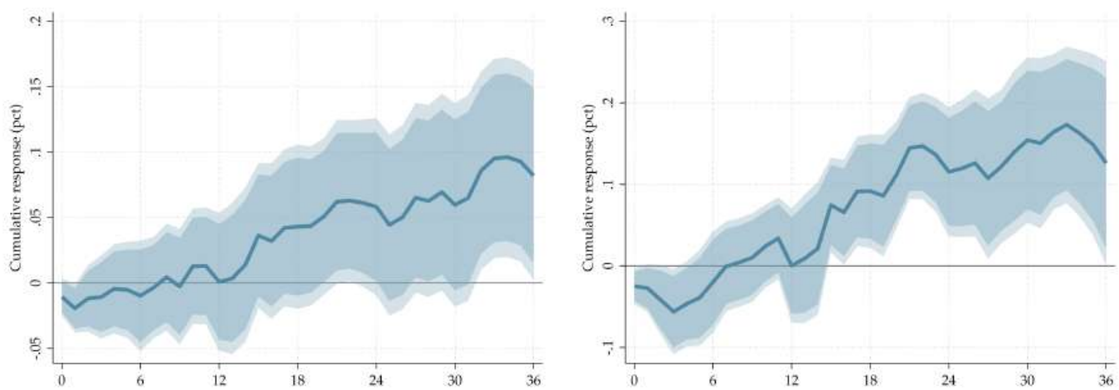
Figure A.14: Robustness – Miranda-Agrippino and Ricco (2021) shock



(a) β_h^{NT} (b) β_h^{W}

Note: errors are clustered at the county level. Lightly shaded areas represent 95% confidence intervals. Darkly shaded areas are 90% confidence intervals. The y-axis represents the cumulative percentage change in employment. The x-axis represents months elapsed since the shock.

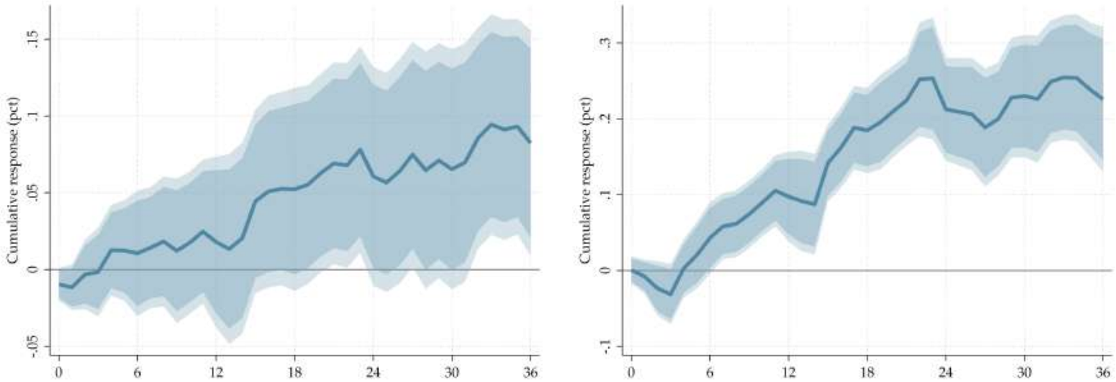
Figure A.15: Robustness – ending the sample in 2006m12



(a) β_h^{NT} (b) β_h^{W}

Note: errors are clustered at the county level. Lightly shaded areas represent 95% confidence intervals. Darkly shaded areas are 90% confidence intervals. The y-axis represents the cumulative percentage change in employment. The x-axis represents months elapsed since the shock.

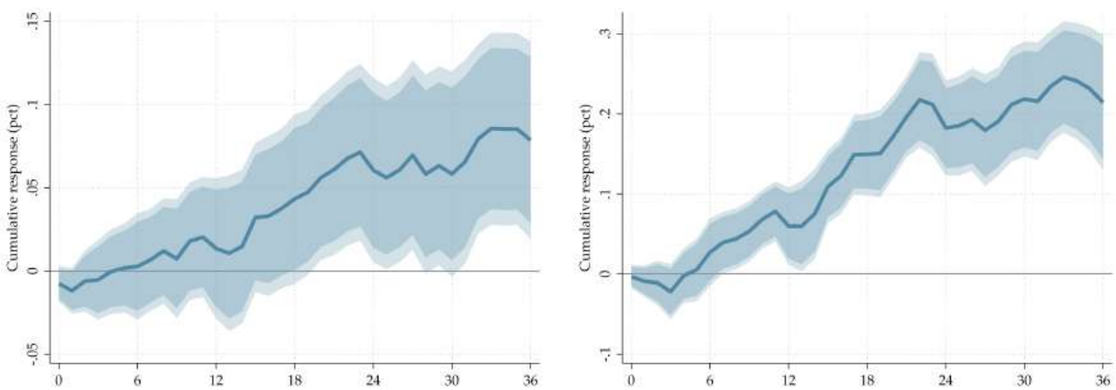
Figure A.16: Robustness – starting the sample in 1997m1



(a) β_h^{NT} (b) β_h^{W}

Note: errors are clustered at the county level. Lightly shaded areas represent 95% confidence intervals. Darkly shaded areas are 90% confidence intervals. The y-axis represents the cumulative percentage change in employment. The x-axis represents months elapsed since the shock.

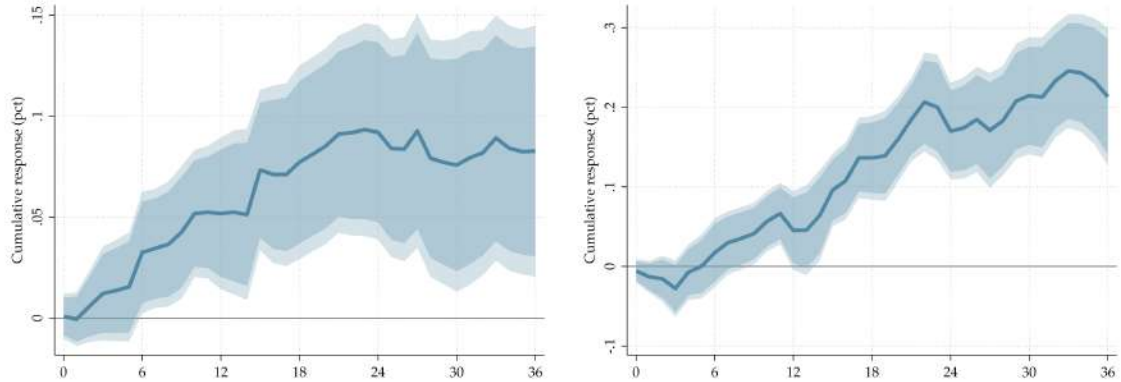
Figure A.17: Robustness – excluding Alaska, Hawaii, and District of Columbia



(a) β_h^{NT} (b) β_h^{W}

Note: errors are clustered at the county level. Lightly shaded areas represent 95% confidence intervals. Darkly shaded areas are 90% confidence intervals. The y-axis represents the cumulative percentage change in employment. The x-axis represents months elapsed since the shock.

Figure A.18: Robustness – excluding Florida



(a) β_h^{NT} (b) β_h^{W}

Note: errors are clustered at the county level. Lightly shaded areas represent 95% confidence intervals. Darkly shaded areas are 90% confidence intervals. The y-axis represents the cumulative percentage change in employment. The x-axis represents months elapsed since the shock.

A.2 Data for Figure 2

In this section, we briefly describe the data used to perform our gain in R-squared exercise presented in Figure 2.

Bank Deposits First, we obtain county-level deposit HHI data from the Federal Deposit Insurance Corporation (FDIC) Summary of Deposits database. This dataset includes annual information on branch-level deposits for the universe of FDIC insured U.S. institutions. Our sample covers the years 1994-2015. For each year t and each county j in the data, we compute the deposit HHI H_{jt} according to the standard formula $H_{jt} = \sum_i^{N_t} s_{ijt}^2$, where s_{ijt} represents the share of deposits held by bank i in county j, year t. We then average H_{jt} for each county over the time period 1994-2015. Finally, in Figure 2 we add the within-bin average of the deposit HHI to the baseline regression of the county-specific coefficient on average stock market wealth per capita and compute the resulting increase in the R-squared.

Housing Cost, Share of Homeowners, Population Density & Temperature We rely on the Social Capital Project to obtain county-level measures of housing costs, the share of homeowners, population density, and temperature. The Social Capital Project is an initiative conducted by the U.S. Congress Joint Economic Committee to collect state and county-level data on a variety of social, economic, health, and religious indicators from different sources.[33] We define housing costs as the share of households for which annual housing costs exceed 35% of yearly household income. Similarly, we define the share of homeowners as the share of houses which are owner-occupied. Both of these measures are based on data from the American Community Survey for the period 2011-2015. Population density is simply defined as the ratio between county population and county size (in square miles). This measure is obtained from the 2010 U.S. census. As for temperature, we consider the mean temperature recorded in the county in the year 2011. This measure is obtained from the North America Land Data Assimilation System. Finally, in Figure 2 we add the within-bin average of each of the 4 variables described above to the baseline regression of the county-specific coefficient on average stock market wealth per capita and compute the resulting increase in the R-squared.[34]

Firm Size Distribution Data on the distribution of firm size come from the County Business Patterns (CBP) dataset published by the U.S. Census. In particular, for each county and each year, we compute the average number of employees per establishment. We then average this measure for each county over our annual sample 1990-2015. Finally, in Figure 2 we include the within-bin mean of the average establishment size to the baseline regression of the county-specific coefficient on average stock market wealth per capita and compute the resulting increase in the R-squared.

Participation Rate, Reallocation Rate & Firm Entry Rate We compute the participation rate directly from our main dataset, i.e., the Local Area Unemployment Statistics published by the BLS. In particular, for each year in our data we define the participation rate as the share of people in the labor force over total county population. We then average this measure for each county across 1990-2015. For the reallocation rate and the firm entry rate, instead, we rely on the Business Dynamism Statistics published by the U.S. Census. The reallocation rate is obtained as the sum of the jobs created and destroyed in a given county and year, as a share of total jobs. Similarly, we define the firm entry rate as the ratio of the number of new establishments opened in a given county-year over the total number of the establishments operating in that county. The data spans 1990-2015. Finally, in Figure 2 we add the within-bin average of each of the 3 variables described above to the baseline regression of the county-specific coefficient on average stock market wealth per capita and compute the resulting increase in the R-squared.

[33] For more details, see jec.senate.gov/public/index.cfm/republicans/socialcapitalproject.

[34] Consistently with the rest of the exercise performed in Figure 2, we add each of these variables one at a time. That is, we perform 4 different regressions and compute the gain in R-squared for each of them.

Land Availability Our data on land availability come from Lutz and Sand (2022). The authors build upon the seminal work by Saiz (2010) and develop a time varying and geographically disaggregated measure of land unavailability using satellite imagery data. We refer the reader to Lutz and Sand (2022) for a thorough description of the construction of land unavailability. The data start in 2002m1. We generate county-level averages of the measure of land unavailability over our time sample 2002m1-2015m12. Finally, in Figure 2 we add the within-bin average of the measure of land unavailability to the baseline regression of the county-specific coefficient on average stock market wealth per capita and compute the resulting increase in the R-squared.

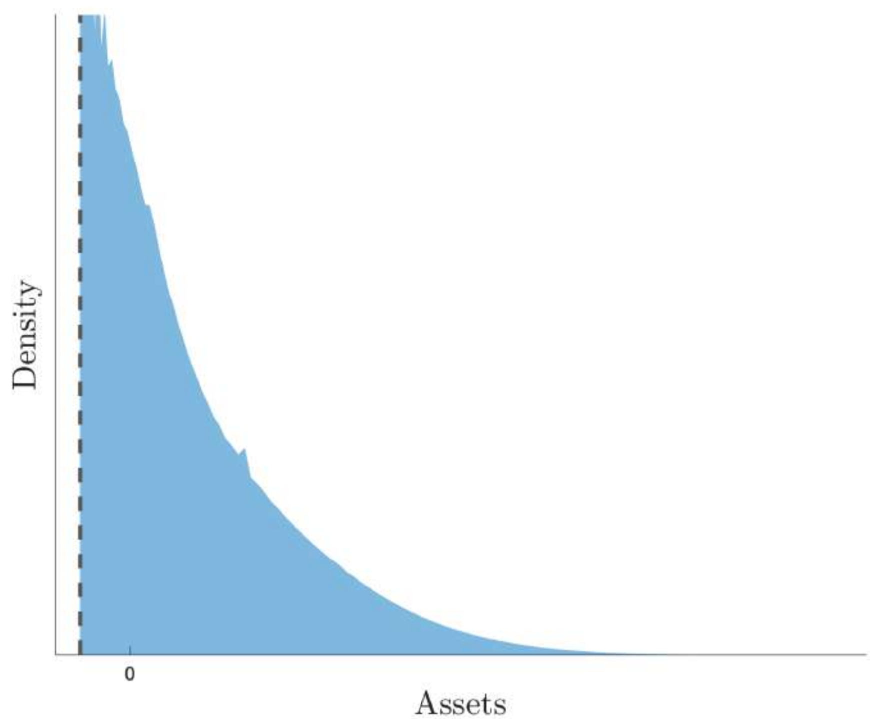
Age Structure, Race Structure & Gender Structure Our data on the age, race, and gender structure come from the Census Bureau's Population Estimates Program. This database includes annual county-level estimates of population by age, race, and gender. To analyze the age structure, we follow Leahy and Thapar (2022) and focus on the share of population within a county which is less than 35 years old and in between 40 and 65 years old. For the race structure, we compute the share of population within a county which is black and the share of population which is hispanic. For the gender structure, we compute the share of women within a county. We then average each of these variables for each county over our annual sample 1990-2015. Finally, in Figure 2 we add the within-bin average of the share of people younger than 35 and the share of people in between 40 and 65 to the baseline regression of the county-specific coefficient on average stock market wealth per capita. Similarly, for the case of race structure, we add the within-bin average of the share of black as well as the share of hispanic population to the baseline regression of the county-specific coefficient on average stock market wealth per capita. For gender structure, we add the within-bin average of the share of women to the baseline regression of the county-specific coefficient on average stock market wealth per capita. In all three cases, we then compute the resulting increase in the R-squared of the regression.

Voting Rate Data on the voting rate come from the County Presidential Election Returns published by the MIT Election Data and Science Lab. In particular, for each presidential election from 2000 to 2020, we compute the total number of votes in each county as a share of county-level population. For each county, we then average the participation rate across the 6 presidential elections that took place between 2000 and 2020. Finally, in Figure 2 we add the within-bin average of the voting rate to the baseline regression of the county-specific coefficient on average stock market wealth per capita and compute the resulting increase in the R-squared.

B Model Appendix

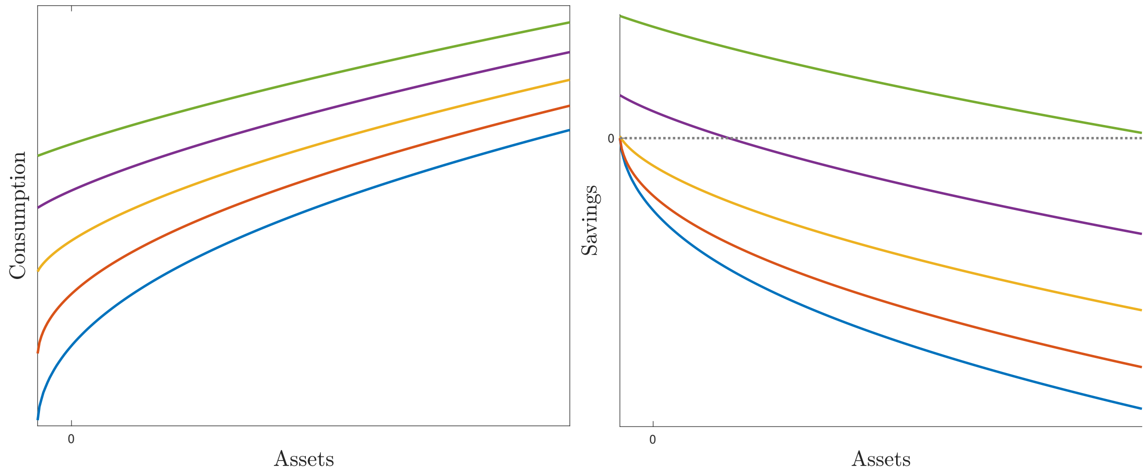
B.1 Steady State Graphs

Figure B.1: Stationary Wealth Distribution



Note: this figure shows the stationary wealth distribution of the economy calibrated according to Table 1. The dashed line represents the borrowing constraint.

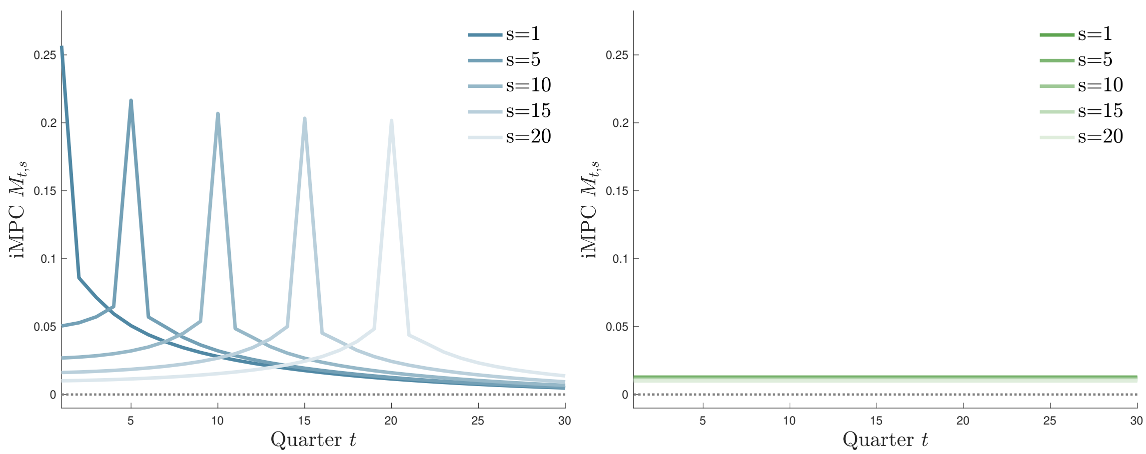
Figure B.2: Consumption and Savings Policy Functions



(a) Consumption policy functions (b) Savings policy functions

Note: this figure shows the consumption and savings policy functions of the economy calibrated according to Table 1. Different colors correspond to different values of the productivity realization e.

Figure B.3: iMPCs over a quarter for HA and RA models

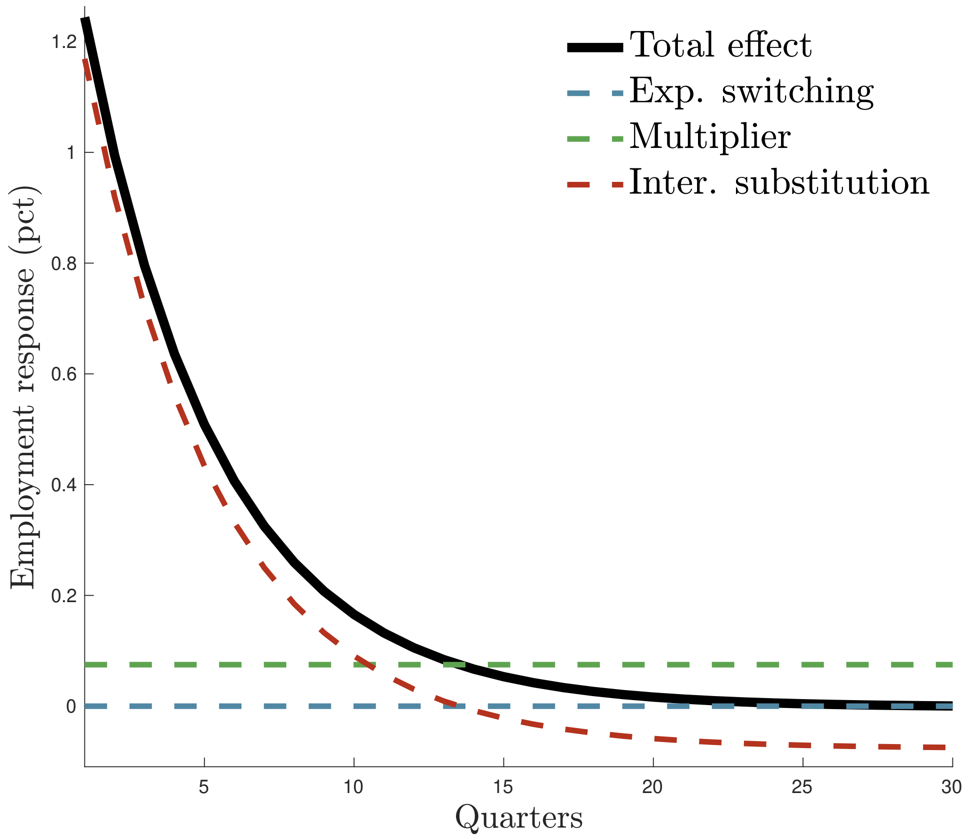


(a) iMPC in the HA economy (b) iMPC in the RA economy

Note: panel (a) the quarterly iMPC of the economy calibrated according to Table 1. Panel (b) shows the benchmark case of a representative agent economy.

B.2 Additional IRF decompositions

Figure B.4: IRF decomposition for the RA closed economy



Note: this figure reports the same decomposition as Figure 8a for the representative agent case.

B.3 Derivations of (15)

Starting with the market clearing condition (14) we have

$$L_{jt}^{NT} = \omega \left(\frac{P_{jt}^{NT}}{P_{jt}} \right)^{-\nu} \mathcal{C}_{jt} \left(\left\{ \frac{W_{jt}}{P_{jt}} L_{jt}, r_{jt} \right\} \right)$$

Taking logs and linearizing around the steady state:

$$d \ln L_{jt}^{NT} = -\nu d \ln \left(\frac{P_{jt}^{NT}}{P_{jt}} \right) + \frac{1}{C_j} \sum_{s=0}^{\infty} \frac{\partial \mathcal{C}_{jt}(\cdot)}{\partial Z_{js}} d \left(\frac{W_{js}}{P_{js}} L_{js} \right) + \frac{1}{C_j} \sum_{s=0}^{\infty} \frac{\partial \mathcal{C}_{jt}(\cdot)}{\partial r_{js}} dr_{js}$$

Now rewriting this equation in matrix notation:

$$d\log \boldsymbol{L}_j^{NT} = -\nu(d\log \boldsymbol{P}_j^{NT} - d\log \boldsymbol{P}_j) + \boldsymbol{M}_j\left(d\log \boldsymbol{W}_j - d\log \boldsymbol{P}_j + d\log \boldsymbol{L}_j\right) + \boldsymbol{M}_j^r d\boldsymbol{r}_j \tag{B.1}$$

Now given the price index, the labor supply equations, the atomicity assumption (which implies that P^T and W^T are exogenous since the rest of the nation doesn't react), using the fact that $P_t^s = W_t^s, s \in \{NT, T\}$ and the law of one price for tradable goods we have:

$$\begin{aligned}
&d\log L_{jt}^{NT} = \eta d\log W_{jt}^{NT} - \eta dW_{jt} + d\log L_{jt}\\
&-\nu d\log W_t^T = \eta d\log W_t^T - \eta d\log W_{jt} + d\log L_{jt}\\
&d\log W_{jt} = \rho_j d\log W_{jt}^{NT} + (1-\rho_j) d\log W_t^T\\
&d\log P_{jt} = \xi_j d\log W_{jt}^{NT} + (1-\xi_j) d\log W_t^T\\
&d\log L_{jt}^T = 0\\
&d\log W_t^T = 0
\end{aligned}$$

Where all the equations above are expressed in log deviations from the steady state and the second equation comes from combining the market clearing condition and labor supply both for domestic tradables. From this we get:

$$\begin{aligned}
d\log W_{jt} &= \frac{1}{\eta} d\log L_{jt}\\
d\log W_{jt}^{NT} &= \frac{1}{\rho_j \eta} d\log L_{jt}\\
d\log L_{jt}^{NT} &= \frac{1}{\rho_j} d\log L_{jt}\\
d\log P_{jt} &= \frac{\xi_j}{\rho_j \eta} d\log L_{jt}
\end{aligned}$$

Replacing in (B.1) and rearranging yields expression (15).

B.4 National response

Note that the following equation is still correct, even in the presence of a national response:

$$d\log \boldsymbol{L}_j^{NT} = -\nu(d\log \boldsymbol{P}_j^{NT} - d\log \boldsymbol{P}_j) + \boldsymbol{M}_j\left(d\log \boldsymbol{W}_j - d\log \boldsymbol{P}_j + d\log \boldsymbol{L}_j - \frac{d\boldsymbol{T}_j}{C_j}\right) + \boldsymbol{M}_j^r d\boldsymbol{r}_j \tag{B.2}$$

Combining the log-linearized expression for the wage index in county j with the labor supply conditions in the tradable and non-tradable market gives:

$$d\log L_{jt}^{NT} = \eta(1-\rho_j)\left(d\log W_{jt}^{NT} - d\log W_t^T\right) + d\log L_{jt} \tag{B.3}$$

$$d\log L_{jt}^{T} = \eta\rho_j\left(d\log W_t^{T} - d\log W_{jt}^{NT}\right) + d\log L_{jt} \tag{B.4}$$

The log-linearized market clearing for tradables reads:

$$d\log L_{jt}^T = \int_0^1 \frac{\bar{C}_i^T}{\bar{L}_j^T}\left[-\nu\xi_i\left(d\log W_t^T - d\log W_{it}^{NT}\right) + d\log C_{it}\right] d\lambda(i) \tag{B.5}$$

Substituting the labor supply conditions for tradable in the expression $d\log L_{jt}^T = d\log L_{it}^T$ $\forall j, i$ gives:

$$d\log W_{it}^{NT} = \frac{1}{\eta\rho_i}\left(d\log L_{it} - d\log L_{jt}\right) + \frac{\rho_j}{\rho_i} d\log W_{jt}^{NT} + \left(1 - \frac{\rho_j}{\rho_i}\right) d\log W_t^T \tag{B.6}$$

We then substitute (B.6) and the log-linearized consumption function $C_{it} = \mathcal{C}_{it}\left(\left\{\frac{W_{is}L_{is}}{P_{is}} - T_{is}\right\}_{s\geq 0}, \{r_{is}\}_{s\ldots}\right.$ into (B.5) to get:

$$\begin{aligned} d\log L_{jt}^T =& \frac{\nu}{\eta}\left(\int_0^1 d\log L_{it} d\lambda(i) - d\log L_{jt}\right) + \nu\rho_j\left(d\log W_{jt}^{NT} - d\log W_t^T\right) + \\ & \int_0^1 \sum_{s=t}^{\infty}\left[\boldsymbol{M}_{i,t,s} d\log L_{is} - \boldsymbol{M}_{i,t,s}\frac{dT_{is}}{C_i} + \boldsymbol{M}_{i,t,s}^r dr_{is}\right] d\lambda(i) \end{aligned} \tag{B.7}$$

Combining (B.4) and (B.7) gives:

$$\begin{aligned} \left(d\log W_t^T - d\log W_{jt}^{NT}\right)\rho_j(\eta+\nu) + d\log L_{jt}\left(1+\frac{\nu}{\eta}\right) =& \frac{\nu}{\eta}\int_0^1 d\log L_{it} d\lambda(i) + \\ & \int_0^1 \sum_{s=t}^{\infty}\left[\boldsymbol{M}_{i,t,s} d\log L_{is} - \boldsymbol{M}_{i,t,s}\frac{dT_{is}}{C_i} + \boldsymbol{M}_{i,t,s}^r dr_{is}\right] d\lambda(i) \end{aligned} \tag{B.8}$$

(B.3) and (B.8) together give the following:

$$d\log \boldsymbol{W}_j^{NT} = d\log \boldsymbol{W}^T + \frac{1}{\rho_j(\eta+\nu)}\left[d\log \boldsymbol{L}_j\left(1+\frac{\nu}{\eta}\right) - \frac{\nu}{\eta}\int_0^1 d\log \boldsymbol{L}_i d\lambda(i) - \int_0^1 \boldsymbol{M}_i d\log \boldsymbol{L}_i d\lambda(i) \ldots\right.$$

$$+\int_0^1 \boldsymbol{M}_i \frac{d\boldsymbol{T}_i}{C_i} d\lambda(i) - \int_0^1 \boldsymbol{M}_i^r d\boldsymbol{r}_i d\lambda(i)\Bigg] \tag{B.9}$$

$$d\log \boldsymbol{L}_j^{NT} = \frac{1}{\rho_j} d\log \boldsymbol{L}_j - \frac{\eta(1-\rho_j)}{\rho_j(\eta+\nu)}\Bigg[\frac{\nu}{\eta}\int_0^1 d\log \boldsymbol{L}_i d\lambda(i) + \int_0^1 \boldsymbol{M}_i d\log \boldsymbol{L}_i d\lambda(i)$$

$$-\int_0^1 \boldsymbol{M}_i \frac{d\boldsymbol{T}_i}{C_i} d\lambda(i) + \int_0^1 \boldsymbol{M}_i^r d\boldsymbol{r}_i d\lambda(i)\Bigg] \tag{B.10}$$

$$d\log \boldsymbol{W}_j = d\log \boldsymbol{W}^T + \frac{1}{(\eta+\nu)}\Bigg[d\log \boldsymbol{L}_j\left(1+\frac{\nu}{\eta}\right) - \frac{\nu}{\eta}\int_0^1 d\log \boldsymbol{L}_i d\lambda(i) - \int_0^1 \boldsymbol{M}_i d\log \boldsymbol{L}_i d\lambda(i)$$

$$+\int_0^1 \boldsymbol{M}_i \frac{d\boldsymbol{T}_i}{C_i} d\lambda(i) - \int_0^1 \boldsymbol{M}_i^r d\boldsymbol{r}_i d\lambda(i)\Bigg] \tag{B.11}$$

$$d\log \boldsymbol{P}_j = d\log \boldsymbol{W}^T + \frac{1}{(\eta+\nu)}\Bigg[d\log \boldsymbol{L}_j\left(1+\frac{\nu}{\eta}\right) - \frac{\nu}{\eta}\int_0^1 d\log \boldsymbol{L}_i d\lambda(i) - \int_0^1 \boldsymbol{M}_i d\log \boldsymbol{L}_i d\lambda(i)$$

$$+\int_0^1 \boldsymbol{M}_i \frac{d\boldsymbol{T}_i}{C_i} d\lambda(i) - \int_0^1 \boldsymbol{M}_i^r d\boldsymbol{r}_i d\lambda(i)\Bigg] \tag{B.12}$$

$$d\log \boldsymbol{P}_j^{NT} = d\log \boldsymbol{W}^T + \frac{1}{\rho_j(\eta+\nu)}\Bigg[d\log \boldsymbol{L}_j\left(1+\frac{\nu}{\eta}\right) - \frac{\nu}{\eta}\int_0^1 d\log \boldsymbol{L}_i d\lambda(i) - \int_0^1 \boldsymbol{M}_i d\log \boldsymbol{L}_i d\lambda(i)$$

$$+\int_0^1 \boldsymbol{M}_i \frac{d\boldsymbol{T}_i}{C_i} d\lambda(i) - \int_0^1 \boldsymbol{M}_i^r d\boldsymbol{r}_i d\lambda(i)\Bigg] \tag{B.13}$$

Substituting (B.9)-(B.13) into and rearranging gives (21).

B.5 Computing the equivalence

$$(1-\widetilde{\boldsymbol{M}}_{HA})^{-1}(\rho \boldsymbol{M}^r_{HA} d\boldsymbol{r}_j + \hat{\boldsymbol{M}}_{HA} d\log W^T) = (1-\widetilde{\boldsymbol{M}}_{RA})^{-1}(\rho_j \boldsymbol{M}^r_{RA} d\boldsymbol{r}_j + \hat{\boldsymbol{M}}_{RA} d\log W^T)$$

$$\left((1-\widetilde{\boldsymbol{M}}_{HA})^{-1}\hat{\boldsymbol{M}}_{HA} - (1-\widetilde{\boldsymbol{M}}_{RA})^{-1}\hat{\boldsymbol{M}}_{RA}\right) d\log W^T = \left((1-\widetilde{\boldsymbol{M}}_{RA})^{-1}\boldsymbol{M}^r_{RA} - (1-\widetilde{\boldsymbol{M}}_{HA})^{-1}\boldsymbol{M}^r_{HA}\right)\rho_j d\boldsymbol{r}_j$$

$$d\log W^T = \left((1-\widetilde{\boldsymbol{M}}_{HA})^{-1}\hat{\boldsymbol{M}}_{HA} - (1-\widetilde{\boldsymbol{M}}_{RA})^{-1}\hat{\boldsymbol{M}}_{RA}\right)^{-1}\left((1-\widetilde{\boldsymbol{M}}_{RA})^{-1}\boldsymbol{M}^r_{RA} - (1-\widetilde{\boldsymbol{M}}_{HA})^{-1}\boldsymbol{M}^r_{HA}\right)\rho_j \boldsymbol{M}^r d\boldsymbol{r}_j$$