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Sectoral Okun's Law and Cross-Country Cyclical Differences

Abstract

We estimate Okun's law, the negative relationship between output and the unemployment rate, at the sector level for the US, the UK, Japan, and Switzerland to test several hypotheses that may explain why the aggregate Okun's coeffcients are different across countries. Specifically, we show that the sectoral composition is not a driver and find that the sectoral coefficients are proportional to the aggregate in all four countries. We also show that the standard deviation of unemployment is the main driver of the cross-country differences. This is consistent with labor market policies being crucial to explain the cross-country cyclical differences in the aggregate Okun's coefficient.

JEL-Codes: E240, E320.

Keywords: Okun's law, cross-country differences, sectors.

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1 Introduction

This paper examines whether the differences in the aggregate Okun's coefficients between four countries are largely driven by factors that affect every sector in the same way or by factors that affect each sector differently. Okun's law is the empirical negative relationship between real gross domestic product (GDP) growth and the unemployment rate. The estimated slope of this relationship is the Okun's coefficient. The four countries we investigate are the US, the UK, Japan, and Switzerland.

The literature on the cross-country differences are driven by factors that can be broadly split into two categories. The first category includes the factors that uniformly affect the overall economy (e.g. Ohanian et al., 2018; Scarpetta, 1996; and Ilzetzki et al., 2013). These factors would affect every sector in a similar way and the cross-country differences of sectoral Okun's coefficients should be proportional to the differences at the aggregate level. For example, different labor market policies regarding hiring and firing would fall in this category, as all sectors are affected in the same way. This contrasts to the second strain of the literature, which categorizes cross-country differences that are largely driven by factors that affect firms or sectors differently across countries (e.g. Bartelsman et al., 2013; Hsieh and Klenow, 2009; Alfaro et al., 2009; Harrigan, 1999; and Haltiwanger et al., 2014). These factors would affect different sectors heterogeneously and the aggregate differences could be explained by this heterogeneity. One such factor could be differences in the production functions. Some sectors are more capital intensive than others, causing them to behave differently along a business cycle and the sectoral composition would drive the cross-country differences.

We contribute to the literature on the cross-country differences by determining in which of the aforementioned two categories the Okun's coefficient falls. Specifically, we test whether the aggregate differences disappear if the sector sizes are the same across countries (e.g. if manufacturing is re-weighted to have the same share of GDP for all countries) and we can reject this. We also examine whether the sectoral coefficients have the same proportions to each other for all countries and we cannot reject this. Next, we inspect whether any sector's coefficient is the same as the aggregate's and we can also reject this. Lastly, we decompose the Okun's coefficient into the correlation between the unemployment rate and GDP, the standard deviation of the unemployment rate, and the standard deviation of GDP to determine which factor is driving the differences. We find that the standard deviation of the unemployment rate is the main driver of the cross-country differences.

It is well documented that the aggregate Okun's coefficients are different across countries (e.g. Ball et al., 2017; Lee, 2000; and Moosa, 1997). However, while there are several studies that look at a sub-national Okun's law, they tend to focus on a single country and sectoral breakdowns are scarce.[1] We contribute to this literature by documenting the cross-country estimates at both the aggregate and sector levels. In addition, we are able to refine the determinants of the aggregate cross-country differences in Okun's coefficients relative to the previous literature by taking advantage of the properties of the sector level estimates. A possible application for these findings could be in a forecasting setting. For example, Ball et al. (2015) has shown that Okun's law can improve forecast at the aggregate level.

This analysis is also important for monetary policy. An extensive amount of literature has linked monetary policy actions to sectoral output.[2] A common finding in this strand of literature is that construction is the most responsive sector to monetary policy shocks. We contribute to this literature by documenting the links of sectoral output to sectoral unemployment rate. Given the full employment mandate of the Federal Reserve, it is very important to know not only how responsive output is to monetary policy but also how responsive unemployment rate in each sector is to output. For example, even though the US retail trade sector output might be more responsive to monetary policy shocks than manufacturing, the output-unemployment rate relationship in retail trade might be weaker than in manufacturing. As a result, the unemployment rate might actually be more responsive to monetary policy in manufacturing. By providing estimates for the sectoral Okun's coefficients, we make a valuable contribution to the sectoral monetary policy literature as well. However, we do not test monetary policy shocks on (un)employment directly. This might be a topic for future research.

Similar to monetary policy, fiscal policy impacts on sectoral output have been studied previously

[1]E.g. see Porras-Arena and Martín-Román, 2019; Guisinger et al., 2018; Durech et al., 2014; Freeman, 2000; Bande and Martin-Roman, 2018; Villaverde and Maza, 2009 for regional differences and Evans, 2018 for demographic differences. Abe and Ohta (2001) investigate Japan and Hartwig (2014) study Switzerland at the sector level and found large differences across sectors.

[2]E.g. see Dale and Haldane, 1995; Ganley and Salmon, 1997; Dedola and Lippi, 2005; Ibrahim, 2005; Alam and Waheed, 2006; Ghosh, 2009; Hayo and Uhlenbrock, 2000; Granville and Mallick (2009) and many others.

(e.g. Bénétrix and Lane, 2010 and Monacelli and Perotti, 2008). Specifically, it was found that the sectoral impact of fiscal policy shocks is not the same as monetary policy shocks. As with monetary policy, we contribute to this strand of literature by estimating the output-unemployment rate relationship. We also contribute to this strand of literature with regards to other shocks as well. For example, Vukotic (2019) looks at the impact news shocks have on sectoral output. Similarly to monetary policy and fiscal policy, addressing the sectoral output-unemployment rate relationship can have important implications to the literature on news shocks as well. We also more generally contribute to cyclical literature (e.g. Mallick and Sousa, 2017 and Cover and Mallick, 2012).

Lastly, we also contribute to the literature on panel data and pooled estimates (e.g. Freeman, 2001 and Lee, 2000). By decomposing the Okun's coefficient into the correlation between output and unemployment as well as standard deviations of the variables, we are able to assess where the heterogeneity across countries originates from. We show for the Okun's coefficient that standardizing the variables can substantially mitigate the heterogeneity in the coefficients. We also show that, while the correlation between unemployment rate and GDP is rather similar across countries, the Okun's coefficient is not.

The remainder of the paper is structured as follows: Section 2 outlines the empirical strategy, Section 3 describes the data sources, Section 4 reports the sectoral Okun's law estimates, Section 5 and Section 6 conduct several hypothesis tests and determine the drivers of cross-country differences in Okun's law, and Section 7 concludes.

2 Empirical Strategy

In line with Ball et al. (2017) and Okun (1963), we estimate the Okun's coefficient with unemployment rate as the dependent variable and output as the independent variable.[3] For our estimation, we mainly use the first difference format:

$$\Delta u_t = \alpha + \beta[100\Delta Y_t] + \varepsilon_t \tag{1}$$

[3]It is sometimes estimated with the roles reversed, where output is the dependent variable and unemployment rate is the independent variable. This does not change the significance of the results.

where Δu_t is the change in the unemployment rate from the previous period and ΔY_t is the log change in output from the previous period. Furthermore, α is a constant term, β is the Okun's coefficient that captures the cyclical co-movement of change in the unemployment rate and changes in output and ε_t is the error term. This approach does not require the estimation of the underlying trend, however, one observation is lost. This approach also assumes that the trend does not change over time (see Ball et al., 2017). We also estimate the Okun's coefficient using the Hodrick-Prescott (HP) filter of the form:

$$u_t - u_t^* = \alpha + \beta[100(Y_t - Y_t^*)] + \varepsilon_t \tag{2}$$

where u_t is unemployment rate and Y_t is log of output. u_t^* and Y_t^* correspond to the natural rate of unemployment and the log of the potential output, respectively. α, β and ε_t are the same representation as in equation (1). Another detrending method we use is the quadratic trend (e.g. Bande and Martin-Roman, 2018 and Adanu, 2005):

$$u_t = c_0 + c_1 T + c_2 T^2 + e_t \tag{3}$$

$$Y_t = d_0 + d_1 T + d_2 T^2 + v_t \tag{4}$$

where T is a time trend. The fitted variables from the two regressions become u_t^* and Y_t^* used to detrend unemployment and GDP in equation (2), allowing the estimation of Okun's law. We mainly present the first difference results due to some of the shortcomings of filtering the series (e.g. see Hamilton, 2018). Specifically, the HP filter is prone to false cycles and both the HP and quadratic trend have problems with a short sample size.[4] Throughout our estimation, the constant term is not reported for the sake of brevity and we use a seemingly unrelated regression (SUR) following Zellner (1962).[5]

In order to estimate the equations at the sector level, it is necessary to obtain data on the sectoral output and unemployment rate. While output data is readily available, there are some conceptional issues regarding unemployment rate. At the national level, the unemployment rate

[4]We do not use Hamilton's suggested filter, as this would remove 8 observations from our short sample.

[5]Because our number of observations is relatively small, we also estimate with system OLS and the results are qualitatively the same.

is the number of people looking for jobs divided by the labor force (the sum of the number of people that are employed and the ones that are unemployed) times 100. While the employed can readily be allocated to specific sectors, there are various ways to allocate the unemployed. The statistical agencies for the four countries report the sector of the previous occupation of the unemployed. We use this report to allocate the unemployed to specific sectors. The unemployed that did not previously work in any of the sectors are excluded from this analysis. This leads to some discrepancies of our measure (the experienced unemployment rate) to the official unemployment figures. Figure 1 shows a time series plot of the aggregate level official unemployment rate and experienced unemployment rate for the US. As expected, the experienced unemployment rate is consistently lower than the official unemployment rate. However, the experienced unemployment rate traces the official employment very closely. Another difference between the aggregate and sectoral estimations is the potential leakage or absorption from one sector to another in the sectoral estimation. For example, an administrator that becomes unemployed after working in one sector can find a new job in another sector. While we do not expect this difference to dramatically change the analysis, it can cause the sectoral estimates to become smaller in absolute terms.

3 Data

We use three main criteria to select countries for this analysis. We look for countries with a range of Okun's coefficients, with sectors that have different sizes, and that have at least 15 years of sectoral data available. To identify countries to use for this paper, we refer to Ball et al. (2017) and estimate the national Okun's coefficients for countries using annual real GDP and unemployment rate data from 1959 to 2018 from the OECD website. Of the countries with the coefficients closest to zero, we chose Japan and Switzerland and at the other end of the scale, we chose the UK and the US. By choosing these countries, we have a range of Okun's coefficients, and these countries provide a different mixture of sectors as well as have the minimal amount of sectoral data needed for the analysis.

We then collect annual sector level data for the US, the UK, Switzerland, and Japan. The output data is retrieved from the Bureau of Economic Analysis for the US, the Office for National

Statistics for the UK, the Swiss National Statistical Office for Switzerland, and the Cabinet Office, Government of Japan for Japan. Unemployment rate series are retrieved from the Bureau of Labor Statistics for the US, the Office for National Statistics for the UK, the State Secretariat for Economic Affairs for Switzerland, and the Ministry of Internal Affairs and Communications for Japan. This data provides us with 15-22 data points per country which is a clear limitation of this analysis and does not allow us to run the analysis in sub-samples which could potentially affect the results.[6]

The data sets cover the years 1997-2016 for the US, 1995-2017 for the UK, 2002-2016 for Switzerland, and 2000-2016 for Japan at the four sector level (agriculture, manufacturing, services, and government). We lose some of the available years due to definition changes at the most disaggregated level possible. Specifically, the samples for the US and Japan are shortened to the years 2000-2016 and 2002-2016, respectively. Figure 3 shows the average gross value added (GVA) composition for these economies over the corresponding sample periods.[7]. All of these four economies are service economies as the service sector accounts for about 60-70% in each of them. Additionally, the agriculture sector and the government account for less than 15% in the economies. However, there are some differences in sectoral shares. For example, the production sector (the sum of manufacturing, mining, and utilities and construction) accounts for less than 20% in the US and UK, while it is more than 25% in Switzerland and Japan. Given that there are substantial differences in Okun's coefficients and there are some differences in sectoral composition, we can make some inference about the impact of the sectoral composition.

The sectoral definitions do not match perfectly across countries. Some countries have more disaggregated data for some sectors than others (e.g. Switzerland breaks down insurance services separately from financial services), or employ different definitions (e.g. different levels of International Standard Industrial Classification (ISIC)). This makes it difficult to match the sectoral definitions across countries. When necessary, the GDP and the unemployment rate are aggregated into the common sector. The most disaggregated definitions we use can be found on Table 4.[8]

[6]Due to the small sample size, we cannot carry out unit root tests. Based on a simulation with 20 observations of white noise, the Augmented Dickey Fullter test cannot reject unit roots in 85% of cases at the 5% level based on 1000 replications. This implies that the sample size is too small for a reasonable inference. However, as the results with all filter methods are in line with each other, we are fairly confident that the results are not driven by unit roots.

[7]The composition based on common samples and employment show similar differences to the GVA in Figure 3.

[8]In addition to annual data, we also collect quarterly data for the US and the UK. As suggested by Bande and Martin-Roman (2018), quarterly data might not allow for economic adjustments to have completely taken place yet.

4 Sectoral Okun's Law

First, we estimate the Okun's coefficients based on equations (1) and (2) at the national level to observe whether our estimation procedure is in line with the literature. Our results are estimated using the seemingly unrelated regression (SUR) for each country and Tables 1, 2, and 3 report the results from the first difference, HP filter, and quadratic trend filter, respectively. All of the coefficients are negative and statistically significant, confirming that Okun's law holds in all four economies at the national level. In absolute value, the coefficients are largest in the US, followed by the UK, Switzerland, and Japan. The first difference specification gave us somewhat smaller coefficients than when using either of the two filters. However, the order of countries and the significance is the same when using this specification or either of the filters. The aggregate economy coefficients are in line with Ball et al. (2017), Grant (2018) and Valadkhani and Smyth (2015). Thus, the aggregate results should not be affected by the specific time period available for each country.

Next, we estimate the coefficients for the four sectors (agriculture, manufacturing, services, and the government) for each country and report the results in Tables 1, 2, and 3 for the first difference, HP filter, and quadratic trend filter, respectively. The sector level results are broadly similar across countries with agriculture and government having no cyclical relationship between the unemployment rate and output, while manufacturing and services exhibit a strong and negative relationship. In terms of the magnitudes, the Okun's coefficients for the latter two sectors are also broadly in line with the aggregate results. Similar to the aggregate results, the sector results remain broadly unchanged no matter which approach is taken to estimate Okun's law. Due to this observation, we report only the results from the first difference approach in equation (1) and do not report the results from the HP filter method or the quadratic trend method.[9]

For a more detailed sectoral estimation, we use the following eleven sectors: agriculture; manufacturing, mining, and utilities; construction; wholesale and retail trade; transportation and information; financial activity; accommodation; education and health; professional and business (ex-

Due to this, we do not report the quarterly results, however, they are available upon request.

[9]The estimates for these two approaches are available upon request.

cluding Japan); other services; government.[10] The results are presented in Table 4. Similarly to the results in the previous tables, the sectoral coefficients broadly follow the pattern of the aggregate with the US having the strongest negative relationship, the UK and Switzerland have a weaker negative relationship than the US and are similar to each other, and Japan has the weakest negative relationship. Manufacturing and some service sectors appear to have the strongest relationship which was also shown at the four sector level. Aside from the sectors already discussed above (agriculture and government), education and health and financial activities do not show a strong output-unemployment rate relationship across countries. Based on these findings, it appears that the same sectors across countries tend to have stronger and weaker output-unemployment rate relationships. This pattern would be expected if the sectoral composition is driving the differences in aggregate coefficients. This sectoral pattern is also broadly consistent with Berman and Pfleeger (1997) who found a large variation across sectors as well. In line with our results, they also found that manufacturing and construction sectors are sensitive to the business cycle while health, education services, and government sectors are less correlated with the business cycle. They attributed this finding to consumers postponing purchases of goods and services that are not necessities. This also implies that monetary and fiscal policies targeting certain sectors can have a higher impact on unemployment.

The last column in all of the four tables show the Chi-squared test results with the null hypothesis that all coefficients in the same row are equal. We test this hypothesis based on the estimates from the common sample periods across countries for each sector. We find that there exists significant cross-country differences in Okun's coefficients at both the aggregate and sector levels.

We find that Okun's coefficients of the aggregate are larger than of the sectors within countries. While determining the exact cause for this relationship is beyond the scope of the paper, we suspect that it could be related to unemployment in one sector being absorbed by another. For example, if GDP and employment go down in the education sector, the workers may be able to find work in the professional and business sector. If the workers find work in the professional and business sector

[10] The agriculture sector in the UK includes mining and utilities, the transportation and information sector in the US includes utilities, the professional and business sector in Switzerland includes real estate, and the other services sector in Japan include the professional and business sector. Following the 11 sector definition, the four sectors are further defined as follows: the agriculture sector includes only itself, the manufacturing sector includes itself and construction, the government sector includes only itself, and the service sector includes all of the remaining sectors.

or another sector, the unemployment rate for the education sector would not increase, leading to a very small coefficient. This effect might be particularly large for sectors with cycles that are not strongly correlated with the aggregate cycle and might explain some of the variation across sectors as well. There is no such absorption effect on the aggregate level and the full decline in employment is captured by the Okun's law coefficient.

5 What Drives the Cross-Country Differences?

To get back to the initial question of what is driving the cross-country differences in Okun's coefficients, there are several hypotheses to test exploiting the sector level estimates. One potential driver could be the sectoral composition of the economies. Figure 3 shows that, while the economies have similarities in their composition, there are clear differences between them. For example, the manufacturing sector in US and the UK consists of less than 20% of their respective GDPs while the sector in Japan and Switzerland accounts for more than 25% of their respective GDPs. As sectors have different coefficients and sizes across countries, this could account for some of the cross-country aggregate differences in Okun's coefficients.

A second possibility is that the differences in Okun's coefficients are driven by factors that affect all of the sectors in the same way. For example, we observe that the aggregate Okun's coefficient for the US (in absolute terms) is two times larger than it is for Japan. Similarly, the coefficient for manufacturing in the US is also two times larger than it is in Japan. If this holds for all sectors and countries in our sample, we cannot reject this. However, if this does not hold then factors that affect sectors in different ways may be driving the differences in Okun's coefficients.

Next, we check if the sectoral coefficients are close to the aggregate. For example, several manufacturing and service sectors are close to the aggregate coefficient. If we cannot reject that the sectoral coefficients are identical to the aggregate coefficient, it would be possible to approximately know the sectoral coefficient by examining the aggregate and vice versa.

5.1 Sectoral Compositions

The cross-country differences in Okun's coefficients may be driven by the differences in the sectoral composition of countries. For example, the US may have a larger Okun's coefficient than Switzerland because the US economy has a larger financial sector. To test this, we re-weight the sectors in each country to match the US sector sizes and estimate the national Okun's coefficients. For output, we use the following equation to transform the sectoral composition of country i into the sectoral composition of the US:

$$GDP_t^{i,USshare} = \sum_s \frac{\alpha_s^{US}}{\alpha_s^i} GVA_{s,t}^i \qquad t = 1, ..., N \tag{5}$$

where $GDP_t^{i,USshare}$ represents GDP in country i with the US sectoral composition, α_s^j represents sector s's GDP share in country j, and $GVA_{s,t}^i$ is the GVA of sector s in country i. For example, if the manufacturing sector's GDP share in the US is 20% and is 40% in Switzerland, then the GVA of the manufacturing sector in Switzerland is divided by two. α_s^j corresponds to averages of sector s's GDP share over the entire sample period. For each country, using the US GDP share, we transform the sectoral numbers of the employed and the unemployed and calculate the unemployment rate:

$$u_t^{i,US} = \frac{\sum_s \frac{\alpha_s^{US}}{\alpha_s^i} U_{s,t}^i}{\sum_s \frac{\alpha_s^{US}}{\alpha_s^i} (U_{s,t}^i + E_{s,t}^i)} \qquad t = 1, ..., N \tag{6}$$

where $u_t^{i,USshare}$ represents unemployment rate in country i with the US sectoral composition, $U_{s,t}^i$ is the number of unemployed in sector s in country i, and $E_{s,t}^i$ is the number of employed in sector s in country i. For example, if the manufacturing sector's GDP share in the US is 20% and is 40% in Switzerland, then the numbers of the employed and the unemployed in the manufacturing sector in Switzerland are divided by two. The re-weighted aggregate GDP and unemployment rate numbers are then used in the estimation of the Okun's coefficient.

Table 5 reports the national Okun's coefficient for each country after re-weighting the countries to match the US GVA sectoral composition. The last column in all four tables show the Chi-squared test results with the null hypothesis that all coefficients in the same row are equal. Looking at the original national level estimates in Tables 1 and 4, the differences between the original and new coefficients are small and the new estimates are within the two standard errors of the original estimates[11]. Thus, changing the sectoral proportions of the economies has very little impact on the aggregate Okun's coefficient. Therefore, at least for those four countries, we can reject that the sectoral composition is the main driver of the cross-country differences in the aggregate coefficient.

5.2 Are Sectors Proportional to the Aggregate?

Next, we investigate whether the sectoral Okun's coefficients have the same proportions to the aggregate coefficients across countries. Specifically, assume that the US and Japan have a country level coefficient of -0.5 and -0.1 respectively. If the US and Japan have sectoral Okun's coefficients that are proportional to the aggregate coefficients, then the sectoral coefficients in the US divided by 5 will be the same as in Japan. In order to test this hypothesis, we create ratios of sectoral Okun's coefficients. We test the following non-linear null hypothesis:

$$\frac{\beta_{s,US}}{\beta_{m,US}} = \frac{\beta_{s,i}}{\beta_{m,i}} \tag{7}$$

That is, the coefficient ratio between sector s and sector m in the US is equal to the same coefficient ratio in country i.

Due to the limited annual data, we are unable to jointly estimate all eleven sectors for all four countries in one system. We hence test a joint hypothesis for the four sector economy vis-a-vis the US[12]. Specifically, we test the hypothesis that the ratio of agriculture to each of the other sectors in the US is the same as this ratio in another country using a joint Chi-squared test. Thus, we jointly examine if the three sectoral ratios in the US are each equal to the respective three ratios in the another country. The results are reported in Table 6 in the row "joint" for each country.

The results show that the ratios do not differ significantly across countries. We repeat this test for the ratio of the manufacturing coefficient to the services coefficient. Again, the results show

[11] For the 4 sector results, all of the estimates are within one standard error of the original estimates. Additionally, to ensure that the results are not biased by the choice of the reference country, we changed the reference country from the US to Switzerland and obtained the same results.

[12] We also investigate if the reference country matters (e.g. if all countries are tested vis-a-vis Japan rather than the US), however, the results remain broadly the same.

that there is no significant difference across countries.[13] Therefore, we are not able to reject the hypothesis that all sectoral coefficients are proportional to the aggregate for all countries. Thus, we cannot reject the hypothesis that the main drivers of differences across countries affect the economy uniformly.

5.3 Is any sector coefficient close to the aggregate?

In the previous section it was shown that the sectors are broadly proportionate to the aggregate and this proportion is the same across countries. Therefore, it might be possible to infer the aggregate differences across countries by analyzing a single sector. We investigate whether there exists a sector that is closest to the aggregate for all countries. To determine whether any sectoral coefficient is close to the aggregate for all of the countries we conduct a two-sample t-test with the null hypothesis that the sectoral coefficient is equal to the aggregate coefficient. We chose a two-sample t-test to take into account that both the aggregate and the sectoral coefficients are estimated. The t-statistics are presented in Table 7.

The results show that the construction sector in the US, the accommodation sector in Switzerland, and the other services sector in Japan are statistically insignificantly different from the corresponding aggregate. Overall, there does not appear to be a single sector that has the same coefficient as the aggregate for all of the countries.

Almost all of the sectors have coefficients that are smaller than the aggregate. While pinpointing the exact reason for this phenomenon is beyond the scope of this paper, one explanation could be that there is some leakage or absorption across sectors. For example, if the manufacturing sector's GVA declines, this could lead to a similar decline in employment in manufacturing. However, some of the recently unemployed may be able to find jobs in other sectors which could then reduce the unemployment rate in the manufacturing sector. In turn, this could lead to a lower Okun's coefficient for the manufacturing sector.

[13] We tested other ratios as well, however, still the results remain qualitatively the same.

6 Decomposing the Coefficient

Based on the results in the previous section, it appears that the cross-country differences in Okun's coefficient are due to drivers that affect all sectors the same way. To further determine what these drivers are, we take a closer look at the coefficients of simple regressions. It is possible to decompose the Okun's coefficient into the correlation between the two variables and their respective standard deviations:

$$\hat{\beta} = corr(\bar{u}_t, \bar{y}_t)\frac{sd(\bar{u}_t)}{sd(\bar{y}_t)}, \tag{8}$$

where $\bar{u}_t$ denotes either the change in the unemployment rate or the deviation from trend, $\bar{y}_t$ is the log change in output or the deviation from trend, $corr()$ is the correlation between the two variables, and $sd()$ represents the standard deviation of the variable.

This decomposition allows us to determine if any of the three components are driving the cross-country differences or, if perhaps, all are contributors. In turn, this can help to determine if there is a specific channel through which the cross-country differences in Okun's coefficient arise. For example, if the variance of output is driving the results, then either macro or micro factors that affect output are the most likely cause for the differences. If instead the variance of unemployment is a strong driver, this would suggest that labor market factors are the main driver of these differences.

Figures 4, 5, and 6 report the correlation of the unemployment rate and output, the standard deviation of output, and the standard deviation of the unemployment rate, respectively. There is no clear pattern of the standard deviation of output nor of the correlation. With regards to the standard deviation of output, Switzerland has the lowest standard deviation of the aggregate, which would imply a high Okun's coefficient. The pattern of the aggregate correlations are similar to each other and it is unlikely that the differences of the correlation drive the variations in Okun's coefficients. However, the standard deviation of the unemployment rate shows a consistent pattern: the standard deviations for the US are the highest, followed by the UK, Switzerland and Japan. This matches closely with the Okun's coefficients. This observation is also true for most of the sectors.

Motivated by the pattern of the standard deviation of the unemployment rate, we estimate equation (1) but divide the change in unemployment rate by its standard deviation:

$$u_{t,adjusted} = \frac{\Delta u_t}{\sigma_{\Delta u}} \tag{9}$$

This specification normalizes the unemployment rate so that the differences in standard deviation of unemployment is eliminated across countries.[14] Based on equation (8), the only remaining factors that can potentially explain the cross-country differences in Okun's coefficients are the standard deviation of changes in output and the correlation between changes in output and the unemployment rate. However, as shown above, these two components do not provide systematic patterns that match the pattern of the Okun's coefficients. It is likely that this normalization causes the Okun's coefficients to become close to each other across countries, but not across sectors.

Tables 8 and 9 show the regression results after normalizing the unemployment rate. The last column in both tables show the Chi-squared test statistic with the null hypothesis that all coefficients in the same row are equal. The test is based on the joint SUR estimation across sectors with common samples. With regards to the national results, the coefficients are no longer significantly different from each other. Indeed, the specific pattern found previously that the US had the most negative Okun's coefficient followed by the UK, Switzerland, and Japan is now gone. This pattern was also present in the sectoral coefficients and it also vanishes once the unemployment rate is normalized. With regards to the four sectors, except for manufacturing, the hypothesis that all Okun's coefficients are the same cannot be rejected at the 5% level. The hypothesis can be rejected for the manufacturing sector because one of the countries have a very different coefficient from the others. While more sectors (manufacturing, construction, accommodation, and other services) show significantly different coefficients across countries, the results from the 11 sectors provide a similar message. Therefore, our results suggest that the cross-country differences in national and sectoral Okun's coefficients are mainly driven by the volatility of the unemployment rate. One additional aspect to note here is that while the international differences appear to be driven by the volatility of the unemployment rate, the differences within a country do not appear to be driven by this. Comparing the standard deviations of unemployment in Figure 5 to the Okun's coefficients of

[14] Note that since we use the first differences across the two variables, the mean is close to 0 and this procedure is similar to standardizing the unemployment rate.

sectors in Table 4 shows no clear relationship. For example, the standard deviations of agriculture and manufacturing are almost the same for the US, however, the coefficient of agriculture is close to zero while the coefficient of manufacturing is a large negative number. Overall, we find that the normalization removes the cross-country differences in the coefficients of the aggregate and in the majority of sectors.

The finding that the standard deviation of unemployment rate matters also has important implications for cross-country studies more generally. In particular, the significance of the results should not be affected by the normalization, however, the actual coefficient and thus the economic interpretation may change. Furthermore, this can impact the decision of whether to pool the data across countries or not. If the coefficients appear to be very different without standardizing variables, a panel setup like Freeman (2001) might be rejected, even if the standardized variables would lead to very similar coefficients. At least for (un-)employment, this can be very important. Before making the decision on running this type of regression in a panel, a researcher should check whether a normalization may alter the results.

6.1 Decomposition Beyond Four Countries

The pattern of the standard deviations as well as the pattern of the correlation suggests that the volatility of unemployment is able to explain a large portion of the variation in Okun's coefficients across the four countries. We further test this hypothesis by expanding the sample to include 38 additional countries at the aggregate level. We again use the OECD data for the aggregate GDP and unemployment rate and estimate the Okun's coefficients using equation 1 across the entire available sample of annual data from 1959 to 2018. As Figure 2 shows, there is a strong positive correlation between the absolute value of the Okun's coefficient and the standard deviation of unemployment. The standard deviation of unemployment explains around 40% of the variance in Okun's coefficients.[15] This is in line with labor market policies being relevant to the differences in Okun's coefficients and thus the cyclical correlation between output and unemployment.

[15] Japan having a higher Okun's coefficient than Switzerland is likely due to the shorter sample for Switzerland in the OECD data, which only starts in 2010 and does not include any full business cycles.

7 Conclusion

This paper estimated the sectoral Okun's law and investigated several potential drivers of the cross-country differences in Okun's law. We found that drivers are affecting the economies uniformly. Further, the decomposition of Okun's coefficient showed that the standard deviation of unemployment rate is the main driver of the differences. This finding is consistent with labor market factors driving the differences in the literature (e.g. Moosa, 1997).

The sectoral composition does not appear to be an important driver of the cross-country differences. Thus, factors affecting sectors differently, such as having different production functions, appear to have minimal effects. In addition, the sector level correlation between output and unemployment appears to be very similar across the four countries. In the broader context of empirical cross-country studies, we showed that it is critical to check whether standardizing variables would change the results. This is particularly important for studies that include employment because standardizing the variables could lead to more precise results.

With regards to policy implications, we showed that the sector level Okun's coefficients are large for cyclical sectors, such as manufacturing, construction, and wholesale and retail trade. Thus, unemployment reacts more strongly to output fluctuation in these sectors. In monetary policy literature (e.g. Ganley and Salmon, 1997 and Ibrahim, 2005), these are also shown to be the sectors whose output is largely affected by monetary policy. This suggests that the impact of policy on unemployment rate will be strong if the policy affects unemployment mainly through output.

Narrowing down the exact driver of the cross-country differences as well as the sectoral differences within a country would be an important topic for future research. While labor market factors appear to be significant at the cross-country level, determining whether macro policy factors or micro factors are the main driver is out of the scope of this paper. This would also be an interesting topic for future research.

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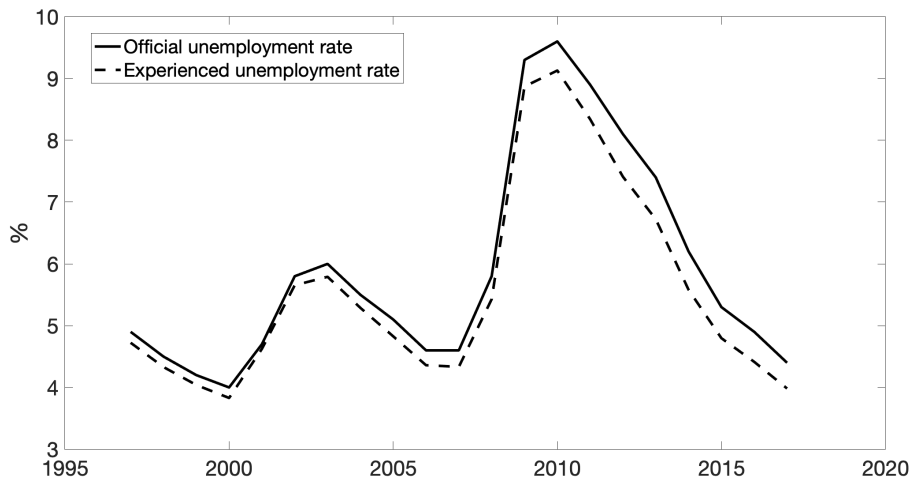
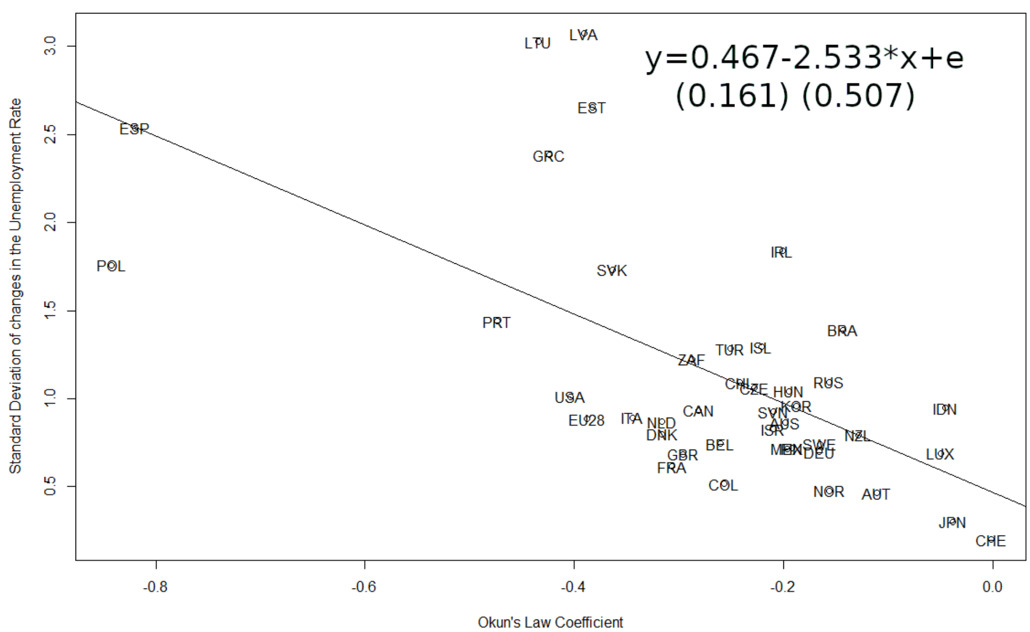
Figures

Figure 1: Official Unemployment Rate vs Experienced Unemployment Rate



Experienced unemployment rate is constructed by aggregating the sector level unemployment and employment.

Figure 2: Relationship Between Unemployment Volatility and Okun's Coefficient



N=42 and R^2 =0.36.

Figure 3: Average Sectoral GVA Shares in Overall GVA

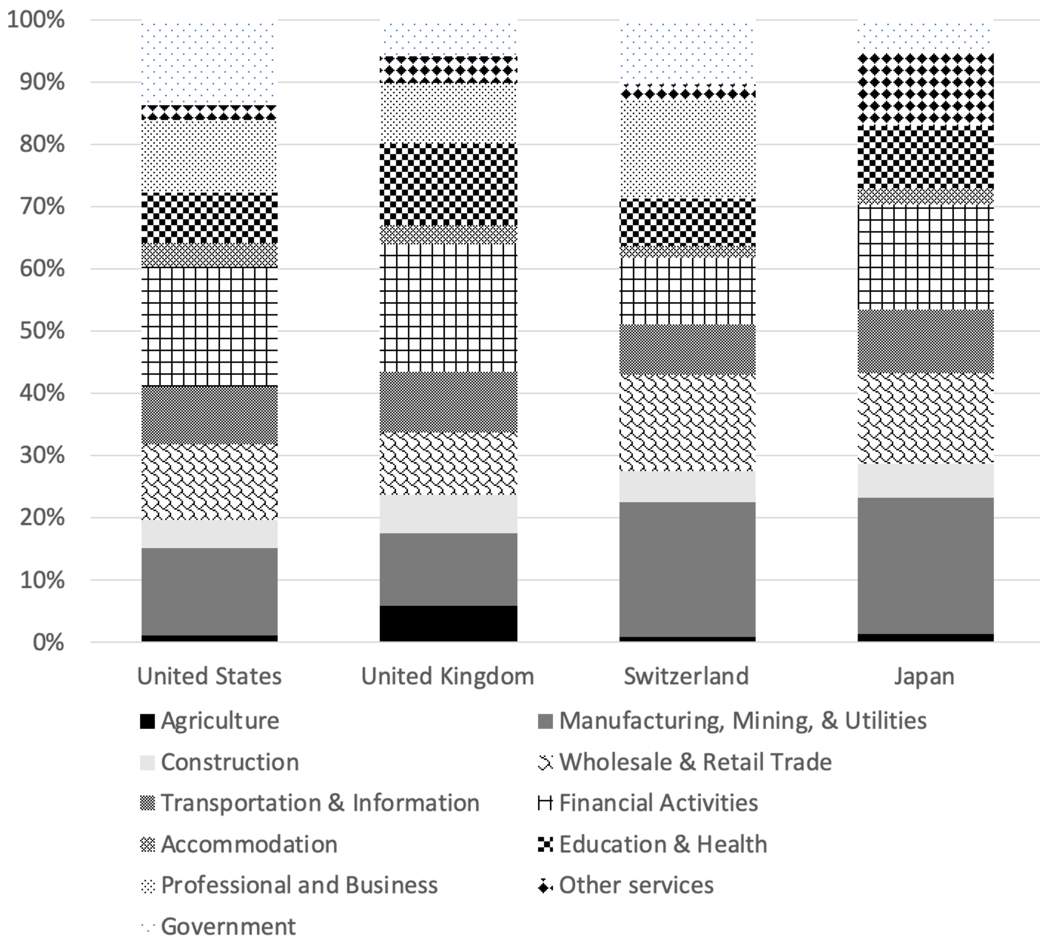


Figure 4: Correlation Between Unemployment Rate and Output for 11 Sectors

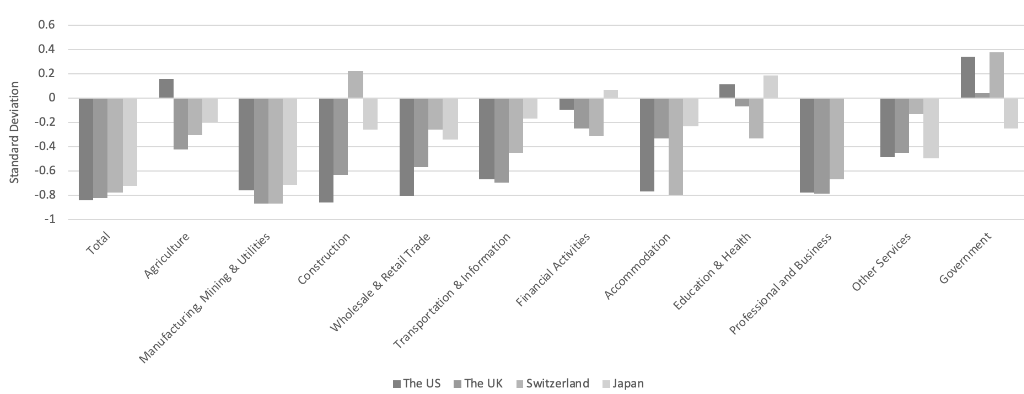


Figure 5: Standard Deviation of Unemployment Rate, $\sigma_{\Delta u}$, for 11 Sectors

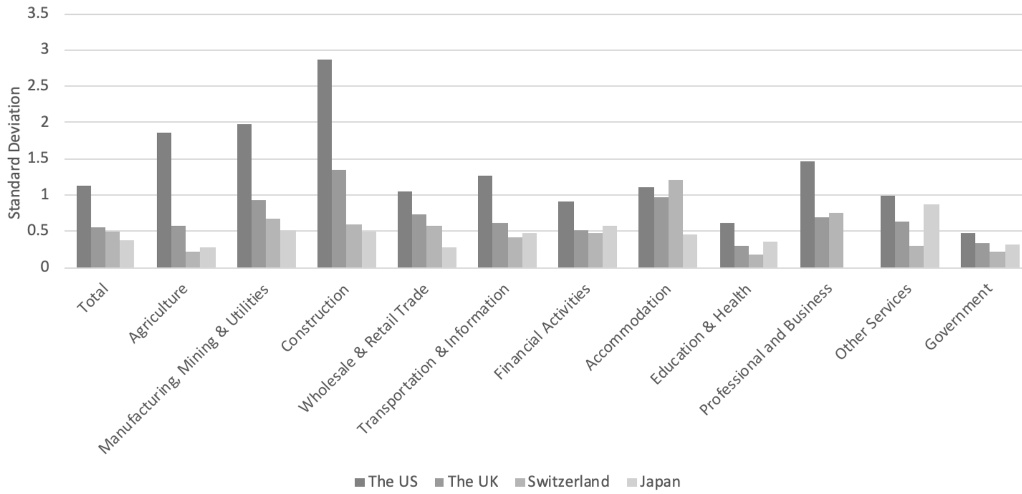
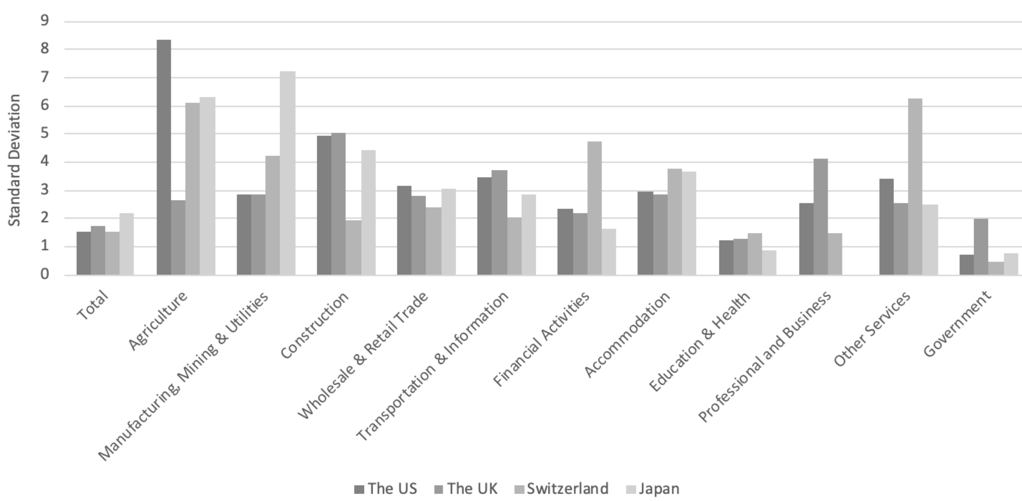


Figure 6: Standard Deviation of Output, $\sigma_{\Delta y}$, for 11 Sectors



Tables

Table 1: First Difference Sectoral Results

Country Period Frequency	The US 1997-2017	The UK 1995-2017 Yearly	Switzerland 2002-2017	Japan 2000-2016	Test
$100 * \Delta Y_t$		Dependent variable: Δu_t			
Total	-0.205***	-0.175***	-0.140***	-0.077***	$F_{3,48}$=13.08
	(0.066)	(0.029)	(0.034)	(0.023)	P-value = 0.00
R^2	0.40	0.60	0.48	0.40	
Agriculture	0.003	-0.073**	-0.001	0.004	$F_{3,48}$=1.17
	(0.039)	(0.038)	(0.008)	(0.007)	P-value = 0.33
R^2	0.01	0.17	0.02	-0.02	
Manufacturing	-0.316***	-0.194***	-0.121***	-0.047***	$F_{3,48}$=14.96
	(0.079)	(0.026)	(0.021)	(0.015)	P-value = 0.00
R^2	0.51	0.67	0.69	0.42	
Service	-0.189***	-0.135***	-0.122***	-0.092**	$F_{3,48}$=7.87
	(0.057)	(0.029)	(0.042)	(0.038)	P-value = 0.00
R^2	0.43	0.46	0.33	0.24	
Government	0.029	-0.008	0.026	-0.051	$F_{3,48}$=3.10
	(0.120)	(0.027)	(0.101)	(0.081)	P-value = 0.04
R^2	0.02	-0.01	0.04	0.04	
N	20	22	15	16	

Standard errors in parenthesis. The last column shows the joint test results of the hypothesis that the Okun's coefficients are the same across countries within a row. *$p < 0.1$; **$p < 0.5$; ***$p < 0.01$.

Table 2: HP Filter Sectoral Results

Country Period Frequency	The US 1997-2017	The UK 1995-2017 Yearly	Switzerland 2002-2017	Japan 2000-2016	Test
$100 * (Y_t - Y_t^*)$		Dependent variable: $u_t - u_t^*$			
Total	-0.473***	-0.218***	-0.179***	-0.122***	$F_{3,52}$= 27.70
	(0.053)	(0.027)	(0.027)	(0.020)	P-value = 0.00
R^2	0.80	0.62	0.58	0.68	
Agriculture	-0.001	-0.134***	0.004	0.002	$F_{3,52}$=5.49
	(0.047)	(0.032)	(0.011)	(0.005)	P-value = 0.00
R^2	0.00	0.45	-0.04	-0.01	
Manufacturing	-0.549***	-0.224***	-0.160***	-0.082***	$F_{3,52}$=22.96
	(0.057)	(0.027)	(0.019)	(0.014)	P-value = 0.00
R^2	0.81	0.64	0.80	0.69	
Service	-0.406***	-0.191***	-0.131***	-0.133***	$F_{3,52}$=12.84
	(0.045)	(0.026)	(0.030)	(0.028)	P-value = 0.00
R^2	0.81	0.54	0.42	0.54	
Government	0.142	0.048***	-0.004	-0.053	$F_{3,52}$=2.06
	(0.129)	(0.017)	(0.112)	(0.085)	P-value = 0.12
R^2	0.08	0.12	0.00	0.04	
N	21	23	16	17	

Standard errors in parenthesis. The last column shows the joint test results of the hypothesis that the Okun's coefficients are the same across countries within a row. *$p < 0.1$; **$p < 0.5$; ***$p < 0.01$.

Table 3: Quadratic Trend Filter Sectoral Results

Country	The US	The UK	Switzerland	Japan	Test
Period	1997-2017	1995-2017	2002-2017	2000-2016	
Frequency	Yearly				
$100 * (Y_t - Y_t^*)$	Dependent variable: $u_t - u_t^*$				
Total	-0.550***	-0.282***	-0.180***	-0.129***	$F_{3,52}$= 52.02
	(0.036)	(0.029)	(0.025)	(0.018)	P-value = 0.00
R^2	0.92	0.66	0.57	0.73	
Agriculture	-0.001	-0.154***	0.004	0.003	$F_{3,52}$= 13.11
	(0.047)	(0.020)	(0.011)	(0.004)	P-value = 0.00
R^2	0.00	0.70	-0.04	-0.02	
Manufacturing	-0.597***	-0.275***	-0.158***	-0.085***	$F_{3,52}$= 33.22
	(0.047)	(0.030)	(0.018)	(0.012)	P-value = 0.00
R^2	0.88	0.71	0.80	0.71	
Service	-0.465***	-0.259***	-0.128***	-0.136***	$F_{3,52}$= 19.31
	(0.032)	(0.029)	(0.028)	(0.024)	P-value = 0.00
R^2	0.91	0.58	0.40	0.63	
Government	0.177	0.089***	-0.066	-0.125	$F_{3,52}$= 4.21
	(0.151)	(0.016)	(0.115)	(0.091)	P-value = 0.01
R^2	0.07	0.27	-0.05	0.12	
N	21	23	16	17	

Standard errors in parenthesis. The last column shows the joint test results of the hypothesis that the Okun's coefficients are the same across countries within a row. $*p < 0.1$; $**p < 0.5$; $***p < 0.01$.

Table 4: First Difference Disaggregated Sectoral Results

Country	The US	The UK	Switzerland	Japan	Test
Period	2000-2017	1995-2017	2002-2017	2002-2016	
Frequency	Yearly				
$100 * \Delta Y_t$	Dependent variable: Δu_t				
Total	-0.505***	-0.182***	-0.193***	-0.069***	$F_{3,48}$= 13.01
	(0.045)	(0.021)	(0.026)	(0.016)	P-value = 0.00
R^2	0.68	0.61	0.56	0.42	
Agriculture	0.023	-0.080***	-0.010**	-0.002	$F_{3,48}$= 0.91
	(0.024)	(0.024)	(0.004)	(0.005)	P-value = 0.44
R^2	0.02	0.17	0.09	0.01	
Manufacturing, Mining & Utilities	-0.418***	-0.226***	-0.124***	-0.029***	$F_{3,48}$= 14.97
	(0.064)	(0.020)	(0.011)	(0.007)	P-value = 0.00
R^2	0.55	0.73	0.74	0.41	
Construction	-0.489***	-0.104***	0.079***	-0.016**	$F_{3,48}$= 17.48
	(0.033)	(0.030)	(0.025)	(0.007)	P-value = 0.00
R^2	0.74	0.34	0.05	0.05	
Wholesale & Retail Trade	-0.227***	-0.085***	-0.057***	-0.025**	$F_{3,48}$= 10.78
	(0.019)	(0.030)	(0.005)	(0.011)	P-value = 0.00
R^2	0.62	0.27	0.06	0.11	
Transportation & Information	-0.167***	-0.070***	-0.084***	0.030	$F_{3,48}$= 3.96
	(0.026)	(0.019)	(0.009)	(0.018)	P-value = 0.01
R^2	0.40	0.40	0.20	-0.09	
Financial Activities	-0.045	0.033	-0.032***	0.013	$F_{3,48}$= 1.63
	(0.035)	(0.033)	(0.004)	(0.020)	P-value = 0.19
R^2	0.01	-0.09	0.09	0.00	
Accommodation	-0.193***	-0.049	-0.171***	-0.016	$F_{3,48}$= 11.36
	(0.029)	(0.031)	(0.037)	(0.016)	P-value = 0.00
R^2	0.52	0.07	0.56	0.04	
Education & Health	0.053**	-0.015	-0.042***	0.041	$F_{3,48}$= 1.16
	(0.024)	(0.029)	(0.006)	(0.046)	P-value = 0.33
R^2	0.01	0.00	0.11	0.03	
Professional and Business	-0.420***	-0.113***	-0.319***		$F_{2,39}$= 4.06
	(0.024)	(0.012)	(0.020)		P-value = 0.03
R^2	0.59	0.60	0.44		
Other Services	-0.044	-0.066**	-0.002	-0.075*	$F_{3,48}$= 11.43
	(0.035)	(0.032)	(0.003)	(0.045)	P-value = 0.00
R^2	0.12	0.17	0.01	0.16	
Government	0.236***	0.006	0.156***	-0.151***	$F_{3,48}$= 2.98
	(0.041)	(0.015)	(0.027)	(0.043)	P-value = 0.04
R^2	0.12	0.00	0.14	0.05	
N	17	22	15	14	

Standard errors in parenthesis. The last column shows the joint test results of the hypothesis that the Okun's coefficients are the same across countries within a row. $*p < 0.1$; $**p < 0.5$; $***p < 0.01$.

Table 5: National Results with the US Sectoral GVA Shares

Country	The US	The UK	Switzerland	Japan	Test
Period	1997-2017	1995-2017	2002-2017	2000-2016	
Frequency	Yearly				
$100 * \Delta Y_{i,US,t}$	Dependent variable: $\Delta u_{i,US,t}$				
Total (4 sectors)	-0.205***	-0.146***	-0.149***	-0.073***	$F_{3,48}$= 13.19
	(0.066)	(0.033)	(0.033)	(0.022)	P-value = 0.00
R^2	0.40	0.47	0.50	0.42	
N	20	22	15	16	
Total (11 sectors)	-0.505***	-0.164***	-0.170***	-0.102***	$F_{3,48}$= 18.38
	(0.045)	(0.023)	(0.021)	(0.020)	P-value = 0.00
R^2	0.68	0.52	0.47	0.51	
N	17	22	15	14	

This table shows the aggregate coefficients when the 4 sectors and 11 sectors are scaled to match the US GVA shares before aggregating them. Standard errors in parenthesis. The last column shows the joint test results of the hypothesis that the Okun's coefficients are the same across countries within a row. $*p < 0.1$; $**p < 0.5$; $***p < 0.01$. Since we do not have the data of the professional service sector in Japan, other service sector in Japan is scaled to match the professional service and other service sector in the US combined. We changed the reference country from the US to Switzerland and obtained the same results.

Table 6: Test Results of Proportionality of Coefficients

UK	Chi Squared	df	P-value
Joint	3.94	3	0.27
Manufacturing and Services	0.13	1	0.71
Japan	**Chi Squared**	**df**	**P-value**
Joint	0.19	3	0.98
Manufacturing and Services	0.03	1	0.86
Switzerland	**Chi Squared**	**df**	**P-value**
Joint	1.75	3	0.63
Manufacturing and Services	0.64	1	0.42

All test statistics relate to the re-estimation of Okun's coefficients in Tables 1 with SUR. The Joint rows test the null hypothesis that the ratio of the US agriculture/US sector i is equal to j agriculture/j sector i for country j for all sectors i, jointly. The Manufacturing and Services rows test the null hypothesis that US manufacturing/US services is equal to j manufacturing/j services for country j. We tested all possible combinations (not shown) and the only ones rejected at the 5% level were Japan/UK and Japan/Switzerland when only services and manufacturing are included (the joint tests were never rejected).

Table 7: Test Results of One Sector's Coefficient Equal to the Aggregate

Country	The US	The UK	Switzerland	Japan
Period	2000-2017	1995-2017	2002-2017	2002-2016
Frequency	Yearly			
	T statistic			
Agriculture	45.56***	16.00***	28.50***	16.52***
Manufacturing, Mining & Utilities	4.87***	-7.57***	9.89***	9.38***
Construction	1.29	10.53***	31.02***	12.64***
Wholesale & Retail Trade	25.12***	13.00***	20.89***	9.42***
Transportation & Information	28.51***	19.80***	16.35***	16.59***
Financial Activities	35.58***	27.19***	24.91***	12.85***
Accommodation	25.63***	17.38***	2.02*	9.48***
Education	48.20***	23.18***	23.06***	9.22***
Professional and Business	7.36***	14.01***	-15.71***	
Other Services	35.31***	14.89***	29.85***	-0.48
Government	53.39***	36.43***	38.67***	-7.28***
N	17	22	15	14

This table reports the T-statistic for the null hypothesis that the sectoral coefficient is equal to the aggregate coefficient for the same country from Table 4. $^{*}p < 0.1$; $^{**}p < 0.5$; $^{***}p < 0.01$.

Table 8: Sectoral Results from $\sigma_{u,FD}$ Adjusted Unemployment Rate

Country	The US	The UK	Switzerland	Japan	
Period	1997-2017	1995-2017	2002-2017	2000-2016	Test
Frequency	Yearly				
$100 * \Delta Y_t$	Dependent variable: $\Delta u_{t,adjusted}$				
Total	-0.206***	-0.311***	-0.282***	-0.206***	$F_{3,48}$=0.76
	(0.067)	(0.051)	(0.069)	(0.061)	P-value = 0.52
R^2	0.40	0.60	0.48	0.40	
Agriculture	0.002	-0.127*	-0.005	0.017	$F_{3,48}$= 1.12
	(0.022)	(0.066)	(0.037)	(0.027)	P-value = 0.35
R^2	0.01	0.17	0.02	-0.02	
Manufacturing	-0.154***	-0.185***	-0.188***	-0.094***	$F_{3,48}$= 4.26
	(0.038)	(0.025)	(0.032)	(0.030)	P-value = 0.01
R^2	0.51	0.67	0.69	0.42	
Service	-0.227***	-0.275***	-0.272***	-0.247**	$F_{3,48}$= 2.57
	(0.068)	(0.060)	(0.093)	(0.102)	P-value = 0.07
R^2	0.43	0.46	0.33	0.24	
Government	0.062	-0.023	0.115	-0.171	$F_{3,48}$= 2.89
	(0.250)	(0.079)	(0.446)	(0.269)	P-value = 0.05
R^2	0.02	-0.01	0.04	0.04	
N	20	22	15	16	

Compared with Table 1, the change in the unemployment rate was normalized by the standard deviation ($\Delta u_{t,adjusted} = \frac{u_t - u_{t-1}}{\sigma_{\Delta u}}$). The regressions for each country are run in seemingly unrelated regression with standard errors in parenthesis. The last column shows the joint test results of the hypothesis that the Okun's coefficients are the same across countries within a row. *$p < 0.1$; **$p < 0.5$; ***$p < 0.01$.

Table 9: Disaggregated Sectoral Results from $\sigma_{u,FD}$ Adjusted Unemployment Rate

Country Period Frequency	The US 2000-2017	The UK 1995-2017	Switzerland 2002-2017	Japan 2002-2016	Test
	Yearly				
$100 * \Delta Y_t$	Dependent variable: $\Delta u_{t,adjusted}$				
Total	-0.449***	-0.322***	-0.387***	-0.187***	$F_{3,48}$=2.36
	(0.040)	(0.036)	(0.053)	(0.042)	P-value = 0.08
R^2	0.68	0.61	0.56	0.42	
Agriculture	0.013	-0.138***	-0.047**	-0.007	$F_{3,48}$= 1.00
	(0.013)	(0.041)	(0.019)	(0.018)	P-value = 0.40
R^2	0.02	0.17	0.09	0.01	
Manufacturing, Mining & Utilities	-0.213***	-0.244***	-0.183***	-0.055***	$F_{3,48}$= 6.31
	(0.033)	(0.022)	(0.016)	(0.014)	P-value = 0.00
R^2	0.55	0.73	0.74	0.41	
Construction	-0.171***	-0.078***	0.132***	-0.032**	χ^2_3= 3.23
	(0.012)	(0.022)	(0.042)	(0.014)	P-value = 0.03
R^2	0.74	0.34	0.05	0.05	
Wholesale & Retail Trade	-0.217***	-0.117***	-0.101***	-0.089**	$F_{3,48}$= 2.34
	(0.018)	(0.041)	(0.009)	(0.038)	P-value = 0.09
R^2	0.62	0.27	0.06	0.11	
Transportation & Information	-0.131***	-0.112***	-0.197***	0.064	$F_{3,48}$= 2.72
	(0.021)	(0.030)	(0.020)	(0.039)	P-value = 0.05
R^2	0.40	0.40	0.20	-0.09	
Financial Activities	-0.050	0.063	-0.069***	0.022	$F_{3,48}$= 1.62
	(0.038)	(0.063)	(0.009)	(0.036)	P-value = 0.20
R^2	0.01	-0.09	0.09	0.00	
Accommodation	-0.173***	-0.050	-0.141***	-0.035	$F_{3,48}$= 3.05
	(0.026)	(0.032)	(0.031)	(0.036)	P-value = 0.04
R^2	0.52	0.07	0.56	0.04	
Education & Health	0.088**	-0.050	-0.230***	0.119	$F_{3,48}$= 1.38
	(0.039)	(0.097)	(0.034)	(0.131)	P-value = 0.26
R^2	0.01	0.00	0.11	0.03	
Professional and Business	-0.287***	-0.162***	-0.426***		$F_{2,39}$=1.70
	(0.016)	(0.018)	(0.027)		P-value = 0.20
R^2	0.59	0.60	0.44		
Other Services	-0.045	-0.105**	-0.006	-0.086*	$F_{3,48}$= 5.98
	(0.036)	(0.052)	(0.011)	(0.051)	P-value = 0.00
R^2	0.12	0.17	0.01	0.16	
Government	0.495***	0.017	0.692***	-0.469***	$F_{3,48}$= 2.97
	(0.086)	(0.044)	(0.118)	(0.133)	P-value = 0.04
R^2	0.12	0.00	0.14	0.05	
N	17	22	15	14	

Compared with Table 4, the change in the unemployment rate was normalized by the standard deviation ($\Delta u_{t,adjusted} = \frac{u_t - u_{t-1}}{\sigma_{\Delta u}}$). The regressions for each sector are run in seemingly unrelated regression with standard errors in parenthesis. The last column shows the joint test results of the hypothesis that the Okun's coefficients are the same across countries within a row. *$p < 0.1$; **$p < 0.5$; ***$p < 0.01$.