Spatial Heterogeneity and Inflation

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December 18, 2023

Abstract

The standard way inflation measured is using a price index for a given bundle of goods. However, we would expect there to be substantive differences across geography in this bundle, which implies different welfare and general equilibrium effects from changes in prices across regions that a simple averaging would not include. Further, what constitutes a "typical" basket of goods also varies by location. Related economic literature is on the importance of heterogeneity in beliefs and how that affects the implementation of policy. But there is currently no analysis on how those beliefs are spatially distributed, or a consideration of dispersion on the consequences and levels of inflation based on characteristics of where people live. It is extremely unlikely questions policymakers, economists, and citizens alike are asking can be fully answered without accounting for these disparities. My research will add to the wealth of heterogeneous agent model analysis of the macroeconomy and inflation by including a spatial component. However, calibrating such a model without access to information about survey respondent's location, which is not in the BLS' public microdata. Because the focus of this project is on the macroeocnomy, there will be no discussion about anything tied to a specific respondent or location. Data outputs resulting from the project will not include references to any specific location, only about (aggregated) location characteristics in general (e.g, output on the relationship between population size and inflation).

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Introduction

The law of one price is almost always assumed in economic modeling, despite significant and widely known deviations. For instance, Handbury and Weinstein (2015) show that, all else equal, cities with higher population tend to have a lower price level, while the Regional Price Parity measure from the BEA suggests states that are less densely populated have a lower price level. There is also an extensive literature on *inflation inequality* which recognizes that consumers themselves face a different price level because the composition of consumption can be fundamentally different along demographic lines, like income or location. In other words, because groups, like wealthy and impoverished people, have unequal expenditure shares across goods, price changes lead to differing rates of inflation. Relevant to this proposal, Zélity (2023) finds persistent differences in inflation between rural and urban areas, showing that from 2001-2021 the average inflation differential was 1.9x (whichever area had more inflation in a given year on average had about twice as much inflation as the other).

Despite these well-documented differences, it's likely they are still underreported. To my knowledge, all research on inflation inequality, following the precedent of Hobijn and Lagakos (2005), assumes that while urban rural areas can have a different price level, prices themselves (in a given product category) grow at the same rates. However, my own analysis of consumer expenditure data from the BLS' public CEX series suggests this assumption creates large downward bias in estimating inflation differences. Zeroing in on food expenditures as an example, notable features of the data include that people in rural areas spend less on food and correlations of rural and urban food expenditures are weak, despite the tendency to comove. These results still hold even when looking at rural and urban consumers in the same income groups, meaning that unless one is willing to say that people in rural and urban areas have intrinsically different, time-variant preferences over food, the price of food must not be changing at the same rate. Similar trends are seen in other product categories as well.

Clearly, rural and urban inflation are distinct objects, but the important question for both policymakers and researchers is do these differences matter. A modal Economist might suggest that rural areas make up a low percentage of both population and GDP, so in the aggregate, the persistent divergence is not noteworthy. While this might be a compelling point for someone interested in measuring economic activity, this proposal is concerned with the hypothesis that these differences have a meaningful equilibrium effect. The intuition behind this hypothesis is that the relationship between consumers and firms, both employee-employer and buyer-seller, ingrains linkages that create a feedback effect that can ripple through supply and demand chains, so these differences in inflation (and inflation expectations) do not occur in a vacuum. As a simple illustration, a firm responding to a supply shock may change their price, which alters consumer (and worker) behavior, leading firms to respond to this response, and so on. We know these sorts of domino dynamics are pervasive in modern economies, and given inflation's

importance to the population, we should expect that varied experience with inflation can create ripple effects that don't happen in isolation.

The next section give a broader overview on the adjacent literature, namely work that informs the models and methods that will be used. The final section, informed by the proposed methodology and empirical exercises, will detail the data usage and institutional relevance of the project, as well as offering a brief conclusion on future direction. For simplicity and to respect length requirements, there will also be an online appendix that has some additional information, including more model details and description of preliminary data analysis.

Approach: Past Literature and Proposed Methods

The quantitative aim of this project is to **(i)** extensively document the inflation disparities that exist along spatial lines and then **(ii)** see if a model in which these differences play an important role can match these differences well. This is a common playbook in the Macroeconomics literature in general, but not in research about differences in inflation experiences, and there is to my knowledge no past research that looks at rural/urban disparities in a general equilibrium context. But to better understand the proposed approach, the proximate research and empirical facts of note will be established. One notable strand of literature is connected on a purely topical basis. Other papers outside of this focus will be presented in the body of describing planned methodology to contextualize modeling approaches.

The term inflation inequality refers to idea that a single headline number for inflation is not representative of the inflation faced by different groups of people. In a research context, the objective of studying inflation inequality is to identify the exact nature of where divergences occur and how they may be relevant for understanding the economy and optimal policy. Hobijn and Lagakos (2005) can be considered the seminal paper for solidifying the current path for the inflation inequality literature, which found non-negligible inflation differences between rural and urban areas, among a host of other individual characteristics. As detailed in the extensive review of Jaravel (2021), most research following this paper has focused on inflation inequality along an income dimension. Specifically, there is good evidence that preferences over goods are not homothetic (meaning types of goods are consumed in equal proportions across income types), which means if we were to form a price level for income groups in a similar fashion to the default of the Consumer Price Index (CPI), these price levels would be different and grow at different rates. Virtually all of the current work on inflation inequality has treated the rural/urban divide as a tangential issue, meaning the careful, preliminary empirical work needed to see out this project on its own would be a contribution to the literature.

As put forward in Hobijn and Lagakos (2005), the biggest stumbling block from studying the issue of inflation inequality between rural and urban households is a measurement issue. Noteworthy inflation measures like the

CPI intend to be representative of almost all of the US' population but explicitly specify that it's a metric for urban areas. In particular, while some rural households are surveyed to calculate the proper weighting of prices (into an aggregate price level), the prices themselves come directly from data in metropolitan areas. Consequently, all research analyzing rural/urban inflation make a simplifying assumption that prices in rural and urban areas change at the same rates across all product categories or use even more indirect measures of rural inflation. Chakrabarti et al. (2023) use a GDP deflator alongside a state's proportion of rural citizens as one indirect method but are transparent about the fact that such approaches are not suitable for peer-reviewed scholarly research. Similar caveats are given in Swagel (2022), a CBO report to Congress on rural inflation, which relies on an even noisier approach of using the proportion of rural citizens in the 9 Census geographic areas. This report also notes the importance of tracking the growth of nominal wages alongside the growth in prices, but again its analysis is hindered by the fact that Census Bureau does not publicly report an individual's location if they live in a county of less than 100,000 people. The BEA posts a Regional Price Parity (RPP) series that is informative for this question, but can only account for state-level data or urban areas.

The quantitative tasks for this project can be put into two categories: data analysis and model+calibration exercises. As alluded to previously, while the former is less sophisticated at face value, because of the measurement stumbling blocks, many basic empirical questions have not been answered. As done in Zélity (2023), one can calculate rural and urban inflation rates by assuming price changes are equal. But it would be useful to perform these calculations at a more granular level and also is critical to relax the assumption of uniform price changes. One way to relax this assumption would be to attempt to infer the price level directly using the Consumption Expenditure series (CEX) from the BLS, in conjunction with publicly available data used to calculate GDP. This approach would be similar to the Geary Index used to create the BEA's RPP series. Using expenditure weights from the CEX, the quantity of a given product category purchased by urban consumers can be estimated, then subtracting the resulting total expenditure from national expenditure and dividing by the implied rural quantity (the leftover amount of domestic consumption) results in a prospective rural price level. These steps would need to be mindful of aggregation bias discussed at length in Jaravel (2021). Another stylized metric of interest is a better accounting of rural wage growth, gathered by extending the work of Swagel (2022) with non-publicly available data. The practicality of the data analysis procedures discussed in this paragraph in the context of restricted data access guidelines will be discussed in the next section

As outlined at the beginning of this section, the ultimate goal of this research is to change the academic understanding of inflation by developing a model that understands these pervasive inflation differences well. Following the recent inflationary episode, many have echoed the prescient words of Tarullo (2017) in highlighting that there is no consensus on very basic questions about inflation, and accounting for the rural/urban gap could provide an important piece of this puzzle. In part because no past research has attempted to answer this question,

the standard check of seeing how other "benchmark" models perform is not relevant (these models essentially assume away the question). So a useful comparison exercise will be evaluating whether the models developed for this project are able to account for other important features of economic data, ones that its not specifically designed to answer. A calibrated model that is able to account for some niche feature of the data well but also outputs that the US economy shrinks every quarter, for example, casts doubt on the story that model is telling. These sorts of considerations will be important going forward to make sure the results are robust to specifications outside of the target area of inflation inequality.

Data, Disclosure, and Relevance

The primary BLS data of interest is the consumer expenditure survey (CEX) series. Currently, the public use microdata (PUMD) available for the CEX series does offer whether a given household resides in a rural or urban area. But as described in the preceding section, rural areas themselves are not structurally homogeneous, in particular with respect to labor markets and industry composition. In a perfect world, the centerpiece of this project would be a model where each US county was treated as an independent region, but not enough data is collected on each county for this to be feasible. The best path forward is to then do some sort of aggregation by clustering counties. One possible partitioning that aligns with the themes of this research would be to use clustering by the makeup (sophistication, scale, and development) of the agricultural industry, which would be able to account for some of the stylized facts we observe. Such a clustering has already been performed and made available by the aforementioned Rasool and Abler (2023). Other, more qualitative, clustering can also be considered, for instance grouping by a simple combination of geography and population.

The first step of data processing will be aggregating CEX data to its corresponding county cluster using its FIPS code. Ideally, this process would yield enough observations for each group of counties such that the data frequency can remain at a monthly basis. This step itself would allow for the ability to conduct further preliminary analysis, such as gauging whether the persistent inflation differences described earlier still remain along these differently aggregated lines. If this is the case for a given clustering, it would speak to the merit of separating counties along these lines, especially in a modeling context.

Referring back to the stated aim of this project at the start of the preceding section, we will use this data grade the performance of the model. However, given the measurement issues at hand, it will be important to test the performance along several lines. To aid in the evaluation portion, as well as document other important facts, data requests have also been made for the BLS' Consumer Price Index (CPI) series and well as the Census Bureau's Current Population Survey (CPS). The former will be useful for checking the robustness of methods. For example, using a breakdown of inflation across c

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The hypothesis that will be tested.

The data set and variables that will be used in the analysis.

The empirical methods that will be used.

The specific data outputs that will result from the project, including a description of whether the research results will be presented as descriptive statistics or frequencies, or via multivariate analysis such as regression coefficients.

A literature review including brief discussion of how the proposed research contributes to the existing body of research.

An explanation of why the research is of interest to BLS and how it furthers the agency's mission.

Timeline The goals of this project can be partitioned into two categories of contributions: model-based and empirical. I first write down the most simplified version of a model and the analysis it allows, and then discuss some ways this model can be made more stylized, especially with the help of these data. Then I overview largely existing empirical exercises which can be strengthened. **Model+Calibration Exercises**

Empirical Exercises

Can be motivated by looking at the differences between how things vary at different points in the size distribution. Also give a more precise calculation of w/p.

Spitballing

- Households consume a different bundle of goods. 3 types of areas with a given measure. Can face their own tech shocks.

Dominant Currency Paradigm

- Demand elasticity (2)
- Risk Aversion (2)
- Frisch elasticity of labor supply (.5)
- home bias
- international gross interest rate
- interest elasticity of debt
- elasticity of substitution across labor varieties

- log SS Wage mark-up
- price stickiness
- wage rigidity
- interest rate sensitivity of marginal cost
- habit stock as a fraction of lagged consumption $H = hC_{t-1}$; h=0.55
- inertia in interest rates
- persistence in shock to interest rates 0.6
- inflation sensitivity
- output sensitivity

This is an extension of the wage-price spiral model of Lorenzoni and Werning (2023) to a partial open economy setting (partial due to the ad hoc restrictions on production) and with multiple sectors. These results are meant to match the case where there are a continuum of labor supply and good varieties (and corresponding monopolistic unions and firms). Because of the form of the production function, firms within industry behave identically to a first order approximation, even in a dynamic setting. So for notational and conceptual clarity, we instead consider a world in which there is a single monopolist in each industry that behaves like a firm in the scenario with variety (also a single union in each country). For transparency, the extension with variety can be found in the appendix.

There are two countries, $n \in \{\text{Urban,Rural}\}$, each populated by a representative agent with the same intrinsic preferences over 3 types of consumables: $i \in I = \{\text{food, goods, services}\}$. We assume there is only source of each for a given country: only Rural produces food, only Urban produces goods, and services are non-tradeable. The utility function, common to both countries, is

$$\frac{C_n^{1-\eta}}{1-\eta} - \frac{L_n^{1+\gamma}}{1+\gamma}$$

where households are subject to a budget constraint (p_{ni} is price in country n of the industry i consumable),

$$\sum_{i \in I} p_{ni} c_{ni} \leq W_n L_n$$

we use a CES aggregator,

$$C_n = \left(\sum_{i \in I} c_{ni}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

and assume the economy is at its (deterministic) steady state. This implies a price index of

$$P_n = \left(\sum_{i \in I} p_{ni}^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$$

Consumption is equal to real income by $C_n = \frac{W_n}{P_n} L_n$

The labor demand for a service sector firm is N_{ns}, while the demand for the food and good sectors are just N_f and N_g. We assume labor is immobile, so labor market clearing is

$$N_{Rs} + N_f = L_R \ \underline{\textbf{and}} \ N_{Us} + N_g = L_U$$

The production processes are

$$Y_{ns} = Z_{ns}N_{ns} \qquad Y_f = Z_f N_f^{1-\alpha_f} \qquad Y_g = Z_g N_g^{1-\alpha_g}$$

Log-linearized nominal marginal products of labor are therefore

$$2z_{ns} \qquad 2z_f - \alpha_f n_f \qquad 2z_g - \alpha_g n_g$$

Now that the basic model is established, we now shift into a dynamic setting in order to consider a shock that pushes the economy away from the steady state.

We assume a Calvo pricing setting and use a continuous time representation with rate of discounting ρ. Firms are randomly selected to reset their price with Poisson arrival λ_p, and unions are selected with arrival λ_w. Optimal price setting dictates that firms set their price equal to an average of future marginal costs, conditional on not resetting. We will denote these "flexible" (log-linear) prices by p^*_{nit}, which is given by

$$p^*_{nit} = (\rho + \lambda_p) \int_t^\infty e^{-(\rho+\lambda_p)(\tau-t)}(w_{n\tau} - mpl_{ni\tau})\mathrm{d}\tau$$

Under a similar philosophy, unions set nominal wage (in case it wasn't clear up until this point – firms are price takers in the labor market) in relation to the marginal rate of substitution between consumption and leisure, which is given by $\eta y_{nt} + \gamma l_{nt}$. We call w^*_{nt} the flexible wage and write it as

$$w^*_{nt} = (\rho + \lambda_w) \int_t^\infty e^{-(\rho+\lambda_w)(\tau-t)}(p_\tau + mrs_{n\tau})\mathrm{d}\tau.$$

where p_τ is the log-linear representation of the earlier derived price index.

The tension in this model is garnered from the fact that the wage w_τ is in the firm's reset problem, and similarly p_τ is in the union's reset problem. This is precisely the wage-price spiral mechanism: nominal prices are set to catch up with future wages, and symmetrically wages are set to match future prices. Shocks that create a diversion in aspirations can yield a "ping-pong" effect that is smoothed out by price-stickiness. Related, this environment does not follow a traditional Bertrand paradigm because actors cannot freely adjust price, and a reasonable calibration of this model will set wages are more rigid than prices to match overwhelming empirical evidence to that effect.

A counterfactual exercise to illustrate the interesting transmission at play: suppose that there is a negative shock to the productivity of the Rural service sector. This leads to a fall in the industry's marginal product of labor. Accordingly, prices will in this sector will rise. This leads to a rise in the nominal wage in Rural, which pushes up the food price level, thus creating inflation in Urban and necessitating a rise in its wages. More specifically, this is where having a continuum of unions/firms makes a difference, but by the law of large numbers these movements will happen eventually, its just which a continuum of firms the movements are smooth. Also, an important factor at play here is that the wage must be equal across industries within countries. This is not merely an imposition of the union structure, but more broadly an equilibrium outcome in a sectoral model in which labor is substitutable across production processes.

Appendix

Now, all industries consist of a continuum of monopolist firms that produce a unique good variety which are aggregated, yielding 3 aggregate consumables. The utility function, common to both countries, is

$$\frac{C_n^{1-\eta}}{1-\eta} - \frac{L_n^{1+\gamma}}{1+\gamma}$$

where households are subject to a budget constraint ($p_{ni}(\theta)$ is price in country n of the variety θ for industry i),

$$\sum_{i \in I} \left\{ \int_{\theta \in \Theta_{ni}} p_{ni}(\theta) c_{ni}(\theta) \mathrm{d}\theta \right\} \leq w_n L_n$$

we use a CES aggregator,

$$C_n = \left(\sum_{i \in I} \int_{\theta \in \Theta_{ni}} \left[c_{ni}(\theta) \right]^{\frac{\sigma-1}{\sigma}} \mathrm{d}\theta \right)^{\frac{\sigma}{\sigma-1}}$$

and assume the economy is at its steady state. This implies a price index of

$$P_n = \left(\sum_{i \in I} \int_{\theta \in \Theta_{ni}} p_{ni}(\theta)^{1-\sigma} \mathrm{d}\theta \right)^{\frac{1}{1-\sigma}}$$

Consumption is equal to real income by $C_n = \frac{w_n}{P_n} L_n$

The labor demand for each firm $N_{ni}(\theta)$ is an aggregate of a continuum of labor varieties $N_{ni}(\theta) = \left(\int_0^1 \left[N_{nij}(\theta) \right]^{1-\varepsilon} \mathrm{d}j \right)^{\frac{1}{1-\varepsilon}}$. Each labor variety j is supplied by a monopolistic union that employs labor from households and turns it, one for one, into specialized labor services of type j. Assuming labor is immobile across countries and imposing market clearing, we integrate over firms and unions for a total labor supply of

$$L_n = \int_0^1 \left\{ \sum_{i \in I} \int_{\theta \in \tilde{\Theta}_{ni}} N_{nij}(\theta) \mathrm{d}\theta \right\} \mathrm{d}j$$

where $\tilde{\Theta}_{ni} \subseteq \Theta_{ni}$ respects the fact that some industries don't exist in a given n.

The production process for the service sector is

$$Y_{ns}(\theta) = Z_{ns} N_{ns}(\theta)$$

The production process for the food sector is

$$Y_f(\theta) = Z_f N_{nf}(\theta)^{1-\alpha_f}$$

The production process for the goods sector is

$$Y_g(\theta) = Z_g N_{ng}(\theta)^{1-\alpha_g}$$