

### Annex 2.1 Data Sources, Sample Coverage, and Variable Definitions

Data sources used in the chapter are listed in Table 2.1.1. The list of economies used for each exercise is provided in Table 2.1.2. The analysis primarily uses data in quarterly frequency.

The primary sources on wages, employment, unemployment, and inflation have been combined by taking one of the sources as the primary and extending backwards and forwards using growth rates from the other available sources. Where available, data from the Organisation for Economic Co-operation and Development (OECD) is taken first, followed by data from the International Labour Organization (ILO), and other sources listed in Table 2.1.1. For quarterly frequency, all original source data that was not seasonally adjusted by the source was seasonally adjusted by the authors using X-13ARIMA-SEATS procedure from the U.S. Census Bureau. For wage data, four series were constructed: 1) wage per hour in local currency, 2) wage per worker in local currency, 3) wage per hour index, 4) wage per worker index. For quarterly frequency, wage data in local currency was annualized. For employment data, four series were constructed: 1) number of people employed, 2) number of employees, 3) total number of hours worked, 4) number of hours worked per employee.

Inflation expectations are sourced from Consensus Forecasts (CF). Since monthly CF surveys provide with expected current- and next-year inflation (i.e., fixed-event forecasts), the twelve-month ahead (fixed-horizon) inflation expectations are constructed as the weighted sum of monthly vintages, following the standard approach in the literature (see Buono and Formai 2018, Methodological Appendix).

### Sector Definitions

Sectors are defined based on the International Standard Industrial Classification of All Economic Activities (ISIC), revision 4. Because sectoral data granularity varies across economies, wages and employment are aggregated separately by economy into two broad sectors: industry and services. *Industry* includes manufacturing; construction; mining and quarrying; electricity, gas, and water supply. *Services* include market services (trade; transportation; accommodation and food; and business and administrative services); and non-market services (public administration; community, social, and other services and activities). Aggregate employment in industry and services is calculated as the sum of employment in each of their respective subsectors. Average wages in industry and services are the employment-weighted average of wages in each subsector.

# WORLD ECONOMIC OUTLOOK

## Annex Table 2.1.1. Data Sources

Indicator	Sources
Inflation	Haver Analytics; International Monetary Fund, World Economic Outlook database; Organisation for Economic Co-operation and Development
Wage (per worker, per hour; by sector)	Eurostat; Haver Analytics; International Labour Organization; Organisation for Economic Co-operation and Development; US Bureau of Labor Statistics
Employment (number of people, hours worked; by sector)	Eurostat; Haver Analytics; International Labour Organization; Organisation for Economic Co-operation and Development; US Bureau of Labor Statistics
Unemployment	Haver Analytics; International Labour Organization; International Monetary Fund, International Financial Statistics and World Economic Outlook databases; Organisation for Economic Co-operation and Development
<b>Additional Sources for Wage Phillips Curve Analysis</b>	
Unemployment-to-Vacancy Ratio	Duval and others (2022); Barnichon (2010); and national authorities (Australian Bureau of Statistics; Eurostat; Statistics Canada; UK Office for National Statistics; US Bureau of Labor Statistics, Job Openings and Labor Turnover Survey)
Output-Side Real GDP in Chained Purchasing-Power-Parity Dollars (mil. 2017US\$) per Worker	Penn World Table 10.0
GDP in Purchasing-Power-Parity Dollars	International Monetary Fund, World Economic Outlook database
Markups	Diez, Leigh, and Tambunlertchai (2018) based on the Industry Classification Benchmark by FTSE Russell
Stringency of Contract Regulation	Indicators of Employment Protection, Organisation for Economic Co-operation and Development
<b>Additional Sources for Wages and Economic Dynamics: Inflation Shocks and Monetary Policy</b>	
Inflation Expectations	Consensus Economics Inc.
Government Long-Term Rates	Organisation for Economic Co-operation and Development
Participation in GVCs	Organisation for Economic Co-operation and Development, Trade in Value Added (TiVA)
Global Supply Chain Pressure Index	Benigno and others (2022); Federal Reserve Bank of New York, Global Supply Chain Pressure Index (GSCPI)
Monetary Policy Shocks	Jarociński and Karadi (2020), updated version by Jarociński as of July 2022.
Index of Inflation Expectations Anchoring	Bems and others (2021)
<b>Additional Sources for Decomposing Changes in Wages, Prices, and Employment</b>	
Inter-Country Input-Output Tables	Organisation for Economic Co-operation and Development, Inter-Country Input-Output Database (ICIO); Organisation for Economic Co-operation and Development, Trade in Employment (TiM)
Household Consumption Composition	United States Census Bureau; USA Trade Online
Commodity Prices	International Monetary Fund, Primary Commodity Price System
International Trade Costs	United States Census Bureau; USA Trade Online
Fiscal Policy	Organisation for Economic Co-operation and Development, Quarterly and Annual National Accounts; United States Bureau of Economic Analysis
Monetary Policy	Haver Analytics; Wu-Xia Shadow Rates (Federal Funds Rate; European Central Bank Policy Rates)
Household Savings Rate	Organisation for Economic Co-operation and Development, Annual National Accounts
<b>Additional Sources for Role of Wage and Price Expectations: Scenarios from a Small DSGE Model</b>	
Real GDP per Capita	Haver Analytics; Brazilian Institute of Geography and Statistics (IBGE); Federal Reserve Economic Data (FRED)
IPCA-15 (Consumer Price Index)	Brazilian Institute of Geography and Statistics (IBGE)
Personal Consumption Expenditures	Federal Reserve Economic Data (FRED)
Federal Reserve Funds Rate	Federal Reserve Economic Data (FRED)
Selic Interest Rate	Central Bank of Brazil
Constant Composition Real Wages	Dizioli and Wang (2022); Howard, Rich, and Tracy (2022)

Source: IMF staff compilation.

Note: DSGE = dynamic stochastic general equilibrium; GVCs = global value chains.

**Annex Table 2.1.2. Sample of Economies Included in Analytical Exercises**

**Figure 2.1**

AEs (33): Australia; Austria; Belgium; Canada; Czech Republic; Denmark; Estonia; Finland; France; Germany; Greece; Hong Kong SAR; Ireland; Israel; Italy; Japan; Korea; Latvia; Lithuania; Luxembourg; Netherlands; New Zealand; Norway; Portugal; Singapore; Slovak Republic; Slovenia; Spain; Sweden; Switzerland; Taiwan Province of China; United Kingdom; United States  
 EMDEs (22): Argentina; Belarus; Brazil; Bulgaria; Colombia; Croatia; Hungary; Kazakhstan; Mexico; Moldova; Peru; Philippines; Poland; Romania; Russia; Saudi Arabia; Serbia; South Africa; Thailand; Türkiye; Ukraine; Vietnam

**Figure 2.2, Figure 2.3, Annex Figure 2.3.1**

See Annex Table 2.3.1

**Figure 2.4, Annex Table 2.4.1**

AEs (31): Australia; Austria; Belgium; Canada; Czech Republic; Denmark; Estonia; Finland; France; Germany; Greece; Hong Kong SAR; Ireland; Italy; Japan; Korea; Latvia; Lithuania; Netherlands; New Zealand; Norway; Portugal; Singapore; Slovak Republic; Slovenia; Spain; Sweden; Switzerland; Taiwan Province of China; United Kingdom; United States  
 EMDEs (15): Argentina; Brazil; Bulgaria; Colombia; Croatia; Hungary; Mexico; Peru; Philippines; Poland; Romania; Russia; Thailand; Türkiye; Ukraine

**Figure 2.5**

AEs (27): Australia; Austria; Belgium; Canada; Czech Republic; Denmark; Estonia; Finland; France; Germany; Greece; Ireland; Italy; Japan; Korea; Lithuania; Netherlands; New Zealand; Norway; Portugal; Slovak Republic; Slovenia; Spain; Sweden; Switzerland; United Kingdom; United States

**Figure 2.6**

Albania; Argentina; Armenia; Australia; Azerbaijan; Bolivia; Bosnia and Herzegovina; Botswana; Brazil; Brunei Darussalam; Bulgaria; Cambodia; Canada; Chile; China; Colombia; Costa Rica; Croatia; Czech Republic; Denmark; Dominican Republic; Ecuador; Egypt; Euro Area (Austria; Belgium; Cyprus; Estonia; Finland; France; Germany; Greece; Ireland; Italy; Latvia; Lithuania; Luxembourg; Malta; Netherlands; Portugal; Slovak Republic; Slovenia; Spain); Georgia; Guatemala; Guyana; Hong Kong SAR; Hungary; Iceland; India; Indonesia; Iran; Israel; Jamaica; Japan; Jordan; Kazakhstan; Kenya; Korea; Kosovo; Kyrgyz Republic; Lao P.D.R.; Macao SAR; Malaysia; Mauritius; Mexico; Moldova; Mongolia; Montenegro, Rep. of; Morocco; Myanmar; New Zealand; North Macedonia; Norway; Paraguay; Peru; Philippines; Poland; Qatar; Romania; Russia; Saudi Arabia; Senegal; Serbia; Seychelles; Singapore; Slovak Republic; South Africa; Sri Lanka; St. Lucia; Sweden; Switzerland; Taiwan Province of China; Tajikistan; Thailand; Tunisia; Türkiye; Ukraine; United Kingdom; United States; Uruguay; Uzbekistan; Vietnam. (For model calibration)

**Figure 2.7, Annex Figure 2.6.1**

AEs (16): Austria; Belgium; Estonia; Finland; France; Germany; Greece; Ireland; Italy; Latvia; Lithuania; the Netherlands; Portugal; Slovakia; Slovenia; Spain

**Figure 2.8**

AEs (10): Estonia; France; Germany; Italy; Lithuania; Latvia; the Netherlands; Slovakia; Slovenia; Spain

**Figure 2.9, Figure 2.10**

United States

**Annex Figure 2.1.1**

AEs (28): Australia; Austria; Belgium; Canada; Cyprus; Czech Republic; Denmark; Estonia; Finland; France; Germany; Greece; Ireland; Italy; Japan; Latvia; Lithuania; Luxembourg; Malta; Netherlands; New Zealand; Portugal; Slovak Republic; Slovenia; Spain; Sweden; United Kingdom; United States  
 EMDEs (7): Bulgaria; Chile; Croatia; Hungary; Poland; Romania; Türkiye

**Annex Figure 2.1.2**

AEs (22): Austria; Czech Republic; Denmark; Estonia; Finland; France; Germany; Greece; Ireland; Italy; Latvia; Lithuania; Luxembourg; Netherlands; Norway; Portugal; Slovak Republic; Slovenia; Spain; Sweden; United Kingdom; United States  
 EMDEs (4): Bulgaria; Hungary; Poland; Romania

**Annex Figure 2.2.1**

AEs (23): Austria; Belgium; Canada; Czech Republic; Denmark; Estonia; Finland; Germany; Greece; Ireland; Italy; Latvia; Lithuania; Luxembourg; Netherlands; Norway; Portugal; Slovak Republic; Slovenia; Spain; Sweden; United Kingdom; United States  
 EMDEs (14): Argentina; Brazil; Bulgaria; Colombia; Ecuador; Hungary; India; Indonesia; Jordan; Peru; Philippines; Poland; Serbia; Vietnam

**Annex Figure 2.2.2**

AEs (22): Austria; Belgium; Czech Republic; Denmark; Estonia; Finland; France; Germany; Greece; Ireland; Italy; Latvia; Lithuania; Luxembourg; Netherlands; Norway; Portugal; Slovak Republic; Slovenia; Spain; Sweden; United States

**Annex Figure 2.4.1, Annex Figure 2.4.2**

AEs (29): Australia; Austria; Belgium; Canada; Czech Republic; Denmark; Estonia; Finland; France; Germany; Greece; Ireland; Italy; Japan; Latvia; Lithuania; Netherlands; New Zealand; Norway; Portugal; Singapore; Slovak Republic; Slovenia; Spain; Sweden; Switzerland; Taiwan Province of China; United Kingdom; United States

**Annex Figure 2.4.3**

AEs (14): Australia; Austria; Belgium; Canada; Finland; Germany; Ireland; Japan; Netherlands; Norway; Portugal; Sweden; United Kingdom; United States

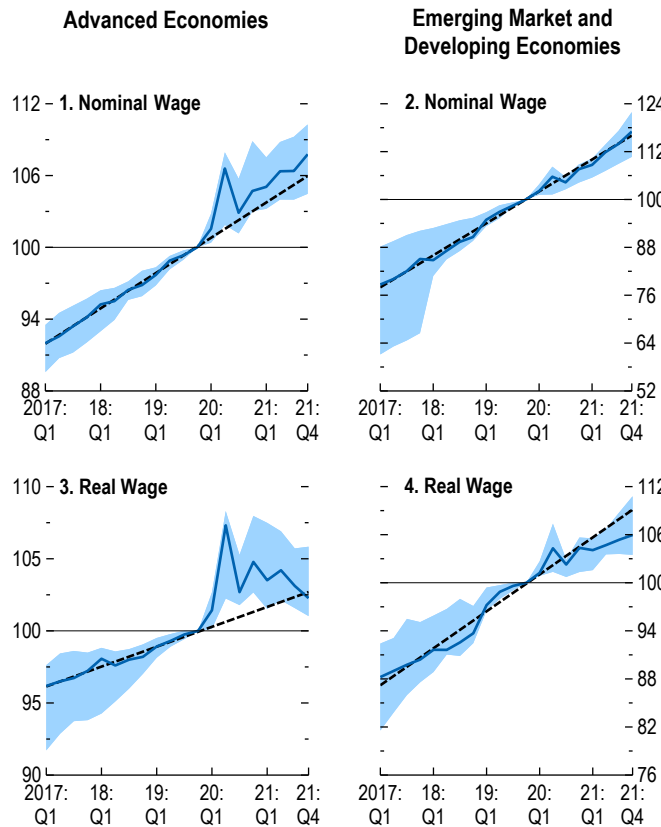
Source: IMF staff compilation.

Note: AEs = advanced economies; EMDEs = emerging market and developing economies.

## Additional Figures

**Wages per hour.** The chapter focused on average wages per worker when describing the dynamics of nominal and real wages. Figures 2.1.1 and 2.1.2 show those dynamics for average wages *per hour worked* in both advanced economies and emerging markets, and across sectors. The distinction between wages per hour and wages per worker was particularly relevant during the pandemic, as hours worked were adjusted for a large portion of workers. As shown in Figure 2.1 in the main text, when the COVID-19 shock hit the economy, wages per worker spiked down, reflecting the negative impact of the pandemic on nominal wages. In contrast, wages per hour spiked *up*, as the adjustment in hours was more severe than the adjustment on wages. Nevertheless, we again find that wages per hour quickly returned to their previous trend and there are no clear signs of severe, above average wage inflation by the end of 2021.

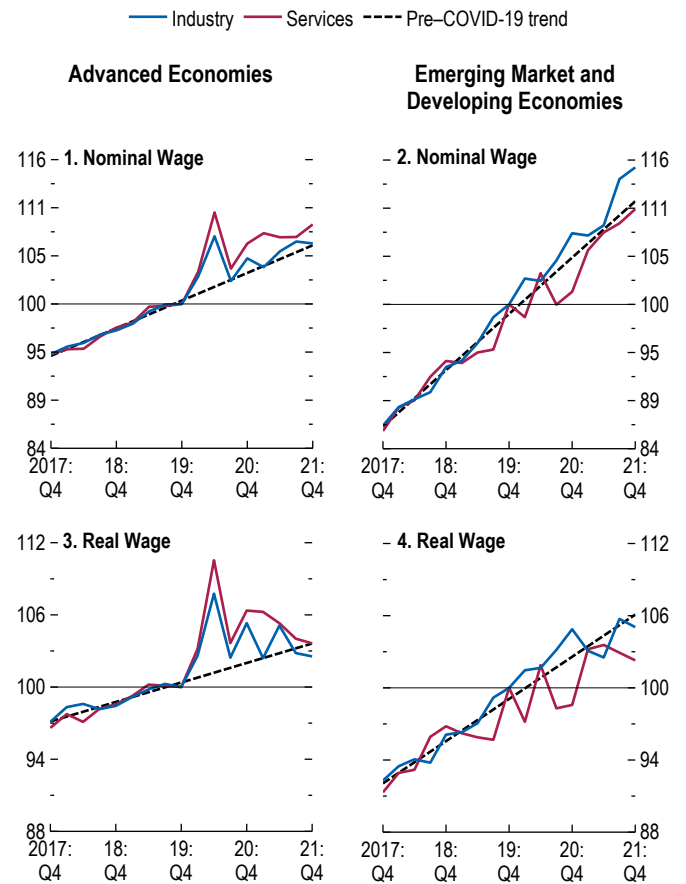
**Annex Figure 2.1.1. Recent Hourly Wage Dynamics**  
(Index, 2019:Q4 = 100, unless noted otherwise)



Sources: Haver Analytics; International Labour Organization; Organisation for Economic Co-operation and Development; US Bureau of Economic Analysis; and IMF staff calculations.

Note: Blue lines represent the median across economies; dashed lines indicate the pre-COVID-19 trend; shaded areas represent the interquartile range across economies. Wages (nominal and real) are calculated on a per-hour-worked basis. See Online Annex 2.1 for details on the sample coverage.

**Annex Figure 2.1.2. Sectoral Perspective on Recent Hourly Wage Dynamics**  
(Index, 2019:Q4 = 100)



Sources: Eurostat; Haver Analytics; International Labour Organization; Organisation for Economic Co-operation and Development; US Bureau of Economic Analysis; and IMF staff calculations.

Note: The figure shows the median value of the distribution of wage indices across economies, where wages (nominal and real) are calculated on a per hour-worked basis. Industry includes manufacturing; construction; mining and quarrying; and electricity, gas, and water supply. Services include wholesale and retail trade; transport; hotels and restaurants; information and communication; financial intermediation; real estate activities; professional and scientific activities; administrative services; public administration; education; health; arts and entertainment; and other service activities. See Online Annex 2.1 for details on the sample coverage.

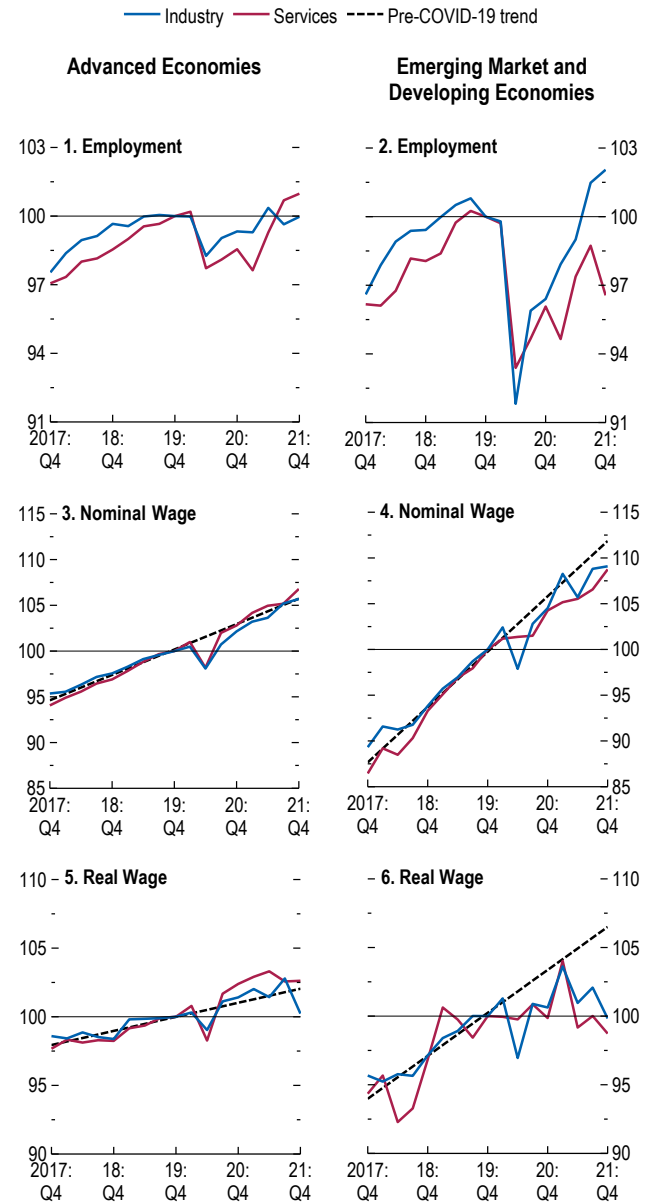
## Annex 2.2. A Sectoral Perspective on Recent Wage Dynamics

With the acute COVID-19 shock impacting contact-intensive services more than goods-producing industries, a first question is whether these early sectoral differences are still evident in recent paths of wages and employment by sector or if there are signs that wage dynamics have converged as the economy recovers. Comparing economy groups, employment in advanced economies is back to its pre-pandemic level in both industry and service sectors on average, while the recovery in emerging market and developing economies has been skewed towards industry (Figure 2.2.1, panels 1 and 2).

In contrast to the lingering differences in employment across sectors, both nominal and real wages have displayed a consistent dynamic for both advanced and emerging market and developing economies—wages across sectors appear to return to (or, in one case, fall short of) the same common, aggregate trend (Figure 2.1.2, panels 1-4, and Figure 2.2.1, panels 3-6). This suggests that any wage pressures are currently broad-based, reflecting wider economic pressures rather than sectoral composition changes.<sup>1</sup>

Despite the sectoral nature of the COVID-19 shock, it does seem that reallocation of labor across sectors has played a relatively minor role in explaining recent wage dynamics. Between 2019 and 2021, less than 5 percent of the change in the average nominal wages per worker can be accounted for by sectoral reallocation of workers within a sample of advanced economies (Figure 2.2.3, panel 1). The bulk of the decline is attributable to wage increases within each sector, reflecting the broad-based nature of recent wage increases. The exact contribution from sectoral reallocation varies across economies and depends

**Annex Figure 2.2.1 Sectoral Perspective on Recent Wage and Employment Dynamics**  
(Index, 2019:Q4 = 100, unless noted otherwise)



Sources: Eurostat; Haver Analytics; International Labour Organization; Organisation for Economic Co-operation and Development; US Bureau of Economic Analysis; and IMF staff calculations.

Note: The figure shows the median value of the distribution of employment and wage indices across economies, where wages (nominal and real) are calculated on a per-worker basis. See Online Annex 2.1 for details on the sectoral composition and sample coverage.

<sup>1</sup> It's important to note that this does not mean that workers' nominal incomes by sectors are back to their previous path. First, to achieve the broadest sample coverage, the chapter focuses on wages per worker. For those economies where the data are available, hourly wages show slightly different dynamics—particularly during the acute pandemic phase—as both hours and employment were adjusted. See also the Online Annex 2.1 for further details. Second, since wage data are only available for the employed, the income loss for workers who became unemployed due to the COVID shock is missed. See Cajner and others (2020) for evidence from the United States on the more adverse impact of the COVID shock on low-income workers.

on how broadly the sectors are defined. For the United States, where more granular sectoral information is available, the contribution is somewhat larger at 10 percent on average during the period, with an even larger contribution during the acute phase of the pandemic (Figure 2.2.3, panel 2).<sup>2</sup>

Real wages across sectors also appear to reflect common patterns, although with few signs of a return to the pre-pandemic trend in emerging market and developing economies. Due to a pickup in nominal wage growth, the average real wage in advanced economies rose after the acute phase of the pandemic. However, the growth in inflation during the second half of 2021 undid a large portion of those gains. As a result, real wages in services are slightly above, while real wages in industry have mostly returned to their levels in the last quarter of 2019. In emerging market and developing economies, real wages across sectors have been generally flat through the whole period. The overall picture across sectoral labor markets aligns with the view that wage pressures are broad-based.

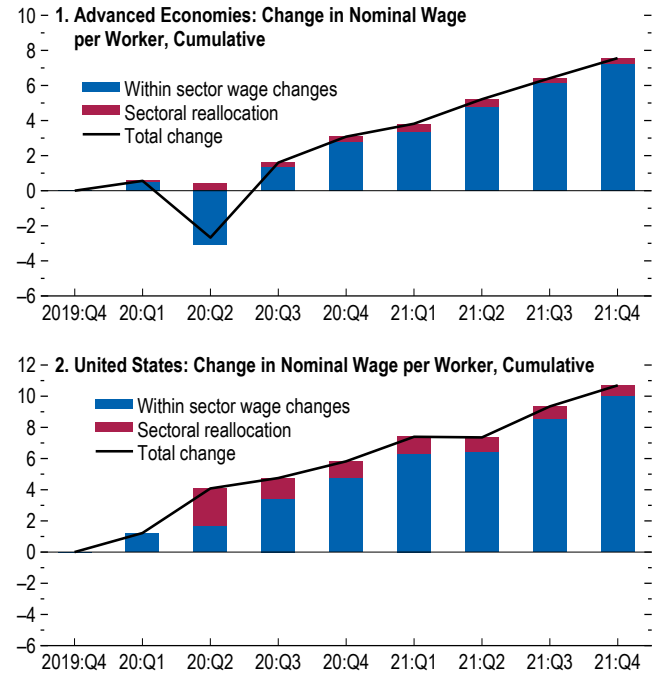
### Sectoral Composition of Wage Growth Calculations

As seen in Figure 2.2.3, the change in wages per workers in economy  $c$  ( $w_{ct}$ ), between time  $t$  and time  $t+k$  can be written as

$$w_{ct+k} - w_{ct} = \sum_s \left( \frac{W_{cst+k}}{E_{cst+k}} - \frac{W_{cst}}{E_{cst}} \right) \frac{E_{cst+k}}{E_{ct+k}} + \sum_s \left( \frac{E_{cst+k}}{E_{ct+k}} - \frac{E_{cst}}{E_{ct}} \right) \frac{W_{cst}}{E_{cst}}$$

where  $W_{cst}$  are total wages in national currencies paid in economy  $c$  at sector  $s$  and time  $t$ , while  $E_{cst}$  is total number of employees in each sector. The first term captures the contribution from within sector wage change, and the second term captures the contribution from sectoral reallocation of labor to the overall change in wage levels. To get the contribution to relative wage growth (from period  $t$ ), the equation is divided through by  $w_{ct}$  and simplified to

**Annex Figure 2.2.2. Sectoral Contributions to Recent Wage Dynamics**  
(Percentage points; 2019:Q4 = 0)



Sources: International Labour Organization; Organisation for Economic Co-operation and Development; US Bureau of Economic Analysis; and IMF staff calculations.

Note: The figure shows the cumulative change in nominal wages per employee from 2019:Q4–21:Q4, decomposed into contributions from within sector wage changes and sectoral reallocation. See Online Annex 2.2 for details on the methodology. Sectoral definition is based on the International Standard Industrial Classification (ISIC) revision 4. Included sectors in panel 1 are B-E, F, G-I, J, K, L, M-N, and O-Q; in panel 2 are A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, and Q. In panel 1, the sample consists of 22 economies. See Online Annex 2.1 for details on the sample coverage.

<sup>2</sup> For the United States, data for 17 sectors are used while only 9 sectors are used for the broader set of advanced economies. However, using a restrictive sample of economies for which these 17 sectors are available does not overturn the conclusion that sectoral reallocation has played a relatively smaller role in explaining the recent nominal wage dynamics. See Online Annex 2.1 for additional details.

$$\frac{\Delta_k w_{ct}}{w_{ct}} = \frac{1}{w_{ct}} \left( \sum_s \Delta_k(w_{cst}) s_{cst+k} + \sum_s \Delta_k(s_{est}) w_{cst} \right)$$

In Figure 2.2.3 (panel 1), this algorithm is applied to data for eight aggregated sectors<sup>3</sup> covering 22 advanced economies over the period 2019:Q4–2021:Q4 (see Table 2.1.2 for sample details). In Figure 2.2.3 (panel 2), the algorithm is applied to a more disaggregated set of 17 sectors for the United States covering the same time period.<sup>4</sup>

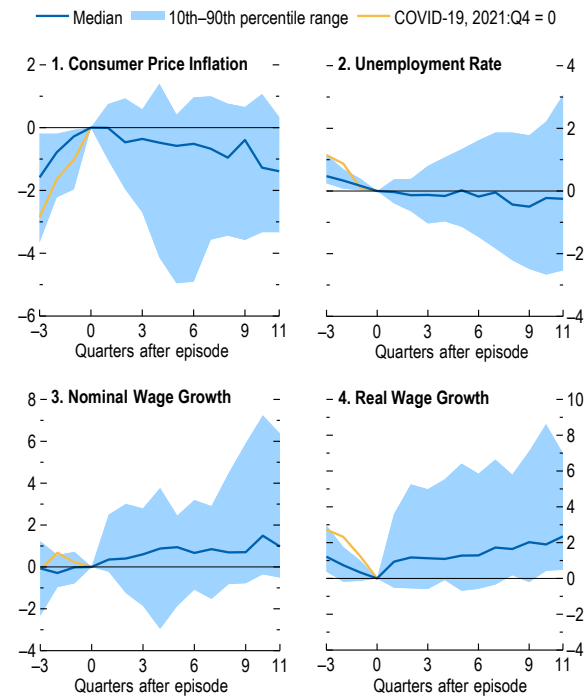
### Annex 2.3. Case Studies

Episodes similar to the current macroeconomic conditions (Figure 2.1) are identified for economies and periods shown in Table 2.3.1. Episodes fulfill the following four criteria for at least three of the last four quarters: (i) year-on-year inflation is increasing; (ii) nominal wage growth is positive; (iii) real wage growth is negative; and (iv) unemployment is flat or falling.<sup>5</sup> Outcomes following these episodes are presented in Figure 2.4. The list of episodes is shown in Table 2.3.2.

The data is also used to identify episodes with accelerating prices and wages. Episodes fulfill the following two criteria for at least three of the last four quarters: (i) year-on-year inflation is increasing; and (ii) nominal wage growth is also increasing. In this way, 79 episodes are identified. The distribution of outcomes following these episodes is presented in Figure 2.5.

To expand time-coverage, an alternative database is compiled using hourly nominal wages for the manufacturing sector (Table 2.3.1). In Figure 2.3.1, the analysis from Figure 2.5 is

**Annex Figure 2.3.1. Changes in Wages, Prices, and Unemployment after Similar Past Episodes**  
(Percentage point differences relative to first quarter in which criteria are fulfilled)



Sources: International Labour Organization; Organisation for Economic Co-operation and Development; US Bureau of Economic Analysis; and IMF staff calculations.

Note: The figure shows the developments following episodes in which at least three of the preceding four quarters have: (1) accelerating prices/rising price inflation, (2) positive nominal wage growth, (3) falling or constant real wages, and (4) declining or flat unemployment rate. Twenty-three such episodes are identified within a sample of 29 advanced economies going back to at the earliest 1960. The COVID-19 episode represents an average of countries in the sample for the period starting in 2021:Q4.

<sup>3</sup> These are (i) Mining and quarrying, manufacturing, electricity, gas steam and air conditioning supply, and water supply (Sector B-E), (ii) Construction (sector F), (iii) Wholesale and retail trade, transportation and storage, accommodation and food service activities (sector G-I), (iv) Information and communication (sector J), (v) financial and insurance activities (sector K), (vi) real estate activities (sector L), (vii) professional, scientific and technical activities, administrative and support service activities (sector M-N), (viii) public administration and defense, education, human health and social work (sector O-Q).

<sup>4</sup> These include Agriculture, forestry and fishing (sector A), Mining and quarrying (sector B), Manufacturing (sector C), Electricity, gas, steam and air conditioning supply (sector D), Water supply (sector E), Construction (F), Wholesale and retail trade (sector G), Transport and storage (sector H), Accommodation and food service activities (sector I), Information and communication (J), Financial and insurance activities (sector K), Real estate activities (sector L), Professional, scientific and technical activities (sector M), Administrative and support service activities (N).

<sup>5</sup> If the four criteria hold repeatedly during a period of three years, only the first episode is selected.

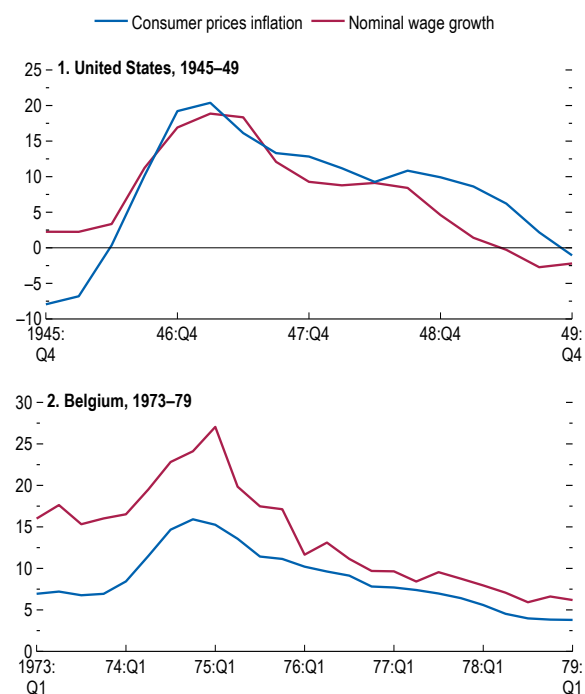
Annex Table 2.3.1. Data Sample for Event Studies

Economy	Aggregated Wages		Manufacturing Wages		Economy	Aggregated Wages		Manufacturing Wages	
	Start	End	Start	End		Start	End	Start	End
Australia	1976:Q3	2021:Q4	1983:Q4	2021:Q4	Korea	1989:Q1	2021:Q4	1992:Q1	2021:Q4
Austria	1995:Q1	2021:Q4	1967:Q1	2021:Q4	Latvia	2002:Q1	2021:Q4	2002:Q1	2021:Q4
Belgium	1995:Q1	2021:Q4	1960:Q1	2021:Q4	Lithuania	1995:Q1	2021:Q4	2000:Q1	2021:Q4
Canada	1981:Q1	2021:Q4	1978:Q4	2021:Q4	Luxembourg	1988:Q1	2021:Q4	1988:Q1	2021:Q4
Czech Republic	1995:Q1	2021:Q4	1993:Q1	2021:Q4	Netherlands	1995:Q1	2021:Q4	1970:Q1	2021:Q4
Denmark	1990:Q1	2021:Q4	1971:Q1	2021:Q4	New Zealand	1989:Q1	2021:Q4	1989:Q1	2021:Q4
Estonia	1995:Q1	2021:Q4	2000:Q1	2021:Q4	Norway	1995:Q1	2021:Q4	1972:Q1	2021:Q4
Finland	1975:Q1	2021:Q4	1973:Q1	2021:Q4	Portugal	1995:Q1	2021:Q4	2000:Q1	2021:Q4
France	1990:Q1	2021:Q4	1990:Q1	2021:Q4	Slovak Republic	1995:Q1	2020:Q3	1993:Q1	2021:Q4
Germany	1985:Q1	2021:Q4	1969:Q1	2021:Q4	Slovenia	1995:Q1	2021:Q4	1998:Q1	2021:Q4
Greece	1995:Q1	2021:Q4			Spain	1981:Q1	2021:Q4	1981:Q1	2021:Q4
Iceland			2005:Q1	2021:Q4	Sweden	1993:Q1	2021:Q4	1971:Q1	2021:Q4
Ireland	1995:Q1	2021:Q4	1983:Q1	2021:Q4	Switzerland	1995:Q1	2021:Q3		
Israel	1995:Q1	2021:Q2	1995:Q1	2021:Q4	United Kingdom	1992:Q2	2021:Q3	1971:Q1	2021:Q4
Italy	1980:Q1	2021:Q4	1960:Q1	2021:Q4	United States	1960:Q1	2021:Q4	1960:Q1	2021:Q4
Japan	1980:Q1	2021:Q4	1960:Q1	2021:Q4					

Sources: Eurostat; Haver Analytics; International Labour Organization; Organisation for Economic Co-operation and Development; US Bureau of Labor Statistics; and IMF staff compilation.

repeated using the longer sample. The results are broadly similar to those in Figure 2.5. In that sample, the United States following World War II and Belgium in the mid-1970s provide further illustrative examples of joint increase in wage and price inflation (Figure 2.3.2). In the post-war years, amid the elimination of price controls, supply shortages, and release of pent-up demand, price inflation and wage growth surged. In 1974 Belgium, consumer price inflation surged for several quarters following the first OPEC oil embargo. Nominal wage growth also picked up – in part owing to wage indexation mechanisms tying wage growth for negotiated wages to observed inflation. In both cases, price and wage inflation eventually subsided.

Annex Figure 2.3.2. Consumer Price Inflation and Nominal Wage Growth (Percent, year-on-year)



Sources: Organisation for Economic Co-operation and Development; St. Louis Federal Reserve Bank; US Bureau of Economic Analysis; and IMF staff calculations. Note: For the United States, nominal wages are measured by the average hourly earnings of production and nonsupervisory employees within the manufacturing sector; consumer prices are measured by the consumer price index for all urban consumers. For Belgium, nominal wages are measured using hourly nominal wages for the manufacturing sector.



## Annex 2.4. Wage Phillips Curve Analysis

### Empirical methodology

The baseline specification relates wage growth to inflation, labor market slack and trend productivity growth using a panel regression. This approach is motivated by the work of Galí (2011), who provide a structural micro-founded interpretation of these empirical relationships. Given both the prominence of inflation expectations in current policy discussions, inflation expectations are included as the main inflation variable, although specifications with lagged inflation are also presented. The following baseline wage Phillips curve is estimated at the quarterly level:

$$\pi_{c,t}^w = \alpha_c + \phi_t + \beta E_t(\pi_{c,t+4}^p) + \gamma_1 u_{c,t} + \gamma_2 \Delta u_{c,t} + \theta g_{c,t} + \varepsilon_{c,t}$$

where  $\pi_{c,t}^w$  is the year-on-year change in nominal wages in local currency,  $E_t(\pi_{c,t+4}^p)$  is a measure of one-year ahead inflation expectations<sup>6</sup>,  $u_{c,t}$  is a measure of labor market slack (unemployment, in the baseline),  $g_{c,t}$  is trend productivity growth over the preceding five-year window<sup>7</sup>,  $\alpha_c$  are economy fixed effects, and  $\phi_t$  are quarterly fixed effects. The coefficients on inflation expectations and labor market slack are identified using cross-economy variation in wage growth changes over time up to 2019:Q4. The post 2020:Q1 pandemic period is excluded for coefficient estimation. Decompositions of wage growth during the pandemic shown in Figure 2.6 in the chapter are obtained by taking the differences in observed wage Phillips curve components relative to 2019:Q4, aggregating across economies using purchasing-power-parity GDP weights.

To explore the role of structural drivers of cross-economy heterogeneity in wage growth responses to unemployment and inflation expectations, an interaction term

**Annex Table 2.3.2. Similar Past Episodes**

Economy	Time	Monetary Policy Stance	Source of Monetary Policy
Australia	1979:Q4	Tightening	OECD (1982)
Australia	1985:Q3	Tightening	OECD (1987)
Australia	1995:Q2	Tightening	OECD (1997)
Austria	2011:Q3	Loosening	OECD (2012)
Austria	2017:Q4	Loosening	OECD (2018b)
Belgium	2010:Q4	Loosening	OECD (2012)
Belgium	2016:Q2	Loosening	OECD (2018)
Canada	2003:Q1	Loosening	OECD (2004)
Denmark	1994:Q3	Tightening	OECD (1996)
Denmark	2011:Q2	Loosening	OECD (2012b)
Estonia	2011:Q1	Loosening	OECD (2012b)
France	2000:Q4	Tightening	OECD (2001)
Germany	1989:Q4	Tightening	OECD (1992)
Israel	2008:Q3	Loosening	OECD (2009b)
Luxembourg	2000:Q4	Tightening	OECD (2001c)
Netherlands	2006:Q3	Tightening	OECD (2009)
Slovenia	2000:Q4	Tightening	IMF (2001)
Spain	1989:Q2	Tightening	OECD (1991)
Spain	2000:Q1	Tightening	OECD (2001b)
Sweden	2011:Q2	Loosening	OECD (2012)
United States	1979:Q2	Tightening	OECD (1980b)
United States	2017:Q1	Tightening	OECD (2018)

Sources: International Labour Organization; Organisation for Economic Co-operation and Development; US Bureau of Economic Analysis; and IMF staff calculations.

Note: The table shows the identified episodes where at least three of the four last quarters had (1) accelerating prices, (2) positive nominal wage growth, (3) falling or constant real wages, and (4) declining or flat unemployment. The subsequent monetary policy stance (over the following 12-months) is characterized by the description in OECD Economic Surveys and IMF Country Reports. For euro area economies the monetary policy stance of the European Central Bank is used. For Australia 1995:Q2, the subsequent monetary policy stance is described as unchanged in OECD (1997) but as this was preceded by a tightening in 1994 the stance has been characterized as a "tightening."

<sup>6</sup> Given that inflation expectations are based on the calendar year, we weight one-year ahead inflation expectations in the current and following year based on the quarter of observation.

<sup>7</sup> Real GDP per worker is used as the productivity measure.

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is added to the baseline specification as follows:

$$\pi_{c,t}^w = \beta_0 E_t(\pi_{c,t+1}^p) + \eta_0 u_{c,t} + \delta_0 \Delta u_{c,t} + High_c * (\beta_1 E_t(\pi_{c,t+1}^p) + \eta_1 u_{c,t} + \delta_1 \Delta u_{c,t}) + \theta g_{c,t} + \alpha_c + \phi_t + \varepsilon_{c,t}$$

where  $High_c$  is an indicator variable for whether economy  $c$  is above the cross-economy median of a specific indicator. The two indicators presented in the chapter are stringency of employment protection regulations and economy-level average markups.<sup>8</sup>

### Additional results

Table 2.4.1 shows regression results for different wage Phillips curve specifications. The first six columns show regressions only including inflation expectations and unemployment variables as the main variables of interest. Columns (6) and (7) report the baseline specification reported in Figure 2.6 in the chapter, while columns (8) and (9) report results adding lagged inflation as an additional dependent variable. Across specifications, there is a positive relationship between wage growth and inflation expectations—with a larger coefficient for advanced economies—and a negative relationship with unemployment variables. When adding lagged inflation as a dependent variable, the coefficient on inflation expectations remains positive, although significance is lost for emerging markets.<sup>9</sup>

Figure 2.4.1 shows additional results. Panel 1 shows changes in wage Phillips curve relationships in advanced economies. Panel 2 shows the same decompositions as in Figure 2.6 in the chapter, focusing instead on the Great Financial Crisis. Although wage movements are less abrupt during this period in both advanced and emerging economies, two patterns are similar to the most

**Annex Table 2.4.1. Wage Phillips Curve Estimation**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Inflation Expectations	1.191*** (0.227)	0.489*** (0.158)			1.012*** (0.162)	0.528*** (0.158)	1.026*** (0.158)	0.503*** (0.149)	1.648*** (0.240)	0.106 (0.315)
Unemployment			-0.476*** (0.140)	-0.578** (0.205)	-0.361*** (0.0900)	-0.601*** (0.123)	-0.364*** (0.0880)	-0.591*** (0.125)	-0.354*** (0.0839)	-0.611*** (0.124)
Unemployment Change			-0.142 (0.201)	-0.790* (0.398)	-0.614** (0.272)	-0.991 (0.592)	-0.595** (0.266)	-1.241** (0.541)	-0.553** (0.243)	-1.276** (0.526)
Productivity							0.127 (0.0828)	0.629** (0.248)	0.122 (0.0776)	0.604** (0.247)
Lagged Inflation									-0.477*** (0.145)	0.354** (0.163)
Number of Observations	2,263	930	2,391	985	2,263	930	2,263	930	2,263	930
Adjusted $R^2$	0.45	0.60	0.51	0.57	0.53	0.62	0.53	0.63	0.54	0.63
Sample	AEs	EMEs	AEs	EMEs	AEs	EMEs	AEs	EMEs	AEs	EMEs

Source: IMF staff calculations.

Note: Unbalanced sample of 31 advanced economies and 15 emerging markets covering 2000:Q1–19:Q4. See Online Annex 2.1 for details on the sample coverage. Clustered standard errors reported in parentheses. AEs = advanced economies; EMEs = emerging market economies.

\*\*\*  $p < 0.01$ ; \*\*  $p < 0.05$ ; \*  $p < 0.1$ .

<sup>8</sup> As noted in the text, coefficients on unemployment and inflation expectations are statistically significant for all groups. However, interaction coefficients are only statistically significant when comparing unemployment coefficients between low and high employment protection groups.

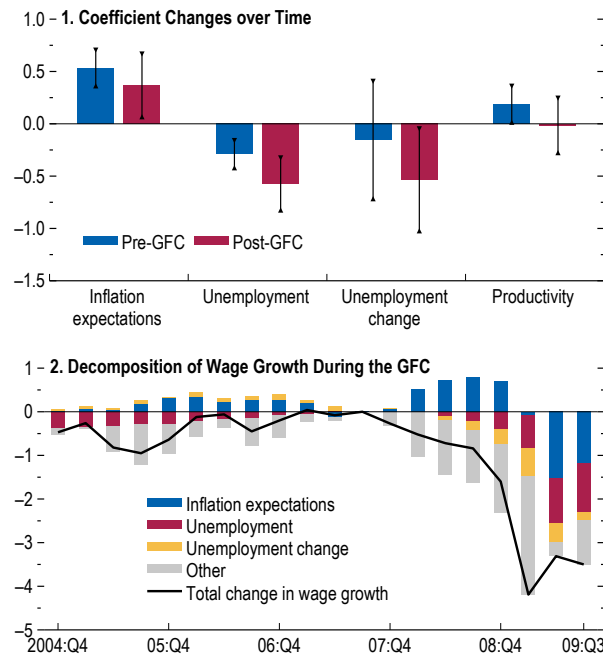
<sup>9</sup> This would be consistent with a more forward-looking wage-setting process in advanced economies than in emerging ones.

recent crisis. The first is the presence of large residuals at the time of the shock. The second is the reduction of those residuals over time.

Figure 2.4.2 shows a decomposition adding hours worked as an independent variable. The conclusions with respect to the role of employment slack and inflation expectations seem to hold when controlling for changes in working hours observed. As an additional exercise, we estimated the baseline specification using alternative slack measures. Figure 2.4.3 panel 1 shows the evolution of alternative employment slack measures, including a standard unemployment gap<sup>10</sup>, a gap measure using an approach proposed by Michailat and Saez (2022)<sup>11</sup>, and the unemployment-to-vacancy ratio. Figure 2.4.3 panel 2 presents the wage Phillips curve coefficients using the unemployment gap as an alternative measure for the full sample of economies. Figure 2.4.4 shows coefficients and a decomposition using unemployment-to-vacancy ratios as slack measures for the US—the only economy for which we have data for the

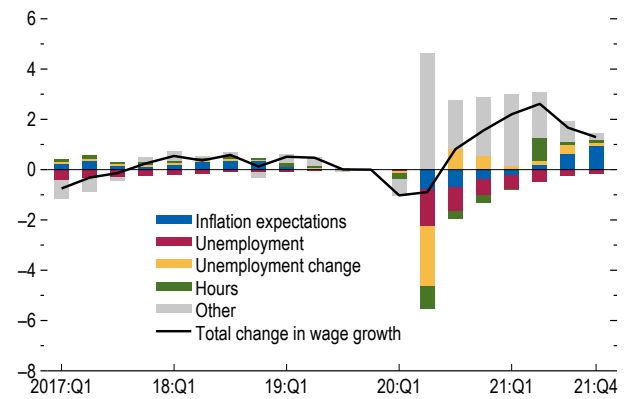
entire post-2000 sample period. Results are broadly consistent with the baseline, although greater tightness reflected in this measure implies greater explanatory power in describing the latest wage dynamics.<sup>12</sup>

**Annex Figure 2.4.1. Wage Phillips Curve over Time**  
(Percentage points)



Source: IMF staff calculations.  
Note: In panel 1, sample includes 29 advanced economies with available data pre- and post-2008. Coefficients estimated on unbalanced panel spanning 1990–2019. Whiskers indicate 90 percent confidence intervals. In panel 2, contributions calculated using pooled wage Phillips curve coefficients from 29 advanced economies, estimated on the sample covering 2000:Q1–19:Q4. Bars illustrate contributions of each component relative to contributions observed in 2007:Q3. Line depicts total per-worker wage growth observed relative to the reference point. Contributions illustrated only include economies with continuously available data throughout the period shown. These are aggregated using GDP purchasing-power-parity weights. Other category contains the productivity growth contribution, as well as time effects, economy effects and the residual. See Online Annex 2.1 for details on the sample coverage. GFC = global financial crisis.

**Annex Figure 2.4.2. Wage Growth Decomposition with Hours**  
(Percentage points)



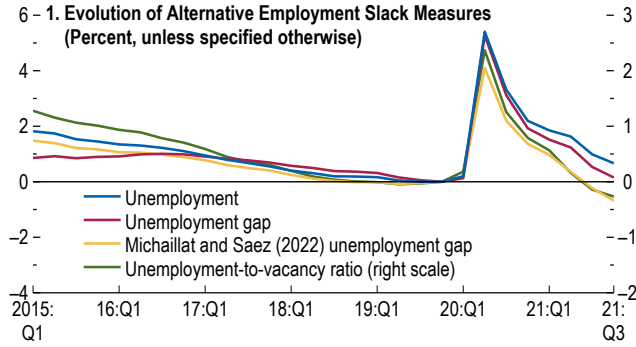
Source: IMF staff calculations.  
Note: Contributions calculated using pooled wage Phillips curve coefficients from 29 advanced economies, estimated on the sample covering 2000:Q1–19:Q4 and augmented with changes in hours-worked. Bars illustrate contributions of each component relative to contributions observed in 2019:Q4. Line depicts total per-worker wage growth observed relative to 2019:Q4. Contributions illustrated only include economies with continuously available data from 2017:Q1–21:Q4 and are aggregated using GDP purchasing-power-parity weights. Other category contains the productivity growth contribution, as well as time effects, economy effects and the residual. See Online Annex 2.1 for details on the sample coverage.

<sup>10</sup> The unemployment gap is calculated as the difference between the unemployment rate and the neutral unemployment rate, where the latter is the result of an HP filter with a parameter of 1,600.

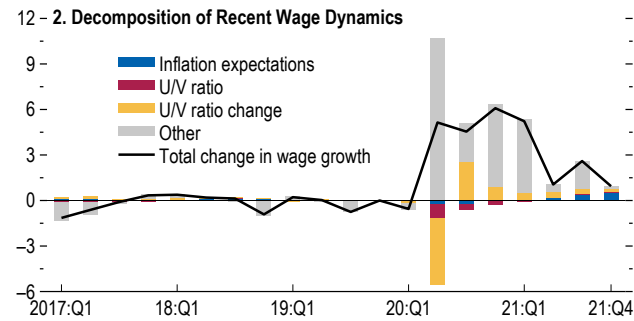
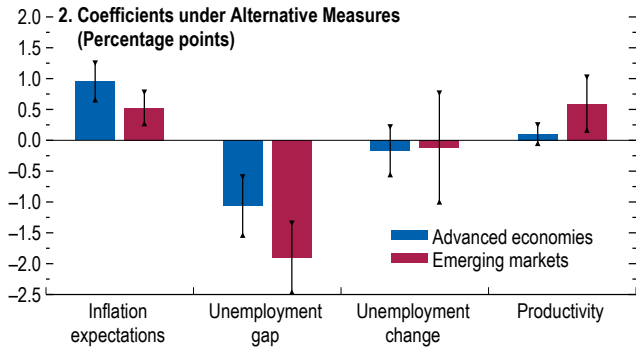
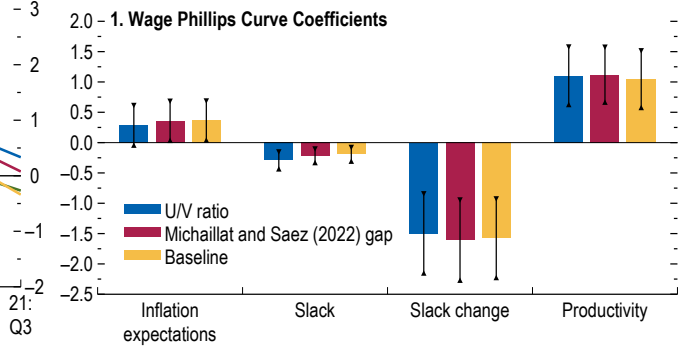
<sup>11</sup> This uses the square root of the product of the unemployed and vacancies as the measure of the efficient unemployment rate.

<sup>12</sup> Additional wage growth decomposition results similar to Figure 2.6 in the chapter are available under alternative measures upon request.

Annex Figure 2.4.3. Wage Phillips Curve under Alternative Slack Measures



Annex Figure 2.4.4. Wage Phillips Curve Using Unemployment-to-Vacancy Ratios: United States (Percentage points)



Source: IMF staff calculations.

Note: In panel 1, averages weighted by purchasing-power-parity GDP across 14 advanced economies with available data. Differences relative to 2019:Q4 plotted. “Michailatz and Saez (2022) unemployment gap” refers to the difference between the unemployment rate and the square root of the unemployment-vacancy product divided by labor force participation. Panel 2 reports estimated coefficients from wage Phillips curve regression, using the unemployment gap as a measure of slack. The sample covering 2000:Q1–19:Q4 consists of 31 advanced economies and 15 emerging markets. Whiskers indicate 90 percent confidence intervals. See Online Annex 2.1 for details on the sample coverage.

Source: IMF staff calculations.

Note: “U/V ratio” refers to estimation using the unemployment-to-vacancy ratio at a quarterly frequency as a slack measure. “Michailatz and Saez (2022) gap” refers to the unemployment gap computed as the difference between the unemployment rate and the square root of the unemployment-vacancy product divided by labor force participation. “Baseline” refers to specification using unemployment rate. Sample covers the United States from 2000:Q1–19:Q4. Whiskers indicate 90 percent confidence intervals. In panel 2, bars illustrate contributions of each component relative to contributions observed in 2019:Q4. Line depicts total wage growth per worker relative to reference point. Other category contains the productivity growth contribution, as well as time effects, economy effects and the residual. U/V = unemployment-to-vacancy.

## Annex 2.5. Contributions of supply and demand shocks to wages and prices

The chapter uses a multi-economy, multi-sector general equilibrium model to study the relative contributions of supply and demand shocks to wages and prices. The model is based on recent work by Baqaee and Farhi (2022a; 2022b) and Gourinchas and others (2021) and relies on a nested constant elasticity of substitution (CES) structure. This means that all decision points—whether they represent households maximizing utility over different consumption goods or firms deciding on a mix of intermediate inputs to minimize costs—can be described by CES aggregators. The economy includes multiple sectors, each modelled via a representative firm, that share input-output links. The model also includes international trade, with partner economies combined into a single rest of the world (ROW) aggregate for numerical tractability.

The model features 2 periods, where the second period can be thought of as

Annex Table 2.5.1. Armington Trade Elasticities

Agriculture and Food	6.3
Energy	22.8
Other Industry	6.8
Construction	1.5
Services	5.0

Sources: Baqaee and Farhi (2022b); Caliendo and Parro (2015).

a return to steady state after all shocks resorb as in Krugman (1998) and Eggertsson and Krugman (2012). Finally, the model includes nominal downward wage rigidities and credit constraints, which generate hand-to-mouth households and endogenous aggregate demand fluctuations. A full description of the model and the economic environment can be found in Baqaee and Farhi (2022b) as well as in Wingender (forthcoming).

### Calibration of structural parameters

The model's main building blocks are derived from inter-economy input-output (ICIO) tables published by the OECD. The tables are used to quantify expenditure, input and factor shares as well as sectoral and trade linkages. Data from 2018 (the last year available) are used to describe both the pre- and post-COVID steady state equilibria. Intermediate and final uses are aggregated into two economies (domestic and foreign) and five categories (agriculture and food manufacturing; energy; other industry; construction and services). There are three types of final demand: household consumption, government consumption and other final demand—the sum of investment, changes in inventories, non-profits and direct purchases abroad by residents. The breakdown of sectoral value-added is not directly published as part of the ICIO tables, but labor and capital shares by economy and sector can be calculated from the Trade in Employment (TiE) database that relies on the same 44 ISIC category classification.

*Households.* Elasticity parameters are calibrated as in Baqaee and Farhi (2022a; 2022b) and Gourinchas and others (2021). Starting with households, a first elasticity of substitution is used to determine intertemporal consumption decisions. The chapter uses a CES coefficient of 0.95, which implies a marginal propensity to consume for Ricardian households of 5 percent (Gourinchas and others 2021). Households also decide on the composition of a consumption basket over the 5 types of goods with a CES parameter of 0.8. Each consumption good in turn consists of an Armington aggregate over domestic and foreign varieties, with trade elasticities given in Table 2.5.1.<sup>13</sup>

*Firms.* Sectoral production by price-taking firms consists of 3 nests. At the highest nest, production combines value-added and intermediate inputs using constant returns to scale technology with CES coefficient equal to 0.6. Value-added consists of labor and capital that are combined using a CES parameter of 0.5. The intermediate input bundle aggregates sectoral output using a CES function with parameter equal to 0.2. Finally, just as for final consumption goods, sectoral output from each economy is combined for domestic use using the trade elasticities in Table 2.5.1 and economy and sector-specific input shares from the ICIO.

*Labor markets.* The chapter assumes downward nominal wage rigidities, meaning that wages cannot decline from their steady state value. When workers in a sector face a lower demand schedule for labor, the market cannot clear, leading to Keynesian unemployment in that sector. As in Baqaee and Farhi (2022b), unemployed households cannot borrow or consume without government transfers, which in turn reduces aggregate demand. Nominal wage rigidities therefore introduce a role for aggregate demand management, and for monetary policy in particular to impact real output and employment.

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<sup>13</sup> Elasticities from Table 2.5.1 are simple averages from the 35 categories used in Baqaee and Farhi (2022a).

### Calibration of supply and demand shocks

As described in the chapter, 7 types of shocks are used to decompose wage and price dynamics in response to the COVID pandemic. Because of the model's simple 2-period structure, only one period of shocks can be considered at a time. Therefore, shocks are calibrated using cumulative changes between the last year of pre-pandemic data and observed values at end-2020 and end-2021. The model is then solved separately for the two years.

On the supply side:

- *Production capacity and labor supply shocks* are calibrated by matching changes in total hours worked by economy and sector between 2019 and 2020 and 2021. As in Baqaee and Farhi (2022b), the chapter assumes only labor supply was affected by lockdowns and social distancing. This means that the decline in hours resulting from the shocks had to be accompanied by increases in hourly wages. In the data, this was the case for all sectors except construction in the United States for 2020.
- *International trade cost shocks* are measured by taking the log difference between the CIF (cost, insurance, freight) and FOB (free on board) values of imports by detailed goods classification published by the United States Census Bureau. The analysis assumes these trade costs are exogenous and increase by the same amount for goods in all other economies. By the 4th quarter of 2021, trade costs had increased by 7 percent compared to 2019 for the manufacturing sector on average. Trade costs are assumed to be zero for services.
- *Commodity price shocks* are calibrated by adjusting total-factor productivity for the food and energy sectors so that the model-based sectoral price changes in general equilibrium match the changes in the Energy and Food Price Indexes published by the IMF Primary Commodity Prices database. The published indexes show that energy and food prices had increased by 85 and 20 percent year-on-year respectively in 2021. In the model, this is the result of the underlying TFP shocks and the endogenous responses of supply and demand.

On the demand side:

- *Consumption composition shocks* are modelled by changing the consumption weights in the household CES utility function to match changes in expenditure shares over time. These shares are calculated for every quarter by detailed consumption categories published by the Bureau of Economic Analysis (BEA) for the United States and then aggregated to the 5-goods aggregation used in the model. For OECD member and selected other economies, only household consumption by durability is widely available in the OECD Quarterly National Accounts or national sources. Food and energy are matched to non-durables, while other industries and construction are considered durables. The share of services is also tracked as a separate category.
- *Fiscal policy support* during the pandemic is calibrated by multiplying government consumption in the input-output tables by changes in the nominal value of government final consumption

in 2020 and 2021.<sup>14</sup> Government spending on transfers to households is not part of the standard input-output presentation. To include this channel in the model, the ratio of transfers to government consumption over time is used. These transfers are then included directly in the budget constraint of hand-to-mouth households. Since the analysis assumes the government’s intertemporal budget constraint must hold, Ricardian households do not respond to the disbursement of transfers.

- *Monetary policy support* is calibrated by using changes in the central bank policy rates. Since the United States and the euro area were at their effective lower bound during the crisis, the shadow policy rates from Wu and Xia (2016, 2017) are used instead.<sup>15</sup>
- *Changes in consumers’ saving behavior* is calibrated by adjusting the discount rate in the consumption Euler equation. The calibration ensures that households’ savings rate in general equilibrium in the model matches aggregate savings rates by economy over time as measured by the OECD’s Annual National Accounts database.

### Annex 2.6. Wages and Economic Dynamics: Inflation Shocks and Monetary Policy

The following equation is estimated using a Local Projection (LP) framework on a quarterly panel of sixteen euro area economies over 1999:Q4–2019:Q4:<sup>16</sup>

$$y_{t+h,i} = \alpha_i^h + \sum_{j=1}^4 \rho_j^h y_{t-j,i} + \sum_{j=0}^4 \beta_j^h s_{t-j} + \sum_{j=0}^4 \gamma^h x_{t-j,i} + \varepsilon_{t,i}^h$$

The outcome variable,  $y_{i,t}$ , is, in turn, the economy’s nominal and real wage growth, unemployment rate, realized inflation and 12-month ahead expected inflation.<sup>17</sup> Each of these variables is considered at different horizon, with  $h=0, \dots, 8$  quarters. The main explanatory variable,  $s_t$ , is the inflationary shock in the first exercise, and the monetary shocks in the second exercise. Furthermore, the specification controls for other factors relevant for each exercise. In the former, the VIX proxies for global financial market uncertainty, and monetary policy shocks control for the policy reaction. In the latter, central bank communication shocks are included to take into account outlook surprises (Jarociński and Karadi 2020). Standard errors are clustered at economy-level, and they are corrected for heteroscedasticity and autocorrelation until the eighth lag.

The Fed Global Supply Chain Pressure Index (GSCPI) (Benigno and others 2022) is used as proxy for inflationary shocks since changes in the index have had a meaningful impact on euro area PPI and goods CPI inflation for the 1997-2021 period (Akinci and others 2022). The index encapsulates information on global factors that pose disruption pressure on supply chains. Two sets of factors are considered: (i) manufacturing data, such as backlogs and delays; and (ii) shipping

<sup>14</sup> For the United States, changes in subsidies on production and imports are also included. This line item saw a large increase in 2020.

<sup>15</sup> For data, see <https://sites.google.com/view/jingcynthiawu/shadow-rates> [downloaded on July 6, 2022].

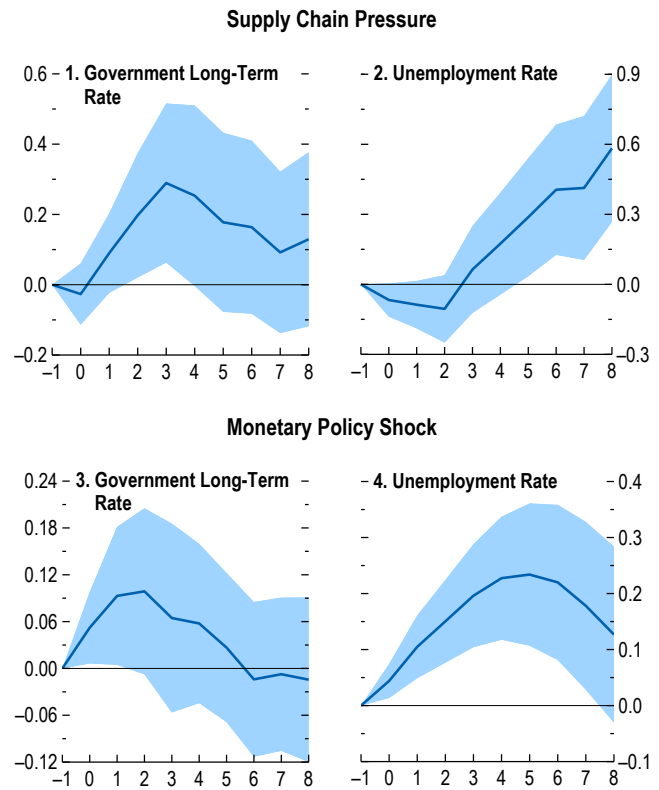
<sup>16</sup> The pandemic period is excluded due to the temporarily structural breakdown induced by lockdowns and discretionary policies. The list of economies included in the analysis is reported in Table 2.1.2.

<sup>17</sup> Sources are reported in Table 2.1.1.

costs and airfreight price indices. The index is the principal components of twenty-seven variables previously purged for demand factors, thus it can be considered a supply-side shock.<sup>18</sup> To address endogeneity concerns, the index enters the equation in a lagged form, and, to account for exposure heterogeneity, the index is multiplied by economy-level openness, defined as the sum of exports and imports as share of GDP, lagged.

In the second exercise, monetary policy shocks are sourced from Jarociński and Karadi (2020).<sup>19</sup> Shocks are identified based on a Bayesian structural VAR with high-frequency data and sign restrictions. The time series of the monetary policy surprises is aggregated at quarterly frequency to match the frequency of the dependent variables. The aggregation is based on the weighting scheme by Ottonello and Winberry (2020).<sup>20</sup> Figure 2.7 in the main text shows the cumulative effect at different horizons on the real and nominal wage growth, as well as expected and realized inflation to a one standard deviation of each shock. Figure 2.6.1 reports the cumulative effect on the government long-term rate and unemployment. Results are robust to different samples (dropping one economy at time and considering only economies in the euro area since 1999), as well as to alternative (i) orders of autocorrelation in the residuals, and (ii) measures of economy's exposure (using the OECD participation in GVCs).<sup>21</sup>

**Annex Figure 2.6.1. Cumulative Effects of Supply Chain Pressure and Monetary Tightening on Unemployment and Government Long-Term Rate**  
(Percentage points; dynamic response)



Sources: Federal Reserve Bank of New York; Haver Analytics; Jarociński and Karadi (2020); Organisation for Economic Co-operation and Development; and IMF staff calculations.  
Note: Lines show the estimated impulse responses of the indicated variable to the indicated shock, with the shaded area representing the 90 percent confidence interval. The horizontal axes show time in quarters, where  $t = 0$  is the initial impact quarter of the shock. The estimation sample includes euro area economies over 1999:Q4–2019:Q4. Panel 1 and 2 are the responses to a supply chain pressure shock, defined as a one standard deviation increase in the Federal Reserve Bank of New York's Global Supply Chain Pressure Index. To account for economies' different degrees of exposure, the index is weighted by an economy's trade openness. Panel 3 and 4 are the responses to a one standard deviation monetary policy shock, as identified as in Jarociński and Karadi (2020). See Online Annex 2.1 for details on the sample coverage.

<sup>18</sup> Refer to Benigno and others (2022) for a more extended description of the GSCPI methodology and data.

<sup>19</sup> We use the updated version of the shocks that considers the first principal component of the unexpected changes in the overnight index swaps (OIS) with one-, three-, six-months and one-year maturities (Jarociński and Karadi 2020, time series downloaded from <https://marekjarocinski.github.io/> on June 2022). We are grateful to the authors to maintain updated the time series.

<sup>20</sup> The authors apply a triangular weighting scheme over the previous and current quarter to incorporate the time that agents take to react. The aggregation considers the fact that shocks occurring at the beginning of the quarter weight more on agents' decisions.

<sup>21</sup> Participation in GVCs is proxied using the sum of an economy's backward and forward participation. These are defined as the foreign and domestic value-added share of gross exports, by the value added of the origin economy.



Finally, to test whether inflation expectations are less sensitive to shocks in economies where inflation expectations are more anchored to start with, the following state-dependent equation is estimated:

$$y_{t+h,i} = D_{t-1,i} * [\alpha_{i,A}^h + \sum_{j=1}^4 \rho_{j,A}^h y_{t-j,i} + \sum_{j=0}^4 \beta_{j,A}^h s_{t-j} + \sum_{j=0}^4 \gamma_A^h x_{t-j,i}] + (1 - D_{t-1,i}) * [\alpha_{i,B}^h + \sum_{j=1}^4 \rho_{j,B}^h y_{t-j,i} + \sum_{j=0}^4 \beta_{j,B}^h s_{t-j} + \sum_{j=0}^4 \gamma_B^h x_{t-j,i}] + \varepsilon_{t,i}^h$$

where  $D_{t-1,i}$  is a time varying dummy indicated that inflation expectations are well-anchored. To identify these cases, we use the Bems and others (2021) index of the strength of inflation anchoring.<sup>22</sup> The indicator is the simple average of three metrics: (i) deviation of long-term mean inflation forecasts from target, (ii) variability of mean long-term inflation forecasts, (iii) dispersion of long-term inflation forecasts. The reference horizon used is 5-year ahead. The dummy  $D_{t-1,i}$  equals one if the index in economy  $i$  at time  $t-1$  is above the cross-economy and cross-time median. Figure 2.8 in the main text, plots the coefficients  $\beta_{j,A}^h$  and  $\beta_{j,B}^h$ , which capture the dynamic effect of the inflationary shocks at each horizon in economies with well- versus less-anchored inflation expectations, respectively. It shows that the impact of inflationary shocks on 12-month ahead inflation expectations is less persistent in economies with better-anchored inflations expectations.

### Annex 2.7 Role of Wage and Price Expectations: Scenarios from a Small DSGE Model

Motivated by the need to better model the expectations formation and to match the inertia of macroeconomic variables, a growing literature has proposed deviations from the standard rational expectations (RE) assumption. The model presented here assumes that economic agents form their expectations based on a simple statistical model informed by a limited set of observed variables. Those agents update their beliefs about the underlying economic relations when new data becomes available. These expectations are called adaptive learning (AL).

Our workhorse model is based on Galí, Smets, and Wouters (2012) and Berg and others (2006), which is a standard New Keynesian model that includes wage and price Phillips curves (PC). The equilibrium equations of the linearized system are given by:

$$\begin{aligned} y_t &= \alpha_{yL} y_{t-1} + \alpha_{yF} y_{t+1} + \gamma(\pi_{t+1} - r_t) + s_{yt} && \text{(IS Curve)} \\ s_{yt} &= \rho_\varepsilon s_{yt-1} + \varepsilon_{yt} && \text{(Shock process)} \\ \pi_t &= \alpha_{\pi L} \pi_{t-1} + \alpha_{\pi F} \pi_{t+1} + k_\pi w_t + \varepsilon_{\pi t} && \text{(Price PC)} \\ \pi_{wt} &= w_t - w_{t-1} + \pi_t && \text{(Nominal wage definition)} \\ \pi_{wt} &= -\alpha_{wL} w_{t-1} + \alpha_{wF} \pi_{wt+1} + K_w y_t + \varepsilon_{wt} && \text{(Wage PC)} \\ r_t &= \rho r_{t-1} + (1 - \rho)(\rho_\pi \pi_{t+1} + \rho_y y_t) + \varepsilon_{rt} && \text{(Policy reaction function),} \end{aligned}$$

<sup>22</sup> Due to limited data availability of the Bems and others (2021) index, the sample is reduced to 10 euro area economies (see Annex Table 2.1.2).

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where  $y$  is the output gap (measure of slack),  $\pi$  is quarter-on-quarter, annualized core inflation rate,  $r$  is the nominal monetary policy interest rate,  $w$  is the constant composition real wage gap (real wage deviations from labor productivity growth) and  $\pi_w$  is real wage inflation.

In an RE model, in the absence of further shocks, the expectation is the same as the future value:  $E_t[x_{t+1}] = x_{t+1}$  given  $\varepsilon_{t+1} = 0$ . Economic agents use information on all the variables in the model and the expected value is a complicated function on the parameters. For the AL model, we use a version of the updating model developed in (Slobodyan and Wouters 2012a; 2012b). In particular, the AL model of economic agents' expectations follows an AR(2) process:

$$E_t[x_{t+1}] = \alpha_t + \beta_t^1 x_t + \beta_t^2 x_{t-1} \quad (\text{forecasting equation})$$

Note that the coefficients in this equation vary over time. They depend on how accurate the forecast is at each period. Since the models is in deviations, we would expect that these coefficients be close to zero in the inflation expectations equation if inflation is well-anchored. That is, expected inflation doesn't change much given current inflation. The fully adaptive expectations case is a particular case of this specification when  $\alpha_t = 0$ ,  $\beta_t^1 = 1$  and  $\beta_t^2 = 0$

At each period, agents update these coefficients using a Kalman filter mechanism, and the learning update vector evolves according to:

$$B_{t|t} = B_{t|t-1} + P_{t|t-1} X_{t-1} [\Sigma_t + X'_{t-1} P_{t|t-1} X_{t-1}]^{-1} * (\text{forecast errors}),$$

where the  $B_{t|t}$  is a vector that stacks all the coefficients of the AR(2) processes,  $P_{t|t-1}$  is the covariance matrix and  $\Sigma_t$  is the variance-covariance matrix of the AR(2) equation residuals.

The model described above is estimated with Bayesian methods and quarterly macroeconomic data from 2000:Q1 to 2019:Q4 for Brazil and the USA. The set of variables included in the estimation are the output gap, the real wage gap, annualized quarterly price inflation deviation from target, and the policy rate. Since our model does not have enough structure to explain workforce composition change, we use the composition-constant real wage calculated by Howard, Rich, and Tracy (2022) for the USA and the one used in (Dizioli and Wang, forthcoming) for Brazil.

The output and real wage gaps were calculated with both HP and linear filters. The results in the next section use the linear filter, which was chosen because the model has better in-sample (Table 2.7. 1) and out-of-sample forecast performance for wages and prices (Table 2.7.2). The modelling strategy contributes to the current debate about adaptive expectations. A price Phillip's curve that only includes the output gap and not marginal cost (real wage gap) directly would predict that, under adaptive expectations, the only way to lower inflation is with a negative output gap. This model shows that a negative real wage gap could enable an anchoring to inflation even with fully adaptive expectations.

**Annex Table 2.7.1. In-Sample Forecast Performance for RE and AL Models**

Log Marginal Likelihood	RE	AL
Linear Filter	-391.1	-341.4
HP Filter	-342.9	-338.5

Source: IMF staff estimates.

Note: AL = adaptive learning; HP filter = Hodrick-Prescott filter; RE = rational expectations.

**Annex Table 2.7.2. Out-of-Sample Forecast Performance for RE and AL Models**

	Real Wage Gap		Output Gap		Policy Rate		Inflation		
	RE	AL	RE	AL	RE	AL	RE	AL	
Linear Filter									
1-Quarter Ahead RMSE	0.15	0.22	0.05	0.11	0.06	<b>0.01</b>	1.41	0.47	
4-Quarters Ahead RMSE	<b>0.95</b>	1.44	0.63	1.11	0.56	<b>0.27</b>	0.66	<b>0.31</b>	
8-Quarters Ahead RMSE	1.39	<b>1.13</b>	1.52	1.52	0.64	0.48	0.31	<b>0.19</b>	
HP Filter									
1-Quarter Ahead RMSE	<b>0.09</b>	0.53	<b>0.02</b>	0.11	0.05	0.03	<b>0.2</b>	0.28	
4-Quarters Ahead RMSE	1.43	1.27	<b>0.5</b>	0.88	0.73	0.44	0.8	0.64	
8-Quarters Ahead RMSE	1.18	1.62	<b>1.02</b>	1.05	1.52	<b>0.25</b>	0.49	0.41	

Source: IMF staff estimates.

Note: Numbers in bold indicate models that performed the best at that horizon. AL = adaptive learning; HP filter = Hodrick-Prescott filter; RE = rational expectations; RMSE = root-mean-square error.

## Comparison of the estimation results for Brazil and the USA

If inflation expectations are well anchored, we would expect the lag inflation coefficients in the household’s forecasting equation above to be small and the mean inflation to be zero. The first striking result in Figure 2.7.1 is that expectations in Brazil depend a lot more on past outcomes than in the US. This can be seen when adding the coefficients on the first two lags of both inflation and wages. The case of real wages expectations is even more striking as they seem substantially more persistent in Brazil. The second result to highlight from this figure is the coefficient stability over the last ten years before the pandemic. The coefficient reflecting the mean expected inflation was zero as households expected inflation to be at the central bank target. The pandemic challenged this stability in both economies, as both started seeing inflation outcomes above target. As inflation expectations respond more to past inflation outcomes in Brazil, there is feedback from inflation to inflation expectations that keep inflation higher for longer for all the shocks in the model, despite stronger monetary policy response in Brazil. Monetary policy has to do more to lower inflation in an EM economy like Brazil, even if they are hit with the same shocks.

## Optimal monetary policy decisions

Instead of using the estimated monetary policy reaction function, this chapter defines the optimal monetary policy path as the interest rate path,  $\{i_t\}$  for  $t=1$  to  $\infty$ , that minimizes the welfare function below:

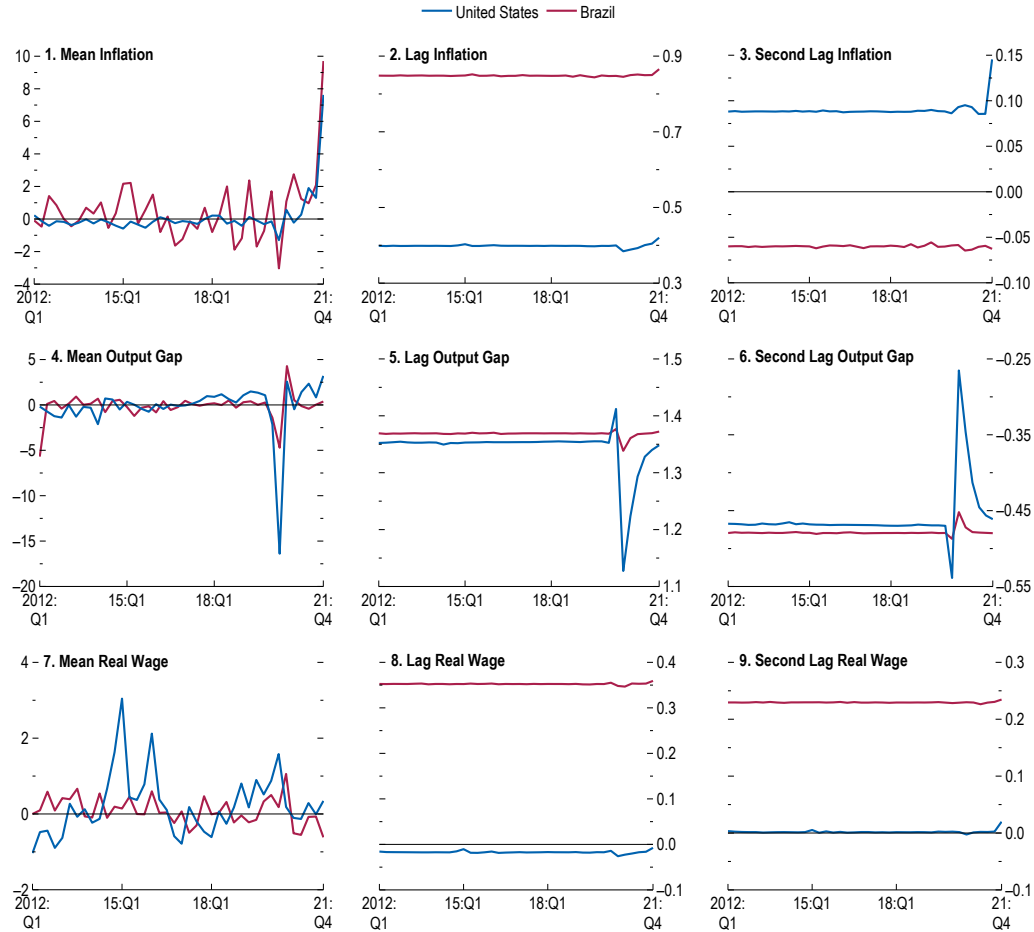
$$\sum_{t=j}^{\infty} \beta^t (0.75(i_t - i_{t-1}) + (y_t - 0)^2 + (\hat{\pi}_t - 0)^2),$$

note that it is assumed an equal weights for output gap ( $y_t$ ) and inflation deviations from target ( $\hat{\pi}_t$ ). It is also assumed a role for interest rate smoothing. Other implicit assumptions are that the central bank has full knowledge of the current shocks hitting the economy, know all the future shocks that will hit the economy and have full knowledge of how their actions impact expectations.

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In the estimated AL model, the central bank has three channels to influence inflation. The standard direct channel in which a tighter policy cools-off demand, lowering the output gap and hence inflation. The other two channels operate through inflation expectations. By tightening policy, the central bank lowers current inflation that enters into the forecasting equation, lowering next period expectations. Finally, the central bank can also affect the coefficients in the forecasting equation. By seeing less inflation this period than they have expected, households update their model of how past inflation matters for future inflation.

**Annex Figure 2.7.1. Dynamic Beliefs on the Adaptive Learning Expectation Process**  
(Unit)



Source: IMF staff calculations.  
Note: Mean inflation is measured as deviation from the inflation target.

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