Gross Metropolitan Product and Okun's Law in Urban Cores

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Abstract

This paper investigates the behavior of Okun's Law in the United States' three largest metropolitan regions: New York City, Los Angeles, and Chicago. Two separate autoregressive distributed lagged (ARDL) model forms are tested to incorporate delayed impacts of prior real output growth and unemployment rate changes on oscillations in current unemployment rates. The first model comprises a simple ARDL model with first-order lags, while the second model incorporates two additional binary indicators for both quarterly recessions and post-coronavirus quarterly recovery periods. This paper finds that the impacts are significantly more pronounced in the three urban cores studied than for the United States as a whole, although the presence of the additional binary indicators modestly lowers the estimates. Dynamics such as more heterogeneous workforces and greater sensitivity to output shifts are attributed as important causes of these higher estimates, as well as the impact that density may have on worker turnover that contributes to more volatile labor markets.

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1 Introduction

Cities are the products of centuries of population growth, intellectual advancement in science and technology, and shifts in transportation infrastructure. As such, large cities, especially sprawling metropolises like New York and Tokyo, tend to have more productive labor forces on average than less urbanized settlements and smaller cities. Behrens et al (2014) estimate an elasticity range of mean urban wage increases to urban population growth of approximately 5%-8% largely attributable to "agglomeration," which is defined as the packing of economic activity and factors of production - including the labor force and capital stock - in a defined area. These contribute to positive externalities associated with greater intermingling between workers in a dense environment resulting in more "knowledge spillovers." Behrens et al (2014) further argue that cities attract more skilled and talented workers as more competition for jobs weeds out less-skilled workers. The same holds true for private firms, whereby only the most profitable institutions withstand the high costs associated with doing business in dense urban regions. Matching also explains the urban-rural wage differentials since more profitable firms hire more talented workers, augmenting the cycle of agglomeration.

One model posits that "efficiency wages," or wages paid in excess of market clearing points to reduce shirking, are higher in urban settings than in rural locales, leading to the stark differences observed in urban and rural incomes (Chin, 1998). When firms pay higher efficiency wages relative to their competitors, they enjoy greater productivity gains that mostly pay for the increased labor costs (Levine, 1992). Greater use of efficiency wages in urban settings may arise from employer concerns regarding turnover, competition from adjacent firms, and bargaining power by stronger unions. This holds in the context of Behrens et al (2014) in that urban firms may hire more talented workers via higher wages in order to innovate more lucrative products and break even with the higher costs associated with doing business in cities.

Cities also make greater use of capital than other factor inputs, and capital on average tends to be more productive relative to labor in cities (Halbert and Attuyer, 2016). One estimate computed the output elasticities of urban capital stocks to be 3-4 times higher on average than those of urban labor forces (Graham, 2007). Economists generally assume that land has little meaningful impact on production in the Cobb-Douglas function. Some models of urban output, such as in the Ciccone-Hall model (Ciccone and Hall, 1993), assume it to be fixed at some quantity $\bar{L}$. Other economists argue that urban productivity gains are inflated by agglomeration because urban production tends to outpace the adjacent growth in land accumulation (Davis et al, 2014), which tracks with the differences in productivity between capital, labor, and land; arguably, those locales with more land employed in production (i.e., rural wards) would see lower levels of productivity than urban regions due to land's lower productivity constituting a "net drag" on regional production relative to urban cores.

Aside from factor inputs, modes of transportation and "walkability" may affect productivity levels. First, urban cores tend to possess dense concourses and hubs of mass transit that move workers more rapidly, more efficiently, and in greater mass than more traditional modes such as highways and parkways. Clogging of major urban corridors by private vehicles may also induce more workers to rely on mass transit as a relatively more efficient transportation mode. Second, walkable infrastructure endemic to major cities may also contribute to more knowledge spillovers and other positive externalities influencing production, as more dense packing of stores and pedestrian-friendly streetscapes implies more inter-business patronizing. Additionally, as proximity to agglomerated regions increases, productivity tends to rise. Melo et al (2017) estimated that productivity gains are highest when commuting from home less than 20 minutes to areas of high employment density.

While cities may experience greater productivity gains than less dense municipalities, they generally face more turbulent labor markets and higher rates of unemployment especially in developing countries. There are two competing models of urban unemployment - one that assumes homogeneous unemployment across metros regardless of residency, and one that argues for the existence of spatial sub-concentrations of unemployment that arise from insufficient employment opportunities within short commuting distances (Morrison, 2005). The former model ignores the natural development of principal central business districts (CBDs) and sub-CBDs in urban cores that furnish "hot-spots" of employment that "break up" the purported homogeneity of unemployment. The second model's proposed unemployment "hot-spots" may hold true in large cities, but it nevertheless ignores the expansion of transport systems as cities grow upward and outward that improves connectivity between the principal CBD and sub-CBDs from the city's ever-expanding peripheries; this, in turn, has the potential to reduce unemployment by shifting working locations away from local neighborhoods and into city centers. Nevertheless, job availability in said neighborhoods - which may be a more critical measure of the health of local labor markets - may consequently decline due to the restructuring of the spatial distribution of jobs.

Much of the volatility may be attributed to a critical implication of the research by Behrens et al (2014) regarding more talented workers and more profitable firms agglomerating within cities: that heightened competition and the density of firms implies more workers leaving previous jobs in order to find their optimal career paths. This is supported by Finney and Kohlhase (2008), who found that young men were more likely to switch jobs more frequently and earlier in their careers when living in dense cities. They argue that the potential opportunity costs associated with job severance are lower in cities due to the concentration of hiring businesses, reduced commuting distances to potential employers, and younger labor forces with less established ties to firms; these collectively may induce more short run turnover than in less dense locales.

If urban jurisdictions enjoy higher productivity while facing more volatile labor markets, the question then arises as to how changes in urban output affect urban unemployment. Economists generally measure this relationship on a national scale through Okun's Law. The general maxim is that a 3% rise in gross output induces a 1% decline in cyclical unemployment (Okun, 1962). However, Prachowny (1993) estimates that, when accounting for the non-accelerating inflation rate of unemployment (NAIRU), or the level of unemployment whereby inflation is static, the same 1% decline in unemployment corresponds to a roughly .67% increase in output. This is largely due to changes in work hours and employers shifting existing labor to other areas of production.

The most commonly accepted base formulation for Okun's Law is the time series "difference" method, which regresses quarterly oscillations in unemployment rates against quarterly growth rates in national income, producing the general univariate form:

$$\Delta U_t = \lambda_0 + \lambda_1 g_t + \epsilon_t. \tag{1}$$

where g_t is the growth rate of real Gross Domestic Product (GDP) per quarter, λ_0 is the intercept rate of change in the unemployment rate, λ_1 is *Okun's coefficient*, or the parameter linking changes in real GDP to those in unemployment rates, and ϵ_t is the disturbance term. There is general consensus that the observed 3% rise in real output and corresponding 1% fall in the unemployment rate by Okun (1962) holds in most normal periods when not incorporating NAIRU, barring any severe shocks or external macroeconomic disturbances. Even if there are shocks present during particular quarters in the short run, these are generally viewed as dynamic revolutions around the long run trend originally observed by Okun (1962). Two major shocks have occurred in recent memory: the Great Recession in 2008 and the COVID-19 pandemic in 2020. Federal Reserve economists have argued that the temporarily accelerated rise in unemployment relative to the decline in GDP observed between 2008 and 2009 was similar to past recessions during the 1900s, including the recession in 1973 brought on by the global energy crisis (Daly et al, 2014a).

However, these same economists also found that while many developed countries between 1970 and 2008 seemed to converge towards an average Okun's coefficient of three-to-one for changes in output to unemployment, there have been notable divergences in both hours worked and labor productivity since the Great Recession, especially in Europe (Daly et al, 2014b). Gordon (2010) found a similar result, whereby the recovery of jobs lost during the Great Recession was largely "traded off" for an aggregate decline in hours worked, leading to what is often termed a "jobless recovery." Gordon (2010) also found that labor productivity did not oscillate procyclically during the 1986-2009 period as it did in the preceding decades, primarily due to rising inequality resulting from immigration, falling unionization rates, and stagnation in minimum wage hikes causing labor to be treated more flexibly by firms.

There also appears to be incongruity for estimates of Okun's coefficient between both developing and advanced economies. Ball et al (2019) found that on average, Okun's coefficient is half in developing nations like Honduras and Tunisia what it would normally be in advanced economies like France and the United States. In many developing economies, the weaker cyclical effects of real GDP growth on unemployment are due in large part to preexisting high levels of unemployment, warfare in a number of beleaguered states, and lower labor force participation rates arising from gender-based violence, restrictive employment laws, and insufficient transportation infrastructure. Among advanced economies, however, Ball et al (2017) observed that the mean Okun's coefficient estimate fell from 0.44 in 1980-1996 to 0.34 in 1997-2013 across 20 surveyed nations, indicating that Okun's coefficient has yet to stabilize across the developed world despite Federal Reserve economists' consensus that Okun's coefficient, at least in advanced economies, is potentially approaching a long run level.

Canarella and Miller (2017) observed a similar breakdown in Okun's Law to Daly et al (2014b) during the 1973 energy crisis and the Great Recession in 2008. Using an autoregressive distributed lagged model (ARDL) in form similar to Weber (1995) and Sögner and Stiassny (2002), they estimate that in the long run, a 1% increase in unemployment coincides with an approximately 0.43% decline in real national income. However, immediately following the Great Recession between 2009 and 2015, there appears to be a collapse in the traditional linear relationship with the Okun's coefficients estimated by Canarella and Miller (2017) falling off at the 5% significance level. Economists have also drawn attention to the still-devastating effects of the Great Recession on the world's labor markets. One hypothesis suggests that the persistence of high unemployment and low output growth after 2008 led to permanent structural shifts in the natural unemployment rate, which may explain the inability of the world economy to return to pre-recession output and employment levels (Kalleberg and von Wachter, 2017).

The COVID-19 pandemic also inflicted unprecedented damage on the world's labor markets. Researchers found labor productivity per hour for British firms fell by 2.6% on average between the second quarter of 2020 and the first quarter of 2022. Furthermore, they observed an approximately 6% fall in the aggregate level of productivity for all factor inputs during this same period (Bloom et al, 2023). Much of these declines are attributed to increased gaps in capacity utilization and contractions in low-productivity sectors resulting from widespread government lockdowns. Interestingly, a slight acceleration in labor productivity was observed in 2020, although this may be attributed to a faster drop-off in working hours relative to output.

Russnak et al (2023) estimate two simple difference regressions of Okun's Law each for the United States, Germany, France, Italy, Spain, and The Netherlands. The first model is run from 1992-2019 to partial out COVID-19's initial effects, and the second is run from 1992-2020 to account for the full impacts of the pandemic. They estimate a pre-pandemic Okun's coefficient of $\hat{\lambda}_1 = -0.42$. However, the presence of an acute recession brought on by the pandemic rose the parameter value to 0.54. Intriguingly, the coefficient fell for all of the European countries surveyed when accounting for the 2020 pandemic year, with an average of 0.41 before the pandemic and 0.22 with the pandemic. This divergence between nations indicates a departure from Okun's Law that should be treated as an anomaly rather than a breakdown in the original maxim. More detailed research from Spain argues that how one measures unemployment matters, as the institution of temporary layoffs to prevent mass unemployment as enacted in some European countries artificially distorted employment statistics and weakened measures of the normal long run relationship between unemployment and output (Porras-Arena et al, 2024).

Mussida and Zanin (2023) found a similar result for nine European states between 1981 and 2021, whereby Okun's coefficient did not stabilize over the three decades studied when accounting for the pandemic. This extends through the pandemic the original findings of Ball et al (2017) regarding the inability of Okun's coefficient to stabilize in the post-Cold War era. The only exception is Norway, which enjoyed a stable coefficient range of 0.45-0.48 when using Ordinary Least Squares (OLS) and 0.43-0.47 when robust M-estimations were included to control for recessionary outliers. This further supports the conclusion that the COVID-19 pandemic constitutes a structural break that should be treated as an exception to Okun's Law in econometric estimations going forward, rather than a major determinant of the observed relationship between output and unemployment.

Major U.S. cities were acutely affected by COVID-19 thanks to their more sensitive labor markets and increased risk of accelerated contagion spread; this "acceleration" is attributable to increased density and more integrated transport systems. Additionally, the commanding presence of suburban and exurban commuters was deflated by lockdown rules restricting movement and transportation, further harming large urban economies and their germane transit networks. For example, while lockdowns did not restrict the use of private vehicles in the United States, social distancing rules and the mass shuttering of in-person business operations in downtowns caused significant declines in transit use, which acutely affected cities that generally rely more on mass transit than private vehicles. Subway ridership in New York City during 2020Q2 was only 8.6% of what it was in 2019Q2 (Office of the State Deputy Comptroller for the City of New York, 2023). Additionally, the damage done by the pandemic still lingers in major U.S. cities and has hampered their labor market recoveries. Nowhere is this more pronounced than in New York City, where the region's recovery post-pandemic has fallen behind the rest of New York State and the country at-large. By March 2022, New York City recovered only 71% of its pre-pandemic employment, whereas the United States recovered close to 95% (Yadavalli et al, 2022).

As discussed previously, cities tend to attract more talented workers and induce the agglomeration of more profitable firms. However, these same workers and firms tended to be more adaptable to remote work during the pandemic, providing a relief valve to workers and reducing the pressure on firms to resort to layoffs. Yet U.S. cities saw substantial increases in unemployment relatively higher than the country at-large. For example, Chicago experienced an approximately 233.64% increase in unemployment in 2020Q2 while Los Angeles saw a rise of 251.33%. While finance and technology workers and generally those employed in knowledge and data analysis fields were spared the worst of the pandemic's labor losses, other sectors were acutely damaged. Leisure and hospitality are hallmarks of city tourism and daily life. However, the presence of lockdowns and inability to shift to remote work meant many workers were either furloughed or permanently laid off. In New York City alone, information-related industries including cultural establishments, guided tours, and publishing houses saw the greatest losses in employment, losing over 60% of their workers between 2019 and 2020. Tourism-related industries such as hotel accommodations saw a mean drop of approximately 40% as the collapse in tourism during the pandemic had an outsized impact on urban economies (Coleman et al, 2022).

The impact of remote learning in K-12 schools on employment during the pandemic also noticeably differed between cities and the American countryside. Large urban public school systems such as those in New York City and Los Angeles were more likely to make the blanket switch to remote learning, whereas rural school systems - which are generally smaller and less exposed to contagion - often resisted the advent of remote teaching. Consequently, Brooks et al (2021) attribute a sizeable portion of the lopsided labor market damage in cities to the inability of many urban workers with children to find alternative childcare arrangements or themselves switch to remote work, whereas rural workers were less likely to face this dilemma and more often chose to work through the pandemic. Furthermore, rural labor markets generally possess more "essential sectors" such as food production than urban labor markets, which contain a greater share of more advanced but vulnerable sectors which were hit hardest during the lockdowns, such as knowledge and information, tourism, and leisure and hospitality.

On their face, these trends confirm the unprecedented economic harm unleashed by pandemic-era lockdowns on some of the United States' largest cities. Yet on a deeper level, they serve as evidence of the more sensitive and volatile labor dynamics generally observed in large urban regions. External shocks and disturbances produce extreme oscillations in urban unemployment the likes of which are comparatively less extreme in less dense locales. As such, when computing Okun's coefficient nationally the variations in geography may "smooth" out said oscillations in urban unemployment by aggregating them with rural and suburban labor market changes. However, this smoothing is virtually non-existent in cities as regional geographies are less varied than on a country-wide level.

This aggregated "smoothing" may occur for two reasons. First, more homogeneous labor pools in non-urban jurisdictions may imply weaker switching effects that limit localized firm restructurings. Second and perhaps more critically, recessionary gaps tend to be larger in cities, which contain the lion's share of economic output. Thus, it is expected that cities should experience the widest swings in unemployment as they possess a greater proportion of jobs and institutions most likely to be affected by crises. Ergo, when nationally estimating Okun's coefficient, rural and suburban wards arguably contribute "dragging" effects in the aggregation that soften the swings in urban unemployment.

2 Data and Methods

This study seeks to dynamically model changes in unemployment rates against growth in real output in the United States' three largest urban regions: Chicago, Los Angeles, and New York City. While the original regression model of Okun (1962) has its merits, as discussed previously urban cores face more extreme unemployment oscillations than less dense settlement typologies and thus are more sensitive to shifts in post-recession recoveries, government policies, and labor trends. Furthermore, past unemployment may affect the willingness of firms to hire more or less labor, while prior shifts in GMP may have acute effects on firms' contemporaneous performance. As mentioned earlier, the Great Recession has led to jobless recoveries in many labor markets as the recuperation in national income has often exceeded the recovery of pre-recession employment levels. Thus, accounting for these lagged dynamics is especially important in modeling contemporaneous shifts in urban labor markets.

While significant research has been undertaken on the behavior of Okun's Law within and across nations, little has been done to investigate the relationship within cities. Available scholarship has focused on either modeling individual labor market dynamics within countries or comparing these dynamics internationally based on country-by-country relationships between output growth and unemployment rate changes. Indeed, much of this siloed focus results from the important macroeconomic policy implications associated with national estimates of Okun's coefficient, prompting a large corpus of academic work investigating this subject matter. However, the dearth of estimations of Okun's coefficient for cities may also be a consequence of the nature of urban economics itself. The field is traditionally viewed as a branch of microeconomics whose orthodox models contain little treatment of urban labor markets; the primary focus has long been on investigating the agglomerating forces behind city formation, expansion, and decay. The few treatments of urban labor markets that exist, such as that of (Morrison, 2005), make little mention of their relationship with urban output.

Compounding this problem, economists may find it difficult to accurately measure urban production. Whereas GDP is more easily be traced within a country's borders, setting exact peripheries for cities is often a core topic of debate amongst urban planners. While this problem is less pronounced for an urban core like New York City - with its stringent borough divisions - tracing urban output for others depends on a given researcher's definition of a city, subjective determination of its borders, and more complicated accounting decisions as to what counts as domestic output. National accounting principles readily aggregate urban, suburban, and rural output within a nation's borders with no need to differentiate the source so long as the production is generated domestically. However, the application of these same principles to a city will result in different estimates of GMP/GCP depending on the aforementioned subjective border configurations.

The cosmopolitan nature of urban cores, in addition to the dawn of remote work, further complicates the determination of urban income flows. For example, a remote worker may live outside of a city but commute to their downtown office one or two days a week. Additionally, fully remote workers may perform all of their work entire states away without ever setting foot in their employer's office in a CBD. Parsing what counts as urban production and what constitutes another region's production accounting may therefore render GMP/GCP estimates more unreliable than when aggregating nationally for GDP; this is anticipated to be a central limitation of this paper's estimates of urban Okun's coefficients.

Recall that national economies contain a variety of settlement typologies and densities that may potentially raise or lower the magnitude of Okun's coefficient. In addition to this "smoothing" effect, large stretches of open land may spread the effects of national output across more disconnected labor markets, further moderating the size of Okun's coefficient. Hence the estimates produced by Ball et al (2017) and Russnak et al (2023) which range from 0.42 to 0.54. Three questions then arise: (i) is Okun's coefficient on average higher for urban regions, (ii) how is Okun's coefficient affected by external shocks within cities, and (iii) what measurable impact does geography have on estimates of Okun's coefficient?

Data on real Gross Metropolitan Output (GMP) and unemployment was collected from the United States Bureau of Labor Statistics (BLS) and S&P Global's *Regional Economics* data portal between 1990Q1-2023Q4. Each urban core is classified by the BLS as a Metropolitan Division (MD) that is a larger aggregate of the major city with surrounding urban counties. The core of the MD comprises a Metropolitan Statistical Area (MSA) of at least 2.5 million residents. The Chicago-Naperville-Arlington Heights MD (Chicago MD) comprises the Illinois counties of Cook, DuPage, Grundy, Kendall, McHenry, and Will. The Los Angeles-Long Beach-Glendale MD (Los Angeles MD) is coterminous with the entirety of Los Angeles County. Finally, the New York-Jersey City-White Plains MD (New York MD) consists of the New Jersey counties of Bergen, Hudson, Middlesex, Monmouth, Ocean, and Passaic, as well as the New York State counties of Bronx, Kings, Queens, New York, Richmond, Rockland, Orange, and Westchester. Real GMP is measured as the summation of all final output generated in the constituent counties of a particular MD for a given calendar quarter. The unemployment rate used is that of the BLS U3 measure. U3 is the most widely used estimate of unemployment that includes all individuals in active search for employment within the last four weeks of the survey reference week and those able and willing to work during said reference week.

BLS MDs were chosen as the unit of analysis because of their consistent descriptive statistics and generous geography; this consistent data allows more accurate modeling for metropolitan regions of varying sizes, densities, and demographics in order to observe the urban variations in Okun's Law, while the inclusion of surrounding counties helps to account for additional urban output resulting from regional sprawl. A larger geography may also capture a greater share of regional remote workers whose production may not consistently occur in the city proper. All three cities' unemployment rates experienced significantly abnormal departures from their long run trends during the coronavirus pandemic, with between 233.6%-298.02% percent changes in unemployment for all three in 2020Q2. This quarter coincides with the implementation of mass urban lockdowns which artificially distorted the relationship between urban output and unemployment. To control for these inflated values, the 2020Q2 observation is removed from the aggregated dataset. Growth rates are calculated in percent form between quarters for both real GMP and U3 unemployment rates, generating a total sample size of $N = 133$ after accounting for lags from 1990Q3-2023Q4.

I test an autoregressive distributed lagged model (ARDL) of two functional forms. The first functional form is a linear model with contemporaneous percent changes in unemployment regressed against percent changes in unemployment lagged by one quarter, percent growth in real GMP lagged by one quarter, and contemporaneous percent growth in real GMP. The second model form employs the first form as its base while adding two binary variables to control for extreme oscillations in unemployment and account for potential structural breaks. The first variable is a binary "recessionary" indicator that signals abnormal acceleration in unemployment growth for a particular quarter. Since urban labor markets may be prone to more aggressive U3 rate swings than non-urban markets, this "recessionary" term may potentially deflate an overestimated Okun's coefficient. The second binary variable is a "recovery" term that accounts for the rapid downward adjustments in unemployment that proceeded from the mass-lifting of COVID-19 lockdowns.

During the 2020 pandemic quarters, federal stimulus spending helped urban economies rapidly recover from large GMP declines while lockdowns artificially rose unemployment (and rapidly decreased unemployment when lifted); this "recovery" term is essential in partialing out the dataset's potential disjoint between both real GMP growth and unemployment rate changes that resulted from these dual policies. Indirectly, both variables together may act as proxies for the spatial "smoothing" effect discussed previously. A threshold of 9% change in the unemployment rate is used to determine a "recessionary" quarter during the entire study period, while declines in unemployment exceeding 9% in any post-2020Q2 quarter between 2020-2021 signal a post-covid "recovery" period.

The following two functional forms are thus generated for each city:

$$\Delta U_t^c = \lambda_0 + \lambda_1 g_t^c + \lambda_2 g_{t-1}^c + \lambda_3 \Delta U_{t-1}^c + \epsilon_t, \tag{2}$$

$$\Delta U_t^{c*} = \lambda_0^* + \lambda_1^* g_t^c + \lambda_2^* g_{t-1}^c + \lambda_3^* \Delta U_{t-1}^c + \lambda_4^* D + \lambda_5^* R + \epsilon_t, \tag{3}$$

where λ_0, λ_0^* are the intercept percent changes in the unemployment rate, g_t^c is the contemporaneous real GMP growth rate, g_{t-1}^c is the lagged real GMP growth rate, ΔU_{t-1}^c is the lagged percent change in the unemployment rate, R is the quarterly "recessionary" variable, D is the distortionary post-pandemic recovery term, and ϵ_t is the contemporaneous disturbance term. The coefficients λ_1, λ_1^*, or Okun's coefficients, measure the immediate effect of the germane MD's GMP growth rate on percent changes in the unemployment rate. In the first model form, the identity $\omega_1^c \equiv \lambda_1 + \lambda_2$ is the aggregate short run effect on unemployment; the representation is the same for the second form as $\omega_2^c \equiv \lambda_1^* + \lambda_2^*$. I represent the long run effect of urban output growth on percent changes in urban unemployment as the identities:

$$\zeta_1^c \equiv \frac{\lambda_1 + \lambda_2}{1 - \lambda_3}, \tag{4}$$

$$\zeta_2^c \equiv \frac{\lambda_1^* + \lambda_2^*}{1 - \lambda_3^*}. \tag{5}$$

Similar to Canarella and Miller (2017), I test for unit roots in both model forms via an Augmented Dickey-Fuller (ADF) test of $k = 4$ lags in Table 1. Only the Los Angeles MD's percent changes in unemployment exhibit unit roots at $\alpha = 0.05$. After estimating both model forms, I then test for structural shifts using a Bai-Perron specification test at the significance level $\alpha = 0.05$. Okun's (1962) original estimation assumed symmetric endogenous responses of ΔU to g. However, shifts in productivity and labor capacity restructuring in times of downturn imply potential non-linear and asymmetric effects which may not translate to direct responses in unemployment that hold between quarters; the model therefore seeks to incorporate potential departures in given quarters by testing for these breaks. A Ramsey RESET test is performed on both model forms to determine potential non-linear effects. White tests are used to detect heteroskedasticity while Breusch-Godfrey Lagrange Multiplier (LM) tests are used for serial correlation.

Finally, a Bounds test is carried out to determine co-integration between the exogenous variables and test the significance of both the short run coefficients ω_1^c and ω_2^c and long run coefficients ζ_1^c and ζ_2^c. I predict that the contemporaneous Okun's coefficient estimates, short run total effects, and long run total effects will be larger in the three MDs than the United States as a whole due to more vulnerable sectors, more acutely

Table 1 ADF test statistics

Metropolitan Division (MD)	Variable	Test statistic (τ)
Chicago-Naperville-Arlington Heights	ΔU_t	-3.551**
	g_t	-4.238**
Los Angeles-Long Beach-Glendale	ΔU_t	-3.125
	g_t	-4.312**
New York-Jersey City-White Plains	ΔU_t	-3.551**
	g_t	-4.742**

This table reports the results from the initial Augmented Dickey-Fuller (ADF) test for all three MDs. ** indicates a significance level of 5%. Note that all relevant terms are significant at the 5% level save for percent changes in the Los Angeles MD's unemployment rate.

productive labor forces, and heightened sensitivity to output oscillations. For example, Ball et al (2017) estimated Okun's coefficient to be anywhere between 0.37-0.42 for the United States while I predict an average for each MD closer to 1. I further predict that the short run coefficients ω_1^c and ω_2^c will be anywhere between 1 and 3, while the long run coefficients ζ_1^c and ζ_2^c are predicted to be closer to 3, above the respective short run and long run estimates of -0.29 and -0.43 by Canarella and Miller (2017).

3 Results

Figures 1-3 display the linear correlations of quarterly percent changes in U3 to quarterly growth in real GMP for each MD excluding the 2020Q2 outlier. This quarter coincides with the World Health Organization's (WHO) declaration of the COVID-19 pandemic on March 11$^{\text{th}}$ and the COVID-19 national emergency declaration by the U.S. Government on March 13$^{\text{th}}$. As discussed, it also coincides with the widespread implementation of strict lockdown protocols across major U.S. cities. During this period, real GMP growth declined between 8.60%-11.74% while unemployment rate rose by between 233.64%-298.02% in all three MDs. Excluding the 2020Q2 anomaly leads to an average U3 percent change range of -0.72%-0.96% (including the post-2020Q2 recovery quarters), while including the 2020Q2 anomaly computes an average of -0.91%-1.32%, demonstrating how much of a skew 2020Q2 constitutes in the original dataset. A clear linear trend is not immediately visible due to the apparent clustering of real GMP growth rates, although a modest inverse relation between U3 percent changes and real GMP growth is visible for all three MDs. However, the relationship appears strongest for the Chicago MD and weakest for the New York MD.

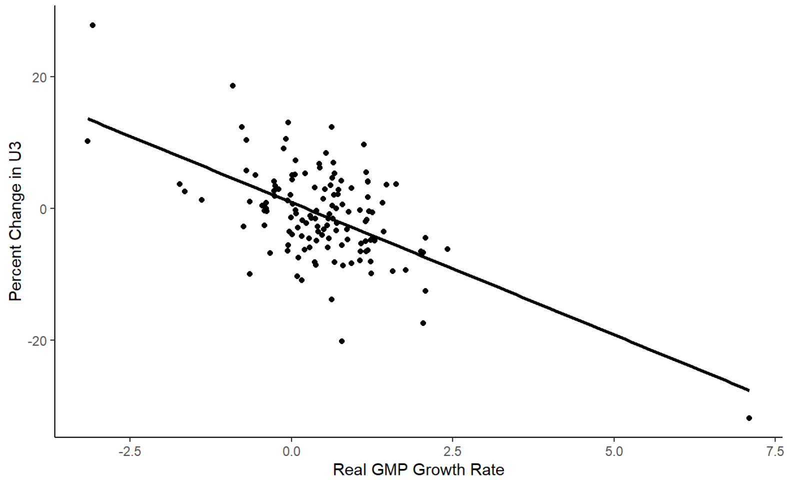

Fig. 1 Okun's Law in the Chicago MD. The trend plot shows perhaps the strongest relationship between real GMP growth and unemployment rate percent changes for the Chicago MD. It is expected that the estimated Okun's coefficient will be largest in magnitude for the Chicago MD.

I estimate the initial ARDL model for all three MDs in Table 2, including coefficient magnitudes and their associated standard errors. Initially, the Los Angeles MD estimation employed differencing for the U3 growth rate. However, this resulted in a worse performing estimation than a model without differencing. Compared to the non-differenced model in Table 2, the differenced estimation produced an F-statistic of 7.51, an adjusted R^2 of 0.130, and an Akaike Information Criterion (AIC) score of 6.04 (compared to the non-differenced score of 5.74); thus, the non-differenced model is preferred. In Table 3, serial correlation was detected in both the New York MD and Los Angeles MD estimations via a Breusch-Godfrey Lagrange multiplier (LM) test at $\alpha = 0.05$, while heteroskedasticity was detected in all three estimations via a White LM test at $\alpha = 0.05$.

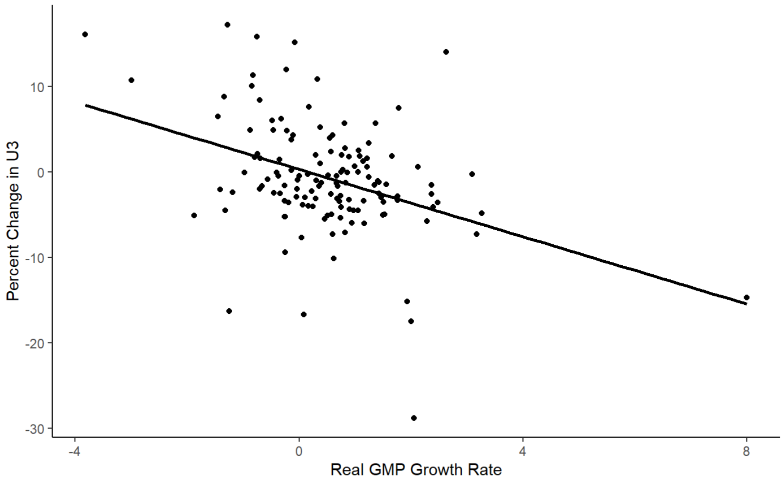

Fig. 2 Okun's Law in the Los Angeles MD. The trend plot illustrates a noticeable inverse relationship between observed growth in real GMP and percent changes in the unemployment rate for the Los Angeles MD. This may induce a larger magnitude for Okun's coefficient.

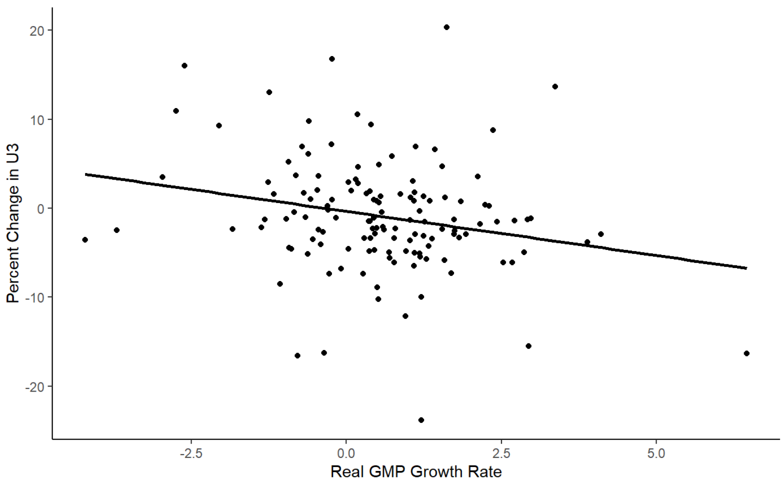

Fig. 3 Okun's Law in the New York MD. The trend plot illustrates a modest inverse relationship in the New York MD between movements in real urban output and percent changes in the unemployment rate. Okun's Law appears to be less pronounced in the New York MD relative to Los Angeles and Chicago.

Heteroskedasticity and autocorrelation-consistent (HAC) errors were computed for both the New York MD and Los Angeles MD estimations via a Newey-West covariance matrix, while heteroskedasticity-consistent Huber-White-Hinkley (HC1) errors were computed for the Chicago MD estimation. All three Okun's coefficient estimates for

Table 2 Initial ARDL model and standard errors

Variable	New York MD	Los Angeles MD	Chicago MD
Intercept	0.779	1.048	1.654**
	(0.420)	(0.640)	(0.607)
g_t	-1.163**	-1.724**	-3.986**
	(0.450)	(0.856)	(0.971)
g_{t-1}	-0.611**	-0.831	-0.771
	(0.239)	(0.499)	(0.471)
ΔU_{t-1}	0.730**	0.593**	0.353**
	(0.067)	(0.121)	(0.091)
Adj. R^2	0.639	0.594	0.510
F-statistic	78.86**	65.42**	46.78**

This table reports the results from the initial ARDL estimation for all three MDs based on the first model form of first order lags. Note that HAC/HC1 errors are reported in parentheses. ** indicates a significance level of 5%.

Table 3 Initial Breusch-Godfrey and White LM test statistics

Metropolitan Division (MD)	Breusch-Godfrey statistic	White statistic
New York-Jersey City-White Plains	16.545**	57.631**
Los Angeles-Long Beach-Glendale	21.685**	59.459**
Chicago-Naperville-Arlington Heights	7.620	55.019**

This table presents the results of the initial Breusch-Godfrey Lagrange Multiplier test for serial correlation and the White Lagrange Multiplier (LM) test for heteroskedasticity. The null hypothesis for the Breusch-Godfrey LM test is that there is no serial correlation up to $k = 4$ lags. The null hypothesis for the White LM test is that the variance across the error terms is constant. ** indicates a significance level of 5%.

$\hat{\lambda}_1^c$ exceed the estimations made by both Ball et al (2017) and Canarella and Miller (2017), supporting the initial conjecture of higher parameter values in urban cores. The New York MD estimated coefficients less the intercept all passed significance at $\alpha = 0.05$, while the Los Angeles MD estimation exhibited a somewhat weaker performance with insignificance of the lagged real GMP growth rate parameter; the Chicago MD's lagged real GMP growth rate parameter is also insignificant at $\alpha = 0.05$. Crucially, the estimated contemporaneous Okun's coefficients are statistically significant and negative for all three MDs at the 5% level. A Ramsey RESET test is performed in Table 4, which indicates possible non-linearities in ΔU_t^c at $\alpha = 0.05$.

Table 4 Initial Ramsey RESET F-statistics

Metropolitan Division (MD)	F-statistic
New York-Jersey City-White Plains	1.466
Los Angeles-Long Beach-Glendale	0.033
Chicago-Naperville-Arlington Heights	0.974

This table reports the results from the Ramsey RESET test for non-linear effects at $\alpha = 0.05$. It tests whether a model with non-linear terms performs better than the originally estimated model. The null hypothesis is that the parameter estimates for the non-linear terms are equal to zero.

I next estimate the short run effect (SRE) parameters ω_1^c and long run effect (LRE) parameters ζ_1^c in Table 5 using a Bounds test. In their initial non-regime model, Canarella and Miller (2017) estimated an SRE parameter of -0.29 and an LRE parameter of approximately -0.43 for the United States, implying that a 1% increase in real GDP growth corresponds to a 0.29% decline in U3 rates in the short run and a 0.43% decline in the long run at the 5% significance level. However, I find that the effects in both the short run and the long run are more substantial when estimated for these urban cores, with a 1% increase in real GMP growth rates inducing anywhere between a 1.77%-4.76% decline in U3 rates in the short run and 6.56%-7.35% in the long run. Note that both the short run and long run effects hold at the 5% level for all three MDs.

Table 5 Initial short run and long run effect parameters

Metropolitan Division (MD)	SRE parameter (ω_1^c)	LRE parameter (ζ_1^c)
New York-Jersey City-White Plains	-1.774**	-6.561**
	(0.351)	(2.159)
Los Angeles-Long Beach-Glendale	-2.555**	-6.278**
	(0.414)	(1.594)
Chicago-Naperville-Arlington Heights	-4.756**	-7.352**
	(0.686)	(1.188)

This table reports the results of the initial Bounds test for both short run and long run effects via cointegration of real urban output growth on percent changes in the unemployment rate. The null hypothesis is that there is no cointegration between the variables. Standard errors from the short run estimates are reported in parentheses from the Error Correction model, while standard errors from the long run estimates are reported in parentheses from the levels equation. ** indicates a significance level of 5%.

To test for structural breaks I employ a Bai-Perron specification test using sup $F_T(\ell)$ test statistics in Table 6. These are estimated via the simple linear regression of Okun (1962) as applied to each MD. Given the computed test statistics, I have sufficient evidence to reject the null hypothesis that there are indeed no structural breaks in either estimation. Within each MD, the most likely structural breaks occur as both recessionary periods during the Dot-com bubble bust in late 2001-2002 and the Great Recession between 2008-2009, and as an unusually rapid recovery period for urban labor markets in late 2020-2021 following the lifting of urban COVID-19 lockdowns.

Table 6 Bai-Perron test statistics

Metropolitan Division (MD)	Test statistic (sup $F_T(\ell)$)
New York-Jersey City-White Plains	21.754**
Los Angeles-Long Beach-Glendale	17.380**
Chicago-Naperville-Arlington Heights	23.628**

This table presents the results of the Bai-Perron test for structural breaks. The null hypothesis is that there are no structural breaks present against the alternative of ℓ breaks. ** indicates a significance level of 5%.

Between 2001Q3 and 2002Q1 during the Dot-com recession, the three urban cores saw a mean quarterly percent change in U3 rates of 9.87%. Between 2008Q2 and 2009Q2 during the Great Recession, the mean percent loss in urban employment for all three MDs was 13.09%. Finally, during the post-pandemic period between 2020Q3 and 2022Q3, all three MDs saw a substantial mean increase in employment of 13.43%. Another potential structural break occurs towards the end of 2020Q1 when the COVID-19 pandemic began rapidly spreading across the U.S., with an average increase in U3 rates for all three MDs of 18.27%. However, the removal of the 2020Q2 observation moderates this quarter's overall effect.

The presence of structural breaks, compounded by the acute changes in U3 rates during the aforementioned recessionary and recovery periods, warrants the inclusion of additional exogenous terms to deflate the initial $\hat{\lambda}_1^c$ estimates. I therefore estimate the expanded model formulation with both the "recessionary" R and post-covid "recovery" D variables. Table 7 displays the results of the expanded ARDL model for all three urban cores. The inclusion of these binary variables, while themselves possessing relatively large parameter estimates, nonetheless moderated down the Okun's coefficient estimates for all three MDs. Even with the downward adjustments, the Okun's coefficient estimates are still above those of Ball et al (2017) and Canarella and Miller (2017). The adjusted R^2 also improved in all three estimations. The variation between the Okun's coefficient estimates is truncated relative to the first model, implying some degree of convergence when partialing out the structural breaks.

Table 7 Expanded ARDL model and standard errors

Variable	New York MD	Los Angeles MD	Chicago MD
Intercept	-0.102	0.365	0.380
	(0.385)	(0.488)	(0.475)
g_t	-0.580**	-1.118**	-2.381**
	(0.186)	(0.422)	(0.594)
g_{t-1}	-0.261	-0.647	-0.444
	(0.170)	(0.356)	(0.415)
ΔU_{t-1}	0.438**	0.385**	0.207**
	(0.101)	(0.140)	(0.085)
D	-8.761**	-7.158	-11.096**
	(1.772)	(4.256)	(2.831)
R	8.109**	8.075**	9.357**
	(1.234)	(1.681)	(1.598)
Adj. R^2	0.757	0.696	0.625
F-statistic	83.34**	61.50**	45.07**

This table reports the results from the expanded ARDL estimation for all three MDs based on the second model form of first order lags and binary indicators for both recessionary and recovery periods. Note that HAC/HC1 errors are reported in parentheses. ** indicates a significance level of 5%.

Additionally, the lagged real GMP growth rate parameter is insignificant at $\alpha = 0.05$ in all three MD estimations, signaling that the delayed impact of real GMP growth on unemployment may be trivial when more directly accounting for abnormal quarterly U3 rate changes. Similar to the initial model, serial correlation and heteroskedasticity were detected for both the New York and Los Angeles MDs, while heteroskedasticity was detected for the Chicago MD. Table 8 displays the results of the LM tests for both serial correlation and heteroskedasticity.

Table 8 Expanded Breusch-Godfrey and White LM test statistics

Metropolitan Division (MD)	Breusch-Godfrey statistic	White statistic
New York-Jersey City-White Plains	16.116**	28.324**
Los Angeles-Long Beach-Glendale	11.151**	25.108**
Chicago-Naperville-Arlington Heights	3.813	28.007**

This table presents the results of the initial Breusch-Godfrey Lagrange Multiplier test for serial correlation and the White Lagrange Multiplier test for heteroskedasticity. ** indicates a significance level of 5%.

I next estimate the expanded model's SRE and LRE parameters ω_2^c and ζ_2^c by MD in Table 9. With the inclusion of both the "recessionary" and "recovery" variables, the effect parameters declined in magnitude for all three MDs. Whereas in the initial model, a 1% increase in real GMP growth rates resulted in a 1.77%-4.76% decline in U3 rates for the short run and 6.56%-7.35% in the long run, in the expanded model this same 1% increase in real GMP growth resulted in a more modest short run decline in U3 rates of 0.84%-2.825% and a long run decline of 1.49%-3.56%. The sharpest impact of the binary indicators is on the New York MD LRE parameter, which substantially moderated from -6.561 to -1.494 between the initial and expanded models. Just as in the initial model, the expanded model's estimations for ω_2^c and ζ_2^c are significant at the 5% level, signaling the durability of both the short run and long run effects of real output growth on percent changes in unemployment. Finally, a Ramsey RESET test is used to detect non-linearities in Table 10. Unlike in the first model form, non-linear effects are only detected in the Chicago MD estimation.

Table 9 Expanded short run and long run effect parameters

Metropolitan Division (MD)	SRE parameter (ω_2^c)	LRE parameter (ζ_2^c)
New York-Jersey City-White Plains	-0.841**	-1.494**
	(0.311)	(0.524)
Los Angeles-Long Beach-Glendale	-1.765**	-2.869**
	(0.377)	(0.776)
Chicago-Naperville-Arlington Heights	-2.825**	-3.561**
	(0.670)	(0.776)

This table reports the results of the final Bounds test for both short run and long run effects via cointegration of real urban output growth on unemployment rate changes. The null hypothesis is that there is no cointegration between the variables. As in the initial Bounds test, standard errors from the short run estimates are reported in parentheses from the Error Correction model while standard errors from the long run estimates are reported in parentheses via the levels equation. ** indicates a significance level of 5%.

Table 10 Expanded Ramsey RESET F-statistics

Metropolitan Division (MD)	F-statistic
New York-Jersey City-White Plains	4.083**
Los Angeles-Long Beach-Glendale	5.508**
Chicago-Naperville-Arlington Heights	0.435

This table reports the results from the final Ramsey RESET test for non-linear effects. ** indicates a significance level of 5%.

4 Discussion

The two model forms presented herein provide varying estimations of Okun's coefficient for the three urban cores in question. Across both forms, the Okun's coefficient estimate was lowest for the New York MD and highest for the Chicago MD. The weaker estimate for the New York MD may be explained by the region's greater historical resilience to shocks relative to the other MDs. The Great Recession left New York City initially unscathed relative to other major urban cores, thanks in large part to a more adaptable labor market and delayed impacts in later years such as 2010 and 2013 (Mielnicki et al, 2017). Furthermore, New York remained a notable outlier during the recovery. While Los Angeles and Chicago experienced negative real GMP growth in early 2009 followed by low positive growth rates into 2010, New York enjoyed positive output growth between 2009Q1 and 2010Q2 of 1.62% on average despite an average increase in the unemployment rate of 6.72%. While the Los Angeles and Chicago MDs generally saw negative real GMP growth when U3 rates increased, the New York MD appears more resilient and uncorrelated. Additionally, the New York MD presented a generally weaker fit between real GMP growth and U3 changes over the entire study period as evidenced back in Figure 1.

The inflated Chicago MD Okun's coefficient is somewhat of an outlier. However, this particular region appears to be more acutely affected by output swings than the New York or Los Angeles MDs, with a tighter and steeper trend fit as evidenced back in Figure 3. Furthermore, the late 1990s in the Chicago MD saw steeper declines in unemployment and slightly faster output growth relative to the New York and Los Angeles MDs. Across the time series, the Chicago MD saw the smallest average real GMP growth rate of 0.47% but the largest average percent change in U3 rates of 0.96%. The Los Angeles MD also experienced some sensitivity to output swings in the 1990s and was not as acutely affected by the Dot-com bubble bust as the New York MD. All three MDs experienced accelerated employment recoveries throughout 2014-2015, potentially lending credence to potential delayed effects of urban output growth on urban U3 rate changes.

As discussed, recent literature has established the anomalous effects of COVID-19 on Okun's Law and its skew of Okun's coefficient. The presence of lockdowns substantially rose urban unemployment rates, while the disbursement of federal stimulus funding helped mollify the pandemic's impact on metropolitan output. The exclusion of 2020Q2 was necessary to control for the unprecedented break in U3 rates from their long run urban averages. Furthermore, excluding 2020Q2 produced cleaner and tighter trend fits for all three MDs. The extreme U3 rate acceleration in 2020Q2 resulted from significant losses in critical employment sectors including leisure and hospitality, tourism, construction, and rideshares as the three MDs were acutely affected by stringent lockdown protocols. Meanwhile, inflationary output gaps post-2020Q2 arose because of the relaxing of lockdown protocols and generous social transfers in the form of enhanced state unemployment outlays, federal stimulus checks, and federal business loan disbursements such as the Paycheck Protection Program (PPP). Even with the recovery term, it is possible that the Okun's coefficient estimates for all three MDs are nevertheless still inflated by this incredibly anomalous period.

Okun's Law is a largely macroeconomic principle meant for application on a national scale. As such, this study does present some limitations as to the estimation of Okun's coefficient for urban cores. First, as explored earlier the subjective measures of which regions constitute "urban," which constitute "exurban," which constitute "suburban," and which are "rural" is a central research problem posed by urban planning scholarship. This problem is pervasive not only for researchers, but also the underlying datasets used in this study. While the use of Metropolitan Divisions helped account for sprawl and remote work that contributes to production within the relevant central business district, it may have moderated down the estimated Okun's coefficients due to the inclusion of less dense adjacent counties. If this study were to use a uniform geography for the case study cities proper (i.e., downtown Chicago, downtown Los Angeles, and New York City's five boroughs), the parameter estimates $\hat{\lambda}_1^c$ and $\hat{\lambda}_1^{c*}$ may have been more aggressive.

The use of ARDL in the method of Canarella and Miller (2017), Weber (1995), and Sögner and Stiassny (2002) was selected as the optimal estimation method for Okun's coefficient. It was initially hypothesised that the use of lagged dynamics would be essential in explaining percent changes in unemployment rates for contemporaneous quarters. This indeed held true for the U3 rate lags, which were significant at the 5% level in both model forms. Nevertheless, the weaker performance of the lagged growth rate dynamics for all three MDs in the expanded model form provides evidence that lags may not be as important as initially hypothesised. This outsized emphasis on contemporaneous effects may result from the "hurried" nature of cities and their concentrated geography. Whereas a recession for the country at large may take months to materialize and spread, a city's density and smaller geography implies that crises have less area to cover in their "spread." Furthermore, the greater concentration and more integrated networks of financial institutions and other sectors vulnerable to downturns means that said crises also spread faster than when entering the suburbs and countryside.

The exclusion of the 2020Q2 quarter from the underlying sample set may prove to be a controversial decision in this paper. Removing particular observations from a sample set, however few, may introduce sampling bias into the model forms. Yet, as this study has shown, it may also be a critical step in deflating overestimated coefficients. For example, when including the 2020Q2 observation, the initial Okun's coefficient for the New York MD is 9.307; the coefficient is 9.799 for the Los Angeles MD and 13.632 for the Chicago MD. If including the recessionary indicator in the expanded model form, $\hat{\lambda}_1^{c*}$ moderates down only slightly but the recessionary parameter $\hat{\lambda}_5^{c*}$ becomes heavily distorted, with a value of $\hat{\lambda}_1^* = -7.770$ and $\hat{\lambda}_5^* = 23.170$ for the New York MD estimation. If isolating 2020Q2 as its own indicator term, the newly introduced estimate λ_6^* becomes 282.485 in the expanded model. The estimate for the New York MD's Okun's coefficient incoherently reduces down to 0.288. The estimation also becomes severely over-fitted with an adjusted R^2 of 0.9804. Therefore, attempts to partial out this extreme outlier through the model itself proved cumbersome and distorted other segments of the results in unjustifiable ways.

The significance of the SREs and LREs at the 5% level in both model forms for all three MDs is a crucial result that may have some important implications for future research in urban labor markets. The significance of ω_1^c and ω_2^c for all three MDs demonstrates the strength of the immediate effects of real urban output and overall lagged dynamics on unemployment rate swings for similarly sized urban cores. On the other hand, the significance of ζ_1^c and ζ_2^c implies that this short run relationship holds stable into the long run. Together, these results support the conclusion that the observed movements in both real urban output growth and urban unemployment rates have meaningful and testable relationships that can be investigated through econometric estimation techniques.

5 Conclusion

This paper sought to open a new avenue of research for urban economics: the application of Okun's Law on a localised scale for major cities. By employing the ARDL methods in similar form to that of Canarella and Miller (2017), Weber (1995), and Sögner and Stiassny (2002), Okun's coefficient, which measures the inverse impact of contemporaneous growth in real output on percent changes in the unemployment rate, was estimated for three major case study cities and their surrounding counties in the United States: Chicago, Los Angeles, and New York City. I test two model forms to isolate potential estimates of Okun's coefficient. In the first form, I replicate the original base formula of Canarella and Miller (2017) with only one lag of $t-1$. In the second (expanded) form, I add binary terms for both recessionary and post-lockdown quarters to partial out the extreme oscillations observed in unemployment and output in cities. I then test the durability of the short run and long run effects of real output growth on percent changes in unemployment.

As hypothesised, Okun's coefficient is larger in both magnitude and impact than those estimated by Ball et al (2017), Canarella and Miller (2017), and Russnak et al (2023). The estimated Okun's coefficients for these three urban cores supports the conclusion that their urban labor markets are more responsive to output oscillations than the United States as a whole. Future research should compare the estimates herein with new estimates for cities and urban regions of varying geographies, demographics, and densities to test whether the varied elements of cities are general causal factors in higher Okun's coefficient magnitudes.

Data availability The data in quarterly format is publicly searchable through the Bureau of Labor Statistics website as well as S&P Global's data portal. However, the specific datasets used in the analysis carried out in this study are available from the corresponding author upon reasonable request.

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