Macroeconomic Volatility at the Zero Lower Bound: Evidence from the OECD

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December 2020

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Undergraduate Honors Thesis
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Abstract

One of the core predictions made in macroeconomic models of the ZLB is that macroeconomic volatility is higher at the ZLB than during normal periods, and that this imposes significant welfare costs. This paper uses data on advanced economies to test whether volatility in inflation and GDP growth was in fact higher at the ZLB than during normal periods across the period from 1990:1 to 2019:3. I find that, contrary to the theoretical predictions, volatility in inflation and GDP growth were not higher at the ZLB than during normal periods. Further, it seems that volatility in these variables was actually lower at ZLB than otherwise, though this result is not necessarily statistically significant.

[1] I would like to sincerely thank Professor Gorodnichenko for his guidance and encouragement. His input and support were invaluable throughout the process of writing this thesis.

1 Introduction

Since the 2008 financial crisis, there has been a great amount of research done by macroeconomists on the significance of the zero lower bound (ZLB) and the optimal policy to address it. While some theorizing had been done by earlier economists, the problem of ZLB, i.e. when short-term interest rates are at or near zero, was previously thought to be relatively uncommon and not particularly relevant, with much of the focus of research on Japan, which had until then been the only example of long-lasting and recurring ZLB. However, the rapid collapse of the global economy caused by the Great Recession returned ZLB to prominence, as many central banks around the world swiftly cut interest rates to record low levels and kept them there for far longer than anyone expected. In many advanced economies, such as the United States or those in Western Europe, nominal interest rates were kept near the ZLB long after the initial crisis in 2007-2008, with the United States only escaping the ZLB in late 2015 and the Eurozone yet to escape. With the coronavirus once again bringing US interest rates to the ZLB and forcing central banks in Europe and Japan to keep them there, it is clear that the ZLB, far from being irrelevant, is a key fixture of the modern macroeconomic structure.

Research on the ZLB has covered a variety of topics, as I will expound upon later, but generally there are two major reasons why economists care about the ZLB. The first is the so-called ZLB constraint, which refers to the inability of macroeconomic policymakers to use interest rate targeting at the ZLB due to the fact that nominal interest rates cannot realistically go below zero, which generates a liquidity trap. Since interest rates are one of the primary levers for policy makers at central banks to adjust monetary policy, this constraint severely limits the conventional options policymakers have to address economic crises when the economy is already at ZLB. In this sense, ZLB is largely something we want to avoid, and much of the focus of

research has been on developing optimal policies for reducing the incidence and length of ZLB. The second reason is that ZLB, and the constraint it places on central banks, leads to great uncertainty about future shocks which generates endogenous volatility in macroeconomics variables such as GDP growth, inflation, and long-term interest rates, causing negative welfare effects. In this sense, the ZLB is not just a constraint on central policymakers trying to attenuate economic shocks, but itself a source of negative welfare effects, which gives an additional reason for why we should aim to avoid the ZLB.

The focus of this paper is to address the second prediction on the importance of the ZLB. Many ZLB models estimating the effect of the ZLB or attempting to determine optimal monetary policies to address incidence of the ZLB take for granted that there is greater volatility in macroeconomic variables at the ZLB, and thus negative welfare effects. However, empirical evidence for greater macroeconomic volatility is rather limited, with few studies attempting to verify whether this relatively fundamental prediction is actually true. Luckily (for researchers), the experience with the recent financial crisis that returned ZLB to prominence also provides a bevy of data to test whether volatility is indeed higher at the ZLB than during normal periods. In this paper I attempt to address this issue using data from on a number of the world's largest and most developed economies using data from the OECD to perform F-tests of equality in variances grouping by ZLB status. Testing volatility of both inflation and GDP growth for four different specifications of the ZLB, I find that there is little evidence to support the prediction that the variance of macroeconomic variables is higher at the ZLB than during normal periods. Further, I find that in many cases, the reverse seems to be true, with volatility at the ZLB actually lower than during normal periods, though not necessarily at a statistically significant level. Thus, using a simple test, I arrive at a powerful result: the irrelevance of the ZLB. This finding is incredibly

significant both for assessing past research on the economic significance of the ZLB and for adjusting how economists will think about and research the ZLB going forward. Moreover, this finding comes at a crucial time, as the ongoing coronavirus pandemic seems well on course to bring the advanced economies once again to an extended period of ZLB.

The remainder of this paper will be as follows. First, I will give a brief overview of the history of the ZLB and why it has only recently risen to prominence in economic discourse. Then, I will present a brief review of the literature of ZLB in order to show why economists care about the ZLB and how they have previously though about and studied it. Having established the background of the ZLB, I will then discuss by data and methodology before presenting my results. Finally, I will end the paper with a discussion of the significance of my findings before concluding.

2 The History of the ZLB

Prior to the 2008 Financial Crisis, the only reference points economists had for the ZLB were from the Great Depression of the 1930s and the special case of Japan starting in the 1990s. Starting in the 1950s under Bretton-Woods and continuing even after the system was abandoned in 1971, interest rates in most developed countries steadily rose, peaking in the 1970s and 80s in the midst of the Great inflation. There are many reasons that macroeconomic policymakers pursued historically high interest rates during this period that I will not get into, but in the context of this paper, this trend was significant because it relegated the ZLB to a purely theoretically phenomenon; with interest rates historically high and even going above 20% at some points, the ZLB was not something most economists or policymakers considered a relevant problem. Even as interest rates began to steadily fall in the 1980s with the Great Moderation, the

ZLB was not considered a significant enough problem to warrant consideration. Of course, Japan entered the ZLB in the early 1990s during its Lost Decade(s), which generated some interest in the theory of ZLB, but was this largely seen as a special case and not something necessarily relevant to economies elsewhere. For most economists and policymakers before 2008, the ZLB was thought to be unlikely to occur, and moreover, not necessarily binding even if it did, so it was of little relevance to macroeconomic policymakers and economic researchers. It was only with the 2008 Financial Crisis that the ZLB became clearly relevant to economists and policymakers, as central banks around the world slashed interest rates to zero or near-zero levels and kept them there for much longer than anyone would have expected.

While this history of the ZLB is quite basic, my aim here is to highlight two key points. First, before 2008, and especially before interests had fallen significantly during the Great Moderation, the ZLB was not a relevant phenomenon since interest rates were so far from zero. Second, the global economic system and systems of macroeconomic management are quite different today than they were in previous periods, such as under Bretton-Woods or during the Great Inflation. For these reasons, much of the scholarship on the ZLB has focused on the period from 1990 onwards, as this is both when the ZLB became a relevant macroeconomic phenomenon and when the modern global economic system fully came into being. In the next section, I will provide a brief overview of some the research that has already been done on the economic significance of the ZLB and what it means for the (ir)relevance of the ZLB to macroeconomic management.

3 The Economic Significance of the ZLB

Economic research on the ZLB has generally proceeded in one of three dimensions: modeling incidence of the ZLB, assessing monetary and fiscal policy at the ZLB, and measuring the effect of the ZLB on other economic variables. In the first dimension, research by a number of scholars has aimed to model the likelihood of the ZLB and determine optimal policy to address it. This research has included attempts to estimate the occurrence and length of ZLB episodes using New Keynesian models (Chung et al. 2012; Dordal i Carreras et al. 2016) as well as prescriptions for the optimal rate of inflation that incorporating concerns about the ZLB (Coibion, Gorodnichenko, and Wieland 2012; Dordal i Carreras et al. 2016; John C. Williams 2009). Such research has highlighted how previous scholarship, relying heavily on the experience of the Great Moderation, has underestimated the likelihood, length, and severity of ZLB episodes (Chung et al. 2012). In a variety of macroeconomics models, ZLB episodes are longer and more common, though still rare, than previously theorized and have been shown to impose large welfare costs on the economy (Dordal i Carreras et al. 2016; John C. Williams 2009). Further research has indicated the importance of nonlinearities at the ZLB and highlighted the asymmetry of ZLB incidence (Fernández-Villaverde et al. 2015). In light of these predictions, multiple scholars have considered what different models of the ZLB imply about optimal inflation rates to avoid its costs (Coibion, Gorodnichenko, and Wieland 2012; Dordal i Carreras et al. 2016; John C. Williams 2009). Though this is just a sample of the literature, as a whole, most models of the ZLB agree that the ZLB is of great economic importance both in terms of incidence and welfare costs, and well worth addressing with macroeconomic policy. However, key to much of this work, as with any models, are certain predictions about the macroeconomic effects of the ZLB and how that imposes negative welfare effects, which is the

domain both of the third dimension of ZLB research and, as will be clear, of this paper. If such predictions about the ZLB are not fulfilled, the significance of the models, predictions, and prescriptions described above becomes much less clear.

In the second dimension of research, the ZLB scholarship can largely be divided into that looking at monetary policy and fiscal policy. In terms of monetary policy, scholarship has included both models for optimal monetary policy at the ZLB and assessments of monetary policies. Models of monetary policy at ZLB have found that ZLB does indeed restrict the ability of monetary policymakers to stabilize the economy, though to a lesser degree than some pessimists have theorized (Eggertsson and Woodford 2003), and highlighted the importance of policy commitment and risk management when taking the ZLB into account (Adam and Billi 2007; Evans et al. 2016). Moving beyond models, scholars have evaluated examples of unconventional monetary policy at the ZLB from Japan and the 2008 Financial Crisis and found that central banks were still able to successfully stimulate the economy despite being unable to access their conventional tools, though there is some disagreement about to what extent (Gambacorta, Hofmann, and Peersman 2014; Schenkelberg and Watzka 2013; Wu and Xia 2016; Wright 2012). As for fiscal policy, most of the debate revolves around whether fiscal multipliers are significantly higher at the lower bound or no different from normal. On one hand there are a large number of scholars who have found that, while government fiscal multipliers are often below one during normal times, they have the capacity to rise significantly above one at the ZLB (Eggertsson 2011; Christiano, Eichenbaum, and Rebelo 2011; Miyamoto, Nguyen, and Sergeyev 2018; Woodford 2011). On the other hand, there is another set of scholars who argue that the fiscal multiplier at ZLB is no different than during normal periods, and that fiscal policy operates essentially the same (Albertini, Poirier, and Roulleau-Pasdeloup 2014; Boneva, Braun, and Waki

2016; Mertens and Ravn 2014; Wieland 2018). Thus in terms of the policy implications of the ZLB, the case is not as clear cut as in the models of the previous section that the ZLB is as great a problem as many expect it to be. Though there is still much disagreement, given the success of unconventional monetary policy it seems that the constraints put on central banks by the ZLB may not be as significant as previously assumed. Further, it remains to be seen whether fiscal policy will provide another lever for governments to stimulate the economy when at ZLB.

The third dimension of ZLB research has mostly focused on the effect of ZLB on uncertainty and the volatility of macroeconomic variables such as GDP and inflation. Conventional models of these dynamics indicate that the ZLB generates endogenously elevated volatility in macroeconomic variables due to the central bank's inability to use conventual policy to counteract economic shocks. These models show how, when the ZLB is binding, uncertainty shocks are more contractionary and volatility of macroeconomic variables is significantly larger, indicating an imposition of severe welfare costs at the ZLB (Caggiano, Castelnuovo, and Pellegrino 2017; Basu and Bundick 2015). It this research on the welfare impact of the ZLB that informs the predictions of the previously mentioned models about the incidence of the ZLB and optimal policies to avoid it. However, some empirical research has shown that, in fact, volatility was not any higher at the ZLB, contrary to the expectations of these models. Debortoli and his coauthors present evidence from the US looking at the volatility of both GDP growth and three measures of inflation over the period from 1984:1 to 2018:2. They find that the ratios of standard deviations between normal and ZLB periods are generally below one for all of these variables, indicating that in the US, macroeconomic volatility was *not* higher at the ZLB during this period. This finding supports one half of what they term the "irrelevance hypothesis", the hypothesis that the economy behaves essentially the same at the ZLB as during normal periods; however, the

authors are quick to note that their study only investigates ZLB in one country during a specific period and that their findings may not extend to complete irrelevance of the ZLB (Debortoli, Galí, and Gambetti 2020). This paper builds on this previous research by investigating whether the irrelevance hypothesis is indeed something generalizable to the ZLB everywhere, which would run contrary to standard or economic models, or whether it only applied to the US during the specific period studied by Debortoli et al. To do this, I perform a more robust analysis of the variance of inflation and GDP at the ZLB and do so for a broader range of countries. In the following sections, I will present my data and methodology, my results, and the significance of my findings for the generalizability of the irrelevance hypothesis.

4 Data and Methodology

4.1 Data Sources

I use quarterly data for the period between 1990:1 and 2019:3 from the OECD Main Economic Indicators – Key Short-Term Economic Indicators dataset, which contains time series data for a large number of short-term macroeconomic variables. The dataset includes time series for all 37 OECD countries as well as aggregates and begins in 1914, though data are not available for all countries that early. Yearly, quarterly, and monthly data are all available, though reporting varies by country. Additionally, data for most variables are available as both a level, ratio, or index and as a growth rate.

The countries in my sample include the largest and most developed members of the OECD who had more than one quarter with interest rates lower than 1%, such as the United States, Germany, and France. Less developed countries in South America or in Eastern Europe, like Argentina or Poland, were excluded in order to capture the effect of the ZLB in only

advanced economies, which has been the focus of most scholarship. Also excluded were very small economies, such as Iceland or Luxembourg, as they tend to be idiosyncratic due to their size. Additionally, a few advanced economies I would have liked to study, such as Australia and South Korea, were excluded from the sample because they did not have more than one period with interest rates below 1%. The final sample includes 10 countries. The time period of the sample begins in 1990:1 and ends in 2019:3. The lower time restriction is due both to the relative irrelevance of ZLB before the 1990s and the vast differences between the global economic system of today and those of earlier periods, as discussed in an earlier section. The upper time restriction is designed to exclude the effects of the coronavirus pandemic which is still ongoing.

The variables pulled from the OECD dataset are GDP growth, the consumer price index, and the three-month interbank rate. GDP growth is measured in levels and is one of the key macroeconomic which modes predict should be more volatile at the ZLB. The consumer price index, measured as a growth rate, is a commonly used metric for inflation and is another key macroeconomic variables whose volatility should be higher at the ZLB. The three-month interbank rate, or the interest rate on short-term loans between banks, is a popular metric for short-term interest rates used in both research and monetary policymaking and, as an interest rate, can be used to see ZLB status. For all variables and countries, quarterly data were complete for the entire period, with two exceptions. First, GDP growth data were missing from the main OECD MEI dataset for Japan for the period between 1990:1 and 1994:1 and for Spain for the period between 1990:1 and 1995:1. This data, however, was still available as individual time series elsewhere in the OECD dataverse. Second, data for the three-month interbank rate in Japan were missing for the period between 1990:1 and 2002:1. This data was not available elsewhere in the OECD dataverse, so the missing information was filled in with data from the IMF

International Financial Statistics dataset, which contains information on a variety of interest rate indicators. Unfortunately, this dataset does not include the three-month interbank rate, so I instead use the treasury bill rate, another common short-term interest rate that should track closely to the three-month interbank rate.

4.2 Empirical Strategy

To assess whether volatility of inflation and GDP growth are higher at the ZLB, for each country I perform a simple lower one-tailed F-test for equality of two variances for both variables, grouping by ZLB status. This method tests, for each country, the following hypotheses on the volatility of both inflation and GDP growth:

$$H_0: \sigma^2_{Normal} = \sigma^2_{ZLB}$$

$$H_a: \sigma^2_{Normal} < \sigma^2_{ZLB}$$

As a base specification for ZLB status, I generate an indicator variable for each country-quarter equal to 1 if interest rates are below 50 basis points and 0 otherwise. As a robustness check, I also test three alternative specifications of the ZLB, defined by interest rates below 25 bps, 75 bps, 100 bps. This method of analysis is very simple, but as will become clear in the next sections, the result is incredibly powerful.

5 Results

Tables 1 and 2 present the results for the F-test for equality of variances for inflation and GDP growth grouping by the base specification for the ZLB (<50bps) for all ten countries in the sample. At this specification, the countries sampled have a wide spread of ZLB incidence. Out of

Table 1—Lower One-Tailed Test of Equality of Variances for Inflation, Grouping by ZLB Status (<50bps)

Country	SD_{Normal}	SD_{ZLB}	F	p-value	N	df_{Normal}	df_{ZLB}
Canada	0.583	0.210	7.724	0.879	119	115	2
France	0.370	0.418	0.785	0.196	119	89	28
Germany	0.478	0.561	0.728	0.133	119	89	28
Italy	0.444	0.335	1.756	0.954	119	89	28
Japan	0.657	0.520	1.599	0.956	119	34	83
Spain	0.831	1.117	0.553	0.019	119	89	28
Sweden	0.924	0.401	5.316	1.000	119	91	26
Switzerland	0.628	0.559	1.261	0.802	119	69	48
United Kingdom	0.649	0.266	5.951	0.974	119	112	5
United States	0.601	0.588	1.044	0.529	119	92	25
Pooled Sample	0.635	0.594	1.142	0.918	1190	878	310

Notes: Data from the OECD Main Economic Indicators – Key Short-Term Economic Indicators for the quarters 1990:1 – 2019:3, on inflation as measured by the CPI and the three-month interbank rate. ZLB status is an indicator variable equal to 1 when the three-month interbank rate is strictly below 50 basis points and 0 otherwise. For the pooled sample, data were first demeaned.

Table 2—Lower One-Tailed Test of Equality of Variances for GDP Growth, Grouping by ZLB Status (<50bps)

Country	SD_{Normal}	SD_{ZLB}	F	p-value	N	df_{Normal}	df_{ZLB}
Canada	0.640	0.426	2.260	0.644	119	115	2
France	0.491	0.299	2.699	0.998	119	89	28
Germany	0.962	0.488	3.885	1.000	119	89	28
Italy	0.747	0.356	4.408	1.000	119	89	28
Japan	1.344	0.739	3.305	1.000	119	34	83
Spain	0.843	0.465	3.284	1.000	119	89	28
Sweden	0.913	0.772	1.400	0.835	119	91	26
Switzerland	0.656	0.496	1.751	0.979	119	69	48
United Kingdom	0.585	0.148	15.617	0.997	119	112	5
United States	0.620	0.442	1.966	0.972	119	92	25
Pooled Sample	0.758	0.564	1.811	1.000	1190	878	310

Notes: Data from the OECD Main Economic Indicators – Key Short-Term Economic Indicators for the quarters 1990:1 – 2019:3, on GDP growth and the three-month interbank rate. ZLB status is an indicator variable equal to 1 when the three-month interbank rate is strictly below 50 basis points and 0 otherwise. For the pooled sample, data were first demeaned.

a total of 119 quarters, six countries, including those in the Eurozone, Sweden, and the US, have around 25-30 quarters at the ZLB, while two countries, the United Kingdom and Canada, have less than 10 quarters at the ZLB. The two other countries, Switzerland and Japan, have substantially more quarters at the ZLB, with Japan actually spending more than two-thirds of the sampled quarters at ZLB. Thus, at the base specification it is clear that for most countries, ZLB was a relevant and not uncommon phenomenon.

Looking at the results of the F-tests for volatility of inflation in Table, there is once again a spread in the results. For seven of the countries in the sample, variance at the ZLB is actually lower than variance during normal periods, contrary to the model prediction, and many of the F-test p-values are near 1. For the three countries where variance at the ZLB was in fact higher than variance in normal periods, in only one (Spain) does the difference in volatility rise to the level of statistical significance, with an F-test p-value of 0.019. Thus, at the base specification, there is little evidence that there is higher volatility at the ZLB than in normal periods, and perhaps even evidence for the reverse. The results of the F-tests for volatility of GDP growth in Table 2 add further weight to the hypothesis of irrelevance. For all ten of the countries in the sample, variance in GDP growth at the ZLB is lower than variance during normal periods, again contrary to the model prediction. The lowest F-test p-value for this test is that of Canada, at only 0.644, and eight of the sampled countries have F-test p-values greater than 0.95. Thus, in the case of GDP growth there is even less evidence that volatility is higher at the ZLB than in normal periods, and more evidence for the reverse.

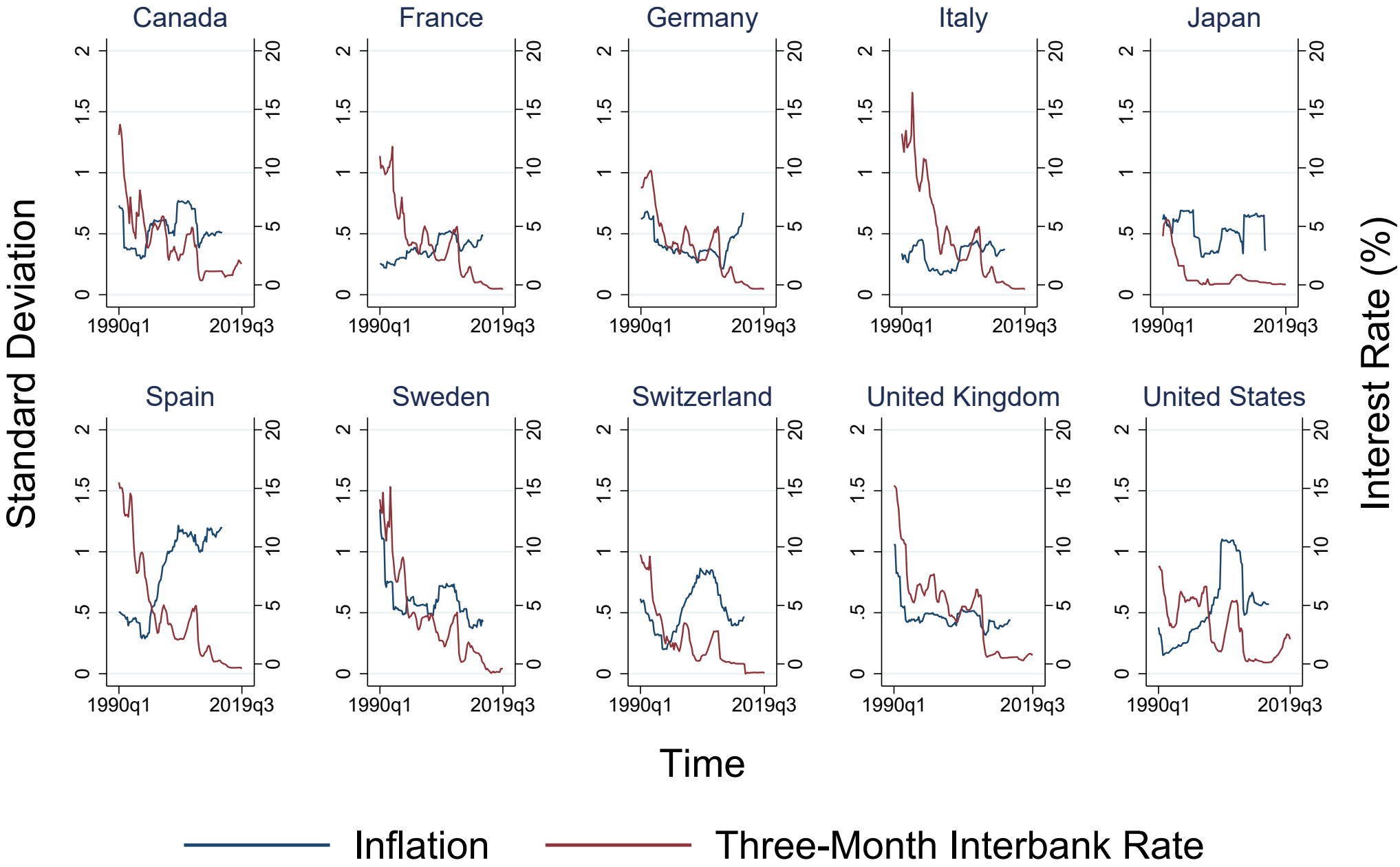
Tables 3-8 in the Appendix present the results of the same analysis replicated for different specifications for the ZLB. Tables 3-6 loosen the ZLB specification, with Tables 3 and 4 taking ZLB as interest rates below 75bps and Tables 5 and 6 taking ZLB as interest rates below

100bps, while Tables 7 and 8 narrow the ZLB specification, taking ZLB as interest rates below 25bps. As is clear from the tables, changing the specification of the ZLB does not significantly change the results of the analysis; in all alternative cases, the preponderance of evidence supports the hypothesis of irrelevance.

Lastly, Figures 1 and 2 graph time series of five-year rolling averages for the volatility of inflation and GDP growth alongside the interest rate. If the model predictions were correct and volatility of GDP growth and inflation were indeed higher at the ZLB, we would expect to see two trends in these graphs. First, we would expect the rolling averages for inflation or GDP growth to be higher when the interest rate is closer to the ZLB. Second, we would expect that as the interest rate approaches the ZLB, the rolling averages for inflation or GDP will increase in a characteristic step-function as they gradually replace normal periods with periods at ZLB in their average. However, in most of the graphs, except that for inflation in Spain, this is not the case.

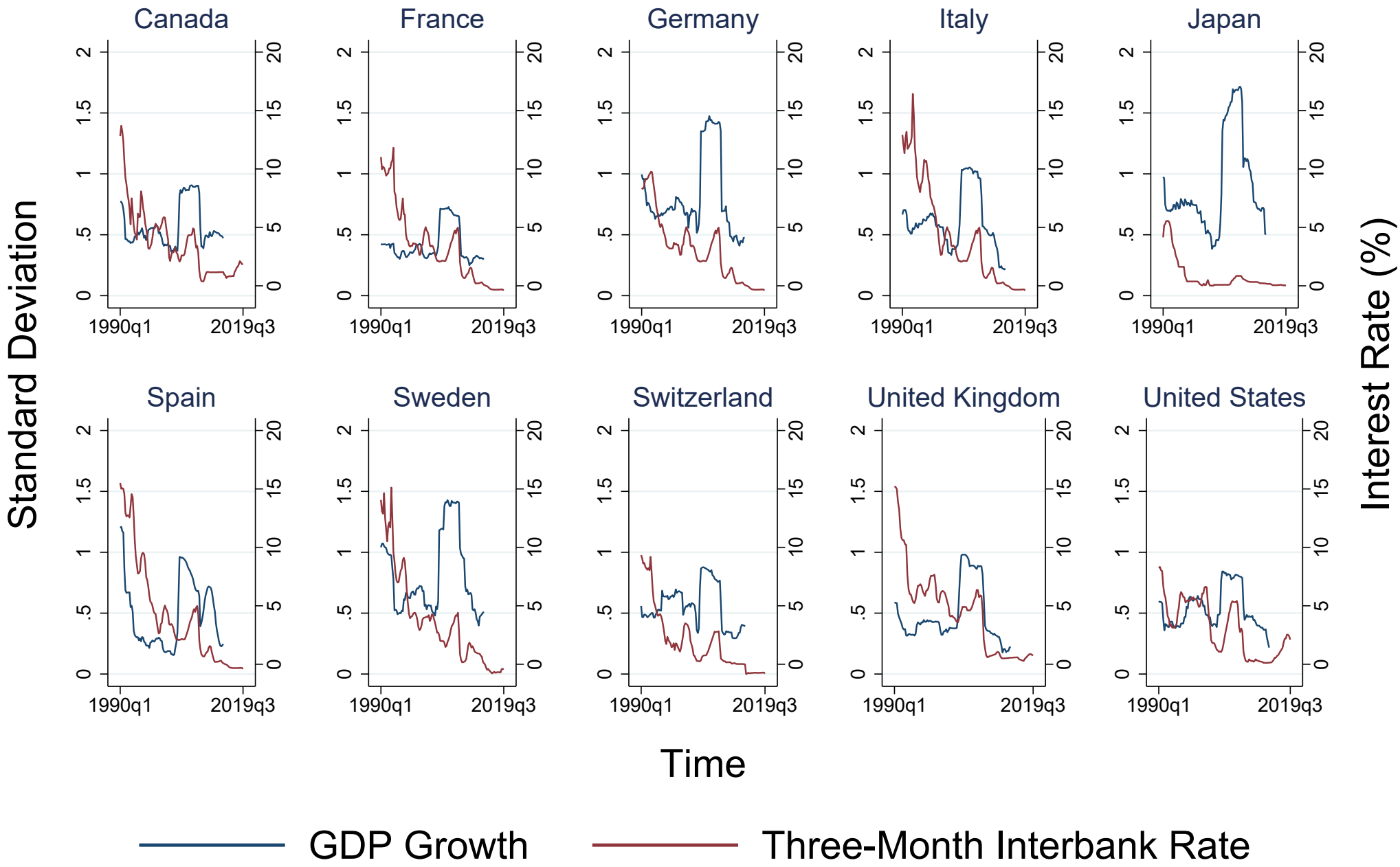
For most countries, we see neither increasing step functions nor generally high volatility when interest rates approach zero. Further, for many countries, it actually seems that volatility in inflation and GDP growth actually decrease as interest rates approach the ZLB. In this sense, the graphs presented in Figures 1 and 2 reflect the results of the earlier analysis, adding further evidence for the irrelevance hypothesis.

Figure 1—Volatility of Inflation by Country, 1990-2019



Notes: Data from the OECD Main Economic Indicators – Key Short-Term Economic Indicators for the quarters 1990:1 – 2019:3, on inflation as measured by the CPI and the three-month interbank rate. The series labeled inflation is a five-year forward rolling average of the variance of inflation as measured by the CPI and is graphed on the primary y-axis. The three-month inter-bank rate is a regular time series and is graphed on the secondary y-axis.

Figure 2—Volatility of GDP Growth by Country, 1990-2019



Notes: Data from the OECD Main Economic Indicators – Key Short-Term Economic Indicators for the quarters 1990:1 – 2019:3, on GDP growth and the three-month interbank rate. The series labeled GDP growth is a five-year forward rolling average of the variance of GDP growth and is graphed on the primary y-axis. The three-month inter-bank rate is a regular time series and is graphed on the secondary y-axis.

6 Discussion and Conclusion

The results of my analysis indicate that the irrelevance hypothesis, which was originally applied to the US by Debortoli et al., can actually be generalized as a feature of the ZLB. Looking at volatility in inflation and GDP growth in advanced economies over the past 30 years, there is little evidence that macroeconomic volatility is higher at the ZLB than during normal periods, contrary to the expectations of most macroeconomic models. Further, it seems that, in general, volatility of key macroeconomic variables, such as GDP growth and inflation, was actually lower during periods at the ZLB, though it is not clear whether this result is significant. There are a few possible explanations for or interpretations of this empirical departure from the models' predictions. The most simple explanation is that the standard economic models scholars use to study the ZLB are wrong; they predict that volatility macroeconomic variables such as GDP growth and inflation should be higher at the ZLB, but it just simply is not true. A more complex explanation, which finds support in Debortoli et al., might be that while macroeconomic volatility at the ZLB may be higher all else equal, this effect was entirely attenuated in recent cases by the successful implementation of unconventional macroeconomic policy; that is to say that, in the real world, the inability of monetary policymakers to move the short-term interest rate might have been offset by other tools, thus making the ZLB irrelevant in practice. though not in theory. Another potential explanation might be that we got lucky during this period; perhaps, in continuation of the trends of the Great Moderation, shocks simply became smaller and so the effect of the ZLB was not as significant as expected, though this seems unlikely.

Regardless of which of these hypotheses is correct, the empirical irrelevance of the ZLB is an important and surprising finding. In terms of economic theory, much of the literature on the

economic significance of the ZLB takes for granted the prediction that macroeconomic volatility is higher at the ZLB and that this imposes significant welfare costs. If this prediction is false, and the ZLB is in fact irrelevant in terms of macroeconomic volatility, it calls into question not only the existing models and research on ZLB but also one of the core predictions underlying why economists study the ZLB at all. In terms of policy, the irrelevance of the ZLB means that we do not need to increase our inflation targets, as some prominent economists have suggested, in order to the avoid the ZLB, and that it might be optimal to actually have lower levels of inflation. It also means that policies like the Fed's average inflation targeting, which were implemented to avoid the ZLB, might not be as important or useful as originally thought. In addition, the success of unconventional monetary policy might indicate that these tools should become a more regular part of the monetary policymaker's toolbox.

It is for these reasons that the evidence I have presented here is incredibly important to economic research on the ZLB. Using a very simple test, I have arrived at a powerful conclusion, and one that should shock economists if true: the irrelevance of the ZLB. Though more empirical research is of course necessary, hopefully these preliminary findings will help economists and policymakers adjust the way they think about, assess, and address the ZLB, especially as we move into another long episode of ZLB on account of the coronavirus.

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Appendix

Table 3—Lower One-Tailed Test of Equality of Variances for Inflation, Grouping by ZLB Status (<75bps)

Country	SD_{Normal}	SD_{ZLB}	F	p-value	N	df_{Normal}	df_{ZLB}
Canada	0.590	0.285	4.276	0.947	119	112	5
France	0.374	0.422	0.786	0.190	119	85	32
Germany	0.487	0.528	0.851	0.275	119	85	32
Italy	0.446	0.356	1.573	0.925	119	85	32
Japan	0.612	0.528	1.340	0.846	119	27	90
Spain	0.822	1.131	0.528	0.011	119	85	32
Sweden	0.925	0.435	4.512	1.000	119	89	28
Switzerland	0.624	0.573	1.186	0.735	119	66	51
United Kingdom	0.690	0.381	3.281	1.000	119	89	28
United States	0.606	0.581	1.090	0.592	119	88	29
Pooled Sample	0.640	0.585	1.198	0.977	1190	820	368

Notes: Data from the OECD Main Economic Indicators – Key Short-Term Economic Indicators for the quarters 1990:1 – 2019:3, on inflation as measured by the CPI and the three-month interbank rate. ZLB status is an indicator variable equal to 1 when the three-month interbank rate is strictly below 75 basis points and 0 otherwise. For the pooled sample, data were first demeaned.

Table 4—Lower One-Tailed Test of Equality of Variances for GDP Growth, Grouping by ZLB Status (<75bps)

Country	SD_{Normal}	SD_{ZLB}	F	p-value	N	df_{Normal}	df_{ZLB}
Canada	0.629	0.834	0.570	0.128	119	112	5
France	0.497	0.305	2.663	0.999	119	85	32
Germany	0.962	0.567	2.878	0.999	119	85	32
Italy	0.755	0.388	3.788	1.000	119	85	32
Japan	1.060	0.923	1.319	0.833	119	27	90
Spain	0.841	0.516	2.655	0.999	119	85	32
Sweden	0.922	0.744	1.534	0.900	119	89	28
Switzerland	0.663	0.495	1.791	0.984	119	66	51
United Kingdom	0.638	0.285	4.995	1.000	119	89	28
United States	0.627	0.432	2.105	0.987	119	88	29
Pooled Sample	0.748	0.627	1.426	1.000	1190	820	368

Notes: Data from the OECD Main Economic Indicators – Key Short-Term Economic Indicators for the quarters 1990:1 – 2019:3, on GDP growth and the three-month interbank rate. ZLB status is an indicator variable equal to 1 when the three-month interbank rate is strictly below 75 basis points and 0 otherwise. For the pooled sample, data were first demeaned.

Table 5—Lower One-Tailed Test of Equality of Variances for Inflation, Grouping by ZLB Status (<100bps)

Country	SD_{Normal}	SD_{ZLB}	F	p-value	N	df_{Normal}	df_{ZLB}
Canada	0.600	0.417	2.071	0.944	119	102	15
France	0.369	0.417	0.784	0.186	119	83	34
Germany	0.490	0.512	0.914	0.363	119	83	34
Italy	0.447	0.348	1.648	0.948	119	83	34
Japan	0.638	0.531	1.444	0.879	119	20	97
Spain	0.814	1.105	0.542	0.013	119	83	34
Sweden	0.918	0.505	3.309	1.000	119	84	33
Switzerland	0.611	0.585	1.088	0.625	119	61	56
United Kingdom	0.717	0.401	3.206	1.000	119	79	38
United States	0.611	0.567	1.165	0.677	119	86	31
Pooled Sample	0.641	0.582	1.215	0.987	1190	773	415

Notes: Data from the OECD Main Economic Indicators – Key Short-Term Economic Indicators for the quarters 1990:1 – 2019:3, on inflation as measured by the CPI and the three-month interbank rate. ZLB status is an indicator variable equal to 1 when the three-month interbank rate is strictly below 100 basis points and 0 otherwise. For the pooled sample, data were first demeaned.

Table 6—Lower One-Tailed Test of Equality of Variances for GDP Growth, Grouping by ZLB Status (<100bps)

Country	SD_{Normal}	SD_{ZLB}	F	p-value	N	df_{Normal}	df_{ZLB}
Canada	0.627	0.705	0.791	0.239	119	102	15
France	0.502	0.300	2.797	0.999	119	83	34
Germany	0.972	0.554	3.078	1.000	119	83	34
Italy	0.762	0.387	3.888	1.000	119	83	34
Japan	0.963	0.951	1.027	0.561	119	20	97
Spain	0.848	0.507	2.790	0.999	119	83	34
Sweden	0.931	0.755	1.519	0.911	119	84	33
Switzerland	0.666	0.504	1.748	0.982	119	61	56
United Kingdom	0.666	0.299	4.951	1.000	119	79	38
United States	0.634	0.418	2.298	0.995	119	86	31
Pooled Sample	0.752	0.633	1.409	1.000	1190	773	415

Notes: Data from the OECD Main Economic Indicators – Key Short-Term Economic Indicators for the quarters 1990:1 – 2019:3, on GDP growth and the three-month interbank rate. ZLB status is an indicator variable equal to 1 when the three-month interbank rate is strictly below 100 basis points and 0 otherwise. For the pooled sample, data were first demeaned.

Table 7—Lower One-Tailed Test of Equality of Variances for Inflation, Grouping by ZLB Status (<25bps)

Country	SD_{Normal}	SD_{ZLB}	F	p-value	N	df_{Normal}	df_{ZLB}
France	0.369	0.436	0.717	0.129	119	92	25
Germany	0.473	0.590	0.642	0.067	119	92	25
Italy	0.446	0.349	1.632	0.918	119	92	25
Japan	0.599	0.526	1.294	0.832	119	64	53
Spain	0.845	1.138	0.552	0.022	119	92	25
Sweden	0.911	0.421	4.686	1.000	119	94	23
Switzerland	0.653	0.493	1.757	0.972	119	79	38
United States	0.593	0.672	0.779	0.231	119	103	14
Pooled Sample	0.636	0.614	1.073	0.738	952	715	235

Notes: Data from the OECD Main Economic Indicators – Key Short-Term Economic Indicators for the quarters 1990:1 – 2019:3, on inflation as measured by the CPI and the three-month interbank rate. ZLB status is an indicator variable equal to 1 when the three-month interbank rate is strictly below 25 basis points and 0 otherwise. For the pooled sample, data were first demeaned. Canada and the United Kingdom were dropped from this table because they did not have more than one period with interest rates below 25 basis points

Table 8—Lower One-Tailed Test of Equality of Variances for GDP Growth, Grouping by ZLB Status (<25bps)

Country	SD_{Normal}	SD_{ZLB}	F	p-value	N	df_{Normal}	df_{ZLB}
France	0.486	0.308	2.493	0.994	119	92	25
Germany	0.949	0.498	3.637	1.000	119	92	25
Italy	0.739	0.352	4.405	1.000	119	92	25
Japan	1.158	0.631	3.370	1.000	119	64	53
Spain	0.837	0.448	3.487	1.000	119	92	25
Sweden	0.912	0.767	1.414	0.827	119	94	23
Switzerland	0.678	0.359	3.567	1.000	119	79	38
United States	0.603	0.448	1.814	0.896	119	103	14
Pooled Sample	0.800	0.504	2.516	1.000	952	715	235

Notes: Data from the OECD Main Economic Indicators – Key Short-Term Economic Indicators for the quarters 1990:1 – 2019:3, on GDP growth and the three-month interbank rate. ZLB status is an indicator variable equal to 1 when the three-month interbank rate is strictly below 25 basis points and 0 otherwise. For the pooled sample, data were first demeaned. Canada and the United Kingdom were dropped from this table because they did not have more than one period with interest rates below 25 basis points