Analysis

Drivers of Dutch inflation during the pandemic era

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Main results and policy recommendations

How do prices and wages interact in times when commodity price shocks hit an historically tight labor market? This is not just an academic question, it has also been at the center of the policy debate. In 2021-2022, the Dutch economy was hit by large commodity price shocks and faced severe supply shortages, much like many other advanced economies. Initially, the debate in the Netherlands centered around the impact of these terms of trade shocks on the real incomes of households and businesses. While firm profits increased ahead of wages, the latter accelerated in 2023, prompting a discussion on the risk of a wage-price spiral. Although commodity prices have recently declined and supply-side disruptions have eased, tight labor market conditions may continue to add to inflationary pressures through their impact on wage growth.

In this report, we analyze the drivers of price and wage growth dynamics in the Netherlands, using a small, semi-structural model developed by Bernanke and Blanchard (2023). This model consists of four estimated linear equations – for wage growth, price growth, short-term inflation expectations and long-term inflation expectations – which explicitly take into account the interactions between price and wage growth through various channels. We find that the pass-through from price growth to wage growth is strong and works through the impact of short-term inflation expectations on wage growth. However, we do not find a similarly strong pass-through from wage growth to inflation, which thereby limits the risks of a wage-price spiral from emerging.

The greatest contributors of Dutch inflation in 2021-2023 were energy and food prices. Our model simulations show that shocks to energy and food prices have a positive effect on price growth that works through a direct and an indirect channel. In particular, higher energy and food prices drive up inflation immediately as they are part of the consumer price index (the direct channel). Subsequently, the rise in inflation raises short-term inflation expectations, which then feeds back to inflation through their impact on wage growth (the indirect channel). However, we find that short-term inflation expectations respond only modestly to changes in actual inflation, and are instead more closely related to (stable and well-anchored) long-term inflation expectations. Combined with our finding that the pass-through from wage growth to price growth is incomplete, this implies that the indirect (or 'second-round') effects of energy and food price shocks on inflation are modest. To the extent that the rise in commodity prices is short-lived, the overall response of inflation to commodity price shocks will be short-lived as well.

The impact of labor market tightness on wage growth is found to be significant, yet relatively weak. Consequently, we find that the contribution from labor market tightness to inflation, that works through wage growth, is modest. Finally, supply shortages, which arose amidst the reopening of the economy from pandemic-related lockdowns, did not contribute strongly to Dutch inflation in the pandemic era.

Returning to the policy debate, policymakers were right to pay close attention to price and wage developments, as our results confirm a significant interaction between inflation and wage growth. However, the risks of a wage-price spiral in the Netherlands are likely to be low, given the incomplete pass-through from wage to price growth and the moderate indirect effects of commodity price shocks on inflation. Moreover, our results also show that

long-term inflation expectations are stable and well anchored in the sense that they are independent from changes in actual inflation. Nevertheless, since many new wage agreements still take into account past increases in inflation and because labor market conditions are expected to remain tight, policymakers should continue monitoring wage developments and ensure that inflation expectations remain closely anchored to the inflation target.

A description of the empirical model and data

We study the drivers of Dutch inflation dynamics using the semi-structural model of Bernanke and Blanchard (2023). The Bernanke-Blanchard model consists of four equations that describe the dynamics of (1) wage growth, (2) price growth, (3) short-run inflation expectations and (4) long-run inflation expectations. Although simple, the model takes into account relevant product- and labor market shocks as potential drivers of inflation and various channels through which wage and price growth may interact. In this section, we describe the model without showing any equations. The Appendix provides a full technical description of the model.

The wage growth equation

The wage growth equation relates wage growth to labor market tightness, short-term inflation expectations, labor productivity and a 'catch-up' term that one could interpret as capturing the impact of higher-than-expected inflation. The latter four explanatory variables are all expected to drive wage growth upwards. A tightening of the labor market prompts firms to bid up their wage offers to attract new workers (or retain existing ones). An increase in short-term inflation expectations makes workers want to demand a higher nominal wage to protect their purchasing power. Higher labor productivity raises the marginal product of labor, which in turn drives up the equilibrium wage rate. Finally, when inflation turns out to be higher than expected, and the nominal wage is set too low to keep up with the rise in the aggregate price level, workers may want to catch up with the unforeseen rise in prices and be compensated for past declines in real labor income through an increase in their wages. The strength of this catch-up effect depends, among other things, on the relative bargaining power of job seekers and employees relative to that of employers, and also on the gap between expected and actual inflation. Intuitively, greater inflation surprises are likely to elicit a stronger effort from workers to bargain for higher wages than smaller inflation surprises, as real income losses are potentially larger.

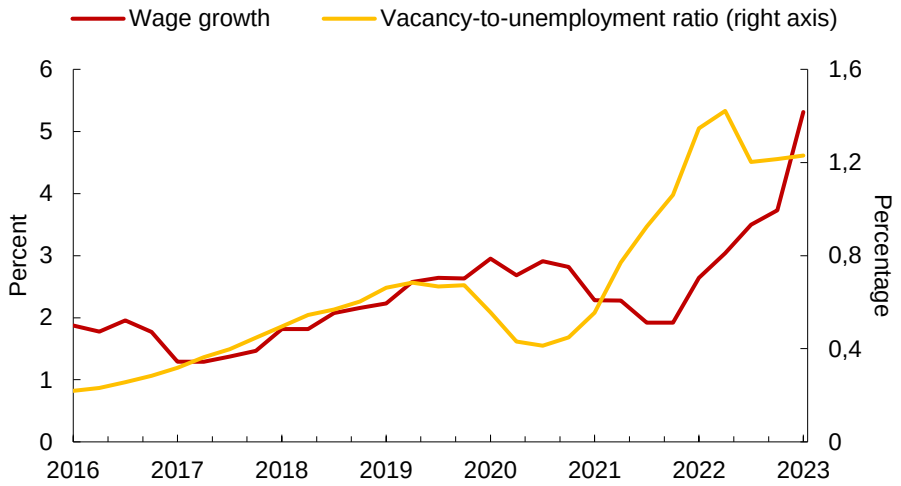
The wage growth equation allows for a rich lag structure that permits current wage growth to depend on multiple past values of the explanatory variables and on its own past values. These lags are important, as wage adjustments to changes in any of the explanatory variables may occur slowly due to the long-term nature of fixed wage contracts. Furthermore, we assume that, in the long run, nominal wage growth moves one-to-one with expected inflation. One can think of this assumption as arising from workers not consistently making errors when trying to predict inflation: at some point, surprise inflation vanishes and expected changes in inflation will be perfectly anticipated and fully translated into changes in nominal wages to keep real wages constant. In economic jargon, this assumption implies that the Phillips curve, i.e. the relationship between wage growth and labor market slack, is vertical in the long run.[1]

Figure 1 plots wage growth along with labor market tightness as measured by the number of vacancies per unemployed. During the pandemic, as the economy entered a deep recession, labor demand fell dramatically, which is reflected by the marked decline in the vacancy-to-unemployment ratio. As the economy recovered from the pandemic crisis, the strong rebound in economic activity led to a sharp increase in the demand for labor and the vacancy-to-unemployment ratio rose to historically elevated levels. Wage growth has moved in tandem with

[1] Relaxing this assumption does not alter our main results much quantitatively.

changes in labor market conditions, yet with a considerable lag, reconfirming the need to allow for a rich lag structure when estimating the model.

Figure 1. Wage growth and labor market tightness



Notes: Wage growth is measured as the year-on-year percentage change in compensation per hour. *Source*: Refinitiv, Statistics Netherlands and own calculations.

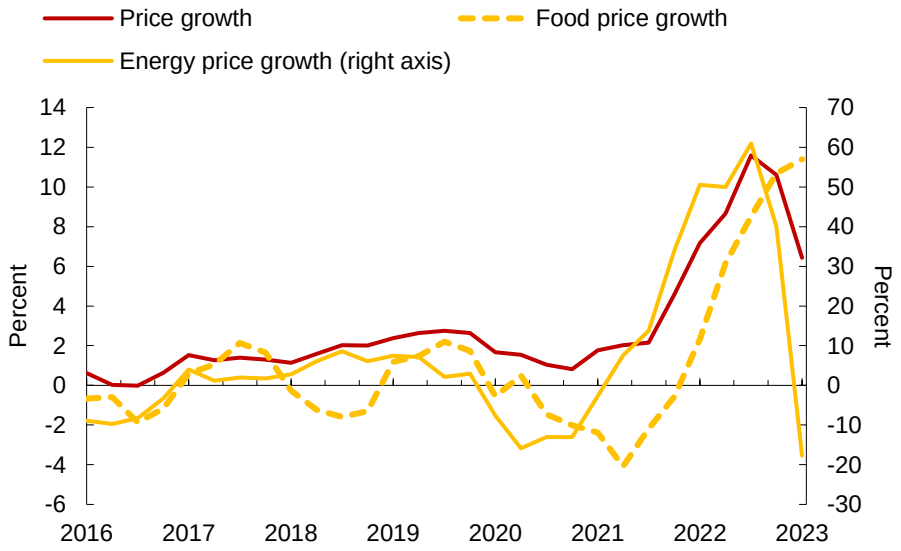
The price growth equation

The price growth equation relates price growth to wage growth, supply shortages, various product market shocks, i.e. energy and food prices, and productivity growth. An increase in wage growth is expected to raise price growth through an increase in firms' marginal costs who, assuming they maintain a constant price markup, will raise their prices in response to an increase in input costs to maximize profits. The extent to which wage increases translate into higher prices depends on multiple factors, such as the degree of competition among firms and the ability of firms to absorb higher wage costs into their profit margins. Supply shortages could capture shortfalls in the availability of intermediate goods or an increase in shipping costs that drives up the price of (imported) inputs used in the production of domestic goods. As with an increase in wages, a rise in the price of intermediate goods will tend to raise the aggregate price level as firms seek to protect their profit margins. The strength of the impact of supply shortages on price growth depends, among other things, on an economy's reliance on (global) supply chains. An increase in energy and food prices has a direct effect on the aggregate price level, as energy and food are part of the consumption basket of households. Thus, the magnitude of this direct effect depends on the consumption share of energy and food in total consumption. A rise in energy and food prices may also affect the aggregate price level indirectly through an increase in prices set by firms that rely strongly on energy and food as intermediate inputs or through an increase in higher wages demanded by workers that aim to protect their purchasing power. We isolate the direct effects from these indirect, or 'second-round', effects by deflating energy and food prices by nominal wages. The model will still be able to capture second-round effects through the catch-up effect in the wage growth equation, the impact of short-term inflation expectations on wage growth and the pass-through of wage to price growth in the price growth equation. Finally, an increase in productivity allows firms to produce the same level of output while using less inputs, which implies a reduction in marginal costs and a decline in the price level.

As the wage growth equation, the price growth equation allows for price growth to depend on its own lagged values and the lagged (and contemporaneous) values of the explanatory variables. Moreover, we again assume a vertical long-run Phillips curve by imposing that price growth moves one-to-one with wage growth in the long run.

Figure 2 plots price growth against energy and food price growth (relative to wages). The figure shows a clear co-movement between, on the one hand, aggregate prices and, on the other hand, energy and food prices, in particular during the inflation surge of the past years (note that aggregate price growth includes the growth rate of energy and food prices). Also note the marked decline in energy prices near the end of the sample, which has been shown to be a strong contributor of the recently observed disinflation (see e.g. Bańbura et al., 2023).

Figure 2. Aggregate price growth, energy price growth and food price growth



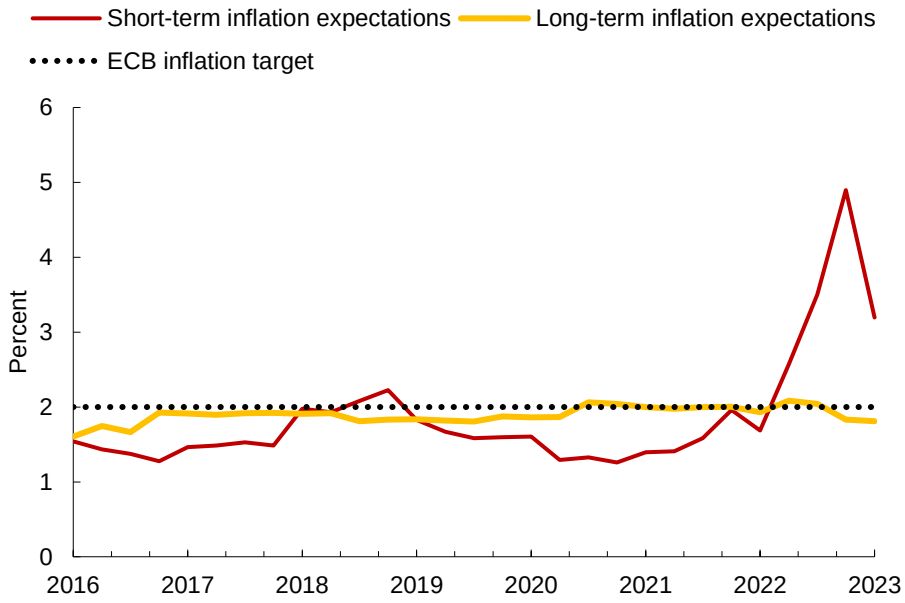
Note: Units expressed in year-on-year percentage changes. Food and energy prices are measured in terms of compensation per hour, to control for second-round effects on aggregate prices. *Source*: Refinitiv.

The equations for short- and long-term inflation expectations

Finally, the two equations characterizing inflation expectations have short-term inflation expectations be related to their own lags, actual (current and past) inflation and (current and past) long-term inflation expectations, while long-term inflation expectations are related to their own lags and actual (current and past) inflation. The short-term inflation expectations equation captures the conjecture that agents, when trying to predict inflation in the near future, are likely to rely on recent inflation developments, but may also anchor part of their inflation expectations to some long-run value they believe inflation will eventually converge to. The long-term inflation expectations equation helps to assess the extent to which inflation expectations are anchored and thereby provides information on the credibility of the central bank and its ability, as perceived by agents, to stabilize inflation at the inflation target in the medium- to long run. When long-term inflation expectations are found to be highly persistent and respond weakly to actual inflation, we say that inflation expectations are well anchored.

Based on survey data, Figure 3 shows that, although short-term inflation expectations have increased during the recent high-inflation period, long-term inflation expectations remained remarkably constant, hovering around the European Central Bank's inflation target of 2% over the medium term, indicating a strong degree of inflation anchoring.

Figure 3. Inflation expectations



Note: Short-term (long-term) inflation expectations refer to survey-based expectations about inflation over the next 12 months (6-10 years). *Source*: Consensus Economics.

Data

In choosing the data, we follow closely the approach by Bernanke and Blanchard (2023). We measure wage growth using compensation per hours worked. A commonly used alternative measure of wage growth is based on compensation per employee. However, job-retention schemes, which were heavily employed during the pandemic, may distort fluctuations in this measure during times of crises, as they aim to stabilize the level of employment and could thereby bias the estimated relationship between wage growth and labor market tightness. Price growth is measured using the consumer price index.[2] This index can be distorted by the fact that, before June 2023, the energy component was based on new (variable-rate) energy contracts, rather than actual energy-related expenditures by households, who typically face fixed-rate contracts. This distortion will be smoothed out over an extended period (e.g. as an overestimation of energy price growth in one year will be offset by an underestimation in the next) yet could have more severe implications for price growth figures in the short run. Short- and long-term inflation expectations are measured by the 1-year and 6-to-10-year ahead inflation expectations from the Consensus Economics survey. Labor market tightness is captured by the vacancy-to-unemployment ratio. Using, instead, the more commonly used unemployment rate as a measure of labor market slack yields results that are close to our main results. For energy and food prices, we use the energy and food

[2] We use the consumer price index as a measure of the price level, as this is the same measure used in Bernanke and Blanchard (2023). Using, instead, the harmonized index of consumer prices does not significantly change our main results.

component of the harmonized index of consumer prices (HICP). Recall that we deflate these series by nominal wages to isolate the direct effects of energy and food prices on the aggregate price level from possible second-round effects. Productivity growth is measured using the eight-quarter moving average of gross value added per hours worked. Supply shortages are captured by the number of Google searches of the term 'shortage' in the Netherlands. Using alternative shortage measures, such as Google internet searches of Dutch terms for shortage, the Global Supply Chain Pressure Index constructed by the Federal Reserve Bank of New York or the first principal component of a wide range of shortage indicators (such as PMI delivery times and backlogs) does not change our main results much. Finally, the catch-up term is calculated as the difference between the average price growth of the past four quarters and short-term inflation expectations from one year ago. Details on the data and their sources are summarized in Table 1.

Table 1 Description of the data

Variable	Measure	Source
Wage growth	Compensation per hour (annualized q-o-q growth rate)	Refinitiv
Price growth	Consumer price index (annualized q-o-q growth rate)	Refinitiv
Short-term inflation expectations	1-year ahead inflation expectations	Consensus Economics
Long-term inflation expectations	6-10-year ahead inflation expectations	Consensus Economics
Labor market tightness	Vacancy-to-unemployment ratio	Statistics Netherlands
Catch-up term	Difference between average price growth rate of past four quarters and short-term inflation expectations from one year ago	Own calculations
Productivity growth	Gross value added per hour, 8-quarter MA (annualized q-o-q growth)	Refinitiv
Energy price growth	HICP energy relative to nominal wages (annualized q-o-q growth rate)	Refinitiv
Food price growth	HICP food relative to nominal wages (annualized q-o-q growth rate)	Refinitiv
Supply shortages	# of Google searches of the term 'shortage' in NL	Google

Results

Insights from the estimated Bernanke-Blanchard model

The model is estimated, equation by equation, using quarterly data that covers the period 2000Q1 to 2023Q1. The results are shown in Tables 2 through 5. The first row lists the explanatory variables that enter the equation. The second row indicates which lags of the explanatory variable enter the equation. The third row reports the sum of the estimated coefficients on each of the explanatory variables. The fourth and fifth rows report the p-value indicating, respectively, whether the sum of the coefficients is statistically significant and whether the coefficients are jointly significant.

Table 2 Wage growth equation

Dependent variable:	Wage growth				
Explanatory variable:	Wage growth	Labor market tightness	Catch-up	Short-term inflation expectations	Productivity growth
Lags	1-4	1-4	1-4	1-4	1
Sum of coefficients	0.14	0.03	-0.18	0.86	0.19
p-stat (sum)	0.62	0.01	0.33	0.00	0.09
p-stat (joint)	0.00	0.00	0.15	0.00	0.09
R^2	0.80				
Number of observations	89				

The estimated wage growth equation points to a significant relationship between wage growth and labor market tightness (Table 2). This implies that a tightening of the labor market is expected to translate into greater wage growth pressures. However, the impact of labor market tightness on wage growth is estimated to be relatively small. In economics jargon, this result points to a rather 'flat' Phillips curve, which in turn implies that, for wage growth to rise by a considerable amount, labor markets would need to tighten severely (holding everything else constant). Or, conversely, for wage growth to decline by a substantial amount (say to pre-pandemic levels), labor markets would need to cool down significantly (again, holding everything else constant). It may, however, be that the relationship between wage growth and labor market tightness has strengthened in recent years (see Bonam et al., 2021). Intuitively, as labor becomes extremely scarce, firms may offer much higher wages to attract workers than what they would have done in times when labor market conditions are less tight. The wage growth equation further shows that the catch-up term has no statistically significant effect on wage growth, suggesting that workers were, on average, not fully compensated for unexpectedly high inflation.[3] Nevertheless, wage growth does respond significantly and substantially to short-term inflation expectations (see also Bonam and Smadu, 2022).

The estimated price growth equation points to a relatively strong pass-through from wage growth to price growth (Table 3). Note, however, that this pass-through is incomplete, i.e. higher wages are not, on average, fully passed on to consumer prices. This result could be explained by the fact that labor costs are not the only type of

[3] While, counterintuitively, the sum of the coefficients on the catch-up effect term in the wage equation is negative (although statistically no different from zero), the coefficient on the second lag of the catch-up term is positive and statistically significant at 5%.

costs faced by firms and by the ability of firms to absorb higher wage costs into their profit margins (see also Bolt et al., 2022). Furthermore, the estimated positive impact of energy and food prices (relative to wages) on price growth is significant and relatively large. This result reflects partly the Dutch economy's reliance on (imported) energy and thereby its exposure to large fluctuations in energy and food prices. Moreover, as expected, the sum of the coefficients on the relative price of energy (0.08) and the relative price of food (0.18) closely match the average share of energy and food in the HICP (0.09 and 0.15, respectively), as shown in Figures 4 and 5. The supply shortage term does not enter significantly, which surprisingly implies that supply bottlenecks have had, on average, no substantial impact on Dutch headline inflation. It may be, however, that the impact of supply shortages on the aggregate price level may take more time to materialize than is implied by the lag structure of the model, as supply chain pressures are found to slowly, but persistently, build up inflationary pressures over time as second-round effects accumulate (Ascari et al., 2024).

Table 3 Price growth equation

Dependent variable:	Price growth					
Explanatory variable:	Price growth	Wage growth	Energy price growth	Food price growth	Shortage	Productivity growth
Lags	1-4	0-4	0-4	0-4	0-4	1
Sum of coefficients	0.38	0.62	0.08	0.18	0.01	-0.03
p-stat (sum)	0.01	0.00	0.00	0.02	0.15	0.79
p-stat (joint)	0.03	0.00	0.00	0.00	0.16	0.79
R^2	0.88					
Number of observations	101					

Figure 4. Energy share in HICP and sum of coefficients on energy price

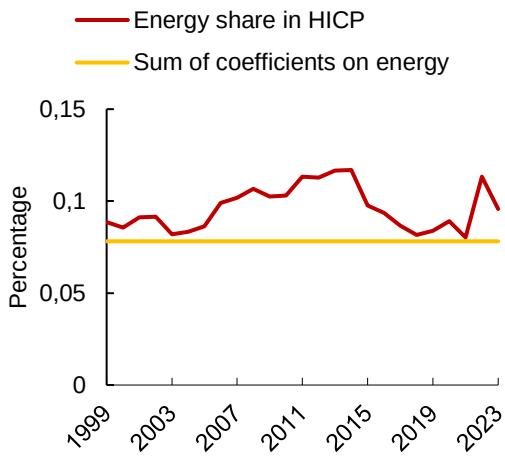
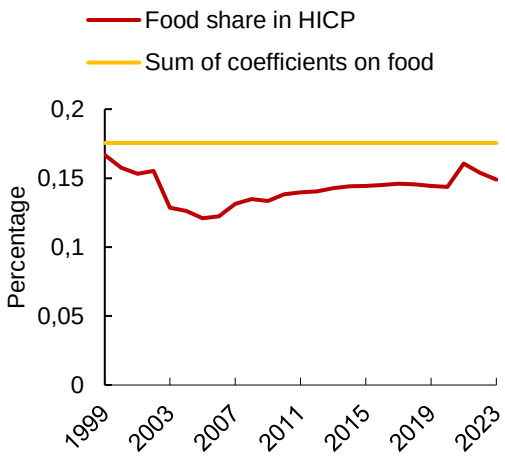


Figure 5. Food share in HICP and sum of coefficients on food price



Notes: The figures plot the sum of coefficients on the relative price of energy (Figure 4) and the relative price of food (Figure 5) as estimated by the price growth equation (Table 3), along with the energy and food share in the harmonized index of consumer prices (HICP). *Source*: ECB Data Portal.

Table 4 Short-term inflation expectations equation

Dependent variable:	Short-term inflation expectations		
Explanatory variable:	Short-term inflation expectations	Long-term inflation expectations	Actual inflation
Lags	1-4	0-4	0-4
Sum of coefficients	0.79	0.17	0.04
p-stat (sum)	0.00	0.02	0.09
p-stat (joint)	0.00	0.09	0.00
R^2	0.85		
Number of observations	109		

Short-term inflation expectations are found to be significantly (albeit weakly) related to actual inflation (Table 4). This implies that actual inflation affects wage growth through their impact on short-term inflation expectations. This mechanism reflects workers' reevaluation of their expectations of future inflation, which in turn affects their wage demands. However, recall that, on average since 2000, workers do not seem to have been compensated for higher-than-expected inflation, as evidenced by the insignificant catch-up term in the wage growth equation. In contrast to short-term inflation expectations, long-term inflation expectations are independent from actual inflation and are also estimated to be highly persistent (Table 5). These results suggest that long-term inflation expectations are firmly anchored, something that was already evident from Figure 3 which shows an extraordinarily stable path of long-term inflation expectations, even during the high-inflation period of recent years.

Table 5 Long-term inflation expectations equation

Dependent variable:	Long-term inflation expectations	
Explanatory variable:	Long-term inflation expectations	Actual inflation
Lags	1-4	0-4
Sum of coefficients	0.999	0.001
p-stat (sum)	0.000	0.903
p-stat (joint)	0.000	0.767
R^2	0.75	
Number of observations	109	

To sum up the results, when estimated on Dutch data, the Bernanke-Blanchard model points to a statistically significant, yet economically weak relationship between wage growth and labor market tightness. Therefore, the post-pandemic inflation surge is unlikely to be explained by the unprecedented tightening of labor market conditions observed in recent years. Similarly, despite the recent surge in supply shortages, these have historically not been significantly related to Dutch inflation. Instead, the strong increase in energy and food prices (relative to wages) in 2022 are more likely to have been behind the high inflation episode, given their significant relationship with the aggregate price level. In the next paragraph, we will further elaborate on the drivers of inflation.

What is driving Dutch inflation?

The estimated Bernanke-Blanchard model provides insights into how various shocks impact inflation and how they contribute to inflation dynamics relative to other shocks. The baseline model features five exogenous variables, i.e. energy prices, food prices, supply shortages, labor market tightness and productivity growth. Since we do not find a (highly) significant impact of productivity growth on wage growth nor price growth (see Tables 2 and 3), we shall focus our attention on the importance of shocks to the former four exogenous variables.

Following a temporary (i.e. one period) shock to either the relative price of energy, the relative price of food or the shortage indicator, the model predicts a positive, yet short-lived response of price growth (Figure 6). These responses are calculated using the estimated model that takes into account both the direct effects of a given shock and the second-round effects that work through the contemporaneous and lagged relationships between wage growth, price growth and inflation expectations. For example, a rise in the relative price of energy has a direct effect on price growth, which in turn affects wage growth (with a lag) through a rise in inflation expectations. The impact of energy and food price shocks dies out relatively quick, due to the limited pass-through from wage to price growth and the modest impact of actual inflation on short-term (and long-term) inflation expectations.

The impact on inflation of a permanently tighter labor market is more persistent than that of the product market shocks (Figure 7). This result is due to the fact that, while relatively weak, the estimated relationship between wage growth and labor market tightness is still significant. Moreover, although we find that long-term inflation expectations are well anchored, short-term inflation expectations exhibit a moderate adjustment in response to actual inflation, which causes inflation expectations to gradually feed through to inflation via their impact on wage growth. Nevertheless, even though the labor market tightening shock is calibrated to match the historically large fluctuations in the vacancy-to-unemployment ratio in the pandemic era, we do not find that these shocks have a quantitatively substantial impact on inflation.

Figure 6. Response of price growth to product market shocks

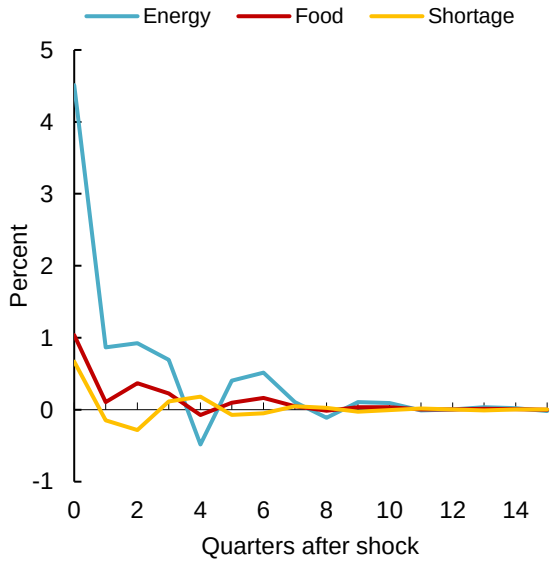
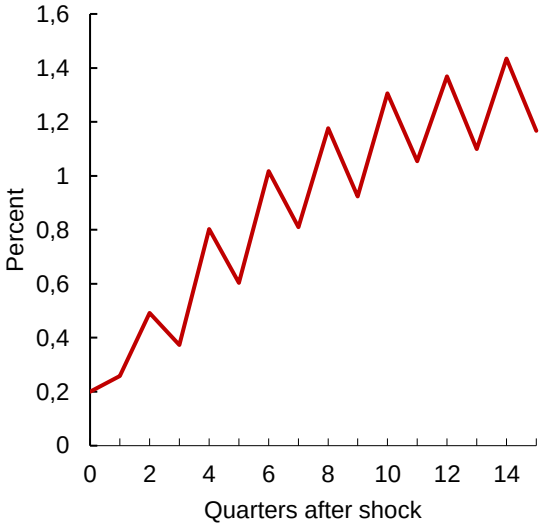


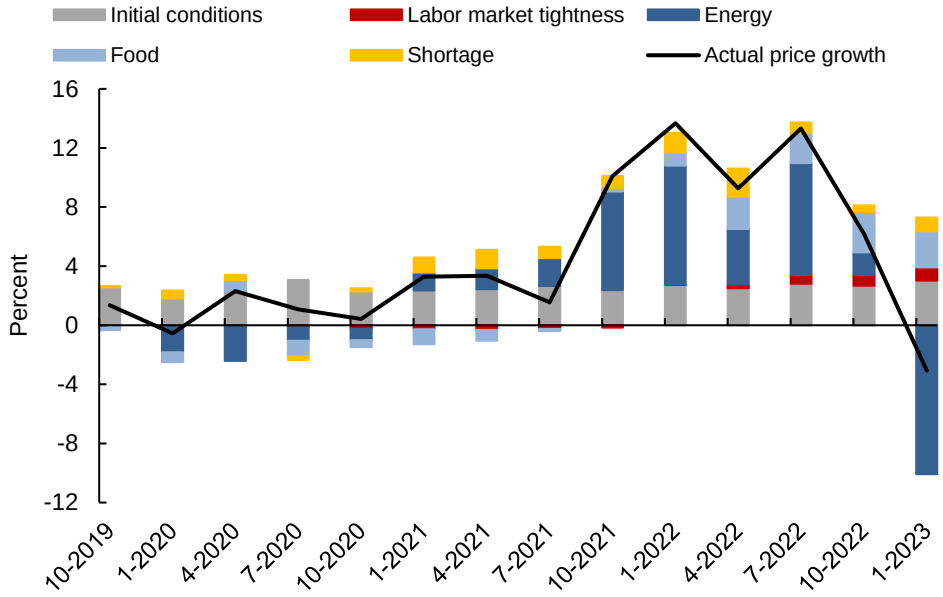
Figure 7. Respons of price growth to a labor market tightening shock



Notes: Shocks to energy and food prices are temporary, i.e. they occur only in one quarter and are absent in all subsequent periods. Note that this implies that there is a permanent effect on the *level* of energy and food prices. The shock to supply shortages is also temporary. The labor market shock is a permanent shock to the vacancy-to-unemployment ratio. The sizes of the shocks are based on the standard deviation of the corresponding variables over the 2020-2023 period. The jagged pattern of the response of inflation to the labor market shock can be explained by the fact that inflation is measured as the annualized quarter-on-quarter percentage change in the consumer price index.

Rather than focusing on the impact of a one-off shock to one of the exogenous variables on inflation, as done in Figures 6 and 7, we can also examine the (relative) contributions of these shocks to Dutch inflation dynamics over time since 2021. To construct such a shock decomposition, we again rely on the estimated Bernanke-Blanchard model that takes into account the dynamic direct and indirect effects of the exogenous (product- and labor market) shocks. We find that energy and food prices were the main drivers of Dutch inflation since 2021, while labor market tightness and supply shortages played a more limited role (Figure 8). Based on the initial conditions (in grey), the model predicts that, absent these shocks, Dutch inflation would have been constant at around 2,5% for much of the pandemic era, and to increase to around 3% towards the end of the sample. The strong contribution of commodity price shocks can explain most of the rise in inflation in 2021 and 2022, while energy prices explain the bulk of the marked drop in inflation in early 2023. The contribution arising from supply shortages has grown since the onset of the COVID-19 crisis, yet has diminished near the end of 2022 as (global) supply bottlenecks started to wane. Finally, while the contribution to inflation arising from labor market tightness is found to be small, its importance has grown in the more recent period. This may be due to the slow adjustment of nominal wage growth to increases in actual inflation.

Figure 8. Sources of Dutch inflation



Notes: The figure shows a decomposition of the sources of inflation, based on the solution of the Bernanke-Blanchard model and the implied impulse response functions shown in Figures 6 and 7. The sum of the bars are the model's forecast of inflation in each period, given initial conditions through 2019Q4 and excluding the effects of equation residuals. The grey bars show the contributions of pre-2020 data and include the contributions of productivity shocks.

Conclusion

We have analyzed the drivers of inflation in the Netherlands, using the four-equations model developed by Bernanke and Blanchard (2023). We find that shocks to energy and food prices were the main contributors to Dutch inflation in 2021 and 2022, while labor market tightness and supply shortages played a less pronounced role. While the effects of commodity price shocks on inflation are positive, we can expect them to be rather short-lived due to weak second-round effects and firmly anchored inflation expectations. Moreover, we find that, while the pass-through from price growth to wage growth is strong, the pass-through going in the other direction is incomplete, which limits the risks of a wage-price spiral.

Our analysis offers some useful insights to policymakers. In particular, while attention has recently been directed to high wage growth, our results indicate that past wage increases are more likely to reflect a (lagged) alignment with previous increases in inflation, rather than a mutually reinforcing relationship between price and wage growth. Moreover, we find that the catch-up effect has historically been statistically insignificant, which means that workers have, on average, not been fully compensated for higher-than-expected inflation, which thereby further lowers the likelihood of wage growth strongly surpassing price growth. Nevertheless, policymakers should continue monitoring wage developments, as many new wage agreements rely on past inflation developments. In addition, given that labor market tightness is found to significantly (although moderately) raise wage growth, we can expect labor market conditions to continue to exert upward pressure to inflation as long as the Dutch labor market remains tight.

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Appendix

Full description of the Bernanke-Blanchard model

The Bernanke-Blanchard model consists of four equations and features four endogenous variables – wage growth, price growth, short-term inflation expectations and long-term inflation expectations – and five shocks – energy and food prices (relative to wages), supply shortages, labor market tightness and productivity growth.

The wage equation relates wage growth to labor market conditions, short-term inflation expectations and a 'catch-up' term that measures surprise inflation, i.e. the difference between actual and expected inflation in the previous year:[4]

$$w_t - w_{t-1} = \beta(x_t - \alpha x_{t-1}) + p_t^e - p_{t-1} + \alpha(p_{t-1} - p_{t-1}^e) + z_{w,t}$$

where w_t is the log of nominal wages, x_t a measure of labor market tightness and p_t (p_t^e) the log of (expected) prices. The parameter β measures the slope of the Phillips curve. The parameter α measures the strength of the catch-up effect that captures the ability of workers to be compensated for last period's unexpected inflation. The variable $z_{w,t}$ captures all other factors that affect wage determination, such as productivity growth. The empirical version of the wage equation allows for a richer lag structure and is given by

[4] This equation is derived by combining two equations, one that relates wages, w_t, to the expected price level, p_t^e, labor market slack, x_t, and an aspiration wage, ω_t^A, i.e.

$$w_t = p_t^e + \beta x_t + \omega_t^A,$$

and an equation that describes the aspiration wage as a weighted average of its past value and past real wages plus a term that captures other factors determining wage determination, $z_{w,t}$, i.e.

$$\omega_t^A = \alpha\omega_{t-1}^A + (1-\alpha)(w_{t-1} - p_{t-1}) + z_{w,t}.$$

$$\pi_{w,t} = c_w + \sum_{k=1}^{4} \rho_{w,k}\pi_{w,t-k} + \sum_{k=1}^{4} \beta_k vu_{t-k} + \sum_{k=1}^{4} \delta_{w,k}\pi^e_{t-k} + \sum_{k=1}^{4} \alpha_k cu_{t-k} + \kappa_w A_{t-1} + u_{w,t}$$

with $\pi_{w,t}$ wage growth, vu_t the vacancy-to-unemployment rate (our measure of labor market tightness), π^e_t short-term inflation expectations, cu_t the catch-up term, which is measured as the difference between the four-quarter moving average of actual inflation and short-term inflation expectations from one year ago, and A_t labor productivity growth. We impose that the sum of coefficients on the lags of wage growth and expected inflation is equal to 1, i.e. $\sum_{k=1}^{4} \rho_{w,k} + \sum_{k=1}^{4} \delta_{w,k} = 1$. This constraint ensures that the long-run Phillips curve is vertical and nominal wage growth moves one-to-one with expected inflation.

The price equation relates price growth to wage growth and various product-market shocks:

$$p_t - p_{t-1} = w_t - w_{t-1} + z_{p,t}$$

where the variable $z_{p,t}$ captures the product-market shocks, but also variations in price markups (which are excluded from the empirical model). The empirical version of the price equation is given by

$$\pi_t = c_p + \sum_{k=1}^{4} \rho_{p,k}\pi_{t-k} + \sum_{k=0}^{4} \mu_k \pi_{w,t-k} + \sum_{k=0}^{4} \eta_k \pi_{EN,t-k} + \sum_{k=0}^{4} \xi_k \pi_{F,t-k} + \sum_{k=1}^{4} \chi_k shortage_{t-k} + \kappa_p A_{t-1} + u_{p,t}$$

with π_t price growth, $\pi_{EN,t}$ and $\pi_{F,t}$ energy and food price growth (relative to wage growth), and $shortage_t$ a measure of supply shortages. We impose that the sum of coefficients on the lags of price growth and on wage growth is equal to 1, i.e. $\sum_{k=1}^{4} \rho_{p,k} + \sum_{k=0}^{4} \mu_k = 1$.

Short-term inflation expectations depend on their own lags, actual past inflation and long-term inflation expectations:

$$p^e_t - p_{t-1} = (1-\delta)(p_{t-1} - p_{t-2}) + \delta\pi^*_t$$

where π^*_t measures long-run inflation expectations. The parameter δ measures the extent to which expectations are anchored to long-run inflation expectations. The empirical version of the short-term inflation expectations equation is given by

$$\pi^e_t = \sum_{k=1}^{4} \rho_{\pi^e,k}\pi^e_{t-k} + \sum_{k=0}^{4} \Upsilon_k \pi^*_{t-k} + \sum_{k=0}^{4} \Gamma_k \pi_{t-k} + u_{\pi^e,t}$$

with the constraint that $\sum_{k=1}^{4} \rho_{\pi^e,k} + \sum_{k=0}^{4} \Upsilon_k + \sum_{k=0}^{4} \Gamma_k = 1$.

Finally, **long-term inflation expectations** depend on their own lags and actual inflation:

$$\pi^*_t = \gamma\pi^*_{t-1} + (1-\gamma)(p_{t-1} - p_{t-2})$$

where $1-\gamma$ measures the degree of de-anchoring of long-run inflation expectations. The empirical version of the long-term inflation expectations equation is given by

$$\pi^*_t = \sum_{k=1}^{4} \rho_{\pi^*,k}\pi^*_{t-k} + \sum_{k=0}^{4} \Gamma^*_k \pi_{t-k} + u_{\pi^*,t}$$

with the constraint that $\sum_{k=1}^{4} \rho_{\pi^*,k} + \sum_{k=0}^{4} \Gamma^*_k = 1$.