

# The US wage-price spiral, before, during and after COVID-19, through the lens of an empirical econometric model

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Part of NFR project no. 324472

26th Dynamic Econometrics Conference  
3-5 April 2024

Preliminary

# Section 1

## Introduction and literature

# Background

- Towards the end of the COVID-19 pandemic, price levels in many countries started to increase faster than had been usual since the 1990s.
- Increasing energy prices were seen as important drivers of inflation already before the Russian invasion of Ukraine.
- A strong bounce back in aggregate demand, together with pandemic related frictions in product and labour markets, were also seen as contributors to higher inflation.
- Then, a faster turning Wage-price spiral, was re-discovered as a source of inflation persistence, after the initial shocks had become a thing of the past.

# The Wage-price spiral

- As we use the term, the Wage-price spiral refers to the joint dependencies between price and wage setters, Blanchard (1987).
- Firms: mark-up prices as a way to compensate for raised costs.
- Workers:
  - ▶ compensation for increased costs of living
  - ▶ secure a share of value added creation (functional income distribution)
- The Wage-price spiral is an interesting object of research even if inflation is not on an unstable or explosive path.
- The Wage-price spiral will in any case affect the persistence of inflation, and it is therefore of interest, in particular for assessing the cost of policies that aim to control inflation, Akram and Nymoen (2009).
- Since the wage-price spiral is generic, it is relevant to use a long sample for modelling, to better study whether it has changed during the COVID-19 era. This is one of the aims of the paper.

# The Wage-price spiral (continued)

- We are able to build on an earlier offering in Bårdsen and Nymoen (2009), where we modelled annual U.S. wage and price data, using cointegration methodology.
- However, a main focus is on the pandemic-era inflation in the U.S., and to supplement the studies that already exist.

## From the literature

Cecchetti et al. (2023):

The choice of sample period is consequential for the model's ability to explain the pandemic era inflation. Phillips curves estimated using data that include the high and volatile inflation episodes of the 1960s and 1970s do a better job of tracking the new rise in inflation, than models that are based on the Great moderation.

This can be interpreted as consistent with other results that indicate a flattening of the Phillips curve during the Great moderation, Blanchard (2016) and Hazel et al. (2022).

However, Phillips curve modellers have also found that the curve may have become steeper again when data from the pandemic is taken into account, see Ari et al. (2023).

## From the literature (continued)

Blanchard and Bernanke (2023): Model based analysis of pandemic era U.S. inflation.

- Theory: Short and long-term inflation expectations together with labour market tightness are the main explanatory variables. In addition comes supply-shocks (not modelled).
- Results:
  - ▶ A tight labour market gave a modest push to inflation early in the pandemic.
  - ▶ Latent demand, when unleashed, increased the price of goods for which supply was inelastic.
  - ▶ Energy prices accounted for much of the rise in overall inflation in late 2021 and first half of 2022.

## From the literature (continued)

di Giovanni et al. (2023): Fiscal stimulus during the pandemic as an inflation factor,

Hagedorn (2023) gives theoretical arguments for inclusion of federal transfers in a nominal demand augmented price Phillips curve, and reports empirical results which support that hypothesis.

None of the above bring import prices into the picture.

Amiti et al. (2024): Global shocks dominated U.S. import price increases for most of the pandemic period. After the middle of 2022, when global price inflation subsided, they found that idiosyncratic U.S. demand and supply components gained in importance (for U.S. import prices).

## Section 2

### Theory: Model category and model types

# Model category

- We model the wage-price spiral as a system of stochastic difference equations for nominal wage- and price changes ( $\Delta w_t$  and  $\Delta p_t$  in a typical notation).
- A D-VAR (VAR in differences) is a special case. Subject to a (low frequency) unit-root, unstable inflation is then implied.
- But generally, the system contains a part (a module) made up of cointegration relationships, between variables in levels (e.g.,  $w_{t-1}$  and  $p_{t-1}$ ).
- Within this model category, we distinguish between Phillips curve models, PCMs, and equilibrium correction models EqCMs.

# PCM and EqCM model types

PCM:

- The cointegration part is in principle very simple: A variable that represents the level of labour market tightness. (How best to operationalize tightness is not a small issue though.)

WP-EqEM:

- The cointegration part of the system consists of relationships between level variables,  $w_{t-1}$  and  $p_{t-1}$  in particular;
- Usually interpreted as long-run wage and price curves.

- In the analysis of U.S. inflation, PCMs are regularly used.
- With good reason, one must assume.
- However, rent-sharing as a phenomenon may thrive under other institutional set-ups than the ones where collective bargaining plays a main role.
- In that case, the WP-EqCM can be a relevant model type for U.S. wage-price inflation.
- We also take some heart from our earlier offering, Bårdsen and Nymoen (2009) where we estimated an interpretable WP-EqCM for U.S. with annual time series.

# Illustrative simulations of the model types

In section 2 of the paper we have included two stylized and calibrated versions of the model types.

- The PCM-specification ( § 2.4 and appendix B) is due to Blanchard and Bernanke (2023).
- The WP-EqECM ( § 2.1-2.3) and Appendix A) builds on our own previous work, including joint work with Dag Kolsrud, see Bårdsen et al. (2017), Kolsrud and Nymoen (2014) as well as earlier publications.

# Expectations

A particular trait of the the Blanchard and Bernanke model (BB hereafter) is the focus on inflation expectations.

- But not in the form of Rational Expectation and NK-PCMs .
- It is a model with adaptive expectations.
- Two main cases: Weak feedback: Expectations are weakly correlated with actual inflation ( “well anchored expectations” ).
- Strong feedback ( the opposite, “not well anchored expectations” ).

One interpretation of the WP-EqECM, is therefore that the inflation expectations variables have been substituted out, with consequences for the coefficients of lagged prices and wages.

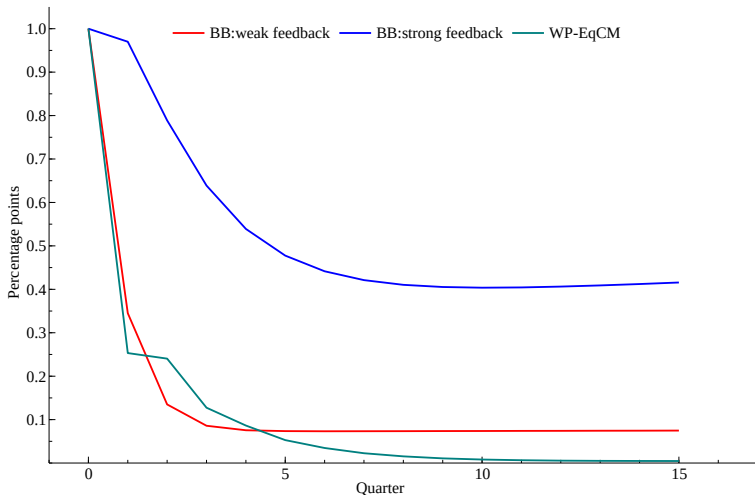


**Figure 1:** Inflation responses to a 1-period shock to  $\Delta p_t$ . Two alternative calibrations of the BB-PCM, together with a simulation of a calibration of the stylized WP-EqCM.

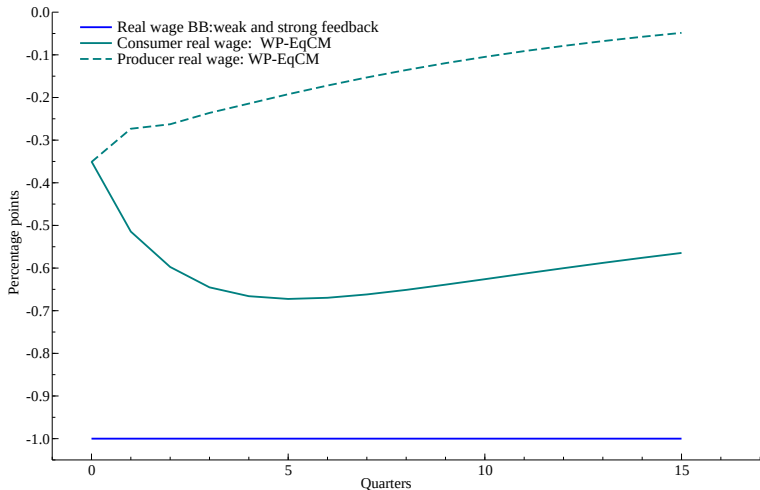


Figure 2: Real wage responses in two alternative calibrations of the stylized model of Blanchard and Bernanke (2023), together with a simulation of a calibration of the stylized WP-EqCM model.

## Section 3

### Data, method and main dependencies in the empirical model

# The time series variables

- Q*: Price index, gross value added, Nonfarm business. 2005=1.
- P*: Price index, personal consumption expenditures. 2005=1.
- PI* : Price deflator of imports of goods. 2005=1.
- W*: Hourly compensation for all employed persons.  
Nonfarm business. 2005=1
- U*: Unemployment Rate. Percent.
- Z*: Labour Productivity (output per hour) for all employed persons.  
Nonfarm business. 2005=1

The empirical model also includes:

- CAPU*: Capacity utilization, total index. Percent of capacity
- OILP*: Spot crude oil price: West Texas Intermediate (WTI).  
Dollars per Barrel.
- TRA*: Federal transfers. Billion dollars
- WAC*: World economic activity index

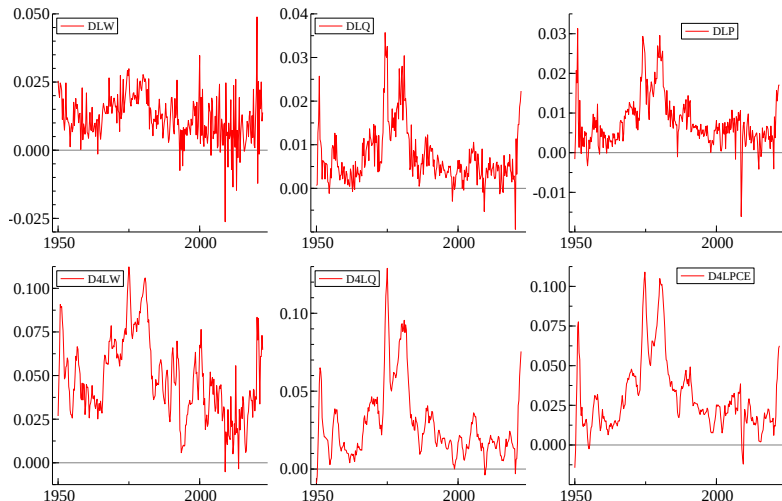
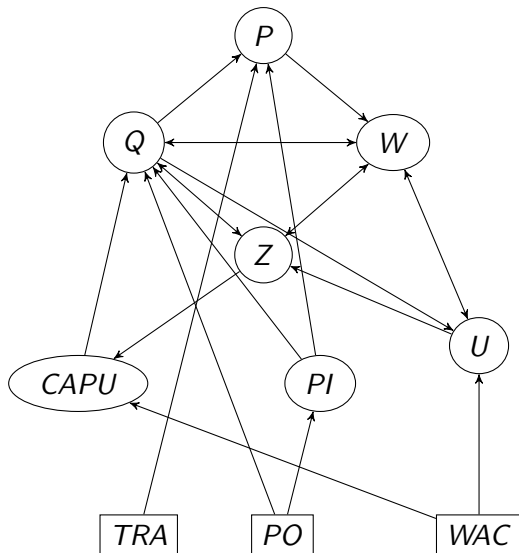


**Figure 3:** Differenced wage and price variables (log-scale). First row: quarterly changes. Second row: four quarter changes (annual growth rate)

# Practical model specification

- Equation by equation modelling.
- Semi-automatic Gets with indicator saturation and OLS.
- Tiny significance levels.
- Finished multiple-equation model re-estimated using system methods:
  - ▶ Small changes in coefficient estimates, perhaps because simultaneous equations block is small.
- Next slide: Main dependencies in the empirical multiple-equation model

Arrows represent simultaneous and/or lagged dependencies



# Section 4

## Detailed model specification

# Producer price

$$\begin{aligned}
 \Delta q_t = & + 0.2181 \Delta_2 q_{t-2} - 0.1147 \Delta z_t \\
 & (0.0197) \quad (0.0251) \\
 & + 0.04241 \Delta pi_{t-2} + 0.008 \Delta_2 po_t \\
 & (0.008) \quad (0.0009) \\
 & + 0.031 \Delta capu_{t-2} \\
 & (0.011) \\
 & - 0.098 [q_{t-1} - 0.69w_{t-1} + 0.21(z - pi)_{t-1} \\
 & (0.011) \\
 & \quad + 0.04(po_{t-1} - (Sl_{72(1)t} + Sl_{86(2)t} + Sl_{99(1)t})] \quad (1) \\
 & + 0.01196 ll_{98(1)t} + 0.0179 \\
 & (0.00286) \quad (0.00168)
 \end{aligned}$$

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|                 |                   |                               |
|-----------------|-------------------|-------------------------------|
| OLS             | 1967(4) – 2023(2) | $\hat{\sigma}100 = 0.28$      |
| AR 1-5 test:    |                   | $F(5, 211) = 0.50[0.077]$     |
| ARCH 1-4 test:  |                   | $F(4, 215) = 1.65[0.04]$      |
| Normality test: |                   | $\text{Chi}^2(2) = 5.4[0.07]$ |
| Hetero test:    |                   | $F(16, 207) = 2.34[0.0002]$   |

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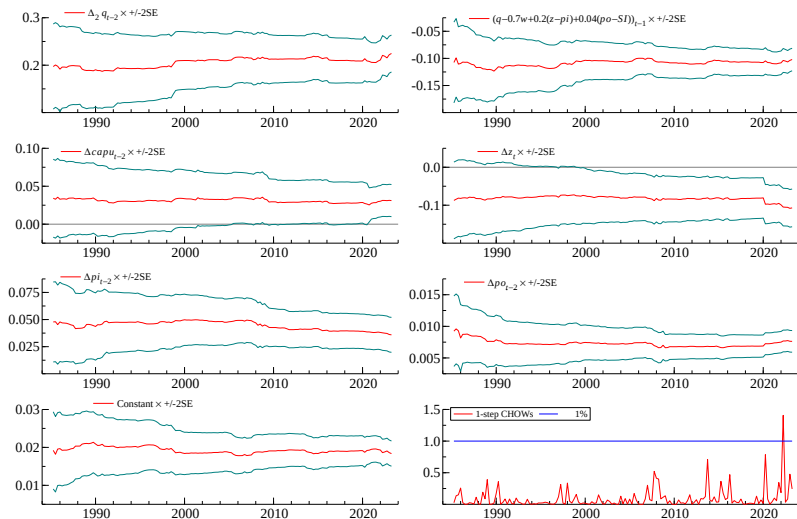


**Figure 4:** Recursive estimation results illustrating empirical coefficient constancy for the producer price equation over the Great moderation, the Great recession

and the pandemic-era.

# Wages

$$\begin{aligned}
 \Delta w_t = & - \frac{0.2}{(0.0521)} \Delta w_{t-1} + \frac{0.2801}{(0.0583)} \Delta z_t \\
 & + \frac{0.3065}{(0.0923)} \Delta q_{t-1} + \frac{0.5759}{(0.103)} \Delta p_t + \frac{0.03154}{(0.00867)} 1/U_{t-3} \\
 & - \frac{0.08372}{(0.016)} [w - q - 0.82z]_{t-1} \\
 & + \frac{0.02936}{(0.00633)} II_{2000(1)t} + \frac{0.02163}{(0.00451)} DI_{2008(4)t} \\
 & + \frac{0.01681}{(0.00447)} DI_{2012(4)t} \\
 & + \frac{0.04817}{(0.00668)} II_{2020(2)} - \frac{0.001779}{(0.00178)}
 \end{aligned} \tag{2}$$

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|                       |                               |
|-----------------------|-------------------------------|
| OLS 1967(1) – 2023(2) | $\hat{\sigma}_{100} = 0.59$   |
| AR 1-5 test:          | $F(5, 210) = 1.88[0.10]$      |
| ARCH 1-4 test:        | $F(4, 218) = 2.51[0.04]$      |
| Normality test:       | $\text{Chi}^2(2) = 6.7[0.04]$ |
| Hetero test:          | $F(16, 207) = 2.34[0.003]$    |

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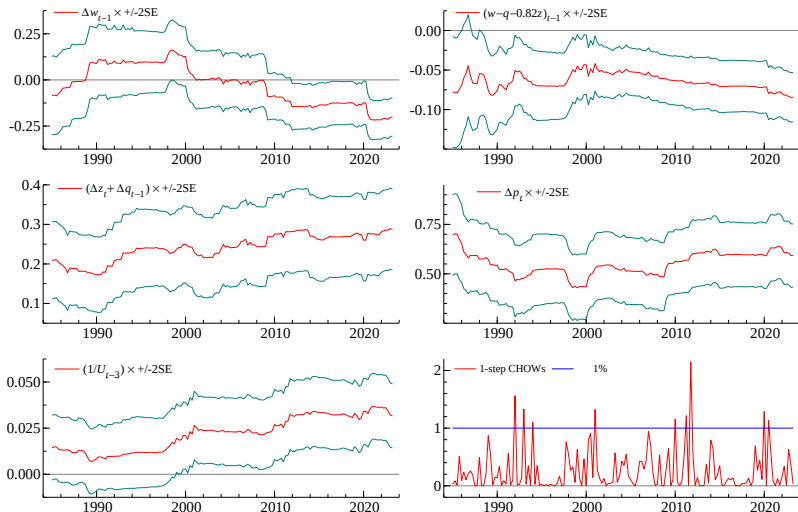


**Figure 5:** Recursive estimation results illustrating empirical coefficient constancy for the wage equation over the Great moderation, the Great recession and the

**Table 1:** Robustness check of wage model equation (2), with respect to inflation expectations (Infexp) and omission of the 1960's and 1970's from the sample:

|                         | I                 | II      | III     |
|-------------------------|-------------------|---------|---------|
|                         | OLS               | IVE     | OLS     |
| $\Delta p_t$            | 0.46**            | 0.38    | 0.53**  |
| $\Delta w_{t-1}$        | -0.23**           | -0.22** | -0.25** |
| $\Delta z_t$            | 0.35**            | 0.34**  | 0.33**  |
| $\Delta q_{t-1}$        | 0.19              | 0.23    | 0.07    |
| $1/U_3$                 | 0.05**            | 0.05**  | 0.05**  |
| $[w - q - 0.82z]_{t-1}$ | -0.11**           | -0.10** | -0.09** |
| Constant                | -0.004            | -0.004  | -0.005  |
| Infexp <sub>t</sub>     |                   |         | -0.002  |
| linfexp <sub>t-1</sub>  |                   |         | 0.002   |
| Sargan-IV               | $\chi^2(1) = 3.0$ |         |         |

Note: Sample period 1982(2)-2023(2). \*\* = significant at 1 %.

## Consumer expenditure prices

$$\begin{aligned}
 \Delta p_t = & \underset{(0.031)}{0.49} \Delta q_t + \underset{(0.028)}{0.094} \Delta q_{t-2} + \underset{(0.027)}{0.082} \Delta q_{t-3} \\
 & + \underset{(0.005)}{0.1} \Delta pi_t - \underset{(0.0051)}{0.0099} \Delta pi_{t-1} \\
 & + \underset{(0.0015)}{0.0025} \Delta tra_t - \underset{(0.0015)}{0.0043} \Delta tra_{t-3} \\
 & - \underset{(0.0047)}{0.038} [p_{t-1} - 0.96q_{t-1} - 0.04pi_{t-1} - 0.04trans_{t-1}] \\
 & + \underset{(0.0013)}{0.0067} DI_{1973(3)t} + \underset{(0.0015)}{0.0058} DI_{1973(4)t} \\
 & + \underset{(0.0013)}{0.0048} DI_{1974(1)t} - \underset{(0.0016)}{0.0079} DI_{1975(1)t} - \underset{(0.001)}{0.0045} DI_{1975(2)t} - \underset{(0.0013)}{0.0088}
 \end{aligned}$$

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$$\text{OLS } 1968(1) - 2023(2) \quad \hat{\sigma}100 = 0.15$$

$$\text{AR 1-5 test:} \quad F(5, 203) = 1.52[0.19]$$

$$\text{ARCH 1-4 test:} \quad F(4, 214) = 2.41[0.05]$$

$$\text{Normality test:} \quad \text{Chi}^2(2) = 8.80[0.013]$$

$$\text{Hetero test:} \quad F(22, 198) = 1.69[0.03]$$


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(3)

# Productivity

$$\Delta z_t = \frac{0.24 (\Delta w_t - \Delta q_t) - 0.073 \Delta p_{i,t-1} + 0.0081 u_t}{(0.047) \quad (0.016) \quad (0.0018)} - \frac{0.1 [z_{t-1} - 1.2(w - q)_{t-1} + 0.07 p_{i,t-1}] - 0.01}{(0.016) \quad (0.0032)}$$

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OLS 1967(4) – 2023(2)  $\hat{\sigma}_{100} = 0.67$

AR 1-5 test:  $F(5, 213) = 1.1650[0.3275]$

ARCH 1-4 test:  $F(4, 215) = 1.7108[0.1487]$

Normality test:  $\text{Chi}^2(2) = 4.7536[0.0928]$

Hetero test:  $F(10, 214) = 2.2884[0.0227]$

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(4)

# Import prices

$$\begin{aligned}\Delta pi_t = & \quad 0.45 \Delta pi_{t-1} + 0.092 \Delta po_t - 0.022 \Delta po_{t-2} \\ & (0.043) \quad (0.006) \quad (0.0063) \\ & - 0.074 \text{II}_{2008(4)t} - 0.036 (pi - 0.18po)_{t-1} - 0.023 \\ & (0.012) \quad (0.015) \quad (0.0096)\end{aligned}$$

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OLS 1981(1) – 2023(2)  $\hat{\sigma}100 = 1.1$

AR 1-5 test:  $F(5, 159) = 2.53[0.03]$

ARCH 1-4 test:  $F(4, 162) = 1.38[0.24]$

Normality test:  $\text{Chi}^2(2) = 0.60[0.74]$

Hetero test:  $F(8, 160) = 2.14[0.08]$

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(5)

# Unemployment rate

$$\begin{aligned}
 U_t = & \quad 1.5 U_{t-1} - 0.47 U_{t-2} - 0.06 U_{t-4} \\
 & \quad (0.025) \quad \quad (0.026) \quad \quad (0.014) \\
 & + 3.5 \Delta(w - q)_{t-4} - 0.0014 WAC_{t-1} + 0.0014 WAC_{t-3} \\
 & \quad (1.5) \quad \quad (0.00038) \quad \quad (0.00038) \\
 & + 0.94 I_{1975(1)t} - 0.94 I_{1975(3)t} + 0.94 I_{1980(2)t} \\
 & \quad (0.12) \quad \quad (0.12) \quad \quad (0.12) \\
 & - 0.47 SI_{1981(3)t} + 0.47 SI_{1982(4)t} + 8.8 DI_{2020(2)t} \\
 & \quad (0.096) \quad \quad (0.096) \quad \quad (0.19) \\
 & + 0.28 \\
 & \quad (0.057)
 \end{aligned}$$

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OLS 1969(1) – 2023(2)  $\hat{\sigma} = 0.207$

AR 1-5 test:  $F(5, 203) = 0.50530[0.77]$

ARCH 1-4 test:  $F(4, 210) = 1.0470[0.38]$

Normality test:  $\text{Chi}^2(2) = 1.4442[0.49]$

Hetero test:  $F(32, 185) = 2.1827[0.007]$

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(6)

## Capacity utilization

$$\begin{aligned}
 \text{CAPU} = & \quad 1.4 \text{ CAPU}_{t-1} - 0.35 \text{ CAPU}_{t-2} - 0.14 \text{ CAPU}_{t-3} \\
 & \quad (0.041) \qquad \qquad (0.062) \qquad \qquad (0.039) \\
 & + 18 \Delta_2 z_t + 0.0069 \Delta_2 \text{WAC}_t - 14 \Delta_2 (w - q)_{t-2} \\
 & \quad (4) \qquad \qquad (0.0012) \qquad \qquad (3.9) \\
 & - 9.5 \text{DI}_{2020(2)t} + 3.6 \\
 & \quad (0.48) \qquad \qquad (1.1)
 \end{aligned}$$

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OLS 1981(4) – 2023(2)  $\hat{\sigma} = 0.60$

AR 1-5 test:  $F(5, 154) = 1.7300[0.13]$

ARCH 1-4 test:  $F(4, 159) = 3.3265[0.01]$

Normality test:  $\text{Chi}^2(2) = 2.7125[0.25]$

Hetero test:  $F(32, 185) = 2.8809[0.007]$

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(7)

# Section 5

## Dynamic simulation of the model

# Before COVID-19



**Figure 6:** Dynamic model simulation 1980(1)-2020(1), conditional on and *TRA*, *PO* and *WAC*. Units are percent. The five first panels show four quarter changes. Panel six shows the rate of unemployment.

# During and after COVID-19 (no indicators)



**Figure 7:** Dynamic model simulation 2020(3)-2023(2), conditional on *TRA*, *PO* and *WAC* (shown in third row). Units are billion USD (*TRA*), USD (*PO*) and index units (*WAC*)

# Shock to import price & oil price



**Figure 8:** The effects to key variables of the full model of an impulse of 0.1 to import price and oil price equations. Deviations of shock-simulation from baseline. Units are percentage points. The seven first variables are measured as four quarter percentage rates.

# Summary

- We specify an empirical WP-EqCM of the U.S. wage-price spiral.
- Firms' ability to pay is an explanatory variable for wages, consistent with the model in Bårdsen and Nymoen (2009).
- The wage model also contains changes in costs-of-living (a standard explanatory variable in PCM).
- The estimated wage function is non-linear in the rate of unemployment.
- Producer prices (and productivity) are related to wage adjustments both in the short and in the long run.
- On the price side of the wage-price spiral, the empirical model also includes import price and the price of oil.
- This means that our model has a broader channel for imported inflation than for example in the recent study by Blanchard and Bernanke (2023).

## Summary (continued)

- Dynamic simulation shows that the model explains quite well the wage and price changes over the four decades that includes the Great Moderation and the Great Recession.
- For the pandemic era, our results indicate:
  - ▶ Wage growth was only moderately high in the period before the pandemic, in part due to labour market tightness.
  - ▶ When the pandemic hit, the sudden surge in unemployment due in particular to layoffs of large swaths of service sector workers, raised both productivity and wage (per hours worked). As this was a composition effect, it was always likely to be temporary.
  - ▶ The increased inflation that started in 2021 was dependent on other factors in addition to wage costs to evolve as it did:
  - ▶ A strong and broad increase in international prices, energy prices and transfers seem to be factors that contributed to pandemic era inflation.
- Bringing import price inflation into the model seems to reduce the “need for” a large domestic price shock to explain inflation in 2020 and 2021.

## Summary (continued)

- But not entirely, and in 2022 there was a considerable gap between between actual and simulated inflation. Explaining this gap will be explored in our further work with this project.
- The wage equation was tested for omission of the inflation expectation variable that Bernanke and Blanchard focus on, and it was found to be robust.
- That does not imply that an integrated approach, with endogenous expectations, should not be attempted in further work.

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