Online Annex 2.1 Empirical Methodologies Using Aggregate Data[1]

Panel Vector Auto Regression

This chapter assesses the dynamic wage-price linkages using the four variable panel vector auto regression (PVAR) framework developed by Love and Zicchino (2006). The multivariate framework of the PVAR allows for assessing the passthrough of wage growth to consumer price inflation while controlling for endogenous feedback effects of import prices and labor market slack. The model is estimated using quarterly data for 27 European countries for the 1995Q1-2019Q1 period. Separate models are estimated for NMS and EU15+3 country groups.

The PVAR model, in its structural form, can be represented as follows:

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ \alpha_0^{21} & 1 & 0 & 0 \\ \alpha_0^{31} & \alpha_0^{32} & 1 & 0 \\ \alpha_0^{41} & \alpha_0^{42} & \alpha_0^{43} & 1 \end{bmatrix} \begin{bmatrix} {\pi^m}_{it} \\ w_{it} \\ \pi_{it} \\ u_{it} \end{bmatrix} = \sum_{l=1}^{L} \begin{bmatrix} \alpha_l^{11} & \alpha_l^{12} & \cdots & \alpha_l^{14} \\ \alpha_l^{21} & \alpha_l^{22} & \cdots & \alpha_l^{24} \\ \alpha_l^{31} & \vdots & \ddots & \alpha_l^{34} \\ \alpha_l^{41} & \alpha_l^{42} & \cdots & \alpha_l^{44} \end{bmatrix} \begin{bmatrix} {\pi^m}_{it-l} \\ w_{it-l} \\ \pi_{it-l} \\ u_{it-l} \end{bmatrix} + X_{it}F + U_{it}\ , \quad (1)$$

where for a given country *i* in period *t*, π^m represents import price inflation, w nominal wage growth adjusted for trend productivity, π core consumer price inflation, and u the unemployment gap. These variables are measured as follows:

- Import price inflation: annual change on import deflator, in percent;
- Wage growth: annual change in nominal compensation per employee index, in percent;
- Productivity growth: annual growth of trend real gross value added per employee; with the trend calculated using the Hodrick-Prescott filter in percent;
- Core consumer price inflation: annual change in core consumer price index, in percent;
- Unemployment gap: difference between unemployment rate and OECD's non-accelerating inflation rate of unemployment (NAIRU).[2]

The matrix *X* captures time-invariant country-specific characteristics, and *U* is a vector of structural shocks that are assumed to be uncorrelated with one another. The lag length is denoted by *L* and is set to four, which is a standard for VAR models with quarterly data.

The matrices $A_l, l = 0,1, \ldots, L$ determine the effects of structural shocks on the dynamics of endogenous variables in the PVAR system. A Cholesky decomposition is used for the identification of the shocks, which implies that the variables are included in the model in the decreasing order of presumed exogeneity. Import prices are assumed to be the most exogenous and the unemployment gap the least exogenous as in Peneva and Rudd (2017). By ordering wage growth before inflation, it is assumed that movements in wage growth have an immediate impact on inflation, but wages take at least a quarter to respond to consumer price movements. The main results presented in the chapter are robust to alternative ordering of the variables within the PVAR and to measuring labor cost as compensation per hour worked instead of compensation per employee.

[1] The authors of this Annex are Raju Huidrom and Sylwia Nowak.

[2] The Hodrick-Prescott filter is used to estimate the NAIRU for those countries unavailable in the OECD database.

Interacted Panel Vector Auto Regression

The chapter uses an interacted panel vector autoregression (IPVAR) model—an extension of the PVAR developed by Towbin and Weber (2013)—to examine the role of various factors or country characteristics in shaping the extent of passthrough. The IPVAR model augments the panel VAR by introducing interaction terms, thus allowing the coefficients to vary with a country characteristic of interest. This results in a framework where model dynamics, and hence impulse responses, are conditional on the country characteristic. For instance, by interacting with the monetary credibility, the IPVAR framework allows to assess estimates of wage passthrough that depends on the level of monetary credibility. The IPVAR model is estimated as a panel using the full sample of European countries. The identification of the shocks relies on the same timing assumptions implicit in the Cholesky ordering as discussed in the section above. The only additional assumption in the IPVAR is that such timing assumptions hold irrespective of the level of the interacting variable.

The IPVAR model, in its structural form, can be represented as follows:

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ \alpha_{0,it}^{21} & 1 & 0 & 0 \\ \alpha_{0,it}^{31} & \alpha_{0,it}^{32} & 1 & 0 \\ \alpha_{0,it}^{41} & \alpha_{0,it}^{42} & \alpha_{0,it}^{43} & 1 \end{bmatrix} \begin{bmatrix} \pi^{m}{}_{it} \\ w_{it} \\ \pi_{it} \\ u_{it} \end{bmatrix} = \sum_{l=1}^{L} \begin{bmatrix} \alpha_{l,it}^{11} & \alpha_{l,it}^{12} & \cdots & \alpha_{l,it}^{14} \\ \alpha_{l,it}^{21} & \alpha_{l,it}^{22} & \cdots & \alpha_{l,it}^{24} \\ \alpha_{l,it}^{31} & \vdots & \ddots & \alpha_{l,it}^{34} \\ \alpha_{l,it}^{41} & \alpha_{l,it}^{42} & \cdots & \alpha_{l,it}^{44} \end{bmatrix} \begin{bmatrix} \pi^{m}{}_{it-l} \\ w_{it-l} \\ \pi_{it-l} \\ u_{it-l} \end{bmatrix} + X_{it}F + U_{it}\,. \quad (2)$$

The difference between equations (1) and (2) lies in allowing the impact matrix A_0 and the coefficient matrices $A_l, l = 1, \ldots, L$ in equation (2) to comprise of time-varying model coefficients that, for any given entry in row j and column k , evolve deterministically according to:

$$\alpha_{l,it}^{jk} = \beta_{1,l}^{jk} + \beta_{2,l}^{jk} factor_{it}\,, \qquad (3)$$

where $factor$ refers to the country characteristic (state variable) assumed to have an impact on the passthrough. The IPVAR model is the joint system of equations (2) and (3). By conditioning the law of motion of the coefficients in these matrices on the country characteristic, as in equation (3), the model dynamics, and hence impulse responses, are state-dependent.

Online Annex 2.2 Empirical Methodologies Using Sectoral Data

To complement the country-level evidence on the link between wage growth and inflation, the chapter examines the passthrough of labor costs to producer prices at the sectoral level. The analysis uses the 2016 release of the Socio-Economic Accounts from the World Input-Output Database (WIOD) (see Timmer and others 2015), which provides annual data for 2000-14 on real and nominal gross output and value added, labor compensation, and number of workers at the sectoral level for 43 economies. Sectors are defined using the ISIC Revision 4, and comprise 56 distinct categories, of which 19 are in manufacturing. As in the aggregate analysis, nominal wage growth is constructed as growth in labor compensation per person employed, and adjusted for productivity growth, measured as growth in real value added per person employed. The Socio-Economic Accounts data are complemented with series from Johnson and Noguera (2017), who construct, using the 2016 release of the WIOD, sectoral final and intermediate imports. These are used to compute import penetration ratios, the ratio of final imports to sectoral gross output, to capture the foreign competitive pressure experienced by various sectors. The analysis focuses on the 34 European economies included in WIOD.

The empirical analysis is based on panel regressions, which relate growth in producer prices, to its lag, growth in productivity-adjusted wages, controlling for country-sector, country-year and sector-year fixed effects (equation 4).

$$y_{s,\mathrm{c},t} = \alpha \cdot w_{\mathrm{s,c,t}} + \beta \cdot y_{s,\mathrm{c},t-1} + \gamma_{s,\mathrm{c}} + \gamma_{s,\mathrm{t}} + \gamma_{\mathrm{c,t}} + \varepsilon_{s,\mathrm{c},t-1}, \qquad (4)$$

where $y_{s,\mathrm{c},t}$ is the growth in the value added deflator of sector s, in country c, in year t (measured as the log difference), $w_{\mathrm{s,c,t}}$ in the growth in the labor compensation per person engaged less growth in real value added per person engaged, $\gamma_{s,\mathrm{c}}$ is an indicator for each sector in each country, $\gamma_{\mathrm{c,t}}$ denote country-year fixed effects, while $\gamma_{s,\mathrm{t}}$ denote sector-year fixed effects. The coefficient of interest is α, which captures the association between productivity-adjusted wage growth and growth in producer prices. The country-year fixed effects capture all country-specific time-varying shocks, such as changes in inflation expectations, economic slack, commodity price shocks and the like. The country-sector fixed effects control for time-invariant differences across sectors within a country, such as in technological requirements that may influence the sectoral cost structure. Sector-year fixed effects capture all changes to a particular sector that are common across countries, such as technological innovations at the sectoral level and the like. Standard errors are clustered at the country-sector level.

To examine the role of foreign competition, equation (4) is augmented to include the interaction between the productivity-adjusted wage growth and the import penetration ratio at the sectoral level, as well as the main effect of import penetration (equation 5).

$$y_{s,\mathrm{c},t} = \alpha \cdot w_{\mathrm{s,c,t}} + \delta \cdot w_{\mathrm{s,c,t}} \cdot m_{\mathrm{s,c,t}} + \mu \cdot m_{\mathrm{s,c,t}} + \beta \cdot y_{s,\mathrm{c},t-1} + \gamma_{s,\mathrm{c}} + \gamma_{s,\mathrm{t}} + \gamma_{\mathrm{c,t}} + \varepsilon_{s,\mathrm{c},t-1}, \qquad (5)$$

The coefficient of interest, δ, captures how the association between wage growth and producer prices is shaped by the competitive pressures experienced by different sectors. If higher competition from abroad indeed lowers the likelihood that firms pass increase in wage costs to the prices they charge for their output, we would expect δ to be negative.

Annex Table 2.2.1 summarizes the key findings of the sectoral analysis. Similar to the results based on aggregate data, we find a positive, statistically significant association between growth in producer prices and productivity-adjusted wage growth. While the magnitude of the results are not directly comparable due to the difference in analytical approach (the lower frequency of data and more limited time coverage of sectoral data precludes us from performing PVAR, and IPVAR analysis), the findings suggest that a 1 percentage point increase in wage growth is associated with a 0.2 percentage point increase in producer price inflation in the same year (Annex Table 2.2.1, columns 1-3).[3] A similar passthrough is estimated for the subset of 19 sectors, classified as manufacturing (Annex Table 2.2.1., columns 4-6).

Annex Table 2.2.1. Effect of Wage Growth on Producer Prices: Sectoral Evidence

	(1)	(2)	(3)	(4)	(5)	(6)
	All sectors			Manufacturing		
Sample	Europe	EU15+3	NMS	Europe	EU15+3	NMS
Wage growth	0.202***	0.236***	0.165***	0.235***	0.249***	0.201***
	(0.026)	(0.031)	(0.035)	(0.040)	(0.052)	(0.049)
Lagged growth in producer prices	-0.077***	-0.076**	-0.064**	-0.073*	-0.018	-0.120***
	(0.025)	(0.038)	(0.030)	(0.044)	(0.068)	(0.038)
Constant	0.022***	0.013***	0.037***	0.014***	0.006***	0.029***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
Observations	21,240	13,436	7,804	7,385	4,673	2,712
R-squared	0.336	0.369	0.365	0.390	0.422	0.428

Source: WIOD and IMF staff calculations.
Note: The dependent variable is growth in sectoral value added deflators (producer prices). All regressions include country-sector, country-year and sector-year fixed effects. Robust standard errors clustered at the country-sector level in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Annex Table 2.2.2 presents the results from estimating equation (5) with alternative measures of exposure to foreign competition. In columns (1) and (4), competitive pressures are measured as the ratio of final imports to gross output. In columns (2) and (5), we use the log of the ratio, while in columns (3) and (6) we use a dummy if the sectoral import penetration is above the sample median. The findings suggest that the passthrough of wage growth to inflation is indeed attenuated in sectors that have higher exposure to foreign competition – the coefficient on the interaction term, δ, is negative and statistically significant for all three measures. This pattern also holds when restricting the analysis to the 19 manufacturing sectors included in the WIOD (columns 4-6). Higher exposure to foreign competition is also directly associated with lower growth in producer prices, similar to the patterns uncovered in Lian and others (2019).

[3] Despite the differences in methodologies, the point estimates are quite similar to the passthrough estimated with the aggregate data after 1 year (0.1) and the short-run response of producer prices to unit labor costs discussed in Box 2.1 and estimated using error-correction mean-group autoregressive distributed lag regressions with sectoral data from Central Europe and the Baltics (results available upon request).

Annex Table 2.2.2. Sectoral Evidence on the Effect of Wage Growth on Producer Prices: The Role of Foreign Competition

	(1)	(2)	(3)	(4)	(5)	(6)
		All sectors			Manufacturing	
Wage growth	0.164***	0.217***	0.258***	0.192***	0.295***	0.319***
	(0.035)	(0.030)	(0.030)	(0.042)	(0.049)	(0.042)
Wage growth * Import Penetration	-0.013*	-0.029*	-0.071*	-0.031***	-0.053***	-0.092*
	(0.007)	(0.017)	(0.041)	(0.011)	(0.020)	(0.054)
Import Penetration	-0.010***	-0.016**	-0.006	-0.020***	-0.012	-0.026*
	(0.003)	(0.008)	(0.005)	(0.007)	(0.008)	(0.016)
Lagged growth in producer prices	-0.079***	-0.078***	-0.078***	-0.076*	-0.078*	-0.075*
	(0.025)	(0.025)	(0.025)	(0.044)	(0.044)	(0.045)
Constant	-0.018	0.025***	0.026***	-0.034*	0.020***	0.036***
	(0.012)	(0.002)	(0.003)	(0.018)	(0.004)	(0.014)
Observations	21,240	21,240	21,240	7,385	7,385	7,385
R-squared	0.339	0.338	0.338	0.401	0.401	0.391

Source: WIOD, Johnson and Noguera (2017), and IMF staff calculations.
Note: The dependent variable is growth in sectoral value added deflators (producer prices). All regressions include country-sector, country-year and sector-year fixed effects. Robust standard errors clustered at the country-sector level in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

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