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Effective Downward Nominal Wage Rigidities*

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Abstract

Downward nominal wage rigidity limits the downward adjustment of nominal wages, especially during recessions. Although macroeconomic models generally suggest that nominal wage rigidity exacerbates employment losses and generates asymmetric business cycles when inflation is low, direct empirical evidence for this effect is scarce. This paper estimates effective downward nominal wage rigidities that account for different inflation environments across 53 countries and finds that downward wage rigidities are driven by minimum wage policies and widespread, though higher in emerging markets. Further empirical results suggest that countries with higher effective downward nominal wage rigidities are subject to more sizable contractions in employment and real GDP per capita during recessions.

Keywords: Downward Wage Rigidities; Recession Dynamics; Unemployment

JEL: F41, E23, E24, E32, J31, J50

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1. Introduction

The widespread theory of "sticky wages" emphasizes that nominal wages are sluggish to respond to economic shocks. Particularly harmful and empirically more relevant are downward nominal wage rigidities (DNWRs), in which employers are unable to cut wages to adverse shocks and instead primarily reduce employment. This effect has stirred a large literature documenting the presence of DNWRs based on micro-level data. Several studies have also analyzed the macroeconomic consequences of downward wage rigidities using both quantitative and theoretical macroeconomic models and found that DNWRs can have profound adverse effects during recessions when inflation is low.[1]

However, no research has yet produced prima facie empirical evidence on how DNWRs impact business cycles, especially recession dynamics during which these constraints possibly bind. As recessions are relatively rare events, it is paramount to assemble a large dataset and construct consistent downward wage rigidity estimates across countries. Unfortunately, cross-country evidence on wage rigidities is limited, and due to various definitions, existing estimates are difficult to compare. This paper aims to close these gaps in the literature while also highlighting forces that drive downward wage rigidities.

In this paper, I make three contributions. First, I define and calculate *effective* DNWRs based on widely available aggregate data for 53 countries, including both major advanced economies (AEs) and emerging markets (EMs). Effective DNWRs are defined analogous to DNWRs but in addition account for inflation, which can grease the wheels and provide a margin to adjust real wages when nominal wages are sticky (Tobin, 1972). To estimate effective DNWRs, I propose an intuitive algorithm that exploits real wage growth rates when downward nominal wage constraints are more likely to bind. My findings suggest both AEs and EMs experience substantial downward wage rigidity. Furthermore, since wage rigidities are estimated in line with the structural literature, the estimates can guide the calibration of wage rigidities in quantitative models.

Second, I provide empirical evidence that downward wage rigidities have detrimental effects on output and employment during recessions. These effects are both statistically and economically significant: countries with sizable effective DNWRs

[1] For empirical papers based on micro data see, for example, Bewley (1999); Gottschalk (2005); Dickens et al. (2007); Messina et al. (2010); Sigurdsson and Sigurdardottir (2016); Elsby and Solon (2019); Kaur (2019); Grigsby et al. (2021); Jo (2021). Structural macro papers include Hall (2005); Gertler and Trigari (2009); Kim and Ruge-Murcia (2009); Benigno and Ricci (2011); Abbritti and Fahr (2013); Schmitt-Grohe and Uribe (2016); Dupraz et al. (2019).

experience a 9 percentage points (pp) greater decline in the employment share during a recession than countries with few or no wage rigidities. Further, these countries also experience a 2.5 pp greater decline in real GDP per capita.

Third, I link downward wage rigidities to minimum wage policies. I find a positive correlation between minimum wage gains and aggregate wage growth, which in turn drives changes in the wage rigidity measure. This finding corroborates micro-level evidence on the importance of minimum wages in driving wage rigidities (Castellanos et al., 2004; Ahn et al., 2022).

In more detail, I define downward nominal wage rigidities according to the recent structural literature as a one-sided constraint (see, for example, Schmitt-Grohe and Uribe, 2016): hourly nominal earnings in any year must be no less than a fraction of last year's nominal earnings. The magnitude of that fraction captures the degree of downward nominal wage rigidities, with a larger fraction referring to stronger rigidities. However, as shown in the literature, the implications of DNWRs on the real economy also depend on inflation, or alternatively, the exchange rate in an open economy setting. Intuitively, labor market outcomes are generally thought of as being determined by real wages. Higher inflation can consequently lower the real wage when nominal wages cannot adjust, which reduces the severity of a nominal wage constraint. It is therefore paramount to adjust for inflation to asses the implications of DNWR on the real economy, which leads to the definition of effective DNWR: the ratio of real earnings between two periods when downward nominal wage rigidities bind. The challenge with the aforementioned definition is that it is impossible to empirically determine when DNWRs bind. The key identification assumption is that DNWRs likely materialize during periods of rising unemployment ('unemployment cycles'), in which labor markets exert downward pressure on nominal and real wages or at least moderate wage growth. In other words real wage growth during unemployment cycles is informative about downward rigidities – either the nominal constraint binds and one can thus directly estimate effective DNWRs. Alternatively, the constraint does not bind or inflation is high, in which case real wage growth is low or negative, suggesting no or minor effective DNWRs.

A cross-country comparison of effective DNWRs based on this procedure reveals two findings. First, downward wage rigidities are on average higher in emerging markets, despite higher average inflation, yet nonetheless substantial in advanced economies. Second, downward wage rigidities show substantial heterogeneity across emerging markets, but less so among advanced economies, likely reflecting the heterogeneity in inflation among emerging markets.

An analysis based on Local Projections (Jordà, 2005) reveals the macroeconomic implications of effective DNWRs on recession dynamics, when wage rigidities are most likely to have an adverse effect. I first extract recession episodes from 53 countries over a 25 year period (1995-2020), which generates a sample of 107 recession cycles and then examine whether countries with severe downward wage rigidities experience more pronounced contractions in employment and real GDP per capita. There are striking differences: the employment share of countries with high effective DNWRs declines nearly 10 percentage points over three years, more than five times the employment decline in countries with low wage rigidities. Differences for output are smaller, but nevertheless significant: countries with high wage rigidities have roughly 2.5 pp lower real GDP per capita after three years.

The approach in this paper differs from the literature in two ways. First, I look for empirical evidence on the aggregate relevance of downward wage rigidities in the data and do not draw conclusions based on calibrated structural models. The results therefore serve as an empirical test for a broad class of models featuring downward wage rigidity constraints. In this regard, the analysis delivers qualitatively similar impulse response functions and hence provides strong support for these models. Second, in contrast to previous applied work which mainly focuses on micro data and indirect evidence based on aggregated data, I provide direct support that downward wage rigidities drive aggregate dynamics. Related to the applied macro literature, Abbritti and Fahr (2013), for example, highlight sticky wages and sizable employment declines during recessions. Such patterns are consistent with downward wage rigidities, but they may also result from compositional biases since unskilled workers are usually the first to loose their jobs during downturns (Solon et al., 1994; Abraham and Haltiwanger, 1995). Related, Calvo et al. (2012) show that financial crises with high inflation tend to feature wageless recoveries while crises with low inflation are associated with jobless recovers. This is in line with predictions of effective DNWRs, where high inflation is able to reduce real wages. Further, Devicienti et al. (2007) find that downward wage rigidities are conducive both to higher turnover flows and to higher unemployment rates at the provincial level in Italy. None of these aforementioned papers, however, estimate wage rigidities, nor do they analyze their direct effect on recession dynamics. In that sense, this paper is closest to Schmitt-Grohe and Uribe (2016) who provide estimates for DNWRs based on aggregate data for the periphery of Europe and Argentina while these countries were subject to low inflation, thus effectively mirroring the interpretation of effective DNWRs in this paper. I build on and extent their algorithm, examine a larger sample, tie wage rigidities to minimum wage policies, and show that wage rigidities directly drive recession dynamics using a large panel of countries.

This paper resorts to country-level data to determine wage rigidities, owing to the lack of consistent micro-level data across countries. A natural question is whether it is feasible to uncover wage rigidities based on this level of aggregation. Three pieces of evidence support the approach. First, the estimation procedure is likely not overly sensitive to a compositional bias – a common argument against using aggregate data. I determine wage rigidities only based on episodes with adverse labor market conditions and not by comparing wage growth between booms and busts. I also average estimates across unemployment cycles for each country. This mutes the effect of particularly severe or benign cycles, which could induce different compositional adjustments in the workforce. Second, the paper provides numerous robustness checks, which explore the implications of effective DNWRs on various labor market related outcomes, like volatility in wages and employment, the zero impact of wage rigidities during expansions, or the sensitivity of wage growth to the unemployment rate. I find that countries with high effective DNWRs perform in a way that is consistent with theories on wage rigidities. Third, the estimated wage rigidities correlate with minimum wage policies, which provides plausible micro-level evidence on the underlying friction. In a similar vein, I also directly contrast the measure with micro-level estimates on downward wage rigidities based on payroll and pay slip data for a subset of overlapping countries (Elsby and Solon, 2019). Both approaches yield similar results, which makes it reasonable to conjecture a similar relationship for countries without available micro-level data.

The remaining paper is structured as follows: Section 2 defines effective DNWRs in a simple structural model. Section 3 estimates effective DNWRs for a large panel of advanced economies and emerging markets. Section 4 analyzes the implications of effective DNWRs on business cycle dynamics. Section 5 concludes.

2. Structural Framework

This section provides a simple structural model which explicitly defines effective DNWR. This definition guides the empirical identification strategy in the next section. In addition, the model emphasizes the role of wage rigidities in driving recession dynamics, a feature that is empirically matched in Section 4.

Consider an economy in which households supply labor inelastically and firms produce output by hiring workers at competitive wages unless downward nominal wage rigidities bind. Labor is the only input for production. The nominal price of output (P_t) and hence inflation ($\pi_t = P_t/P_{t-1}$) is exogenously determined. With this setup, real wages (w_t), labor (l_t), and output ($y_t = A_t F(l_t)$) are entirely pinned down by labor demand, the wage constraint and a process for inflation.

Labor Market: Competitive firms choose labor to maximize profits. If the wage constraint does not bind, real wages equal the marginal product of labor:

$$w_t = A_t F'(l_t).$$

The function F is strictly increasing and concave. The variable A_t represents an exogenous technology process.

Nominal wages (W_t) must equal at least γ times the nominal wage in the previous period, which puts a floor on nominal wages. Formally:

$$W_t \geq \gamma W_{t-1}.$$

The parameter γ captures the strength of the nominal wage rigidity. If $\gamma = 0$, wages are fully flexible. This constraint is common in the literature (see, for example, Schmitt-Grohe and Uribe, 2016 or Ottonello, 2021). The wage constraint can be cast in terms of real wages:

$$w_t \geq \underbrace{\frac{\gamma}{\pi_t}}_{\eta(\pi)} w_{t-1}.$$

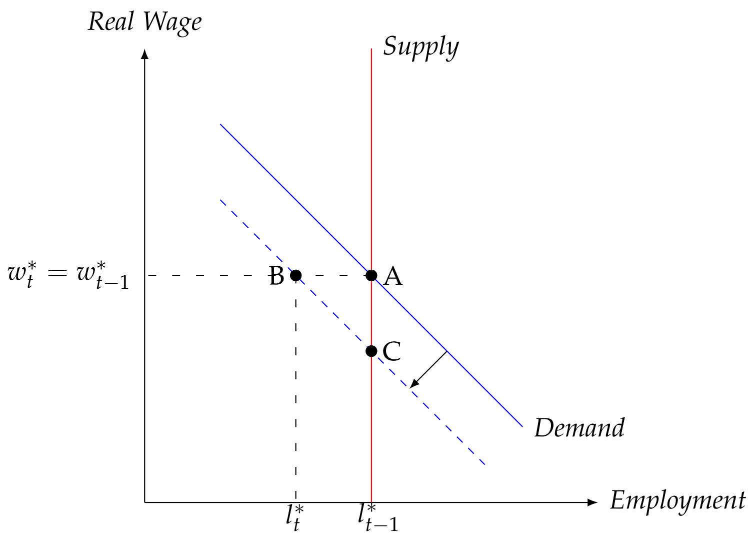
The key is that higher inflation is able to lower real wages when nominal wages cannot fall. Because the labor market equilibrium depends on real wages, inflation can mitigate the adverse effects of a binding downward nominal wage constraint. Further, for a small open economy, which is the relevant setting for many emerging markets, inflation co-moves with the depreciation of the domestic currency.[2] I define the ratio of downward nominal wage rigidity (γ) and inflation as the effective downward nominal wage rigidity (η) and estimate this object in Section 3.

Equilibrium: The labor market equilibrium during two arbitrary periods is illustrated in Figure 1. The solid red line represents labor supply, the solid blue line initial labor demand. The slopes are determined by the inelastic labor supply and the diminishing returns to labor as encapsulated in F. The intersection between both lines determines

[2]To see this, assume that the law of one price applies. Then $P_t = E_t P_t^*$, where E_t is the nominal exchange rate. If one assumes that the foreign price (P_t^*) is exogenous to the small open economy and constant (which is a standard assumption), then $\pi_t = \frac{E_t}{E_{t-1}}$.

the initial labor market equilibrium (point 'A'). Now suppose a negative technology shock hits the economy driving down labor demand (dashed line). With flexible wages, firms would respond by cutting nominal wages to accommodate the inelastic labor supply (point 'C'). With rigid wages, firms have to cut down employment, unless inflation offsets the nominal rigidity. Thus, if $\gamma = 1$, and if $\pi_t = 1$, employment declines (point 'B'). However, if $\gamma = 1$ and if $\pi_t \geq \frac{\gamma}{A_t/A_{t-1}}$, employment does not fall (point 'C'). In this case, inflation lowers real wages enough, which prompts an increase in the nominal wage according to the first order condition of the firm. The nominal wage constraint no longer binds. In other words, the extent to which downward nominal wage rigidity adversely affects employment and hence output crucially depends on the level of inflation.

Figure 1: *Labor Market*



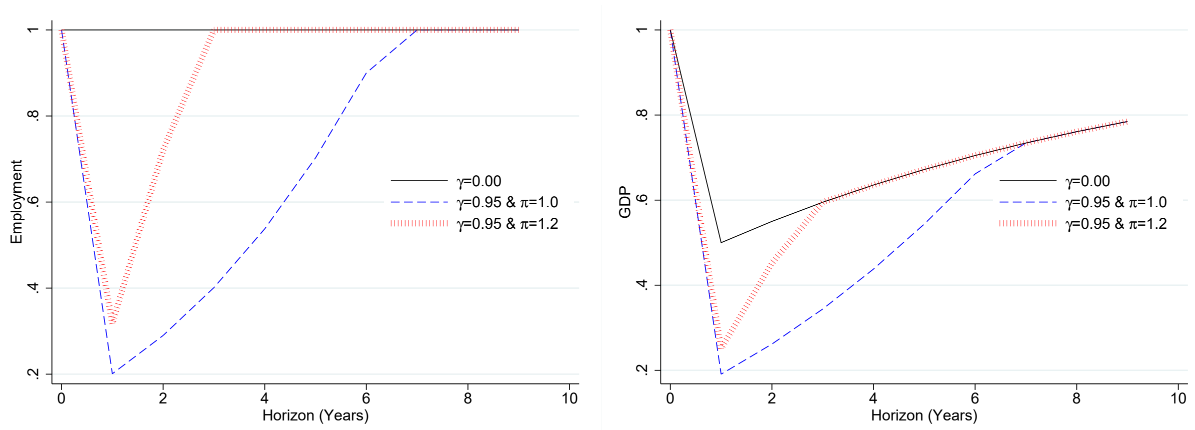
Notes: *The red line represents labor supply, the blue line labor demand. The initial equilibrium is marked (point 'A'). The chart highlights the consequences of a negative shock to A_t when $\gamma = 1$. The negative shock reduces labor demand. If $\pi_t = 1$, real wages cannot adjust and firms hire fewer workers generating involuntary unemployment and output losses (point 'B'). However, with positive inflation real wages fall despite a nominal wage constraint and full employment is restored when $\pi_t \geq \frac{\gamma}{A_t/A_{t-1}}$ (point 'C').*

Recession Paths: Figure 2 visualizes the theoretical impulse response functions from an unanticipated technology shock for employment (Panel (a)) and output (Panel (b)) to illustrate the importance of effective DNWRs in driving aggregate dynamics. Each plot consider three experiments. In the first experiment (black solid line) the nominal wage constraint never binds, regardless of the level of inflation ($\gamma = 0$). In the second scenario (blue dashed line), the wage constraint binds from periods 1 to 7 ($\gamma = 0.95$ and $\pi_t = 1 \; \forall \; t$). In the third scenario (red dotted line), inflation is positive ($\gamma = 0.95$ and $\pi_t = 1.2 \; \forall \; t$). Because inflation is able to alleviate nominal wage rigidities, the constraint only binds during periods 1 and 2.

As expected employment does not respond when $\gamma = 0$. In contrast, employment contracts when the wage constraint binds, but less so when inflation is positive. The response of GDP depends on the persistence of the technology process and the wage constraint. The recession worsens considerably when the wage constraint binds. Once again, the response is less severe when inflation is positive, highlighting the importance of inflation when assessing the significance of DNWRs on recession dynamics.

Figure 2: *Theoretical Recession Paths*

(a) *Employment* ***(b)*** *GDP*



Notes: *Impulse response functions due to a shock to A_t on employment and GDP as a function of γ and π. Functional forms: $F(l_t) = l_t^{\alpha}$, $A_t = \rho_0 + \rho_1 A_{t-1} + \epsilon_t$. Calibration: $l^{max} = 1$, $\alpha = 0.6$, $\rho_0 = 0.1$, $\rho_1 = 0.9$, $A_1 = 0.5$.*

3. Determining Downward Wage Rigidities

This section serves several purposes: First, I present a simple test to distinguish effective DNWRs from downward real wage rigidities. Then, I propose an algorithm to extract effective DNWRs from aggregate data. Towards, the end, I link the estimates to minimum wage policies, which provides micro-level evidence for the underlying friction.

Effective DNWRs are implicitly defined based on the wage constraint:

$$w_{i,t} \geq \eta_{i,t} w_{i,t-1}, \tag{1}$$

where $w_{i,t}$ refers to the real wage in country i and year t. $\eta_{i,t}$ determines the country- and time-specific severity of the downward wage constraint. A higher value reflects more relevant downward wage rigidities. As detailed in the previous section, $\eta_{i,t}$ is inversely related to inflation. Higher inflation greases the wheels and lowers the real wage when nominal wages cannot adjust, therefore reducing the adverse effect of the nominal wage constraint on the economy.

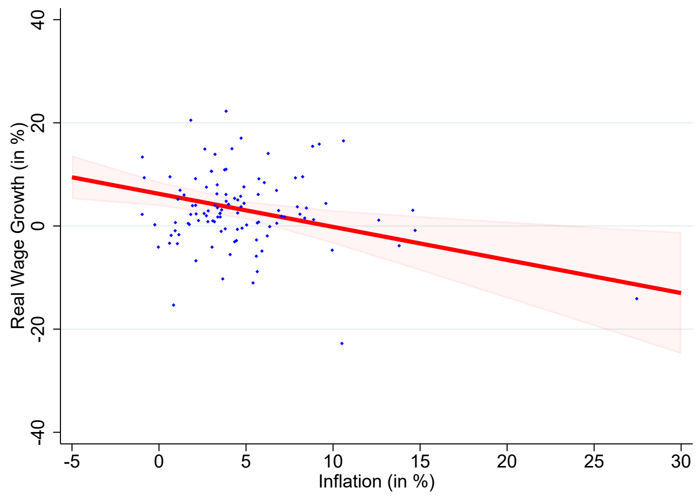
Just to be clear, equation (1) could be misinterpreted for a downward real wage constraint, which looks almost the same, except that $\eta_{i,t}$ would not necessarily depend on inflation. The next section provides empirical evidence that strongly supports an interpretation in terms of effective DNWRs.

3.1. Nominal or Real Downward Wage Rigidities

It is crucial to distinguish downward nominal from downward real wage rigidities, both for the interpretation of the results, but also for potential policy implications that may arise from the analysis.

The existing empirical literature on downward wage rigidities cited in the introduction strongly favors DNWRs based on available micro-level data. An economy with a binding downward nominal wage constraint should feature few nominal wage cuts and an abundance of nominal wage freezes. Both features are consistently reported in the literature. There is to my knowledge no similar evidence for real wages. The underlying friction at the micro-level therefore relates to nominal rather than real wage rigidities.

Figure 3: *Effective DNWRs and Inflation*



***Notes**: The figure portrays a bivariate OLS regression between real wage growth ($\eta_{i,t}$) and inflation when downward nominal wage rigidities likely bind. The next section provides more details on the estimation of $\eta_{i,t}$. 90% predictive margins and observations are added. Emerging markets only.*

Fortunately, one can also directly test one key prediction from equation (1). If $\eta_{i,t}$ represents effective DNWR, then according to the structural framework in Section 2, $\eta_{i,t}$ should be negatively correlated with inflation. However, if the constraint relates to real wage rigidities, then as inflation increases, nominal wages would increase proportionally depending on the value of $\eta_{i,t}$. In other words, downward real wage rigidities do not have a built-in relationship with inflation. I test this hypothesis in Figure 3 for a subsample of emerging markets, which unlike advanced economies, experienced sizable variation in inflation. The chart provides results from a bivariate regression relating estimates of $\eta_{i,t}$ (real wage growth, when the nominal wage constraint likely binds) to inflation at the same time. Clearly, both series are negatively related, that is, the wage rigidity estimates are smaller when inflation increases. I next go into details on how to estimate $\eta_{i,t}$.

3.2. A Simple Algorithm to Estimate Effective DNWRs

Data: It is important to recognize that real wages in equation (1) refer to per-unit labor rather than monthly or annual income (see, also Section 2). To account for that I collect annual data on hourly earnings from the International Labor Organization (ILO) and the OECD.[3] I rely on the OECD series for advanced economies, because of their limited coverage in the ILO dataset. Both measures include overtime pay and regularly recurring cash supplements, but exclude benefits. Hourly earnings are expressed in local currency and hence deflated by the local consumer price index. The unbalanced sample contains 53 countries, 21 of which are advanced economies, from 1995-2020. Table A1 in the appendix lists all countries. Additional variables are described in the appendix.

Identification: One could in principle estimate $\eta_{i,t}$ in equation (1) by calculating gross real hourly earnings growth between two periods, in this case two consecutive years. However, this approach is only legitimate if the constraint happens to hold with equality, which is unobservable. Hence the subsequent algorithm starts with a simple method to select periods in which this wage constraint *plausibly* binds. There are three key observations that I subsequently explore.

First, the level of unemployment is not (very) informative about the presence

[3] The ILO hourly earnings' time coverage differs across 'vintages'. For example, a new vintage can start at a later date than the previous one or even exclude certain countries. I took great caution in combining different vintages in order to maximise time series coverage. Specifically, observations from two vintages are only merged when (i) overlapping periods indicate identical values, or (ii) when a country is only featured in one vintage. Individual outliers were also cross-checked for consistency with historic accounts.

of binding DNWRs. Based on the structural framework in Section 2, equation (1) binds whenever unemployment is positive. However, the model abstracts from important real world features, most notably frictional and structural unemployment.[4] Positive unemployment per-se therefore provides little guidance on whether the wage constraint binds or not. High unemployment rates of course could coincide with a binding wage constraint. However, it appears daunting to determine the relevant unemployment rate threshold, which is also plausibly varying by country. Hence I do not pursue this route. Second, favorable economic conditions in which unemployment declines tend to put upward pressure on wages and are thus not informative about downward wage rigidities. Third, periods of rising unemployment impose downward pressure on wages (or at least wage growth) and are therefore informative about downward wage rigidities. In particular, high real wage growth, despite positive inflation, is indicative of downward nominal or real wage rigidities. Similarly, if inflation is very high and real wages decline, although by less, then nominal wage rigidities could still bind, but effective DNWRs are likely muted. In contrast, if real wages decline when inflation is modest, DNWRs are less of a concern, and the effective DNWR estimate based on real wage growth would be small. In sum, periods of rising unemployment are informative about effective DNWRs.

Implementation: The first step in estimating effective DNWRs involves identifying unemployment cycles in the data. A cycle is defined by consecutive years with a rising unemployment rate. Each cycle lasts at least one year, but a cycle can also last multiple years in case a country experiences prolonged adverse effects on labor markets. Table E1 in the appendix lists the year prior to each individual cycle. Each year therefore indicates a local minimum in the unemployment rate. Overall, this procedure classifies 198 unemployment cycles, 113 for emerging markets and 85 for advanced economies.

The second step is to back out one estimate for downward wage rigidity per unemployment cycle. At this point it is necessary to introduce notation. Individual cycles in country i are indexed by $c(i) \in \mathbb{Z}$ for $c(i) = 1, ..., C(i)$, that is, there are $C(i)$ unemployment cycles in country i. Related, the last calendar year of cycle $c(i)$ is indexed by $T(c_i)$, and the year preceding the cycle by $0(c_i)$. The duration of each cycle is characterized by $H(c_i)$. With these conventions, the effective DNWR estimate of cycle $c(i)$ can be calculated as:

$$\widehat{\eta_{c(i)}} = \left(\frac{w_{i,T(c_i)}}{w_{i,0(c_i)}} \right)^{\frac{1}{H(c_i)}}. \tag{2}$$

[4] A model extension in Appendix C introduces positive unemployment absent a binding downward nominal wage constraint due to search and matching frictions.

The statistic simply measures annualized gross real wage growth during cycle c for country i. Equation (2) is closely linked to equation (1): If equation (1) binds, $\eta_{i,t}$ corresponds to gross real wage growth during one year of an unemployment cycle. I could therefore obtain one estimate per year and cycle, and subsequently average all estimates for each cycle to back out one estimate per cycle. This is exactly what equation (2) does. The distribution of $\widehat{\eta_{c(i)}}$ split by AEs and EMs is portrayed in Figure D1. Individual estimates for each country are available in Table E2.

In most of the subsequent applications, I further average over the cycle-specific wage rigidity estimates of country i. This paper centers around evaluating the impact of downward wage rigidities on recession dynamics. However, recessions are defined based on contractions in real GDP which only partially overlap with unemployment cycles. There is hence no transparent mapping between individual wage rigidity estimates and recessions. Besides this practical issue, there is also a more fundamental reason why one would average over individual country-specific estimates: a potential compositional bias as I will subsequently explain in more detail. For reference, the country-specific effective DNWR $\widehat{\eta_i}$ is defined as:

$$\widehat{\eta_i} = \frac{\sum_{c(i)=1}^{C(i)} \widehat{\eta_{c(i)}}}{C(i)}. \tag{3}$$

A well known concern related to using aggregate data is that low-skilled workers are more likely to lose their jobs during recessions. This counter-cyclical compositional bias dampens fluctuations in aggregate wage growth rates between recessions and expansions even absent wage rigidities (Solon et al., 1994; Abraham and Haltiwanger, 1995). By default, cycle-specific wage rigidity estimates already partially correct for this issue, since they are exclusively calculated based on wage growth rates during adverse labor market conditions. However, not every unemployment cycle is of the same magnitude. In other words, there could be differences in the compositional bias depending on the severity of the downturn. Calculating average effective DNWRs for each country mutes this concern and implicitly controls for the size of the shock.[5] The approach is further supported in Figure D3. The chart points to a sizable positive correlation between subsequent individual wage rigidity estimates for the same country. Wage rigidity estimates from preceding unemployment cycles therefore predict the subsequent estimate. In other words, within country variation, while at times large for individual countries, is on average relatively subdued, which limits the

[5] The average unemployment cycle could in principle differ significantly between countries. However, due to 25 years of data and multiple unemployment cycles per country, average dynamics are relatively similar.

information loss from averaging.

3.3. Estimation Results

Effective DNWRs are widespread, but overall larger across emerging markets. Tables 1 and 2 provide an overview on effective DNWRs for emerging markets and advanced economies respectively. Column 2 portrays estimates for η_i. A value above one points to real wage growth, despite rising unemployment. Just to reiterate, this does not necessarily imply that DNWRs actually bind. Rather countries with a high $\widehat{\eta}_i$ are more likely subject to economically meaningful downward wage rigidities. Overall, estimates vary widely among emerging markets. Six countries experience real wage declines ($\widehat{\eta}_i < 1$) driven by elevated inflation and/or limited DNWRs. In either case, effective DNWRs are small. The majority of emerging markets, however, face real wage growth when unemployment rises. Estimates for advanced economies are less dispersed, likely due to more stable inflation. Japan is the only developed economy with negative real wage growth. On average, real wage growth during unemployment cycles is higher in emerging markets (3.8%) than in advanced economies (1.8%), which may suggest more pronounced effective labor market rigidities in emerging markets. This is a noteworthy finding, considering that inflation is higher in emerging markets on average, which lowers real wage growth for a given level of DNWRs.

The third column in Tables 1 and 2 displays a labor productivity adjusted variant of $\widehat{\eta}_i$, which is simply denoted as $\tilde{\eta}_i$. The computation follows the same steps as detailed in the previous section. However, in addition to normalizing nominal earnings by the price index, earnings are also adjusted by long-run labor productivity growth. The latter is calculated as the country-specific sample average of real GDP per capita growth. Because of positive average real GDP per capita growth, adjusted real wages grow less and $\tilde{\eta}_i$ is smaller than $\widehat{\eta}_i$. Why do the tables present productivity adjusted rigidity estimates? Most macro models abstract from trend growth in productivity and impose a zero inflation steady state. The estimates in column 3 could therefore guide the calibration of models with DNWRs without trend inflation or productivity growth. Even with this adjustment, wage rigidities appear more prevalent in EMs rather than AEs (1.2% versus 0.1% productivity adjusted real wage growth). Last but not least, column 4 portrays the number of cycle-specific estimates for each country. The United States for example experienced three periods of rising unemployment between 1995 and 2020.

At this point it is useful to compare effective DNWRs in this paper with the estimates from Schmitt-Grohe and Uribe (2016). The authors estimate DNWRs

Table 1: *Effective DNWRs: Emerging Markets*

Country	$\widehat{\eta}_i$	$\tilde{\eta}_i$	#Estimates
Argentina	1.15	1.144	2
Cambodia	1.124	1.069	3
Chile	1.108	1.083	2
Honduras	1.098	1.088	5
Mauritius	1.094	1.063	4
Thailand	1.094	1.07	1
Peru	1.088	1.062	5
Mongolia	1.086	1.043	2
Vietnam	1.078	1.025	4
Sri Lanka	1.066	1.027	2
Panama	1.057	1.028	4
Philippines	1.054	1.027	3
Malaysia	1.045	1.02	3
Bolivia	1.039	1.021	5
Armenia	1.036	.98	3
Hungary	1.034	1.009	3
Turkey	1.034	1.005	3
Costa Rica	1.031	1.008	6
Pakistan	1.03	1.015	2
Poland	1.03	.992	4
Bosnia and Herzegovina	1.022	.948	2
Indonesia	1.019	.993	2
Uruguay	1.019	.999	2
Paraguay	1.005	.994	8
Mexico	1.004	.997	3
Brazil	1.002	.993	6
South Africa	.997	.99	3
Dominican Republic	.983	.952	7
El Salvador	.981	.972	5
Guatemala	.98	.968	4
Colombia	.976	.963	2
Ecuador	.85	.843	4
Average	1.038	1.012	

***Notes**: Column 2 displays effective DNWRs for each country ($\widehat{\eta}_i$). A higher value signals more pronounced rigidities. A value greater than one, suggests on average positive real wage growth during unemployment cycles. $\widehat{\eta}_i$ is defined in equation (3). The estimates in Column 3 adjust $\widehat{\eta}_i$ for long run productivity growth ($\tilde{\eta}_i$). Column 4 presents the number of cycle-specific estimates in each country.*

for Argentina and selected European countries while these countries pegged their exchange rate and therefore experienced limited inflationary pressures. These estimates can therefore be interpreted as representing effective DNWRs. Just as in this paper, the authors focus on periods of rising unemployment and calculate nominal wage growth adjusted for inflation and average productivity growth based on GDP per capita. Estimates in Schmitt-Grohe and Uribe (2016) range between $[0.990, 1.022]$, and are thus similar to the productivity adjusted estimates in this paper for countries and time periods that are available in both samples.

Table 2: *Effective DNWRs: Advanced Economies*

Country	$\hat{\eta}_i$	$\tilde{\eta}_i$	#Estimates
Lithuania	1.087	1.035	2
Latvia	1.041	.995	3
Czech Republic	1.026	1.005	1
Portugal	1.023	1.014	3
United States	1.02	1.006	3
Finland	1.019	1.003	4
Spain	1.019	1.01	3
Slovak Republic	1.016	.984	5
Germany	1.015	1.005	3
Iceland	1.015	.997	5
New Zealand	1.015	1.001	5
Sweden	1.015	.999	4
Austria	1.014	1.004	6
France	1.013	1.006	5
Korea, Republic of	1.013	.98	6
Denmark	1.012	1.001	4
Belgium	1.01	1	6
Italy	1.009	1.009	2
Luxembourg	1.008	.995	7
United Kingdom	1.008	.998	4
Japan	.986	.981	4
Average	1.018	1.001	

***Notes**: Column 2 displays effective DNWRs for each country ($\hat{\eta}_i$). A higher value signals more pronounced rigidities. A value greater than one, suggests on average positive real wage growth during unemployment cycles. $\hat{\eta}_i$ is defined in equation (3). The estimates in Column 3 adjust $\hat{\eta}_i$ for long run productivity growth ($\tilde{\eta}_i$). Column 4 presents the number of cycle-specific estimates in each country.*

3.4. Minimum Wages and Downward Wage Rigidities

In line with structural work by, for example, Hall (2005) or Schmitt-Grohe and Uribe (2016), this paper was so far agnostic on the underlying frictions causing downward nominal wage rigidities. This section ties the wage rigidity estimates to minimum wage policies, which serves two purposes: First, it links aggregate estimates to micro-level frictions, which adds to the plausibility of the measure. Second, the finding complements existing studies like Castellanos et al. (2004), or Ahn et al. (2022) who relate minimum wage policies to downward wage rigidities.

The narrative around minimum wages is straightforward: During recessions, firms would like to cut wages, but they may be unable if subject to a wage floor. Minimum wages can therefore introduce downward wage rigidities. Estimates on their prevalence generally vary widely across countries, but are sizable (Castellanos et al., 2004; Harasztosi and Lindner, 2019).

The downward wage rigidity measure calculated in this paper is closely associated with minimum wage growth. Figure 4 plots results from a simple bivariate regression where I regress the unemployment cycle-specific effective DNWR measure ($\widehat{\eta_{c(i)}}$) on real minimum wage growth during the same period. Nominal minimum wages are adjusted by the price level for consistency with the wage rigidity measure. The chart excludes periods with zero nominal minimum wage growth. As apparent, minimum wage growth is associated with higher hourly earnings and, as a consequence, higher downward wage rigidities.

Figure 4: *Explaining Wage Rigidities: Minimum Wages*

Notes: *The figure presents results from a bivariate OLS regression. Dependent variable (y-axis): Effective DNWRs ($\widehat{\eta_{c(i)}}$). Independent variable: Gross real minimum wage growth (x-axis). Minimum wage growth is computed during unemployment cycles. 90% predictive margins and observations are added. Unemployment cycles with zero nominal minimum wage growth are excluded, as well as episodes with real minimum wage growth exceeding 30% or below -10%.*

3.5. A Road Map and Micro-Level Evidence on Wage Rigidities

Wage rigidities in this paper are computed based on aggregate hourly real earnings during unemployment cycles. Just to be upfront, I resort to aggregate data due to the lack of consistent micro-level data across a large set of countries. But how reasonable is this approach? In this section, I first compare the aggregate wage rigidity estimates with micro-level evidence from payroll data. Both approaches provide similar results for an overlapping subsample. Then, I provide an outline on further robustness checks in subsequent sections.

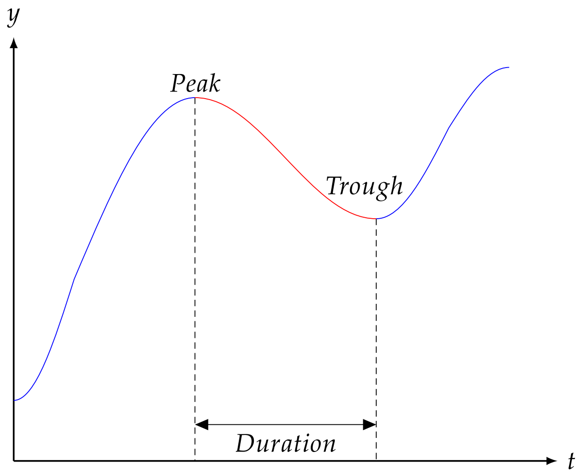
Micro-level Estimates: Elsby and Solon (2019) survey the literature on downward wage rigidities and collect estimates from various country-specific studies based on individual payroll and pay slip data. Importantly, their review contains 12 countries, most of which are advanced economies and also part of the sample in this paper, which makes a direct comparison possible. Of course this is not without a caveat: countries have different reporting standards for payroll data, the definition of wage freezes as a measure for downward wage rigidities also varies slightly by study, and, last but not least, the country-specific studies also consider a distinctive workforce. That said, I find resemblance between effective DNWRs and a payroll based measure as evident from Figure B1, Panel (b), and Table B1. I defer a thorough discussion, including how to construct payroll-based effective DNWRs from nominal wage freezes to the appendix, but highlight the main takeaways: First, among advanced economies with overlapping data, Portugal stands out as subject to the highest level of effective DNWRs based on both approaches. Second, many advanced economies have wage rigidities that are not too distinct from each other driven by relatively stable inflation over the sample period as discussed earlier. This is also mirrored in the payroll based measure. Third, because of this homogeneity, the precise ranking of effective DNWRs differs somewhat, but countries tend to appear in the same bracket across both rankings with the exception of Italy for which the sample periods do not overlap. Fourth, according to both approaches, effective DNWRs decrease with inflation.

Road Map: Section 4 provides further insights into the plausibility of the wage rigidity measure. I derive, test, and verify predictions based on the structural wage rigidity literature on how countries with high wage rigidities should behave relative to countries with low wage rigidities. Some of these hypotheses, like higher wage growth during downturns for countries with high wage rigidities are mechanically satisfied based on how I calculate wage rigidities. However, I also examine a host of other hypothesis that are not related to the construction of effective DNWRs in this paper, like the volatility in wage growth and unemployment, the path of employment during booms, or the amplitude and duration of recessions. These myriad of exercises suggest that the measure indeed captures effective DNWRs *and* that downward wage rigidities have macroeconomic implications across a large set of advanced economies and emerging markets.

4. Downward Wage Rigidities and Recession Dynamics

This section examines how effective DNWRs influence business cycles, focusing on recession periods. Specifically, I investigate if countries that are subject to more pronounced wage rigidities (higher $\widehat{\eta}_i$) experience more severe recessions in terms of employment and GDP losses. I also provide a series of descriptive statistics on the interplay between the wage rigidity measure and labor market dynamics.

Figure 5: *Filtering Turning Points*



Notes: *The solid line represents a hypothetical upward trending path in real GDP per capita (y). The blue sections represent expansions and the red sections contractions. The Bry and Boschan (1971) algorithm filters out contractions, defined by peak, trough and duration.*

4.1. Turning Points in Economic Activity

Downward wage rigidities represent a one-sided constraint. If these rigidities have macroeconomic consequences, they should materialize during a downturn. It is therefore necessary to distinguish recessions from expansions and focus on the former. Though it may be surprising, most countries do not have agencies that determine turning points in economic activity. I hence cannot resort to official statistics and instead implement the Bry and Boschan (1971) algorithm, the closest algorithmic interpretation of the NBER's definition of recessions (Jorda et al., 2011). Business cycles are determined based on real GDP per capita. The algorithm then essentially searches for local minima and maxima in business cycle activity (real GDP per capita). Each maximum is labeled as a peak and the subsequent minimum as the corresponding trough. A recession is subsequently defined as the period between peak and trough. Figure 5 illustrates the approach.

The algorithm extracts 107 recessions from 53 countries. Table E3 lists all individual peaks. Most recessions are related to the Asian Financial Crisis, the Global Financial Crisis and the European Debt Crisis. One may also wonder about the Covid-19 Pandemic. I do not include pandemic related recessions: The pandemic provoked unprecedented monetary and fiscal intervention. Recession paths are therefore dominated by the policy response and the spread of the virus. It is unlikely to observe significant effects from wage rigidities. Figure D2 provides insights on the duration of the 107 recessions. Most recessions last between one and three years.

4.2. Descriptive Evidence

Business Cycle Facts: Table 3 presents a series of descriptive statistics on the employment share and real GDP per capita during recessions stratified by the degree of wage rigidity. The table provides the average cumulative decline in pp (employment share) or % (GDP per capita) ('amplitude'), the average 'duration' of a recession in years and the annualized decline ('rate') defined as 'amplitude' over 'duration'. A country is subject to high (low) effective DNWRs if $\widehat{\eta}_i$ is above (below) the sample median. The table also list the number of observations, characterized by the number of recessions, in each bin. Some emerging markets have limited data on employment, hence the imbalance in observations for the employment to population ratio.

Table 3: *Business Cycle Facts*

	Amplitude		Duration		Rate	
	High $\widehat{\eta}_i$	Low $\widehat{\eta}_i$	High $\widehat{\eta}_i$	Low $\widehat{\eta}_i$	High $\widehat{\eta}_i$	Low $\widehat{\eta}_i$
Employment Population Ratio						
Mean	1.486	.853	1.474	1.6	.864	.567
Observations	38	45	38	45	38	45
Real GDP Per Capita						
Mean	4.386	3.773	1.426	1.642	3.163	2.07
Observations	54	53	54	53	54	53

Notes: *Amplitude is the peak to trough cumulative decline in pp (employment) or % (GDP per capita). Duration is the peak to trough time in years. Rate is the annualized decline from peak to trough computed as Amplitude/Duration. The sample is split by the degree of wage rigidities. High $\widehat{\eta}_i$ (low $\widehat{\eta}_i$) refers to subsamples with effective DNWRs above (below) the sample median.*

The employment share drops by 1.5 pp during a recession if the country is subject to higher effective DNWRs, but only by 0.9 pp if subject to no/muted rigidities. This difference persists on an annualized basis with 0.9 pp versus 0.6 pp. With regard to real GDP per capita, it appears that economies experience more severe contractions if subject to higher wage rigidities (4.4% versus 3.8%). The annualized decline is roughly 1.1 pp larger.

Labor Market Volatility: Table 4 characterizes the volatility (standard deviation) of the employment to population ratio, the unemployment rate and real wage growth relative to the extent of downward wage rigidities. As visible, countries with high effective DNWRs (based on median threshold) experience much more volatile changes in employment and unemployment, but less volatility in wage growth. In more detail, the standard deviation of changes in the employment ratio is about 2 for high wage rigidity countries but only 1.4 for countries with low downward rigidities. A similar pattern emerges for changes in the unemployment rate. However, the standard deviation of wage growth is 18 for low wage rigidity countries but only 6.5 for high wage rigidity economies. Overall, all of these numbers suggest that countries with a high wage rigidity estimate (high $\widehat{\eta}_i$) are more likely to have binding wage constraints. Hence employment adjusts more forcefully, while wages are less volatile.

Table 4: *Wage Rigidities and Volatility*

	sd(Δ Employment)		sd(Δ Unemployment)		sd(Δln Wage)	
	High $\widehat{\eta}_i$	Low $\widehat{\eta}_i$	High $\widehat{\eta}_i$	Low $\widehat{\eta}_i$	High $\widehat{\eta}_i$	Low $\widehat{\eta}_i$
Mean	2.063	1.393	1.281	1.088	6.471	18.025
Observations	497	554	675	650	437	523

Notes*: The table portrays the standard deviation of changes in the employment to population ratio, the unemployment rate (both in pp) and real wage growth (in %). The sample is split by the degree of wage rigidities. High $\widehat{\eta}_i$ (low $\widehat{\eta}_i$) refers to subsamples with effective DNWRs above (below) the sample median.*

Wage and Employment Distributions: Next, I analyze the annual wage and employment change distributions for countries with high and low downward wage rigidity (threshold based on median) stratified by the business cycle phase. The idea is that countries with higher effective DNWR should exhibit higher real wage growth during recessions. Similarly, employment should decline by more. However, these features should vanish once countries enter expansionary territory. Figure 6 confirms the aforementioned predictions. Panel (a) plots annual real wage growth for countries with high downward wage rigidities (blue) and low wage rigidities (red) during recessions. Solid lines represent kernel densities. Clearly, the distribution for countries with low wage rigidities exerts stochastic dominance over the distribution of high wage rigidity countries. In other words, wage growth during recessions is higher for countries with high downward wage rigidities. This is of course an artifact of the estimation procedure. Countries with higher effective DNWRs are expected to be subject to higher real wage growth during downturns. Hence this is more of a sense check, rather than a new insight. However, the algorithm does not condition on employment losses. Panel (b) provides results from a similar exercise just for changes in the employment to population ratio rather than wage growth. As apparent, the employment change distribution of countries with high downward wage rigidities stochastically dominates the distribution of low downward wage rigidity countries, implying larger employment losses. Figure D4 provides corresponding distributions for expansions. There is no difference between countries with high/low downward wage rigidities. Effective DNWRs as as calculated in this paper only matter during recessions, just as implied by the theory.

Wage Growth and Unemployment: According to theories about downward wage rigidities, wages in countries with high rigidities should not be sensitive to the

Figure 6: *Wage Rigidities and Labor Markets during Recessions*

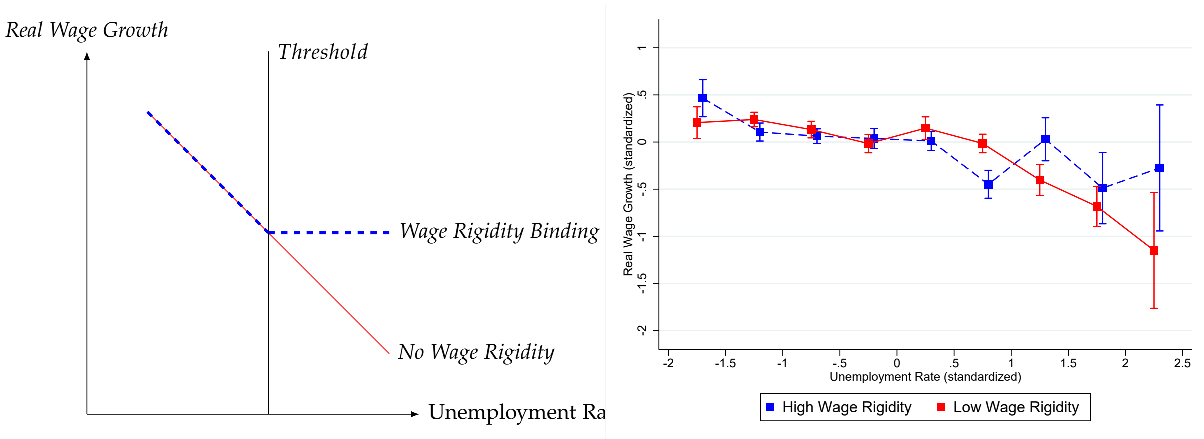
(a) *Δln Wage* ***(b)*** *Δ Employment*

Notes: *Real wage growth (in %) and changes in the employment to population ratio (in pp) at annual frequency during recessions based on the degree of downward wage rigidity. Recessions are defined by negative real GDP growth. Solid lines represent kernel densities and bars the raw data. "Low (High) Wage Rigidity" refers to subsamples with effective DNWRs below (above) the median.*

unemployment rate once unemployment is elevated and the wage constraint binds. In contrast, when the unemployment rate is relatively low, or when downward wage rigidities do not bind, higher unemployment exerts downward pressures on nominal or real wages.

Figure 7: *Wage Growth and Unemployment: The Role of Downward Wage Rigidities*

(a) *Benchmark* ***(b)*** *Data*



Notes: *Panel (a) provides a theoretical benchmark for the relationship between wage growth and the unemployment rate depending on whether the downward wage constraint binds or not. Panel (b) adds empirical evidence. Real wage growth and the unemployment rate are standardized for each country. The unemployment rate is discretized into 0.5 standard deviation bins and 1 standard error bands around point estimates are added. A country is subject to high (low) downward wage rigidities if effective DNWRs are above (below) the sample median.*

Figure 7, Panel (a), provides a theoretical benchmark for the relationship between wage growth and the unemployment rate. Just to be upfront, the model in Section 2 does not feature unemployment when the wage constraint does not bind. I therefore extent the baseline framework in Appendix C along the lines of Blanchard and Galí (2010). In more detail, their model incorporates Nash bargaining and search costs that are increasing in labor market tightness which introduces involuntary unemployment even when the wage constraint does not bind. In this extension, rising unemployment exerts downward pressure on wage growth as long as the one-sided downward wage constraint does not bind. However, once downward wage rigidities bind, as indicated by the black vertical line, wage growth is unrelated to the unemployment rate (dashed blue line). For a country that is not subject to wage rigidities, higher unemployment continues to push wage growth lower (red line).

Panel (b) provides matching empirical evidence. Real wage growth and the unemployment rate are standardized to account for differences in level and volatility across countries. The standardized unemployment rate is further discretized into bins of 0.5 standard deviations each. The blue (red) line and dots refer to countries with high (low) effective DNWRs, defined relative to median wage rigidities as before. Two findings emerge. First, when the unemployment rate is low, there are no noticeable differences across countries with high or low downward wage rigidities. A higher unemployment rate does seem to lower real wage growth. Second, when the unemployment rate increases to relatively high levels, wage growth in countries with high downward wage rigidities becomes unresponsive to the unemployment rate, while wages in countries with low wage rigidities continue to decline.

Overall, the wage rigidity estimates provide theoretically consistent predictions on various dimensions. The section also provided preliminary evidence on recession dynamics conditional on the degree of effective DNWRs. The subsequent section expands these insights by means of a formal regression analysis.

4.3. Formal Analysis based on Local Projections

This section formally examines the effects of downward wage rigidities on employment and GDP during recessions via Local Projections (Jordà, 2005). Two results stand out. First, countries with higher effective DNWRs experience a significantly larger contraction in employment relative to countries with lower downward wage rigidities. This effect is also economically large. Three years into a recession, the employment to population share cumulatively drops by roughly 10 pp for countries with high downward wage rigidities, but less than 2 pp for countries with low downward wage rigidities. Second, the impact of effective DNWRs on GDP is somewhat more muted but still significant at a horizon of three years, with real GDP per capita cumulatively declining roughly 8.5% in countries with high rigidities at the end of the third year since the beginning of a recession, relative to a 6% decline in countries with low rigidities.

To provide more details on the analysis, the 'Recession Local Projection' tracks the effects of effective DNWRs on the average path of real GDP per capita and the employment to population ratio for up to three years since the last business cycle peak. There are few recessions in the data that last beyond three years, hence this particular threshold. Just to be upfront, the results should not be interpreted in a causal sense. There is no exogenous sources of variation in wage rigidities, nor are there obvious natural experiments available. Wage rigidities are clearly endogenously determined. However, the impulse response functions shed light on how the path of the economy would be, if wage rigidities had deviated from its conditional mean.[6] To add context, I estimate:

$$\Delta_{\tau(r)+h} y_i = \sum_{h=1}^{H(r)} \beta_h Pk_{i,\tau(r)+h} + \sum_{h=1}^{H(r)} \phi_h Pk_{i,\tau(r)+h} \frac{\widehat{\eta}_i - \overline{\eta}}{sd(\widehat{\eta}_i)} + \epsilon_{i,\tau(r)+h}, \tag{4}$$

which follows the specification of Jordà et al. (2013) in a different context. The dependent variable y_i represents the logarithm real GDP per capita, or the employment share of country i. $\Delta_{\tau(r)+h} y_i = y_{i,\tau(r)+h} - y_{i,\tau(r)}$ is hence defined as the cumulative change in y_i between years $\tau(r)$ and $\tau(r) + h$. I use the notation $\tau(r)$ to refer to the calendar year of the r-th business cycle peak and h to indicate the number of years after the most recent peak.

The variable $Pk_{i,\tau(r)+h}$ is a binary indicator. The indicator equals one, if country i experienced its last peak h years ago. The coefficient vector $\{\beta_h\}_{h=1}^{H}$ characterizes the cumulative recession path of the dependent variable for a country with average wage rigidities. The second term in equation (4) captures the interaction between the recession response and effective DNWRs. I standardize $\widehat{\eta}_i$ in the regression analysis. Consequently, one can interpret the term $\frac{\widehat{\eta}_i - \overline{\eta}}{sd(\widehat{\eta}_i)}$ as excess effective DNWRs in units of standard deviations. The parameter ϕ_h therefore represents the cumulative marginal effect of a one standard deviation treatment applied to the wage rigidity measure. The parameters (β, ϕ) are of chief interest, and provide the conditional path for the response of each dependent variable. Finally, it is well known that error terms in Local

[6] A particular concern is reverse causality. As a prior it appears plausible to argue that more severe recessions induce more downward pressure on real wage growth. If so, the estimates are downward biased and therefore conservative. Further, wage rigidities are computed during unemployment cycles and not recessions. These episodes only partially overlap.

Projections are serially correlated. In light of the panel structure, I therefore estimate robust standard errors clustered at the level of each recession cycle.

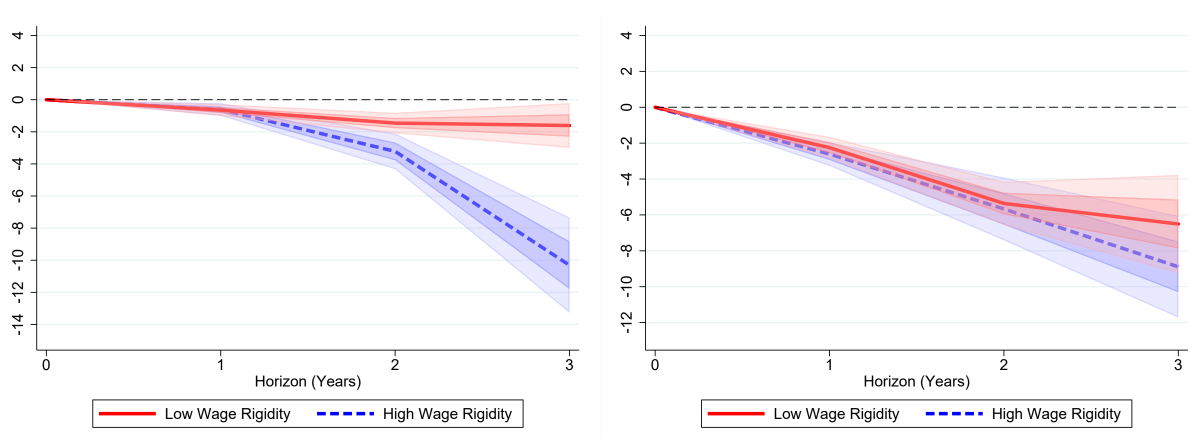
With this notation in mind, it is straightforward to derive impulse response functions. I plot two responses, with effective DNWRs equal to plus/minus x=0.5 standard deviations of the sample mean. The recession paths are therefore:

$$\{\beta_h + x\phi_h\}_{h=1}^{H}: \quad \text{Avg.+xStd.Dev.}$$
$$\{\beta_h - x\phi_h\}_{h=1}^{H}: \quad \text{Avg.-xStd.Dev.}$$

Main Results: The baseline results for the entire sample of advanced economies and emerging markets are presented in Figure 8. The solid red line displays the average recession path of a country with wage rigidities 0.5 standard deviations below the sample mean ($\beta_h - 0.5\phi_h$). The dashed blue line characterizes the path for a country with wage rigidities 0.5 standard deviations above the sample average ($\beta_h + 0.5\phi_h$). The difference between both paths is the effect of a 1 standard deviation change in effective DNWRs. Shaded red and blue areas represent one and two standard error cluster robust confidence bands.

***Figure 8:** Recession Paths: All Countries, Wage Rigidity Treatment +- 0.5 Standard Deviations*

***(a)** Employment* ***(b)** GDP*



***Notes**: Local Projections as specified in equation (4). Dependent variables: Cumulative change in the employment to population ratio (in pp) (Panel (a)), cumulative change in real GDP per capita (in %) (Panel (b)). "Low (High) Wage Rigidity" corresponds to the response of a country with -0.5(+0.5) standard deviations in effective DNWRs from the mean. Shaded areas are 1 and 2 cluster robust s.e. bands around response estimates.*

Focusing on Panel (a), the employment to population ratio declines by 0.6 pp during the first year of a recession. There are no noticeable differences across countries with high or low effective DNWRs. This finding however dramatically changes during years 2 and 3. In year 2, the employment share for countries with high wage rigidities drops by 3.2 pp cumulatively, relative to 1.4 pp for countries with low downward wage rigidities. This gap widens in year 3, with 10.3 pp versus 1.6 pp. Figure D5 in the appendix plots the difference between both lines including confidence bands and confirms the statistically and economically significant difference between the two responses in years 2 and 3. Turning to output, real GDP per capita declines by roughly 2.4% in year 1 and 5.5% by year 2. Wage rigidities do not appear to drive the response until year 3. In year 3, the Local Projection estimates a contraction of 8.9% for countries with high wage rigidities, but only 6.5% for countries with low rigidities. This difference is sizable, and significant as highlighted in Figure D5. In sum, effective DNWRs have a strong impact on employment during most of the recession cycle. However, the impact on real GDP is more muted and only observable in year 3, that is, only for recessions that actually lasted that long. The more pronounced impact on labor markets should however not surprise. Wage rigidity is a friction that foremost affects labor markets. Output in turn is driven by a host of factors, the labor market is only one of them.

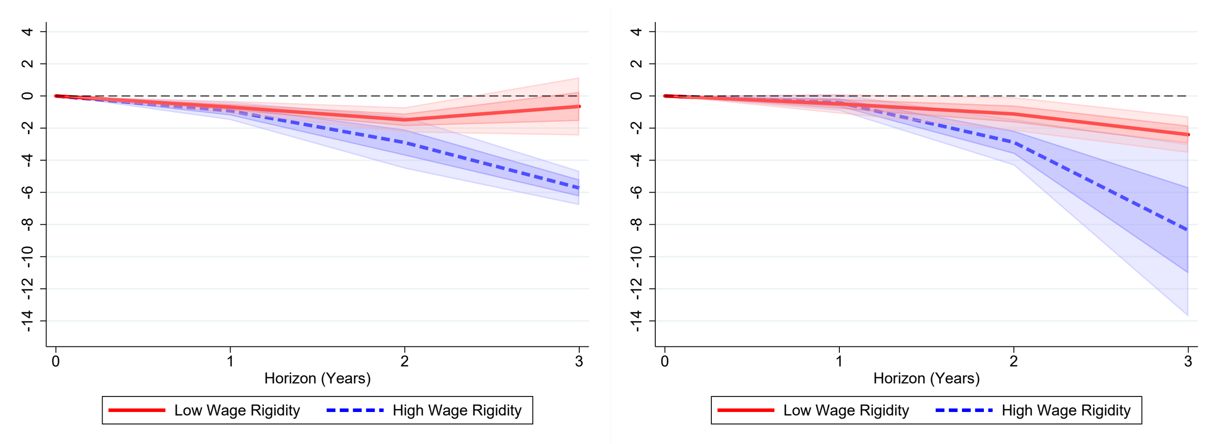
Next, I explore if effective DNWRs primarily matter for advanced economies or emerging markets for two reasons: First, much of the literature around downward wage rigidities centers around advanced economies. Hence it is natural to ask if one can observe similar implications for employment and GDP for emerging markets as well. Second, a large share of the variation in $\widehat{\eta}_i$ is due to the heterogeneity in emerging markets. The results for the whole sample could therefore stem from the variation across emerging markets. Put differently, the responses in Figure 8 are an average across recession cycles in the sample, weighted by relative share of recessions in AEs and EMs respectively, but a priori, it is not clear if the responses are driven by AEs, EMs, or both.

Figure 9 provides insights for employment and Figure 10 for output. The approach is very similar to the baseline analysis with one exception: I focus on subsamples, and as a consequence, also standardize effective DNWRs relative to the specific subsample.[7] As apparent from Figure 9, the responses for employment are quite similar: The contraction in employment is somewhat more pronounced for EMs with an additional roughly 2 pp drop, however the difference between countries with high and low wage rigidities remains stable. Thus, high wage rigidities negatively affect employment in both AEs and EMs. Figure D6 plots the difference between the responses for high and low wage rigidities and confirms the similarity.

[7]This step is necessary to interpret ϕ_h as the effect from a one standard deviation treatment to effective DNWRs. However, the results are nearly identical without the re-normalization.

Figure 9: Recession Paths: Employment, Advanced Economies versus Emerging Markets

(a) Advanced Economies *(b) Emerging Markets*



***Notes**: Local Projections as specified in equation (4). Dependent variable: Cumulative change in the employment to population ratio (in pp). "Low (High) Wage Rigidity" corresponds to the response of a country with -0.5(+0.5) standard deviations in effective DNWRs from the mean. Shaded areas are 1 and 2 cluster robust s.e. bands around response estimates.*

Wage rigidities influence output in advanced economies, but less so in emerging markets. Based on Figure 10, Panel (a), the recession path in AEs is somewhat more muted for countries with low wage rigidities during the first 2 years, but the difference is not significant as confirmed in Figure D7. The response gap between high and low wage rigidities in the third year is however sizable with 8.6 pp. Turning to emerging markets in Panel (b), wage rigidities once again do not influence output contractions during the first two years. The difference by year 3 equals 2.1 pp, which is noticeable and statistically significant as highlighted in the appendix. Overall though, from the perspective of the response gap, effective DNWRs primarily affect output dynamics in AEs. The difference could be related to the large informal sector in EMs, which might absorb employment losses in the formal sector.[8]

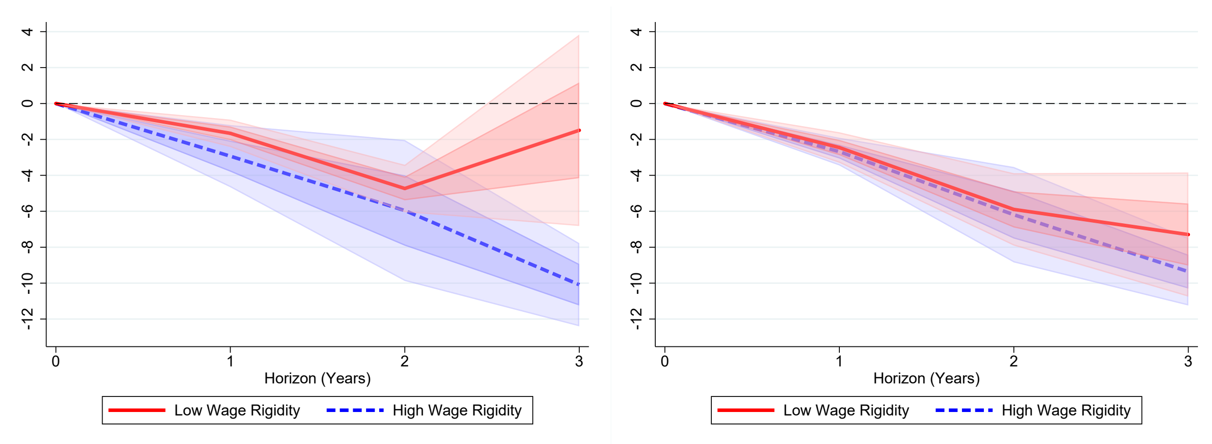
Adding Control Variables: To add robustness to the baseline results I include a variety of control variables as highlighted in the following specification:

$$\Delta_{\tau(r)+h} y_i = \sum_{h=1}^{H(r)} \beta_h Pk_{i,\tau(r)+h} + \sum_{h=1}^{H(r)} \phi_h Pk_{i,\tau(r)+h} \frac{\widehat{\eta}_i - \overline{\eta}}{sd(\widehat{\eta}_i)} + \Gamma X_{i,\tau(r)+h} + \epsilon_{i,\tau(r)+h}. \quad (5)$$

[8]The idea is that with downward rigid wages in the formal sector, and with large employment losses, former formal sector workers might transition to the informal sector, which is plausibly less rigid. This substitution is not captured in the employment to population ratio, which is only based on formal employment. Goods and services produced informally but sold in regular markets in contrast count towards GDP. Due to a lack of data about informal sectors, I however cannot test this hypothesis formally.

Figure 10: *Recession Paths: GDP, Advanced Economies versus Emerging Markets*

(a) *Advanced Economies* ***(b)*** *Emerging Markets*



Notes*: Local Projections as specified in equation (4). Dependent variables: Cumulative change in real GDP per capita (in %). "Low (High) Wage Rigidity" corresponds to the response of a country with -0.5(+0.5) standard deviations in effective DNWRs from the mean. Shaded areas are 1 and 2 cluster robust s.e. bands around response estimates.*

The new feature is a vector of control variables, $X_{i,\tau(r)+h}$, with coefficient vector Γ. I consider two sets of control variables: control variables that are possibly related to wage rigidities and control variables that are known to drive business cycle dynamics. Control variables possibly related to wage rigidities include the prevalence of collective bargaining between workers and firms, the union density, de jure labor market rigidities, and minimum wage growth. As these variables may contain information about wage rigidities, they may potentially weaken the estimated effects of effective DNWRs on employment and GDP. The results are summarized by Figures D8 and D9, and confirm this hypothesis. In particular, comparing the left panel of these figures with the benchmark (i.e., the left panel in Figure D5), downward wage rigidities no longer exert a significant effect on employment during the first two years. The effect of downward wage rigidities on GDP also weakens somewhat.

I also consider several control variables that are important in driving a country's employment and GDP dynamics during recessions: credit growth prior to a recession defined as the annualized change in the credit-to-GDP ratio over three years prior to the recession (see, for example, Jordà et al., 2013), the export-to-GDP ratio to control a country's vulnerability to external shocks, the bilateral exchange rate (relative to the U.S. dollar) to control for business cycle fluctuations due to currency variations (see, for example, Obstfeld et al., 2019) and the oil price as some primarily emerging markets rely on oil exports, which in turn drives domestic developments. Overall, these variables capture country-specific factors and may isolate the impact of the wage rigidity measure on employment and GDP. As shown in Figure D10, including these variables keeps the results largely unchanged relative to the benchmark case (Figure D5). The effect of wage rigidities on employment decreases somewhat, but the results for GDP are more significant.

Finally, including both sets of control variables resembles the findings from just including the four variables possibly related to the wage rigidity measure as evident from Figure D11. The analysis in this subsection thus provides supporting evidence that the main empirical results are robust.

Placebo Regressions based on Expansions: To further assess the validity of the downward wage rigidity measure I now examine its effects on employment during expansions. The idea is that, if $\widehat{\eta}_i$ in equation (3) picks up downward wage rigidities, it should not affect labor markets during an expansion when the wage constraint usually does not bind. The placebo regression reads:

$$\Delta_{\tau(r)+h} y_i = \sum_{h=1}^{H(r)} \beta_h Tr_{i,\tau(r)+h} + \sum_{h=1}^{H(r)} \phi_h Tr_{i,\tau(r)+h} \frac{\widehat{\eta}_i - \overline{\eta}}{sd(\widehat{\eta}_i)} + \epsilon_{i,\tau(r)+h}. \quad (6)$$

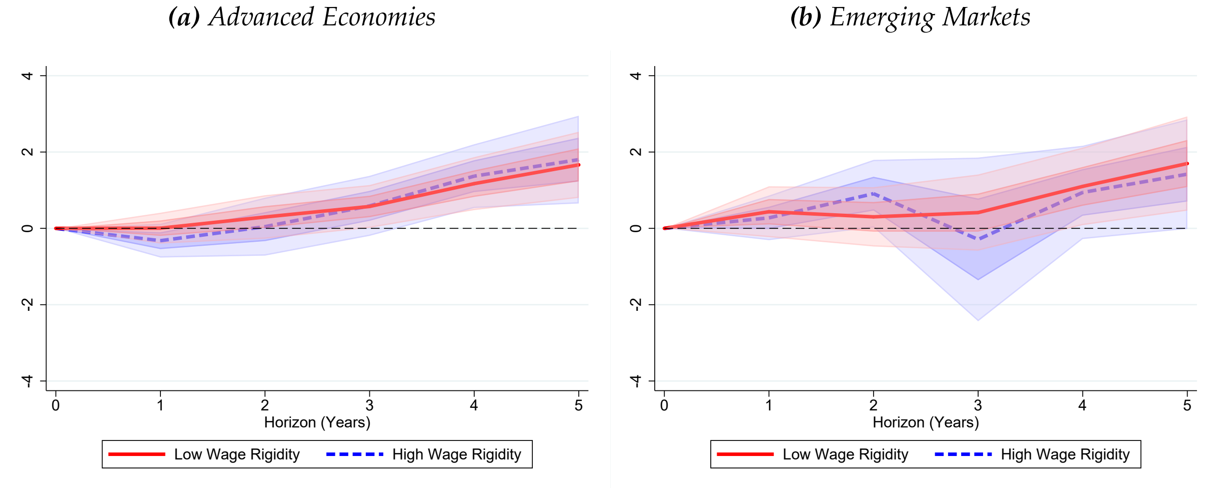
The equation is similar to the baseline recession projection (4) with one notable exception: I examine expansionary paths instead of recession dynamics and therefore replace the peak dummy $Pk_{i,\tau(r)+h}$ with a trough dummy $Tr_{i,\tau(r)+h}$. The dummy is one, if a country experienced its last trough h years ago. Because expansions last longer than recessions, it is feasible to analyze up to five years from the most recent trough. The relevant null hypothesis is then whether the vector $\{\phi_h\}_{h=1}^{H}$ equals zero.

Figure 11 plots the employment response path during expansions, depending on the degree of effective DNWRs. The employment share moves upward among AEs and EMs. This trend is delayed by one year for AEs, which is a well known business cycle fact (Stock and Watson, 1999). However, the important insight from these projections pertains to the indistinguishable difference between countries with high or low downward wage rigidities. Indeed, the solid red and blue dashed lines basically overlap. The employment path during expansions hence does not depend on downward wage rigidities. This supports the notion that $\widehat{\eta}_i$ only matters during recessions, just as predicted by the one-sided wage constraint.

5. Conclusion

This paper provides a simple framework to calculate effective DNWRs in aggregate data over a wide range of countries. The approach preserves consistency and shows

Figure 11: Placebo: Employment Expansion Path



***Notes**: Local Projections as specified in equation (6). Dependent variable: Cumulative change in the employment to population ratio (in pp). "Low (High) Wage Rigidity" corresponds to the response of a country with -0.5(+0.5) standard deviations in effective DNWRs from the mean. Shaded areas are 1 and 2 cluster robust s.e. bands around response estimates.*

widespread wage rigidities across advanced and emerging economies. As an additional benefit, the estimates are readily available as a reference when calibrating quantitative structural models. Furthermore, to the best of my knowledge, this paper is the first to provide direct cross-country empirical evidence on the relevance of downward wage rigidities in driving recession dynamics: Countries with noticeable downward wage rigidities perform worse in terms of employment and real GDP.

The analysis also provides two important policy implications. First, downward wage rigidities are related to minimum wage growth, suggesting that policymakers need to be cautious in raising minimum wages when labor markets are slack. Second, inflation can grease the wheels and improve macroeconomic outcomes when nominal wages are downward rigid: Inflation lowers effective DNWRs, which in turn mute negative recession dynamics. This analysis hopefully stimulates further discussions on the relevance and determinants of wage rigidities and how to attenuate its negative effects.

A. Appendix: Data

***Table A1:** Country List*

EMs			
Argentina	Costa Rica	Malaysia	Philippines
Armenia	Dominican Republic	Mauritius	Poland
Bolivia	Ecuador	Mexico	South Africa
Bosnia and Herzegovina	El Salvador	Mongolia	Sri Lanka
Brazil	Guatemala	Pakistan	Thailand
Cambodia	Honduras	Panama	Turkey
Chile	Hungary	Paraguay	Uruguay
Colombia	Indonesia	Peru	Vietnam
AEs			
Austria	Germany	Lithuania	Sweden
Belgium	Iceland	Luxembourg	United Kingdom
Czech Republic	Italy	New Zealand	United States
Denmark	Japan	Portugal	.
Finland	Korea, Republic of	Slovak Republic	.
France	Latvia	Spain	.

Variables and Data Sources

Collective Bargaining: Number of employees whose pay/conditions of employment are determined by a collective agreements as a percentage of the total number of employees. (Source: ILO)

CPI: Consumer price index. Inflation is constructed as the log difference. (Source: IMF)

Credit to GDP Ratio: Domestic credit to private sector as a percent of GDP. (Source: World Bank)

De jure Labor Market Restrictions: De jure rigidity of employment protection legislation. (Source: Campos and Nugent, 2012)

Employment to Population Ratio: For ages 15+ in percent. (Source: ILO)

Exchange Rate: Local currency units per U.S. dollar. (Source: World Bank)

Export to GDP Ratio: Exports of goods and services as a percent of GDP. (Source: World Bank)

GDP: Gross domestic product per capita in constant local currency. (Source: World Bank)

Hourly Earnings: Nominal hourly earnings data combined from the OECD MEI and ILOSTAT. (Source: OECD and ILO)

Minimum Wage: Nominal hourly minimum wage. (Source: ILO)

Oil Prices: U.S. dollars per barrel at year end. (Source: Bloomberg)

Unemployment Rate: Unemployment as a percent of the total labor force. (Source: ILO)

Union Density: Number of union members who are employees as a percentage of the total number of employees. (Source: ILO)

B. Appendix: Evidence from Payroll Records and Pay Slips

This section compares effective DNWRs ($\widehat{\eta}_i$) with micro-level estimates from payroll and pay slips data. Micro-level studies are usually country-specific, but Elsby and Solon (2019) summarize and compare individual payroll based studies across 12 economies. Figure B1, Panel (a) portrays the share of workers subject to nominal wage freezes and the level of inflation in a scatter plot based on their data. Nominal wage freezes are a common proxy for DNWRs. Each dot corresponds to a specific country and year. Strikingly, the share of workers with nominal wage freezes decreases with inflation. The prevalence of DNWRs therefore decrease with inflation just as implied by the measure in this paper.

Given that countries have different inflation environments, I normalize the share of wage freezes by inflation to measure wage freezes in excess of what would be predicted by inflation. This mirrors the approach in this paper on effective DNWRs. I thus estimate the following regression:

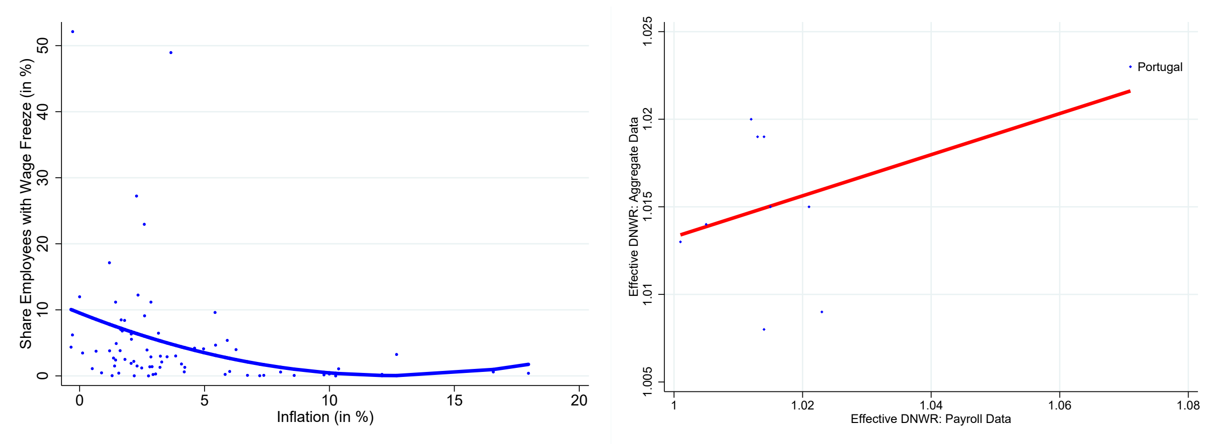
$$Freeze_{i,t} = \alpha + \beta_1 \pi_{i,t} + \beta_2 \pi_{i,t}^2 + \epsilon_{i,t},$$

which is also portrayed in Figure B1, Panel (a). The second order polynomial is chosen to account for the non-linearity between inflation and nominal wage freezes. All subsequent results will go trough with alternative non-linear specifications such as third order polynomials or flexible splines. The error term $\epsilon_{i,t}$ in this regression measures excess downward wage rigidity normalized by inflation and thus resembles $\widehat{\eta_{c(i)}}$, that is, the inflation adjusted DNWRs. I subsequently average the estimated residuals for each country and normalize this average to match the mean and standard deviation of $\widehat{\eta_{c(i)}}$.

Figure B1, Panel (b) plots the downward wage rigidity measure based on payroll data against $\widehat{\eta}_i$. As apparent, the correlation between both is positive. Particularly, Portugal is identified as the most rigid in the overlapping sample based on both measures. One might be worried that the positive slope is entirely driven by this observation, but a rank statistic, which is less sensitive to outliers, provides similar

***Figure B1:** Downward Wage Rigidities based on Payroll Data*

***(a)** Nominal Wage Freezes and Inflation* | ***(b)** Effective DNWRs and Payroll Evidence*



***Notes**: Panel (a): The panel presents results from a bivariate second order polynomial OLS regression. Dependent variable (y-axis): Share of employees receiving nominal wage freezes in %. Independent variable: Inflation in % (x-axis). Observations are added. Observations with more than 25 % annual inflation are deleted. Panel (b): Scatter plot with line of best fit representing the relationship between effective DNWRs in this paper ($\widehat{\eta}_i$) and the measure based on payroll data.*

patterns. Table B1 provides more details and tabulates both measures. In terms of outliers, both measures agree on Portugal as having very high wage rigidities; both measures are close for the United Kingdom, which is identified with mild downward wage rigidities in the payroll data. The measures differ for Italy, which is classified as more rigid in the payroll data, but that may be explained by non-overlapping time periods. Overall though, most advanced economies have similar wage rigidities according to both measures.

***Table B1:** Comparison: Aggregate Data versus Payroll Evidence*

Country	$\widehat{\eta}_i$	Payroll
Portugal	1.023	1.071
United States	1.02	1.012
Finland	1.019	1.013
Spain	1.019	1.014
Germany	1.015	1.021
Sweden	1.015	1.015
Austria	1.014	1.005
Korea, Republic of	1.013	1.001
Italy	1.009	1.023
United Kingdom	1.008	1.014

***Notes**: This table compares effective DNWRs based on aggregate data (column 2) with evidence from payroll records (column 3). A higher value signals more pronounced rigidities. The table omits Ireland, which is not in the sample of this paper, and Mexico as the only emerging market in Elsby and Solon (2019).*

C. Appendix: Model Extension

This section provides an extension to the baseline framework in Section 2, which features involuntary unemployment even when the downward wage constraint does not bind.

In addition to baseline setup, suppose that the representative household is made up of a continuum of members with a total size of one. Employment at the firm evolves according to:

$$l_t = (1-\delta)l_{t-1} + h_t.$$

The parameter δ is an exogenous job separation rate and h_t represents new hires. l_t continues to indicate labor, that is, the share of household members who are employed. Unemployment at the beginning of the period is characterized by:

$$u_t = 1 - l_{t-1} + \delta l_{t-1}.$$

The first term refers to the share of individuals who were unemployed at the end of last period, and the second term to the newly unemployed. I assume that hiring costs (g_t) are proportional to labor market tightness defined as new hires over the number of unemployed with $\xi > 0$:

$$g_t = \left(\frac{h_t}{u_t}\right)^{\xi}.$$

The hiring costs also indicate the firm's surplus from a match with a worker. The surplus for a worker is for simplicity assumed to be proportional to the wage. The proportionality factor (κ) includes future wage income if a match is not separated. Prospective workers and firms engage in Nash bargaining. Hence:

$$\kappa w_t = \psi g_t.$$

The parameter ψ represents the relative bargaining power of workers. Intuitively, the equation implies that wages decline in the number of unemployed workers, precisely because a weak labor market reduces hiring costs for firms, which diminishes the value of an existing match. Without loss of generality and to keep the framework tractable, I assume that $\psi = \kappa$. Firms choose new hires to maximize profits. If the downward nominal wage constraint does not bind, firms equate the marginal product of labor with the hiring costs:

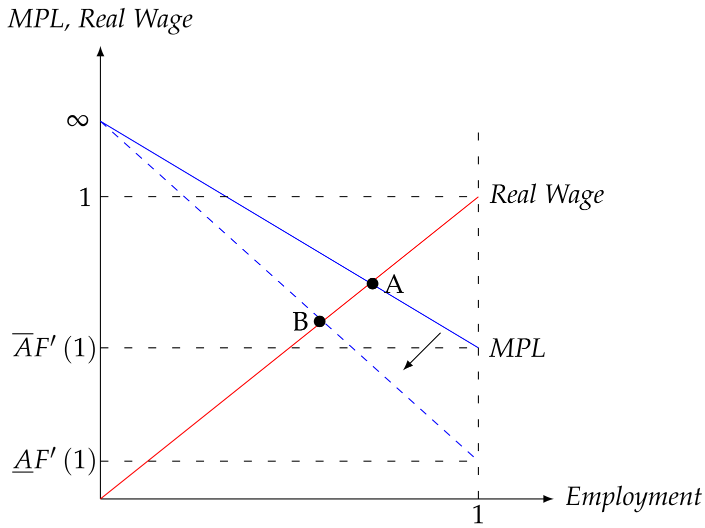
$$A_t F'\left((1-\delta)l_{t-1}+h_t\right)=\left(\frac{h_t}{1-l_{t-1}+\delta l_{t-1}}\right)^{\xi}.$$

In contrast, if the downward wage constraint binds, w_t, and hence the right hand side of the previous equation, will be determined by the wage constraint.

I subsequently analyze steady states when the economy is subject to an unanticipated and permanent adverse technology shock. In steady state, labor is determined by the following equation:

$$AF'(l)=\left(\frac{\delta l}{1-(1-\delta)l}\right)^{\xi}.$$

Figure C1: *Labor Market: Extended Model*

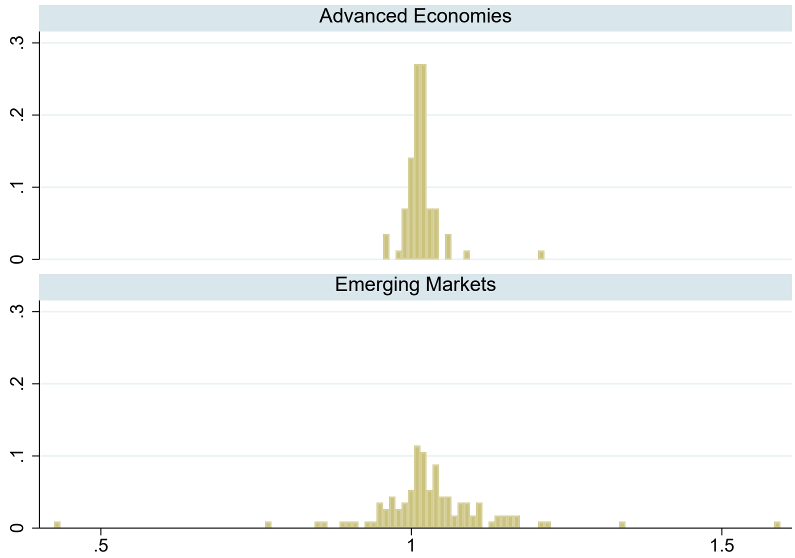


Notes: *The red line represents the real wage, the blue line the marginal product of labor. The initial equilibrium is marked (point 'A'). The chart highlights the consequences of a permanent negative shock to A from $\overline{A}$ to $\underline{A}$. The negative shock reduces the marginal product of labor and equilibrium employment (point 'B').*

The effect of a permanent negative productivity shock on labor is illustrated in Figure C1. The adverse shock reduces the marginal product of labor, while it has no direct effect on search costs and hence wages. As a consequence, employment declines, or equivalently unemployment increases. The less tight labor market reduces hiring costs and therefore real wages. This establishes the negative relationship between wages and unemployment when the borrowing constraint does not bind, as portrayed in Figure 7, Panel (a).

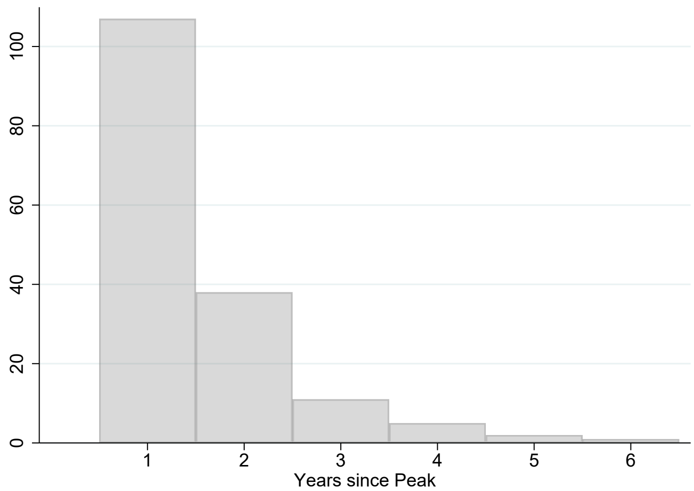
D. Appendix: Figures

Figure D1: *Cycle-specific Downward Wage Rigidity Estimates* ($\widehat{\eta_{c(i)}}$)



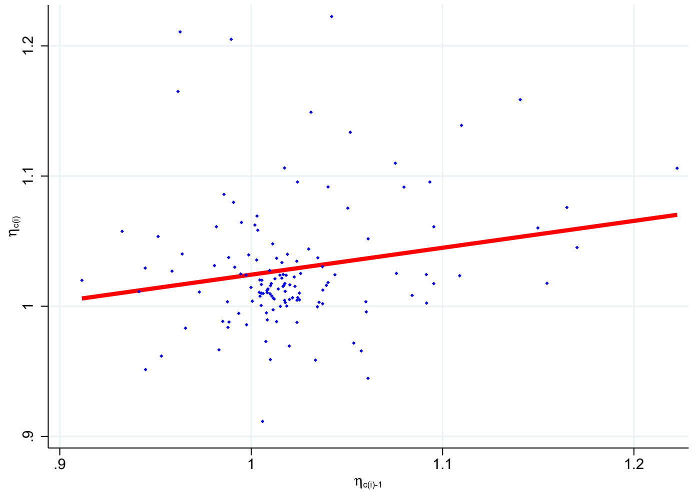
Notes: *Distribution for* $\widehat{\eta_{c(i)}}$ *as specified by equation* (2) *split by advanced and emerging markets.*

Figure D2: *Duration of Recessions*



Notes: *Each bar represents the number of ongoing recessions h years after the peak for the entire sample. Each recession by construction lasts at least one year.*

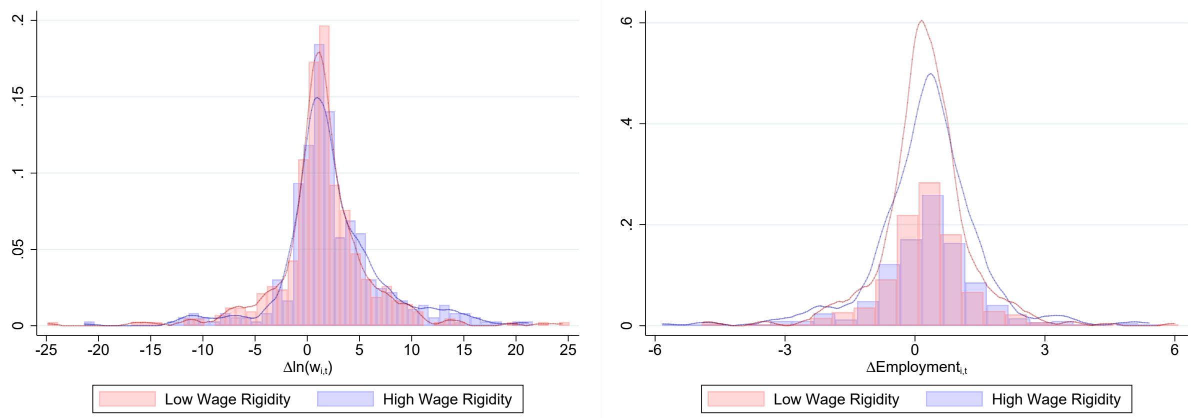
Figure D3: *Within Country Correlation of Downward Wage Rigidities*



Notes: *The figure portrays the relationship between country-specific downward wage rigidity estimates based on a bivariate OLS regression. Dependent variable (y-axis): $\widehat{\eta_{c(i)}}$. Independent variable: $\widehat{\eta_{c(i)-1}}$. Observations are added. The chart excludes outliers defined as $\widehat{\eta_{c(i)}} > 1.3$ or $\widehat{\eta_{c(i)}} < 0.9$.*

Figure D4: *Wage Rigidities and Labor Markets during Expansions*

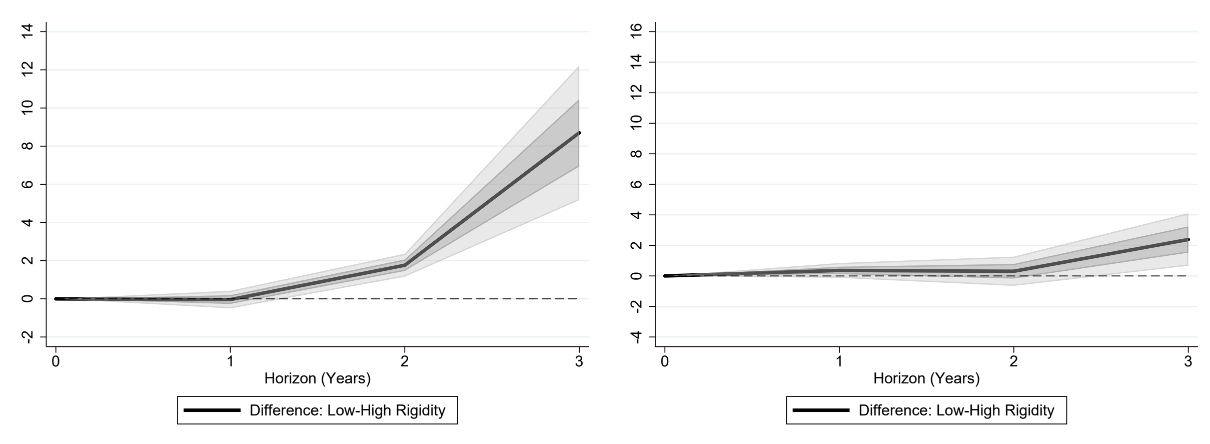
(a) *Δln Wage* ***(b)*** *Δ Employment*



Notes: *Real wage growth (in %) and changes in the employment to population ratio (in pp) at annual frequency during expansions based on the degree of downward wage rigidity. Expansions are defined by positive real GDP growth. Solid lines represent kernel densities and bars the raw data. "Low (High) Wage Rigidity" refers to subsamples with effective DNWRs below (above) the median.*

Figure D5: *Recession Paths: All Countries, Low minus High Downward Wage Rigidity*

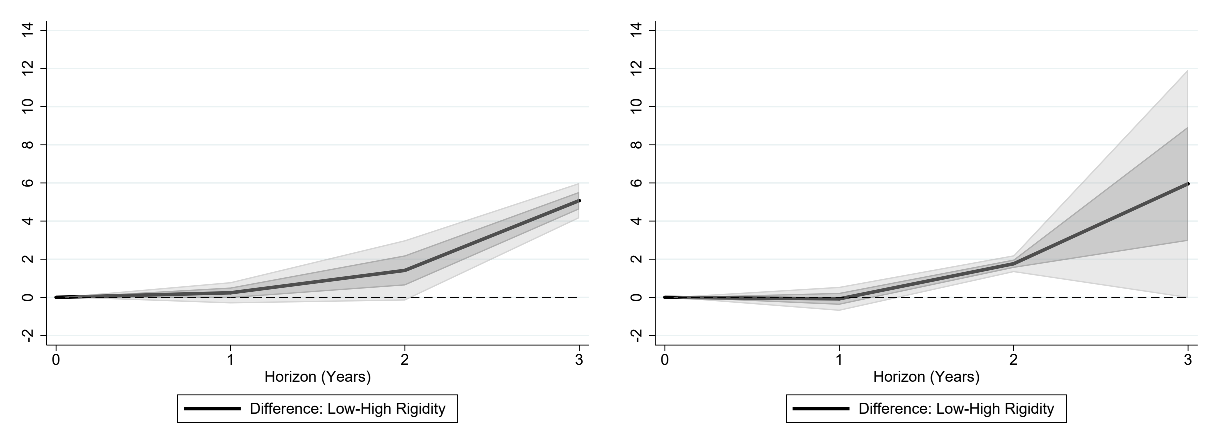
(a) *Employment* ***(b)*** *GDP*



Notes: *Local Projections as specified in equation (4). The charts plot the cumulative difference (in pp) between the low and high rigidity response for the employment to population ratio (Panel (a)) and real GDP per capita (Panel (b)). "Low (High) Wage Rigidity" corresponds to the response of a country with -0.5(+0.5) standard deviations in effective DNWRs from the mean. Shaded areas are 1 and 2 cluster robust s.e. bands around response estimates.*

Figure D6: *Recession Paths: Employment, AEs versus EMs, Low minus High Downward Wage Rigidity*

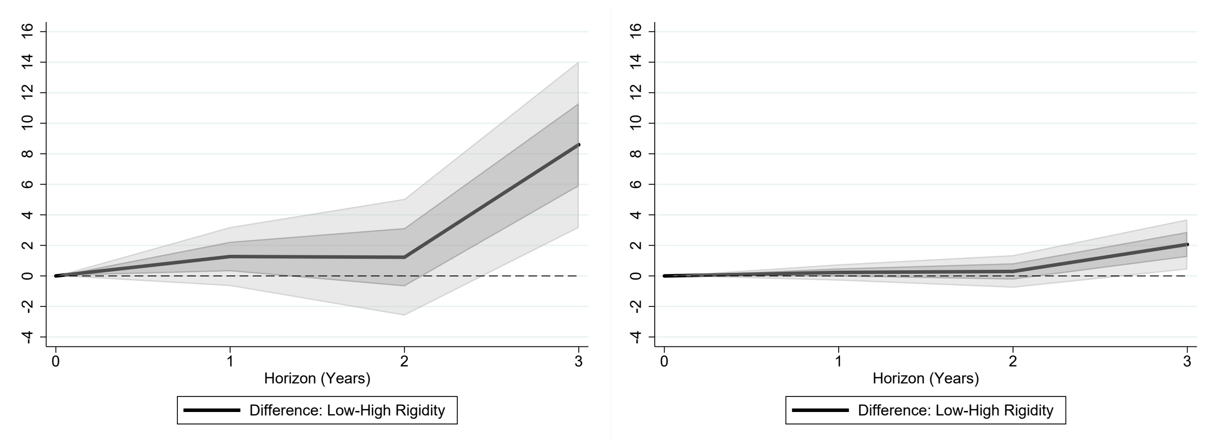
(a) *Advanced Economies* ***(b)*** *Emerging Markets*



Notes: *Local Projections as specified in equation (4). The charts plot the cumulative difference (in pp) between the low and high rigidity response for the employment to population ratio among advanced economies (Panel (a)) and emerging markets (Panel (b)). "Low (High) Wage Rigidity" corresponds to the response of a country with -0.5(+0.5) standard deviations in effective DNWRs from the mean. Shaded areas are 1 and 2 cluster robust s.e. bands around response estimates.*

Figure D7: *Recession Paths: GDP, AEs versus EMs, Low minus High Downward Wage Rigidity*

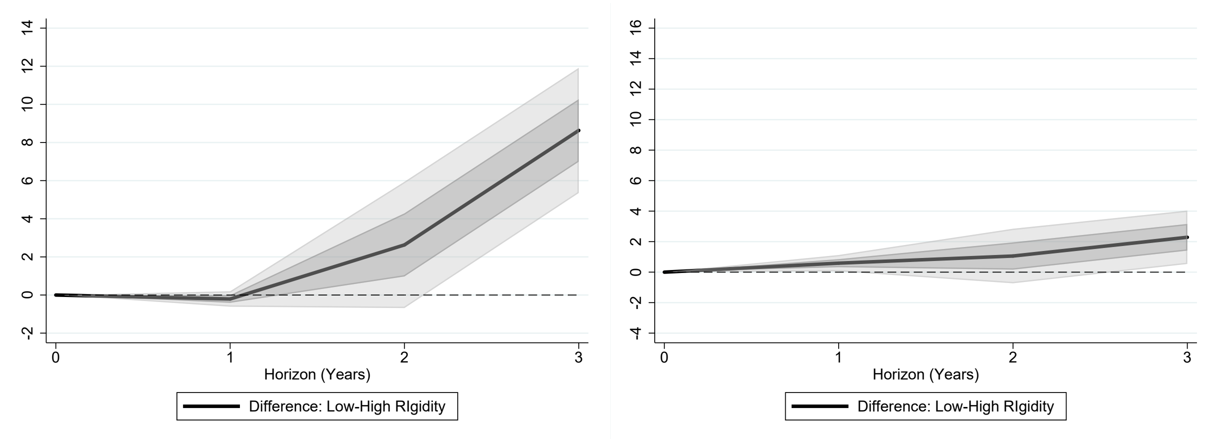
(a) *Advanced Economies* ***(b)*** *Emerging Markets*



Notes: *Local Projections as specified in equation (4). The charts plot the cumulative difference (in pp) between the low and high rigidity response for real GDP per capita among advanced economies (Panel (a)) and emerging markets (Panel (b)) "Low (High) Wage Rigidity" corresponds to the response of a country with -0.5(+0.5) standard deviations in effective DNWRs from the mean. Shaded areas are 1 and 2 cluster robust s.e. bands around response estimates.*

Figure D8: *Robustness Check: Including Variables Related to the Rigidity Measure (All Countries)*

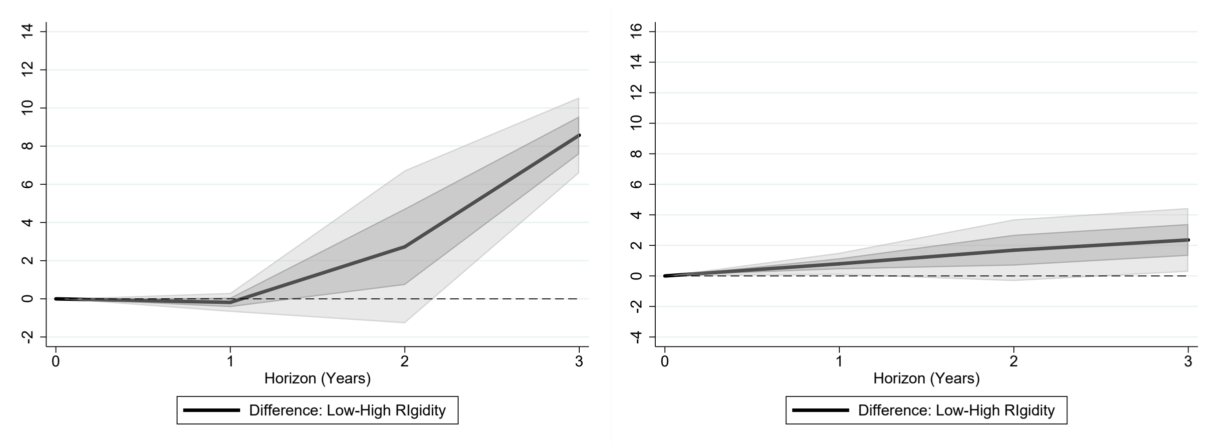
(a) *Employment* ***(b)*** *GDP*



Notes: *Local Projections as specified in equation (5), which include three control variables that are possibly related to downward wage rigidities: collective bargaining, union density, and de jure labor market rigidities, all of which are Incorporated as country-specific averages. The charts plot the cumulative difference (in pp) between the low and high rigidity response for the employment to population ratio (Panel (a)) and real GDP per capita (Panel (b)). "Low (High) Wage Rigidity" corresponds to the response of a country with -0.5(+0.5) standard deviations in effective DNWRs from the mean. Shaded areas are 1 and 2 cluster robust s.e. bands around response estimates.*

Figure D9: *Robustness Check: Including Minimum Wage Growth (All Countries)*

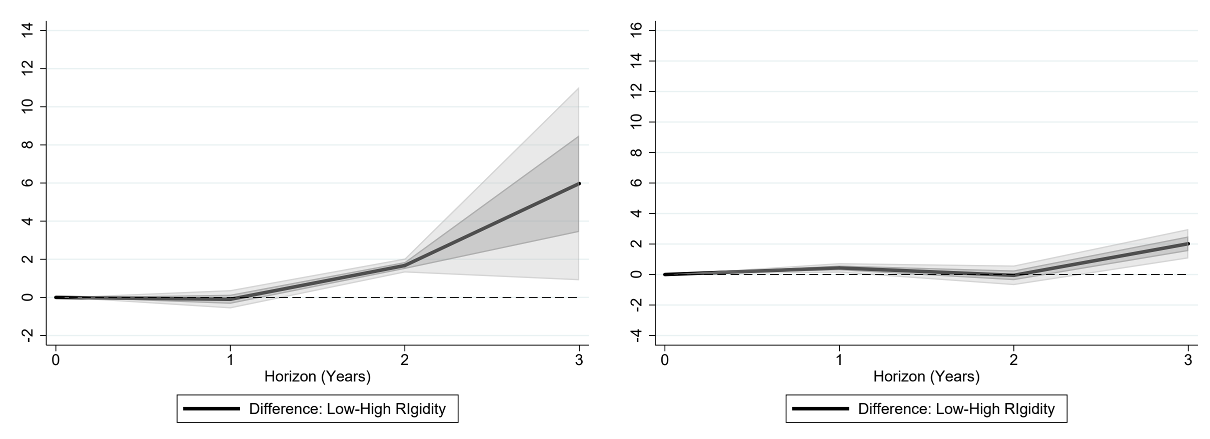
(a) *Employment* ***(b)*** *GDP*



Notes: *Local Projections as specified in equation (5), which add minimum wage growth to the three remaining labor market related control variables (collective bargaining, union density, and de jure labor market rigidities incorporated as country-specific averages). Minimum wage data are not available for 19 countries. The charts plot the cumulative difference (in pp) between the low and high rigidity response for the employment to population ratio (Panel (a)) and real GDP per capita (Panel (b)). "Low (High) Wage Rigidity" corresponds to the response of a country with -0.5(+0.5) standard deviations in effective DNWRs from the mean. Shaded areas are 1 and 2 cluster robust s.e. bands around response estimates.*

Figure D10: *Robustness Check: Including Other Variables (All Countries)*

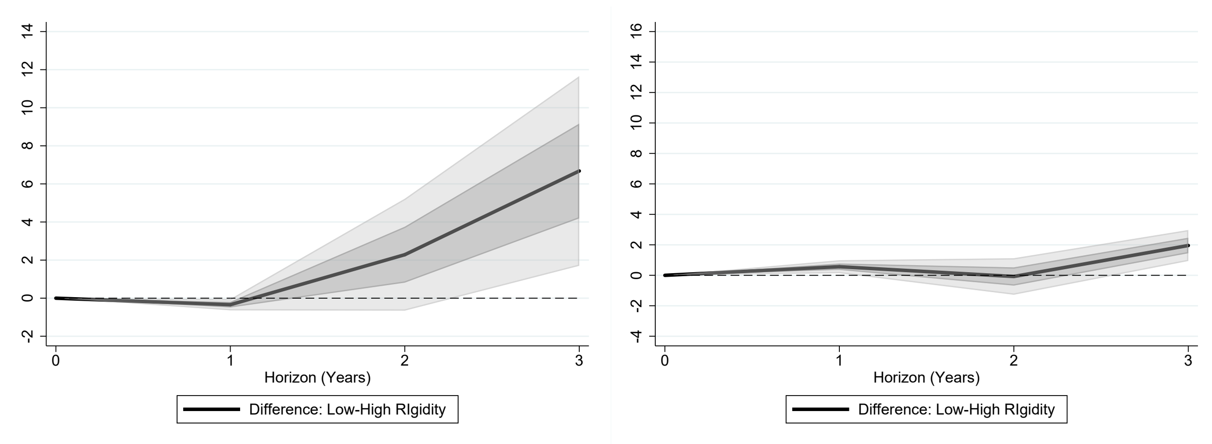
(a) *Employment* ***(b)*** *GDP*



Notes: *Local Projections as specified in equation (5), which include four control variables that are not directly related to downward wage rigidities, but may influence recession dynamics: the credit-to-GDP ratio prior to recessions, the export-to-GDP ratio, oil prices, and the bilateral exchange rate relative to the U.S. dollar. The charts plot the cumulative difference (in pp) between the low and high rigidity response for the employment to population ratio (Panel (a)) and real GDP per capita (Panel (b)). "Low (High) Wage Rigidity" corresponds to the response of a country with -0.5(+0.5) standard deviations in effective DNWRs from the mean. Shaded areas are 1 and 2 cluster robust s.e. bands around response estimates.*

Figure D11: *Robustness Check: Including All Variables (All Countries)*

(a) *Employment* ***(b)*** *GDP*



Notes: *Local Projections as specified in equation (5) which include all control variables, i.e., the two sets of variables included in Figures D8 and D10. The charts plot the cumulative difference (in pp) between the low and high rigidity response for the employment to population ratio (Panel (a)) and real GDP per capita (Panel (b)). "Low (High) Wage Rigidity" corresponds to the response of a country with -0.5(+0.5) standard deviations in effective DNWRs from the mean. Shaded areas are 1 and 2 cluster robust s.e. bands around response estimates.*

E. Appendix: Tables

Table E1: *Unemployment - Trough Preceding Cycle*

EMs								
Argentina	2008	2011						
Armenia	2013	2016	2019					
Bolivia	2001	2008	2012	2014	2019			
Bosnia and Herzegovina	2008	2013						
Brazil	2002	2004	2008	2011	2014	2019		
Cambodia	2009	2013	2015					
Chile	2013	2015						
Colombia	2007	2015						
Costa Rica	2000	2004	2007	2010	2013	2017		
Dominican Republic	2000	2002	2004	2008	2010	2014	2017	
Ecuador	2001	2007	2013	2018				
El Salvador	2002	2004	2008	2013	2015			
Guatemala	2006	2012	2015					
Honduras	2008	2012	2015	2017	2019			
Hungary	2002	2007	2019					
Indonesia	2014	2019						
Malaysia	2012	2014	2018					
Mauritius	2002	2008	2011	2013				
Mexico	2005	2012	2018					
Mongolia	2008	2012						
Pakistan	2007	2014						
Panama	2001	2011	2013	2018				
Paraguay	1998	2001	2005	2008	2010	2012	2015	2017
Peru	2001	2003	2012	2014	2019			
Philippines	2007	2013	2019					
Poland	1998	2008	2011	2019				
South Africa	2011	2013	2018					
Sri Lanka	2014	2017						
Thailand	2019							
Turkey	2006	2012	2017					
Uruguay	2011	2013						
Vietnam	2011	2014	2016	2018				
AEs								
Austria	1997	2001	2003	2008	2011	2019		
Belgium	1997	2001	2004	2008	2011	2019		
Czech Republic	2019							
Denmark	1998	2001	2008	2019				
Finland	2001	2008	2012	2019				
France	2001	2003	2008	2011	2019			
Germany	2001	2008	2019					
Iceland	1996	2001	2005	2007	2018			
Italy	2007	2011						
Japan	1997	2000	2007	2019				
Korea, Republic of	1996	2002	2008	2013	2017	2019		
Latvia	2001	2007	2019					
Lithuania	2007	2018						
Luxembourg	1997	2001	2005	2007	2010	2014	2017	
New Zealand	1996	2005	2007	2011	2019			
Portugal	2000	2008	2019					
Slovak Republic	1996	2003	2008	2011	2019			
Spain	2001	2007	2019					
Sweden	2001	2007	2011	2018				
United Kingdom	2001	2004	2007	2019				
United States	2000	2007	2019					

Notes*: The table displays the year prior to each unemployment cycle, that is, the local minimum in the unemployment rate. Only cycles with data on real wages are included.*

Table E2: *Cycle-specific Effective DNWRs Estimates*

EMs								
Argentina	1.141	1.159						
Armenia	1.035	1.003	1.069					
Bolivia	.991	1.08	1.092	1.024	1.007			
Bosnia and Herzegovina	1.022	1.023						
Brazil	.991	1.03	1.044	.89	1.019	1.04		
Cambodia	1.042	1.223	1.106					
Chile	1.17	1.045						
Colombia	.941	1.011						
Costa Rica	.953	.962	1.165	1.076	1.025	1.005		
Dominican Republic	1.012	.859	1.15	1.06	.996	.847	.959	
Ecuador	.424	1.005	1.01	.959				
El Salvador	.933	1.058	.966	.983	.967			
Guatemala	.951	1.054	.972					
Honduras	1.006	.912	1.02	.969	1.586			
Hungary	1.037	1.002	1.062					
Indonesia	.999	1.039						
Malaysia	1.04	1.092	1.002					
Mauritius	1.05	1.075	1.11	1.139				
Mexico	.994	.995	1.025					
Mongolia	1.155	1.018						
Pakistan	1.011	1.048						
Panama	.982	1.061	1.052	1.134				
Paraguay	1.069	.772	1.044	1.024	1.095	1.061	.945	1.029
Peru	1.338	.897	1.008	.99	1.205			
Philippines	.981	1.031	1.149					
Poland	1.084	1.008	1.011	1.017				
South Africa	1.008	.973	1.011					
Sri Lanka	1.109	1.023						
Thailand	1.094							
Turkey	1.035	1.037	1.03					
Uruguay	1.023	1.015						
Vietnam	1.093	1.095	1.017	1.106				
AEs								
Austria	1.014	1.013	.988	1.037	1.012	1.021		
Belgium	1.018	1.011	.997	1.024	1.005	1.008		
Czech Republic	1.026							
Denmark	1.017	1.015	1	1.014				
Finland	1.026	1.025	1.01	1.016				
France	1.012	1.006	1.01	1.01	1.028			
Germany	1.005	1.017	1.024					
Iceland	1.039	1.016	1.034	.959	1.027			
Italy	1.019	1						
Japan	.985	.988	.988	.984				
Korea, Republic of	.964	1.04	1.018	1.024	1.035	1		
Latvia	1.06	1.003	1.058					
Lithuania	.963	1.211						
Luxembourg	1.008	1.012	1.006	1.02	1.005	1.001	1.004	
New Zealand	1.018	1.017	1.004	1.02	1.016			
Portugal	.998	.986	1.086					
Slovak Republic	1.004	1.011	1.008	.995	1.064			
Spain	1.018	1.003	1.036					
Sweden	1.017	1.016	1.022	1.007				
United Kingdom	1.015	1.024	.988	1.003				
United States	1.009	1.013	1.037					

Notes: *The table displays individual* $\widehat{\eta_{c(i)}}$ *estimates. The ordering resembles the unemployment cycles in Table E1.*

Table E3: *Business Cycle Peaks*

EMs					
Argentina	1998	2008	2011	2013	2015
Armenia	2008	2015			
Bolivia	1998	2000			
Bosnia and Herzegovina	2008				
Brazil	1997	2002	2008	2013	
Cambodia	2008				
Chile	1998	2008	2016		
Colombia	1997	2016			
Costa Rica	2008				
Dominican Republic	2002	2008			
Ecuador	1998	2008	2014		
El Salvador	2008				
Guatemala	2000	2008			
Honduras	1998	2008			
Hungary	2008	2011			
Indonesia	1997				
Malaysia	1997	2000	2008		
Mexico	2000	2007			
Mongolia	2008	2015			
Pakistan	1996	2007	2009		
Panama	2000	2008			
Paraguay	1997	2008	2011		
Peru	1997	2000			
Philippines	1997	2008			
South Africa	1997	2008	2013		
Sri Lanka	2000				
Thailand	1996	2008			
Turkey	1998	2000	2007	2018	
Uruguay	1998				
AEs					
Austria	2008	2012			
Belgium	2007	2012			
Czech Republic	1996	2008	2011		
Denmark	2007	2011			
Finland	2008	2011			
France	2007	2011			
Germany	2001	2008			
Iceland	2001	2008			
Italy	2002	2007	2011		
Japan	1997	2001	2007		
Korea, Republic of	1997				
Latvia	2007				
Lithuania	1998	2008			
Luxembourg	2007	2010	2014	2016	
New Zealand	1997	2007			
Portugal	2002	2008	2010		
Slovak Republic	1998	2008			
Spain	2007				
Sweden	2007	2011			
United Kingdom	2007				
United States	2007				

Notes*: Business cycle peaks as identified with the Bry and Boschan (1971) algorithm.*

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