Pattern wage bargaining and exchange rate volatility in Norway

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Abstract

The Norwegian nominal exchange rate exhibits the typical characteristics of floating exchange rates—namely, a dominant random walk component and excessive volatility. At the same time, pattern wage bargaining creates a direct channel from the exchange rate to domestic wages, raising concerns about its compatibility with inflation targeting and the potential for a wage-exchange rate spiral.

This paper presents a model in which pattern bargaining and inflation targeting coexist without creating 'over-determination' in wage and price setting. Using a combination of analytical results and numerical simulations, the study demonstrates that wage and price dynamics remain stable under reasonable parameter assumptions—even when allowing for two-way causality between inflation and depreciation. Moreover, the comparative dynamics of the theoretical model align with those of an empirical model of the Norwegian economy.

The findings help explain why, after 25 years of inflation targeting, pattern bargaining persists despite repeated predictions of its demise. The forecasting environment for wage setters under a floating exchange rate remained fundamentally unchanged: institutionalized cost-of-living forecasts continued to rely on a given exchange rate. Earlier critiques arguing that wage-setting institutions had to adapt to inflation targeting were based on models that failed to capture the core dynamics of pattern bargaining, weakening their practical relevance.

1 Introduction

Bouts of currency depreciation and high pandemic-era inflation have raised concerns that Norway's system of Pattern Wage Bargaining (PWB) may not be well suited to a regime with floating exchange rates and inflation-targeting monetary policy.

Two key aspects of Norway's implementation of PWB are at the center of this debate. First, since the wage norm is set by organizations negotiating in industries exposed to foreign competition, pattern bargaining directly links total wage growth and inflation to exchange rate fluctuations. As a result, while PWB promotes coordination in wage

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growth across industries, it may come at the cost of higher-than-necessary wage and inflation volatility. Second, if prolonged periods of significant currency depreciation occur, the overall level of inflation may rise above what it would have been in the absence of wage-setting norms driven by the internationally competitive sector. Finally, critics have suggested the possibility of a feedback loop in which the foreign exchange market reacts to higher inflation with further currency depreciation, potentially triggering a wage-exchange rate spiral.

Despite the inherently dynamic nature of inflation and exchange rate movements, most existing attempts to formalize and test these concerns have relied on static models and comparative statics. To address this limitation, this paper employs dynamic models that explicitly capture how price and wage levels evolve jointly with the exchange rate, ensuring a more rigorous framework for analyzing these interactions

The rest of the paper is organized as follows. Section 2 provides a brief overview of how PWB functions as a practical framework for voluntary coordination in wage setting. Section 3 examines the argument that PWB may amplify imported inflationary pressures. If this were the case, the temporal properties of Norway's nominal exchange rate would differ from those of other countries that do not practice PWB, where nominal exchange rates are typically weakly connected to other macroeconomic variables. Section 4 investigates this claim and shows that, rather than being an outlier, Norway's nominal exchange rate exhibits the same time series properties as other floating exchange rates.

Given this, it is useful to develop and analyze a model in which the nominal exchange rate is one of several factors in the inflation-generating process and where exchange rate pass-through does not necessarily lead to dynamic instability in the wage-price setting mechanism. The theoretical framework is presented in Section 5. Section 6 presents simulation results using an operational empirical model of the Norwegian economy. Finally, Section 7 summarizes the findings and outlines directions for future research.

2 Coordinated wage setting through pattern wage bargaining

As the postwar period unfolded, with *de facto* full employment, and with a commitment to free collective bargaining, the management of the economy in Norway centered around the trade balance, exchange rate policies and a creeping inflation, Nymoen (2017). In Norway, as in many other countries, inflation became a problem for reaching important goals, it was not seen as an instrument towards attainment of those goals.[1]

Inflation was also regarded as relevant for, and part of, the processes that governed the international cost competitiveness of Norway's export and import competing industries. The central role of wage formation in these processes was clearest conceptualized in a report written by a group of Norwegian experts in 1967, and was dubbed the 'main-course model'.[2] The basic idea was that price and productivity increases create a rent that will

[1]Contrary to the academic 'Phillips curve myth' that emerged between 1975 and 1977, there are almost no evidence of Phillips curve inflationism in Britain, as Forder (2014) shows convincingly. One can certainly say the same about Norway, where inflation was unpopular among union leaders and members, Bergh (2009, p 118).

[2]Re-labelled as 'A Norwegian Model of Inflation' by Aukrust (1977), perhaps in an attempt by Aukrust, who headed the 1967-group, to coin something different than the term 'Scandinavian model' after Edgren et al. (1969). On the role of the main-course model in Norwegian economic planning, see Bjerkholt (1998).

be divided between capital and labour by the forces that shape the functional income distribution. They are usually a combination of "pure" market forces and the results of collective actions (by unions and the organizations of firms and capital owners).

The distribution of value added per hour takes place in both the internationally competitive sectors (henceforth the tradables industries) and in the sectors sheltered from international competition (the nontradables sector). There is however, as Aukrust pointed out, important differences in the strategic situation that capital owners find themselves in. In the non-tradables sector, firm owners can secure their share of the value added by adjustment of product prices after the wage level there has been fixed. This is not an option for firms owners in the tradables industries (as a simplification, think horizontal demand curves). Hence, there is a coordination problem, in particular in a situation with practically full employment, where non-tradables firms can become tempted to "bid up" wages.

In order to avoid unhealthy wage competition, and also to secure that enough capital was invested to maintain a tradables sector, coordination became a sought after property in national wage setting. The solution that Aukrust came up with, was to derive a wage norm from the premise that a required rate of return is needed to attract capital to the tradables industry, and to adjust wages in both sectors with the change in that norm. That is, at least as a tendency and over the longer term, which is why Aukrust called the evolution of the wage norm the 'main-course'. He also considered it an oversimplification to assume that the actual wage level was identical the wage norm. More realistically, if the coordination worked in practice, it would sometimes be above the norm, sometimes it would sink below. But always, in a statistical sense, the wage level should be attached to the norm.[3]

As pointed out by Calmfors (2025), there may have been considerable acceptance for centralized bargaining outcomes between the national peak organisations on both the employer and the trade union side. But as the number of organization has increased and labour markets have become more complex, the importance of industry level bargaining has also grown. The strive for coordinated wage setting has not disappeared, though. In our era, coordination is done through pattern wage bargaining, PWB, where manufacturing, as a representative of the tradables sector, concludes the first agreement in the annual rounds of wage adjustments, which determines a norm for wage increases for other sectors to follow.[4]

This system of coordination has in recent years been favourably reviewed in OECD surveys of Norway: "The system of collective bargaining based on coordinated annual wage increases works well, providing top-level guidance on wage increases that is anchored in macroeconomic realities",OECD (2019, p.37). However, there has also been critique, e.g., about rigid relative wages which can slow down or hinder desirable labour re-allocation, see Calmfors and Seim (2013).

[3]To illustrate his idea, Aukrust (1977) included a picture showing a line graph labelled 'Main course', increasing as a function of time, inside "The Wage-Corridor' indicated by dashed lines labelled "Upper boundary" and "Lower boundary". Later, the main-course theory was formulated as an hypothesis about cointegration between the log of the wage level and the log of the main-course variable. Early studies for Norway includes Nymoen (1989,1991), Rødseth and Holden (1990) and Johansen (1995a) among others.

[4]Calmfors (2025) provides insightful discussion of pattern wage bargaining in Denmark, Finland, Norway and Sweden.

3 Pattern bargaining and the floating exchange rate: Over-determination and inflation-depreciation spiral?

Questions about the raison d'être of the inherited pattern of wage bargaining have been raised before, particularly after Norway transitioned from a fixed to a floating exchange rate regime in 2001.[5]

The key argument at the time was that the effectiveness of having the internationally competitive sector as the wage leader depended on a fixed exchange rate regime. In 2002, Norges Bank published a theoretical assessment concluding that, for wage bargaining to be logically consistent with the new policy regime, the traditional pattern needed to be reversed, Norges Bank (2002, p. 28-29).

In the mathematical model presented by Norges Bank, a floating exchange rate regime would imply that wage growth is determined from two sides, resulting in what we hereafter refer to as *over-determination*. To ensure logical coherence with the new monetary policy framework, they argued that under a floating exchange rate, the wage norm should instead be derived from Norges Bank's inflation target and the required rate of return on capital in the non-tradables sector. This, in turn, would allow for a sustainable and parallel wage development across both sectors.

At first glance, this approach appeared to leave the rate of return on capital in the internationally competitive sector unanchored. However, Norges Bank's analysis suggested that this would not be the case, as the nominal exchange rate would adjust endogenously to maintain a stable functional income distribution. In effect, the foreign exchange market would assume the role previously held by wage-setting institutions in shaping the functional income distribution.[6]

However, the wage setters themselves were unimpressed by Norges Bank's analysis. After 2001, pattern wage bargaining continued as before, as if nothing had changed in the exchange rate policy regime. Nevertheless, as noted, the perspective was never fully set aside. It resurfaced when pandemic-era inflation triggered renewed concerns about wage-price spirals and the knock-on effects of a depreciating krone.

In the rekindled debate, defenders of the incumbent system acknowledge that a bout of foreign inflation will (as an intended consequence) lead to higher overall wage growth in the economy. As a result, inflation may be somewhat higher than it would have been under an alternative wage formation system. However, setting aside the possibility of inherent dynamic instability, this effect is not permanent and does not, in itself, trigger self-generating wage-price spirals. Critics, however, argue that this reasoning implicitly assumes a fixed exchange rate.

According to Calmfors (2025), who cites theoretical work in Norwegian by Røisland (2023), the reaction pattern described above could instead lead to an exchange rate depreciation, which in turn would induce further wage increases in the tradables sector to counteract declines in the wage share. To prevent such a wage-exchange rate spiral, the central bank would need to raise interest rates sufficiently.

[5] There was a transition period with hybrid regimes, but the shift was finalized and formalized as an inflation-targeting regime in early 2001.

[6] Calmfors (2025) revisits this argument, though explicitly as a normative model. Calmfors further notes that the erratic behavior of exchange rates poses a practical challenge for a reversed ordering of collective wage bargaining.

However, these analyses rely on models composed of static equations for the log levels of price, wage, exchange rate, and productivity, or on relationships between constant growth rates.[7] Because the underlying theory is static, the implicit assumption is that wage growth and inflation are always in equilibrium and evolve along deterministic steady-state paths—an assumption that is both highly restrictive and empirically implausible.[8]

The models used by Calmfors (2025), Røisland (2023), and Norges Bank (2002, p. 28-29) therefore provide no insights into how adjustment mechanisms operate when the system deviates from its deterministic steady state. Below, I present an alternative yet equally simple theoretical model that is more relevant, as it explicitly accounts for wage and price setting outside equilibrium.

It is therefore possible to see why Norges Bank's 2002 analysis about the supposedly logically necessary reshaping of pattern bargaining failed to make an impression on real-world wage setters.

First, there was little evidence to support the idea that the exchange rate could reliably act as an equilibrium-correcting mechanism for the functional income distribution in the tradables sector. Second, inflation forecasts used by bargaining parties to form expectations about the cost of living continued to be based on the most recent observation of the exchange rate. This approach was entirely rational, as we demonstrate in the next section: the floating nominal exchange rate exhibits random-walk-like properties. As a result, the forecasting environment that wage setters faced in practice did not differ qualitatively from that of the previous regime, where the exchange rate was fixed but subject to intermittent adjustments.[9]

4 The nominal exchange rate and the macro economy

Given the central role of the exchange rate in the preceding arguments, it is essential that theoretical models align with the empirical properties of the exchange rate and its relationship with other macroeconomic variables.

The nominal exchange rate represents the relative price of currencies. In this paper, it is denoted by V_t, the price of foreign currency in units of kroner. A depreciation (or weakening) of the krone corresponds to an increase in V_t.

There is considerable consensus about the time series properties of exchange rates, from a period with a floating exchange rate regime, cf. the survey by Itskhoki (2021):

1. The natural logarithm of the nominal exchange rate, denoted by $v_t = log(V_t)$ is well approximated by a random-walk process without drift.

2. The rate of depreciation, measured as the quarterly change Δv_t or the annual change $\Delta_4 v_t$, is excessively volatile.

3. The are no robust empirical relationships between rates of depreciation and other macroeconomic variables.

[7] These growth rates are obtained, implicitly, by differencing the static equations.

[8] Adding a white-noise error term to the growth rate equation for the wage-leading manufacturing sector contradicts the assumed long-run relationship between the level of these variables, as noted in section 5.

[9] The Technical Calculation Committee (TCC) was established in 1967 by a tripartite agreement, and is vested with elaborating a common understanding about recent wage developments and about the forecast for cost of living, and other parameters of relevance for the upcoming agreement revisions.

Table 1: Descriptive statistics. Annual change in the Norwegian effective exchange rate, national wage level and in CPI and CPIAET, 2001q1-2024q3. Units in percent, except coefficient of variation, which is in percentage points.

	Depreciation	Wage growth	CPI-inflation	CPIAET-inflation
Mean	0.6	3.9	2.4	2.1
Median	0.1	4.1	2.2	2.0
St.dev	5.2	1.3	1.3	1.2
Variation	23.7	6.9	8.0	6.4
$\chi^2_n(2)$	0.6[0.72]	0.48[0.78]	30.1[0.00]	64.0[0.00]
Note: Rates of annual change: $\Delta_4 x_t \equiv x_t - x_{t-4}$. Percentage change is approximated as $\Delta_4 x_t 100$.				

These findings indicate that under a floating exchange rate regime, the data generating process(DGP) of v_t appears to be dominated by a random-walk component. Importantly, this random walk lacks a long-term drift, meaning there is no systematic trend of appreciation or depreciation over time. As a consequence, the rate of depreciation Δv_t behaves similarly to a white-noise process, making it difficult to predict with any accuracy.

At first glance, this might seem at odds with studies identifying variables—such as oil prices and risk premia—that appear to have explanatory power for the exchange rate Benedictow and Hammersland (2023); Risstad et al. (2023); Akram (2020); Klovland et al. (2021), or, as found later in this paper, changes in interest rate differentials. However, when the purpose is forecasting, many of these explanatory variables must themselves be predicted. As a result, multi-equation exchange rate models often perform no better than a simple random walk.

Consistent with the dominance of the random walk property, floating exchange rates tend to be highly volatile. It is not uncommon for annual depreciation rates to have standard deviations of 10% or more. By contrast, other macroeconomic variables, such as inflation, exhibit significantly lower volatility—often an order of magnitude smaller than the nominal exchange rate.

Data for the sample period 2001(1)-2024(3) show that the exchange rate of the Norwegian krone (NOK) shares many of these features. For the NOK/USD rate, the standard error of the annual rate of depreciation is indeed 10% percent. Table 1 shows that the effective exchange rate, which is a basket of 44 bilateral rates, has a standard deviation of 5% , which is still five times greater that for wage and price inflation.

A dominating random-walk component is not unique or special for v_t. In fact, low-frequency variability was identified as a *typical* feature of macroeconomic time series as early as the 1960s Granger (1966).[10] If we assume that the data generating processes of the exchange rate, wages, and prices can all be approximated by random walks, the key distinction lies in the presence (or absence) of a systematic drift. The numbers for the mean and median in the table below indicate that while wages and prices exhibit a clear upward trend over time, the exchange rate does not, reinforcing the idea that v_t follows a driftless random walk.

The differences in variances and in means are also clear in the time graphs in Figure 1. Hence, the properties of the Norwegian nominal exchange rate closely align with the well-established stylized facts of floating exchange rate regimes. In particular, the absence of a

[10]Granger introduced the term "typical spectral shape," but the underlying idea is the same; see Nymoen (2019) for a textbook exposition.

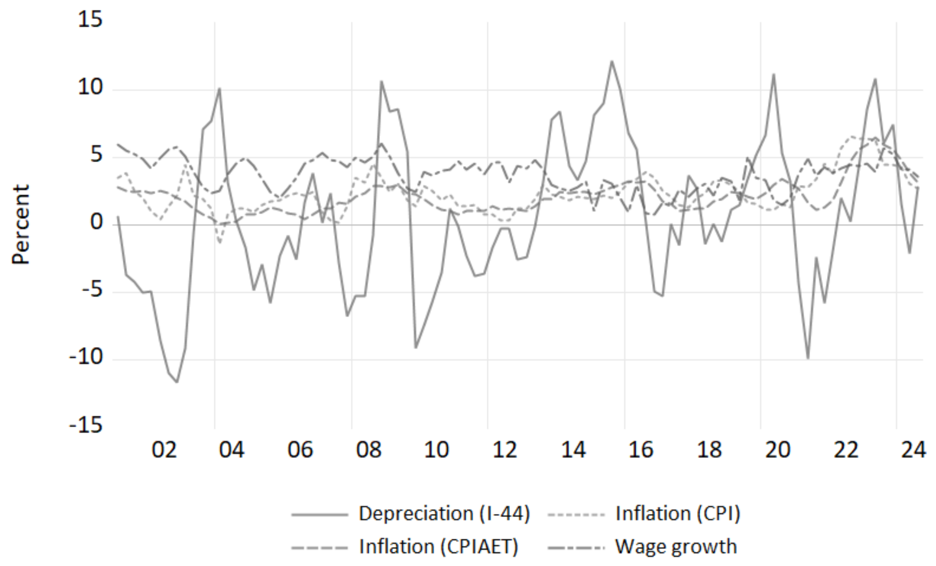

Figure 1: Depreciation of effective exchange rate (I-44) and inflation, annual changes 2001q1-2024q3.

clear drift (Fact 1 above) and the significantly higher volatility of depreciation compared to price and wage growth (Fact 2) are both evident in the Norwegian case.

Fact 3, often referred to as the macroeconomic disconnection property, might initially seem more plausible for large countries (or currency areas) than for small open economies. In its narrow sense, the disconnect property dates back to Meese and Rogoff (1983) and suggests that Δv_t exhibits little contemporaneous correlation with other macroeconomic variables. For the variables in the table, the correlations are: -0.3 (wage growth), 0.1 (CPI inflation), and 0.3 (CPIAET inflation), which do not provide strong evidence against the disconnection property.

Another perspective on the disconnection property can be obtained by testing the relative purchasing power parity (PPP) hypothesis using Norwegian data. The real exchange rate, which measures relative price levels across countries in a common currency, is denoted by v_{pt}. In log terms, it is defined as:

$$v_{pt} \equiv v_t + p_t^f - p_t,$$

where p_t and p_t^f represent domestic and foreign price levels, respectively.

By definition, v_{pt} captures deviations from relative PPP. If these deviations are minimal—evidenced by small or moderate autocorrelation coefficients—we would expect a high correlation between nominal depreciation, Δv_t, and the inflation differential, $\Delta(p_t^f - p_t)$. Conversely, a low contemporaneous correlation would contradict relative PPP and align with the broader phenomenon of nominal exchange rate disconnection.

However, a weaker form of the relative PPP hypothesis is more widely accepted in modern macroeconomics. This version suggests that while short-term deviations from relative PPP may occur, the real exchange rate v_{pt} should exhibit long-run stationarity.

The random-walk property of the nominal exchange rate is captured by the assumption that v_t is integrated of order one, denoted as $v_t \sim I(1)$, following standard notation.

The long-run stationarity of the log of the real exchange rate can then be examined empirically by testing the null hypothesis that v_t and $(p_t^f - p_t)$ are not cointegrated, against the alternative hypothesis that they are cointegrated.

As noted in Itskhoki (2021)'s survey of the real exchange rate literature, there is no conclusive empirical support for the assumption of long-run stationarity in the real exchange rate. Consequently, the well-known PPP puzzle (Rogoff (1997)) remains unresolved.

The empirical relevance of weak relative PPP has direct implications for inflation modeling in a small open economy. To address this, I report several tests of relative PPP for the Norwegian effective exchange rate in the appendix. In line with existing literature, these tests consistently fail to reject the null hypothesis that relative PPP does not hold, at conventional levels of significance.

Another connection point between the nominal exchange rate and the macroeconomy is with the difference between domestic and foreign money market interest rates. In the Appendix, the strength of this channel is investigated. The result is that the change in the difference between interest rates, denoted $\Delta(r_t - r_t^f)$ is a significant and robust explanatory variable for Δv_t. The *level* of the short-term interest rate differential is insignificant, numerically and statistically.[11]

In summary, the investigation of the empirical relationship between the exchange rate and short-term interest rate shows evidence of a short-term relationship which is however compatible with (and does not overturn) the main feature of the nominal exchange rate: namely as random-walk series without a systematic trend (drift) up or down.

However, small contemporaneous correlations between depreciation and wage and price increases, and weak (if at all) evidence in favour of relative PPP, should not lead us to accept the disconnect property more generally. After all, a plausible explanation for the weak connection is that the tested relationships were aggregate and 'confluent', and that one must dig deeper to come to grips with the more structural connection between the exchange and e.g., wage and price setting.

In a small open economy, a nominal depreciation will lead to higher prices on imports, and to increased compensation to workers in export oriented industries, and so on. At least under ceteris paribus conditions. In the next section I therefore set up a structural model of wage and price dynamics. The model allows the nominal exchange rate to be a factor in both price and wage setting, but also identifies points in the causal chain that can mitigate the effects of changes in the nominal exchange rate.

5 The exchange rate's walk through a pattern wage bargaining model

In this section, a model of PWB with floating exchange rates is presented and analyses. It is simplified compared to empirical models of wage and price setting in Norway which is much more detailed, both in order to fit the data and because disaggregate results are in demand from model users. That said, the goal has been not to distort (by over-simplification) the core functional relationships for wage setting in the empirical

[11] In section 6, where a bigger information set is used, the results indicate that a difference between a domestic and foreign *long-term* interest rate has explanatory power.

explanatory models of the Norwegian macroeconomy.[12]

5.1 Model equations

The model is a system of dynamic equations, given as (1)-(11). The symbols used for variables and coefficients (parameters) are explained in Table 2 for easy reference.

The framework builds on Kolsrud and Nymoen (2023) who analysed the dynamic properties of a model of pattern wage bargaining after shocks, and found that there was a return to stable price and wage growth for a large range of unemployment levels. Hence, dynamic stability in their model did not depend on standard natural rate of unemployment dynamics. In Kolsrud and Nymoen (2023), a random walk for the log of the exchange rate was assumed. In the current version of the model, there is endogenous influence on the nominal exchange rate. However, the specification reconciles that endogeneity with the dominant low-frequency stochastic trend that we have seen is typical for the logs of nominal exchange rates.

Even if it is simplified and stylized, the model is specified so that it is consistent with the salient time series properties of real wold data that we have discussed above. Therefore, equation (1) generates the price (in foreign currency) in the wage leading industry q^f_{1t} as a trending series, modelled as a random-walk with drift. Hence $\phi^f_1 > 0$ and ϵ^f_{1t} is defined as a white-noise series (zero mean and constant variance). Equation (2) and (3) generates two productivity trends, one for the wage-leading industry, z_{1t}, and z_{2t} for the wage-following sector.

There is no feed-back from the other variables in the model to the generation of the three trending variables in (1)-(3), and in each period q^f_{1t}, z_{1t}, and z_{2t} are therefore pre-determined in the other equations of the system.

Equation (4) is the equation for the nominal exchange rate. It is a simplified version of the econometric equation in the appendix, and which was mentioned above. Therefore, the equation includes the change in the interest rate difference $\Delta(r-r^f)_t$ as an explanatory variable, with negative coefficient ($-\delta_1 < 0$).

$$\Delta q^f_{1t} = \phi^f_{q1} + \epsilon^f_{q_1 t}, \tag{1}$$
$$\Delta z_{1t} = \phi_{z1} + \epsilon_{z_1 t}, \tag{2}$$
$$\Delta z_{2t} = \phi_{z2} + \epsilon_{z_2 t}, \tag{3}$$
$$\Delta v_t = -\delta_1 \Delta(r - r^f)_t + s_t \delta_2 \Delta p_{t-1} + \epsilon_{vt}, \tag{4}$$
$$mc_t = \Delta q^f_{1t} + \Delta v_t + \Delta z_{1t} + mc_{t-1} \tag{5}$$
$$\Delta w_{1t} = -\alpha_1((w_1 - mc_1)_{t-1} - \omega^*_1) + \alpha_2 \Delta mc_t + \alpha_3 \Delta p_t + \alpha_4 \Delta p_{t-1} + \alpha_5 u_{t-1} + \epsilon_{w_1 t} \tag{6}$$
$$\Delta w_{2t} = \beta_1 \Delta w_{1t} - \beta_2 (w_{2t-1} - w_{1t-1} - \omega^*_2) + \epsilon_{w_2} \tag{7}$$
$$\Delta q_{2t} = \gamma_1(\Delta w_{2t} - \Delta z_{2t}) + \gamma_2((w_2 - q_2 - z_2)_{t-1} - \varpi^*_2) + \epsilon_{q_2 t} \tag{8}$$
$$\Delta p_t = \varphi \Delta q_{2t} + (1 - \varphi)(\Delta q^f_{1t} + \Delta v_t) \tag{9}$$
$$\Delta u_t = \lambda_1(r_{t-1} - \Delta p_{t-1}) + \lambda_2 \Delta u_{t-1} - \lambda_3 u_{t-1} - \lambda_4 x_t + \epsilon_{ut} \tag{10}$$
$$\Delta r_t = \tau_1(\Delta p_{t-1} - \pi^*) - \tau_2 u_{t-1} - \tau_3 r_{t-1} + \epsilon_{rt} \tag{11}$$

The second term in equation (4) is used to represent a structural break in the v-equation. s_t is a step-dummy that can be 0 or +1. When $s_t = 0$, the nominal exchange rate is not

[12] Documentation of how PWB is treated in operational macro model are found in Nymoen and Bårdsen (2023) and Hove et al. (2022). Recent research articles with results of econometric modelling are Gjelsvik et al. (2020),Dalnoki (2020),Boug et al. (2023).

Table 2: Symbol definitions used in model (1)-(11).

Variables	Definition (t in subscript denotes time)
q_{1t}^f	Price on tradables products, in foreign currency
z_{1t}, z_{2t}	Productivity in tradables, (1) and non-tradables, (2)
v_t	Nominal exchange rate
mc_t	Main-course
q_{2t}	Product price in sector non-tradables
w_{1t},q_{2t}	Wage wage-eader (1) and wage-fowllower (2)
p_t	Consumer price
u_t	Unemployment rate
r_t	Domestic interest rate
x_t	Exogenous part of u
s_t	Regime-shift variable
ϵ_{q1t}^f, ϵ_{z1t},ϵ_{z2t},ϵ_{vt},ϵ_{w1t},ϵ_{w2t},ϵ_{q2t},ϵ_{ut},ϵ_{rt}	Uncorrelated white-noise variables
Coefficients	
$\phi_{q1}^f > 0, \phi_{z1} > 0, \phi_{z2} > 0$	Drift coefficients, foreign price and productivity
$\delta_i > 0$,$i = 1, 2$	Exchange rate equation (4)
$\alpha_i > 0$,$i = 1, .., 5$,$\omega_1^* > 0$	Wage-leader equation 6)
$\beta_i > 0$,$i = 1, 2$,$\omega_2^* > 0$	Wage-follower equation(7)
$\gamma_i > 0$,$i = 1, 2$,$\varpi_2^* > 0$	Non-tradables price equation (8)
$\lambda_i > 0$	Unemployment equation (10)
$\tau_i > 0$,$i = 1, 2, 3$	Interest rate equation (11)

directly connected to domestic inflation. The connection is only indirect, via the change in the interest rate differential. However, when $s_t = 1$, currency depreciation is directly linked to inflation (with coefficient δ_2).

Below, we solve the model for two cases. In the first solution, the "No break" case, $s_t = 0$ for all t. We also think of this as the baseline-solution. In the other case (and solution) $s_t = 0$ for $t < t_{break}$ and $s = 1$ for $t \geq t_{break}$. We label this solution the "Break in v-eqn" case. This gives a simple way of representing the hypothesis that in normal times, there is no inflation-depreciation spiral, but also that in times were the trust in the monetary system has become severely reduced, there can be a structural break in the data generation process that connects the nominal exchange rate to the nominal path of the domestic economy.

One remark is that if the purpose had been to specify a positive theory of v_t in accordance with the PPP hypothesis (but keeping in mind the weak empirical evidence), a better specification would have been with the inflation difference $(\Delta p_{t-1} - \Delta p_{t-1}^f)$, instead of with Δp_{t-1}. However, according to PPP, the mean of $(\Delta p_{t-1} - \Delta p_{t-1}^f)$ is close to zero, and the implication of solving the model for $s_t = 1$ instead of for $s_t = 0$ would then only be a modification of the short-term dynamics. The exchange rate data generating process would not be qualitatively affected, and the 'counterfactual' $s_t = 1$ would not represent a real stress-test of the wage-setting system.

Equations (5)-(9) is the module for wage and price setting within the wider system of equations.

The definition (5) gives the evolution of mc_t, the nominal value (in kroner) of productivity in the internationally competitive industry. mc_t is the main-course variable in the tradables sector, the factor behind the secular trend in wages according to Akurust's main-course theory mentioned in section 2.

A related terminology in the literature is that mc_t represents the *scope* for cumulation of wage increases that are consistent with a constant wage-share, and therefore also profit-share, in the long-run.

A logical consequence of this interpretation is represented by the first term on the right hand side of (6): Assuming that $\alpha_1 > 0$, the wage adjustments in the tradables sector contributes to equilibrium correction of the wage share $(w_{1t} - mc_t)$ with respect to an equilibrium wage-share denoted by ω_1^*.[13]

The other variables in (6) represent other plausible (and indeed empirically supported) explanatory variables of wage formation in the internationally competitive sector. $\alpha_2 \Delta mc_t$ represents a contemporaneous effect a change in the scope variable. Estimates of $\alpha_2 > 0$ are typically less than 1, and smaller than the sum of the coefficients associated with current and lagged CPI-inflation, $\alpha_3 > 0$ and $\alpha_4 > 0$. It is standard to include a measure of labor market tightness, which is the unemployment rate u_t in (6).

Theoretical analyses based on the main-course theory is often presented in growth rate form, e.g., Norges Bank (2002) and Calmfors (2025). With the notation above, the growth rate version of the wage equation in the tradables sector becomes:

$$\Delta w_{1t} = \Delta q_{1t}^f + \Delta v_t + \Delta z_{1t} + \epsilon_{w_{1t}}, \tag{12}$$

which is a special case of (6) obtained by setting $\alpha_1 = \alpha_3 = \alpha_4 = \alpha_5 = 0$, and $\alpha_2 = 1$.

It may be tempting to regard (12) as a convenient simplification. However, care must be taken, since equation (12) is inconsistent with log-run proportionality between the wage level and the main-course, see e.g. Bårdsen et al. (2005, Ch 3).

The internal inconsistency arises since the only way to recover a long-run levels equation for w_t is to integrate (12), which leads to:

$$w_{1t} = \omega_1^* + mc_t + e_{w_{1t}}, \text{ where } \; e_{w_{1t}} = e_{w_{1t-1}} + \epsilon_{w_{1t}}, \tag{13}$$

and so the error term $e_{w_{1t}}$ is a random-walk, accumulating the $\epsilon_{w_{1t}}$, Hendry (1995, Chapter 7.4). Hence, there is an internal inconsistency, since a core idea in the theory is that w_{1t} has a long-term connection with mc_t, while (12) says that w_{1t} can deviate from mc_t by an infinite amount at any point in time.

The resolution to this conundrum is to assume from the outset that the coefficient α_1 is non-zero, as we have done above. A common further assumption is $0 < \alpha_1 < 1$, which implies smooth equilibrium correction.

Some presentations simplify the growth rate equation by dropping the white-noise error term. In (13), we then get $e_{w_{1t}} = 0$, so instead of no-relationship between wage-level and main-course, there is a perfect fit. Hence, in this interpretation the wage is always evolving along an deterministic equilibrium path. Again, the formulation fails to capture the gist of the theory, namely of the main-course variable as a factor that determines the long-term trend in the wage level, but that at a plausible data generation process will include impulses from other variables, and equilibrium correction in wages with respect to those shock.

Equation (7) and (8) represent wage and price setting in the non-tradables sector. The equation for wage setting is specified (for simplicity) as a "pure" wage follower equation, where the parameter ω_2^* is interpreted as a long-term relative wage. The price equation

[13] Later theoretical derivations in the literature, using formal bargaining theory, find that $\alpha_1 > 0$, is implied by collective bargaining, see Forslund et al. (2008).

(8) is of the mark-up type consistent with the assumption of monopolistic competition in non-tradables product market. ϖ_2^* represents the equilibrium wage-share in the wage-following sector of the economy.

Equation (9) is a stylized definition equation for the change in the consumer price index, hence there is no error term in this equation.

The two last equations (10) and (11) are used to close the model, in a simple way. Equation (10) is a dynamic equation for the rate if unemployment with the real interest rate $(r - \Delta p)_{t-1}$ as an explanatory variable ($\lambda_1 > 0$). In addition, it is convenient to include an exogenous variable x_t, defined with a negative coefficient, $-\lambda_4 < 0$.

Finally, in equation (11), the interest rate is modelled as function of domestic inflation ($\tau_1 > 0$) and the rate of unemployment ($\tau_2 < 0$), in order to mimic (the effect of) inflation targeting interest rate setting on market interest rates. The dating of the arguments in the function is not important for the purpose we have in mind, but would be in an empirical analysis. Interestingly, Choo and Kurita (2015) present a specification that have similarities with (11) and which is data congruent on sample that covers both the last period before the change to float, and the first fifteen years with inflation targeting in Norway.

5.2 Long-run analysis

Assuming that the model has a long-run solution, the differences of the endogenous variables are constants.[14]

We first give the steady-state solution for the baseline version of the model, defined by $s_t = 0$. From (1)-(3) and (5)-(9):

$$\pi_{w1} = \phi_1^f + \phi_{z1} + \pi_v \tag{14}$$

$$\pi_{w2} = \pi_{w1} \tag{15}$$

$$\pi_{q2} = \pi_{w1} - \phi_{z2} \tag{16}$$

$$\begin{aligned} \pi_p &= \varphi(\phi_1^f + \phi_{z1} + \pi_v - \phi_{z2}) + (1-\varphi)(\phi_1^f + \pi_v) \\ &= \phi_1^f + \pi_v + \varphi(\phi_{z1} - \phi_{z2}) \end{aligned} \tag{17}$$

where π_{w1},π_{w2},π_v,π_{q2} and π_p denote the steady-state growth rates of w_{1t}, w_{2t},v_t,q_{2t} and p_t. From (4), given that the domestic and foreign interest rates are constant in the assumed steady-state (the differences are zero):

$$\Delta(r - r^f) = 0 \Rightarrow \pi_v = 0 \text{ (from (4) when } s = 0). \tag{18}$$

In the baseline version of the model, the rate of steady-state inflation π_p is therefore determined by the (trend part of) foreign inflation and the difference between the rates of productivity growth in the two domestic sectors. π_p is therefore pre-determined in the long-run version of equation (10) and (11):

$$0 = \lambda_1(r - \pi_p) - \lambda_3 u - \lambda_4 x \tag{19}$$

$$0 = \tau_1(\pi_p - \pi^*) - \tau_2 u - \tau_3 r \tag{20}$$

which are two simultaneous equations that can be solved to determine the steady-state values of u and r as functions of π_p, ,π^* and x.

[14]Formally, the expectations of the differences, but to simply notation and since all the error-terms are assumed have expectation zero, consider we can consider the deterministic steady-state.

We now consider the case of $s_t = 1$, where there is a structural break in the Δv_t equation (4).

The equations for price and wage grow rates (14)-(17) hold also in this regime. However, the equation for steady-state depreciation rate is now:

$$\pi_v = \delta_2 \pi_p \text{ (from (4) when } s = 1), \tag{21}$$

which affects the solution for the steady-state growth rates for wages and prices. For inflation, the steady-state is:

$$\pi_p = \frac{\phi_1^f + \varphi(\phi_{z1} - \phi_{z2})}{(1 - \delta_2)} \text{ (Break in } v\text{-eq)}, \tag{22}$$

and for the two wage growth rates:

$$\pi_{w1} = \pi_{w2} = \phi_1^f + \phi_{z1} + \frac{\phi_1^f + \varphi(\phi_{z1} - \phi_{z2})}{(1 - \delta_2)} \text{ (Break in } v\text{-eq)} \tag{23}$$

In the same way as in the baseline case, the steady state inflation rate is pre-determined in the sub-system that determines u and r in the more counterfactual long-run solution based on $s_t = 0$.

5.3 Dynamic analysis

The long-run analysis above provides no information about short- to medium-term movements of the variables around their steady-state levels or trend. Shorter term dynamic properties can be equally important and more relevant for economic analyses with a limited horizon. If the economy is in equilibrium and experiences a permanent shock, say an exogenous shift in foreign price inflation, how much and for how long do the variables react to the shift? And how do the dynamic responses become affected by the regime shift that makes the nominal exchange rate become connected to domestic inflation? To answer these question, we supplement the theoretical steady-state analysis with dynamic analysis.

Since the model has eleven endogenous variables, second order dynamics in the levels of the variables, and has simultaneity as a feature, algebraic dynamic analysis would probably be too complex to be of much help, even if was feasible. The practical form of analysis will therefore be simulation of the *cointegrated VAR* form of the model, cf. Appendix B.[15] By using that representation, we can simulate two data generating processes (DGPs) where there is dynamic interaction between the exchange rate and wages and prices, and where the difference between the DGPs is how the nominal exchange is determined.

Intuitively, the long-run relationships of pattern wage setting, with the tradables sector as the wage leader, which is built into the VAR, will contribute to stabilize the solution. For example, we may expect the wage-shares in the two sectors, and the wage ratio between them, to reach stationary steady states, at least for many reasonable choices of parameter values. However, it is difficult to say in advance whether the stationary values depend on the exchange rate dynamics.

[15] In order to simplify notation, a small number of variables in the simulated model, were omitted from (1)-(11). This does not affect the long-run analysis above.

Similar remarks apply to the rate of inflation: The long-run analysis above indicated that steady-state inflation is higher in the *Break in v-eq* solution than in the default solution, with no structural break in the v-equation. However, that conclusion hinges on the DGP for inflation is dynamically stable, and only dynamic analysis can support or weaken that assumption.[16]

Stable dynamics

We now show an example of simulations that are characterized by stable dynamic, also in the version of the model where there is a structural break in the v_t-equation. The detailed structure of the cointegrated VAR can be inspected in Appendix B. The calibration of the parameters can be considered as reasonable, compared to empirical econometric models of the Norwegian economy (using annual and quarterly time series).

Figure 2 shows two solutions in each panel. Common for them is that they are conditional on given initial conditions (starting values). The randomly generated shocks to the equations are also the same for the two solutions.

The line graphs labelled "No break in v-eq" show the solutions when $s_t = 0$ for the whole solution period. The "Break in v-eq" line graphs shows the solutions when $s_t = 0$ from the start of the simulation to $t = 299$, and $s_t = 1$ from period $t = 300$ and until period $t = 400$. In order to better inspect the dynamics toward a deterministic steady-state, all random-shocks to the model are switched off after period 350.

Panel (a) shows the solutions for the nominal exchange rate (v_t). From the start of the plot to period 300, the solutions are identical, and they are consistent with the dominating random walk-component in the DGP. As explained above, the solution is affected by changes in the interest rate, Δr_t. It can be gauged from panel (i), which shows r_t, that Δr_t is stationary with zero mean, and therefore do not impute a trend in v_t.

The explanation for the difference between the two solutions for v_t, visible shortly after period 300 is therefore that v_t becomes connected to inflation in the "Break in v-eq" solution. Inflation is a variable with positive mean, and therefore v_t behaves as a random walk *with drift* in the period from 350 to the end of the simulation period. As the appendix shows, the coefficient of the inflation variable is not huge (it is set to $\delta_2 = 0.15$).

Panel (b) shows the solutions for the main-course variable (denoted mc above) in the wage-leading sector (tradables). As there is no trend in the exchange rate before the structural break, the seminal trend is due to productivity and trending product prices on the world market (in foreign currency). After the break, the nominal exchange rate begins to contribute to the trend in the main-course variable. A main function of collective bargaining is to distribute the increased 'rent' between workers and investors (owners), to stabilize the functional income distributions. We see that happening relatively fast in panel (c), even though the simulation is based on parameter values that give non-instantaneous wage adjustment with respect to the exchange rate (the instantaneous parameter is $\alpha_2 = 0.2$).

It is interesting that the wage-share in the non-tradables sector is more permanently affected by the break in the exchange rate equation, panel (d). Apparently, the shift forces a change in the equilibrium of the functional income distribution in that sector. A similar development is seen in (panel (e)), where the model solutions for the relative

[16]The model can be written in companion form with a high dimensional recursion matrix. Dynamic stability depends on the eigenvalues of that matrix. However, a "mapping" from the coefficients of e.g., (1)-(11) to those eigenvalues will be too complex to be of much help.

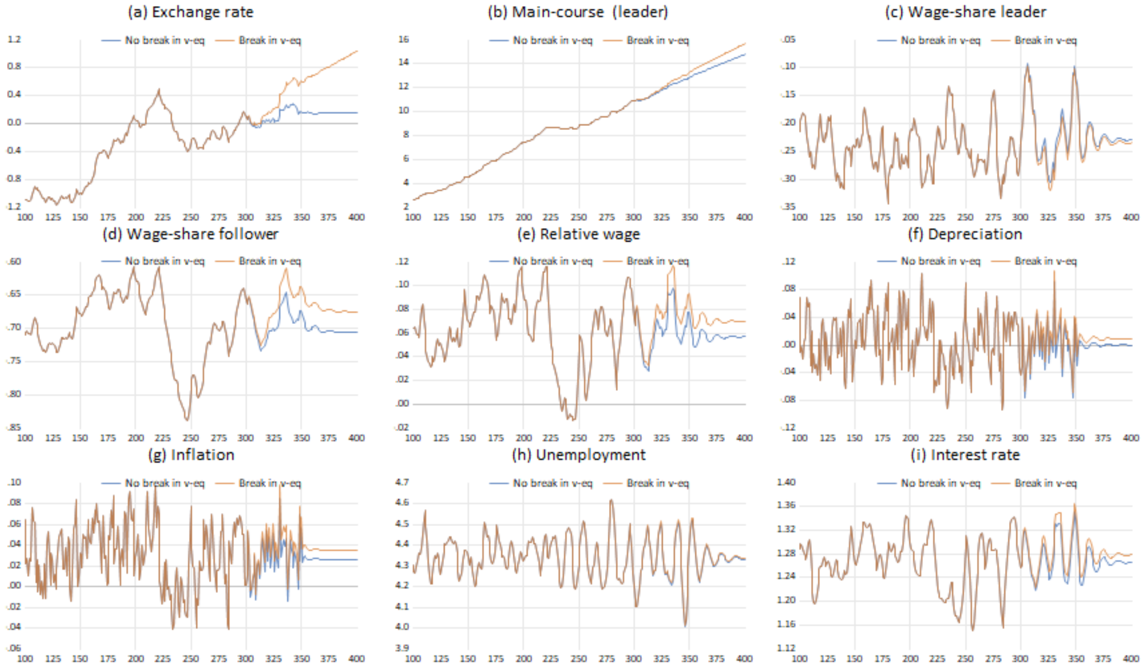

Figure 2: Simulated model solutions, without and with a structural break in period 300 (the exchange rate becomes connected to inflation). Random shocks have been set to zero after period 350.

wage between wage-leaders and wage-followers are plotted.

In panels (f), the consequence that the break in the v_t equation has for depreciation is seen, and in panel (g) for inflation. They show that, for the chosen parameterization, the long-run analysis above is supported by stable dynamics.

The two last panels show the solutions for the rate of unemployment and for the interest rate. In the model, it is the interest rate which is most affected by the structural break in period 300, because of its close connectivity with the rate of inflation.

Unstable dynamics

Systems of the type that we simulate here are not inherently stable (despite the embedded cointegration relationships). One source of dynamic instability is the Δp_t effect in the exchange rate equation. All other things equal, the higher we set the value of δ_2, the closer we get to a tipping point when the model no longer has a steady-state.

In the simulation with break in the v_t equation above, the coefficient of Δp_{t-1} was set to 0.15. In Figure 3 the line graphs that shows these solutions are labelled "Weak inf connect". The graphs labelled "Strong inf connect" shows solutions when the connection parameter between Δp_{t-1} and Δv_t was set to $\delta_2 = 0.55$.

One qualitative differences between the solutions is that the graphs for inflation and deprecation do not reach stationary values in the "Strong inf connect" version of the model, which is a sign that this solution is (at least) close to being dynamically unstable. Similar remarks apply to the interest rate and to the income distribution in the wage following sector (panel d), and the relative wage (panel e).

A further perspective on the simulation results comes from previous analysis of the

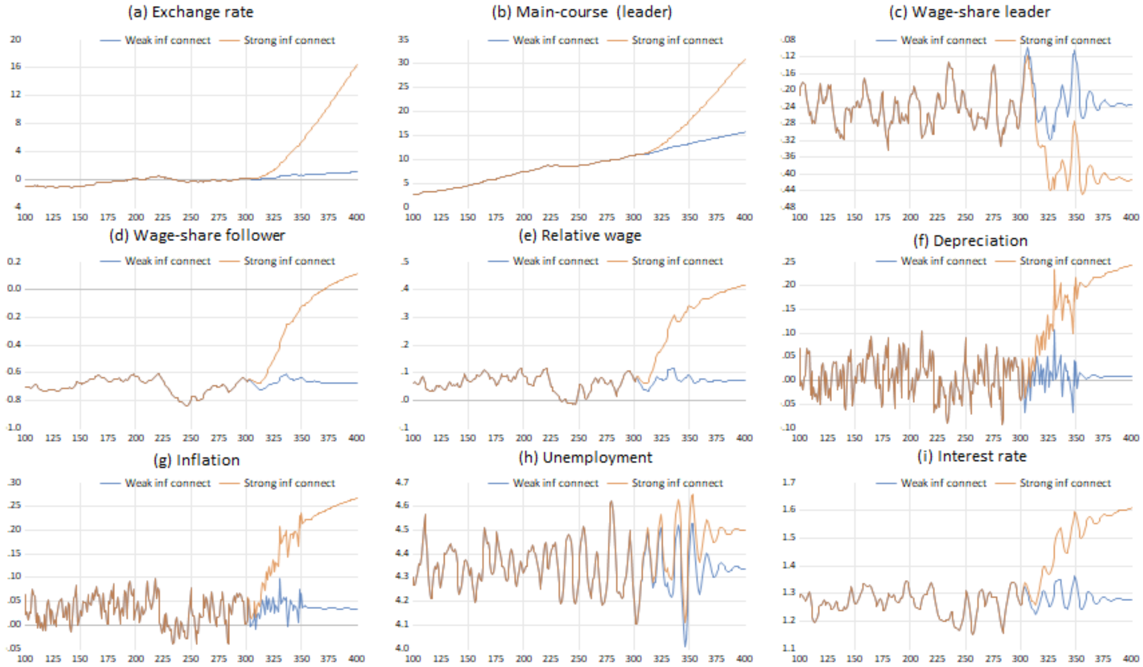

Figure 3: Simulated model solutions, structural break in period 300 (the exchange rate becomes connected to inflation). "Weak inf connect" refers to the same value of δ_2 as used in the simulation shown in Figure 2, $\delta_2 = 0.15$. "Strong inf connect" refer to a simulation using $\delta_2 = 0.55$. Random shocks have been set to zero after period 350

dynamic functioning of a wage-price spiral. Nominal rigidity, understood as partial and delayed responses of wage and price to changes in each other and to changes in other variables, is central for the degree of persistence that characterize wage-price dynamics, and ultimately to the question about dynamic stability or instability.

To these inherent (classical) wage-price dynamics, the model adds endogenous depreciation responses. Dynamics are system properties, and instability may come as a consequences of structural break other places in the system than in the exchange rate equation. Based on previous studies, it is plausible that certain restrictions on the system, that imply loss of equilibrium correction, or specific forms of dynamic homogeneity, can imply dynamic instability on the model we have simulated, cf. Kolsrud and Nymoen (2014).

Comparative dynamics

Figure 4 shows dynamic responses to a foreign inflation shock. For simplicity we assume the shock takes place just before the break in the exchange rate equation in period 300. The line graphs in figure 4 therefore show the responses that are differences from the two baseline simulations shown in Figure 2.

The foreign price shock is implemented as a 0.10 increase in import prices, which last for one period (an impulse). The price for the tradables products get the same initial price increase, see panel (a) in Figure 4. There is some persistence in the price response, but after ten periods the price increase in the wage-leader sector of the model economy is back to where it was before the shock. However, since the price-response plotted in

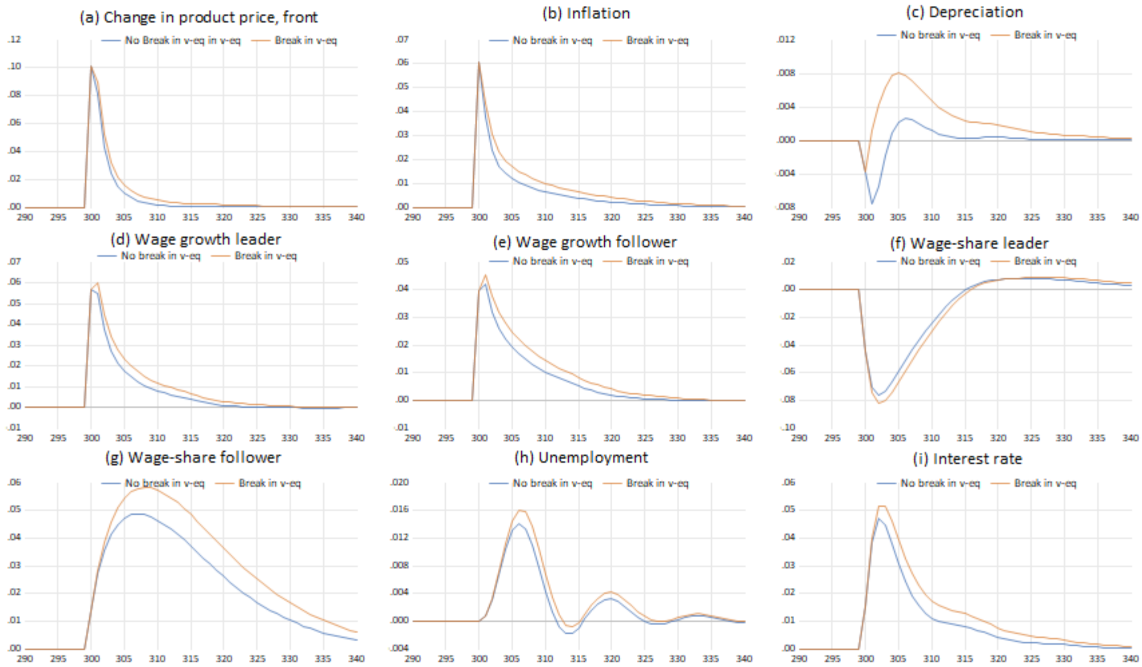

Figure 4: Theoretical responses to a shock to foreign inflation.

panel (a) is for price in domestic currency, the response is somewhat slower in the case where depreciation is directly connected to inflation, cf. panel (b).

The impression about small differences between the two responses apply to the other panels as well. The difference is easiest to spot in the panel that shows the depreciation responses. The implication for the level of the exchange rate is that it is permanently depreciated in the case where there is a break in the exchange rate equation that coincides with the inflation shock. In the regular (disconnect) case, the exchange rate may even appreciate somewhat, due to the increase in the interest rate.

6 Empirical responses to a foreign inflation shock

In this section we supplement the theoretical comparative dynamics by simulated responses of the empirical model NAM, Nymoen and Bårdsen (2023).[17]

In the model, the supply side has been modelled with the aim that it should generate many properties of the data for wages and prices, and that it should be consistent with wage-setting institutions, and with PWB. Hence, manufacturing is the wage leader, while the rest of the private business sections and government administration are wage followers. The system of pattern wage-bargaining has also been given econometric treatment in Gjelsvik et al. (2020), Dalnoki (2020), Hove et al. (2022) and Boug et al. (2023).

In the same way as in the theory model above, we need to be clear about how the foreign exchange market is treated in the model. The empirical exchange rate equation

[17] https://normetrics.no/nam/

used in the simulation is documented in Appendix A.3. It takes the following form:[18]

$$\begin{aligned}\widehat{\Delta v_t} = & -\underset{(0.62)}{3.44}\Delta(r_t - r_t^f) - \underset{(0.24)}{0.87}(r_{bt-1} - r_{bt-1}^f) - \underset{(0.01)}{0.1}\,\Delta p_{oilt} \\ & - \underset{(0.02)}{0.1}\,\Delta\Delta(pa - paw)_{t-3} - \underset{(0.02)}{0.06} I_{2020(2)}\end{aligned} \quad (24)$$

With little risk of misunderstanding, the variables v_t, r_t, and r_t^f, now refer to the operational definitions used in the estimation. The definition are found in Table 3 (in the appendix section of the paper). However, a brief descritions is: v_t is the log for the effective nominal exchange rate. r_t and r_t^u are money market interest rates, at home and abroad. r_{bt} and r_{bt}^f are ten-years bond yields, domestic and foreign. $p_{\text{oil}t}$ is log of oil price (in USD) and pa and paw are two stock price indices, Akram (2004). pa is the Norwegian stock market index, and paw is the a global stock price index.

As explained in the appendix, (24) was obtained by a automatic variable selection method, referred to as OLS-IIS, where IIS is acronym for Impulse Indicator Saturation.[19] The method estimates unknown break points (that takes the form of intermittent intercept shifts). It is interesting to note that of the 95 possible indicators, Autometrics-IIS retained a single one: $I_{2020(2)}$ which is one in 2020 second quarter, and zero elsewhere.

There is no estimated constant term in (24), so the equation is consistent with a data generating process for v_t which is of the random-walk type, without drift.

Compared to the theoretical exchange rate equation (4), we see that the term $\delta_1\Delta(r_t - r_t^f)$, is "re-found" in the empirical model with a negative coefficient of -3.44. The interpretation is that a one percentage point increase in r_t reduces v_t by 3.44 percent, everything else equal. If the interest rate is kept at the new level in the following periods, the exchange rate remain at the appreciated level, all other things constant (in particular, no change in the Δr_t^u).

In NAM, there are long-term interest rates as well as money market rates. It is of interest, and possibly of relevance for monetary policy, that the difference $(r_{bt-1} - r_{bt-1}^f$ between the *level* of a Norwegian and a foreign bond rate is an explanatory variable in the equation. This variable adds a channel that was not present in the theoretical model

The imported inflation shock has been implemented by increasing inflation abroad by 3 percentage points in the first period of the experiment. The difference between scenario and baseline increases to 7 points in the first quarter of the scenario. Thereafter, the shock abates more or less monotonously, as shown in panel (a) in Figure 5.

In order to mimic what would probably happen in such a scenario, the interest rate level abroad is increased so that it is 4 percentage points higher than in the baseline after four quarter. Thereafter, the difference between scenario and baseline is gradually reduced, cf. panel (b) in Figure 5.

Panel (c)-(i) show the differences between scenario (shock) and baseline for seven of the models dependent variables. Import price growth (c) increase strongly, which in the model is explained by even stronger response in foreign producer prices than in consumer prices. The response in Norwegian inflation (CPI-AET measure) is quite strong, cf. panel (d).

In order to mimic a monetary policy response, the following equation has been in-

[18]Sample period 2001(1)-2024(3), OLS estimates with standard errors in parentheses.

[19]As implemented in *Autometrics* in the econometrics software package PcGive, see Doornik and Hendry (2022a,b)

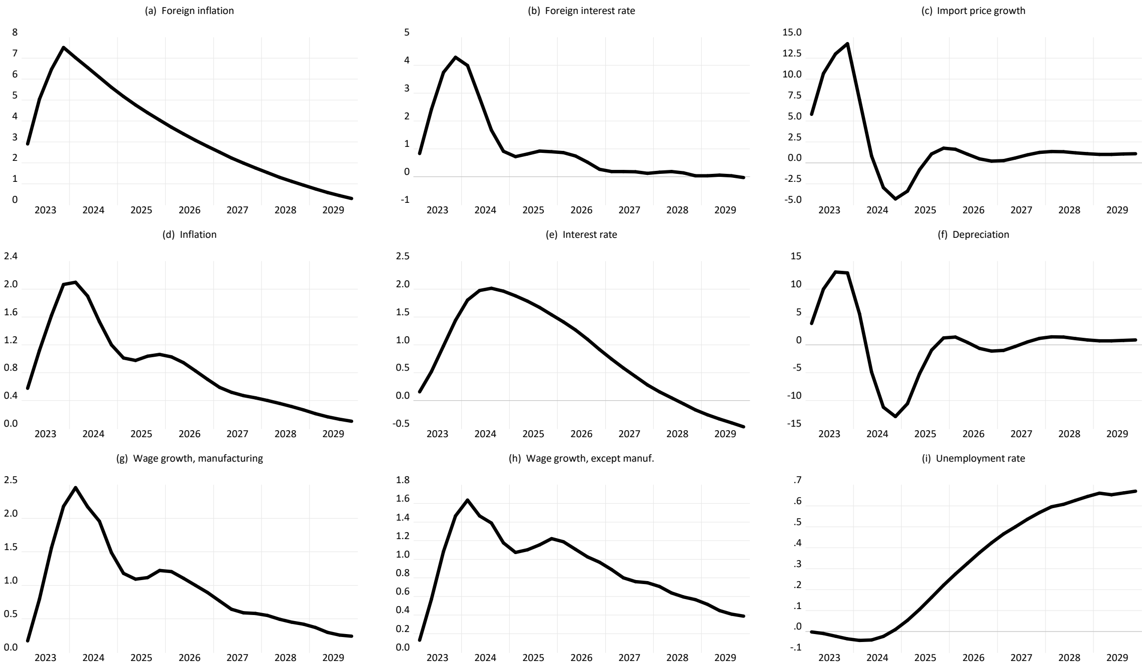

Figure 5: Simulated responses in NAM to a shock to inflation among Norway's trading partners. The units on the vertical axes are percentage points. Quarters on the horizontal axes.

cluded in the model:[20]

$$\begin{aligned}\widehat{\Delta r}_{nb,t} = \underset{(1.15)}{3.23}(\Delta_4 p_{\text{aet},t} - 0.025) - \underset{(0.03)}{0.1}\, U_t \\ + \underset{(0.02)}{0.04} r^u_{t-1} + \underset{(0.03)}{0.5}\, \Delta r^{nb}_{t-1} - \underset{(0.02)}{0.07} r_{nbt-1} \\ + \text{other deterministic terms.}\end{aligned} \tag{25}$$

r$_{nbt}$ is the policy interest rate, $p_{\text{aet},t}$ is log of CPI-AET and U_t is the unemployment rate (cf. Table 3).

The increase in Norwegian money market interest rate in figure (e) is partly due to the domestic policy response, and partly due to the linkage to international interest rate (integrated financial markets).

Panel (f) in the figure shows a large krone depreciation initially, which is due to the difference between Norwegian and international interest rates. For the same reason, i.e., the interest rate difference, depreciation is changed to appreciation after one year. Thereafter, the rate of depreciation follows a cyclical path towards zero.

The weakening of the exchange rate (the level, not shown in the figure) is 13 %, three quarters after the shock hits. Four quarters later it is still 7 %. Thereafter the difference between the baseline and the scenario becomes much smaller.

The graphs in the third row shows wage growth in manufacturing (wage-leader) and in the rest of the private business sector, panel (g and h) and in the unemployment rate (panel i). The wage responses are qualitatively the same as in the theoretical model, reflecting the close correspondence in the specification of PWB.

[20]Same sample and method as for (24).

The last panel shows, with a lag, unemployment increases semi-permanently, which is a qualitative difference from the responses found for the theory model. However, this is not a puzzle, as it is explained by the more complex transmission of interest rate changes in NAM, compared to the stylized relationship in the theoretical formulation above. Concretely, the combination of higher inflation and interest rates in the model leads to reduced private consumption expenditure, lower real housing prices and fewer housing starts.

Returning to one of the main issues in our analysis, one might ask: How important for the responses is that the real exchange rate is excluded (on empirical grounds) from the exchange rate equation (24)? As shown in the appendix, $v_{pt-1} \equiv v_{t-1} + p^u_{t-1} - p_{t-1}$ is insignificant if it is "put back" as a right-hand side variable in (24). When the inflation-shock experiment is done with the lagged PPP-deviation in the equation, the results are therefore as good as unchanged from Figure 5.

In order for the PPP-variable to have any noticeable effect, its coefficient in the exchange rate equation must therefore be forced to be a good deal higher than the estimated coefficient. Experimentation shows that one order of magnitude change (e.g., -0.3 instead of -0.03) was necessary to give any noticeable difference in responses. For example, the largest depreciation was reduced from 15 to 10 percent. However, qualitatively speaking (sign and shape) the responses were the same. Hence, the NAM responses appear to be robust with respect to this part of the specification of the exchange rate equation.

7 Summary and conclusions

In Norway, the belief that pattern bargaining contributes to strong macroeconomic performance remains widely held among policymakers and representatives of labour market institutions. However, some critics have pointed to issues such as rigid relative wages and other stress factors. For instance, since pattern wage bargaining is a voluntarist system, its future depends on broad acceptance among wage earners outside the manufacturing sector. This acceptance could be undermined if the wage norm set by the manufacturing industry is persistently weakened by sluggish productivity growth.

This paper has analyzed another critique, which questions the *rationality* of maintaining pattern wage bargaining in a regime with a floating exchange rate and inflation targeting. Historically, the system in which the competitive industry serves as the wage leader originated in an era of fixed exchange rates, credit controls, and minimal monetary policy influence on short-term economic activity. However, those conditions disappeared decades ago. As a result, the coexistence of inflation targeting and pattern bargaining may render wage-price dynamics *over-determined* and difficult to predict.

One recommendation, put forward by Norges Bank and others, has been to reverse the sequence of bargaining: first determining wage increases in the non-tradable sector to align with the inflation target, then deriving the permissible wage adjustment for the manufacturing sector. However, this recommendation has not influenced real-world wage-setting practices. The system, in which the manufacturing sector remains the wage leader, has coexisted with inflation targeting for a quarter of a century—posing a puzzle if the critique of internal contradictions and over-determination were compelling.

A spin-off of the first critique, which gained attention during the inflation surge of the pandemic era, argues that the current system of national wage-setting may heighten the risk of wage-exchange rate spirals. This perspective suggests that endogenous responses in the foreign exchange market have been overlooked. Like the earlier critique, the wage-exchange rate spiral argument lacks empirical backing. Another shared characteristic is that the theoretical models used in these critiques are static, relying on comparative statics for analysis.

In this paper, I employ a combination of empirical and theoretical models to analyze the coexistence of, and potential conflicts between, two data-generating processes: pattern bargaining in wage and price formation, and the floating exchange rate with inflation targeting in monetary policy.

I examine the time series properties of the Norwegian krone's exchange rate and find that it exhibits the typical characteristics of nominal exchange rates in floating regimes—specifically, a dominant random walk pattern without any significant long-term trend toward depreciation or appreciation. Additionally, Norwegian data supports the *disconnection* of nominal exchange rates. A key example is the lack of evidence for the relative purchasing power parity (PPP) hypothesis, suggesting that the nominal exchange rate remains largely detached from price and inflation differentials between Norway and its trading partners.

An implication of the empirical investigation is that the change from fixed to floating exchange rate regimes may not have been as consequential as first thought by some analysts. For example, inflation forecasts that are conditional on the last observation of the are used in by the organization in the preparation of the annual bargaining rounds. The difference from a fixed exchange rate regime, were the forecast could condition on the official exchange rate, may be more formal than real.

The overall random walk behavior of the nominal exchange rate—without a trend—does not preclude the existence of short-term dependencies. Empirical modeling indicates that changes in the short-term interest rate differential serve as an explanatory variable for movements in the nominal exchange rate. In the theoretical section of this paper, I incorporate this type of exchange rate equation into a dynamic model of pattern wage formation, where interest rates and unemployment are treated as endogenous variables.

In the theoretical dynamic model used in this paper, there is no logical inconsistency (over-determination) between pattern bargaining and inflation targeting. In this framework, the relationships described in static models of pattern wage bargaining appear merely as attractors guiding wage and price adjustments. Moreover, the central bank does not determine inflation, though the inflation gap plays a role in the interest rate function. Thus, the formal over-determination critique can be understood as a byproduct of the assumption that wages and prices strictly adhere to predefined long-run relationships—relationships that are static and do not account for dynamic adjustments.

Since the model is dynamic, the theoretical analysis can be conducted in steps. In the long-run analysis, it is assumed that a steady state exists, allowing us to recover results similar to those of the Scandinavian model of inflation. For instance, inflation aligns with foreign inflation and the difference between productivity growth in the tradable and non-tradable sectors of the economy.

In one version of the model, where the exchange rate is allowed to be influenced by domestic inflation, the steady-state relationships are modified. Specifically, the long-run rate of depreciation is not necessarily zero but tends to be positive in general within the model.

In the dynamic analysis of the model, simulations illustrate that the model can generate solutions that are dynamically stable but can also produce unstable or explosive outcomes. Unsurprisingly, when the exchange rate is directly linked to inflation in the model, explosive solutions become more likely than in the default version, where the nominal exchange rate follows a random walk—without trend—and is modified by short-term interest rate changes.

The second empirical investigation in this paper serves as a counterpart to the comparative dynamics explored in the theoretical model. Specifically, it is a simulation study examining the dynamic responses of an empirical econometric model of the Norwegian economy to an inflation shock in trading partner countries. Qualitatively, the responses align with those of the theoretical model (in the version without a direct two-way link between the exchange rate and inflation). However, the empirical responses also reflect the influence of additional economic relationships beyond pattern bargaining, which delay or limit the pass-through of nominal exchange rate fluctuations to domestic wages and prices.

Further research in this field should be encouraged and met with interest. Given the relevance of dynamic theoretical models that do not assume stability from the outset, developing methods that enhance the generality of results regarding dynamic stability—or instability—would be highly valuable. A combination of mathematical analysis and numerical simulation may be a feasible approach.

Another promising area for research, given the potential for macroeconomic destabilization, is the development of methods for the timely detection of an emerging drift component in the exchange rate's data generating process. Advances in methods for detecting structural breaks provide reason for optimism. However, it remains an open question whether the high volatility of the exchange rate reduces the possibility the empirical identification of breaks. One potential research avenue could be to explore whether incorporating information on the timing of wage settlements improves test power compared to univariate time series tests for breaks in the exchange rate's data generating process.

A Appendix: Data definitions and econometric results

For completeness the variable definitions used in the empirical equations are summarized in Table 3 and Table 4 . For the exchange rate data, time series from the BIS databank was used to test robust with respect to choice of measurement system.

A.1 Test of PPP

In the main text I follow custom and distinguish between to versions of the PPP-hypothesis: *Relative PPP* and *Weak relative PPP* (cointegration). In addition I use the term *Modified weak relative PPP* for the case where the cointegration relationship involves additional variables (to v_t,p_t and p^u_t).

Below are the test-results for the three versions of relative PPP.

a) System test of weak-relative PPP

Consistent with the view that PPP is a system property is to make use of multivariate cointegration analysis, Johansen (1995b). We study the vector $\boldsymbol{y}_t$ that has v_t og $(p^u_t - p_t)$ as elements. We assume that the variables are integrated of order one, $\boldsymbol{y}_t \sim I(1)$

The test is based on the autoregressive model (deterministic terms have been dropped

Table 3: Variabel definitions, NAM databank.

Symbol	Definition	Name in NAM databank[†]
v_t	log of effective exchange rate index (I-44)	CPIVAL
p_t	log of CPI.	CPI
p_{aett}	log of CPIAET	CPIAET
p_t^f	log of CPI in trading partneres.	PCKONK
r_t	3 month interest rate	RSH
r_t^f	Foreign 3 month interest ratee	RSW
$\bar{r}_t$	$r_t - \Delta_4 p_t 100$	
$\bar{r}_t^f$	$r_t^f - \Delta_4 p_t^f 100$	
r_{nbt}	Policy interest rate	RNB
r_{bt}	Norwegian bond rate	RBOTENY
r_{bt}^f	Foreign bond rate	US10Y
p_{oilt}	Log of oil-price, in USD	SPOILUSD
pa_t	Log of domestic stock price index	PW
paw_t	Log of global stock price index	PAW
U_t	Unemployment rate	UAKU

[†] Nymoen and Bårdsen (2024)

Table 4: Variabel definitions, BIS databank.

Symbol	Definition	Name in BIS databank
v_t^n	log of exchange rate index. Narrow basket, 25	M.N.N.NO
v_t^b	log of exchange rate index. Broad basket, 64	M.N.B.NO
q_t^n	log of real exchange rate index. Narrow basket, 25	M.R.N.NO
q_t^b	log of real exchange rate index. Broad basket, 64	M.R.B.NO

Monthly time series were downloaded from BIS Data Portal
and aggregated to quarterly data using monthly averages.

to simplify notation):

$$\Delta \boldsymbol{y}_t = \boldsymbol{\Pi} \boldsymbol{y}_{t-1} + \boldsymbol{A} \Delta \boldsymbol{y}_{t-1-i} + \boldsymbol{\varepsilon}_t, \tag{26}$$

where $\boldsymbol{\Pi}$ and $\boldsymbol{A}$ are matrices with coefficients and $\boldsymbol{\varepsilon}_t$ is a vector with two gaussian white-noise error terms.

For (26) to be a balanced equation there must exist a matrix $\boldsymbol{\beta}$ with contegration parmaters so that:

$$\boldsymbol{e}_t \equiv \boldsymbol{\beta}' \boldsymbol{y}_t \sim I(0) \tag{27}$$

This implies that $\boldsymbol{\Pi}$ has rank equal to 1. Zero rank implies that the two time are are not-cointegrated, and rank equal to 2 is logically inconsistent with the assumption of $\boldsymbol{y}_t \sim I(1)$.

I use a standard test of reduced rank. It is based on the estimation of a VAR model for v_t and the relative price index $(p_t^u - p_t)$. The test is known as the Trace-test, Johansen (1991).

In the cointegration analysis I used a VAR with four lags, and with unrestricted intercepts in the two rows. If we put the issue of residual non-normality to one side for

Table 5: Cointegration test based on a VAR(4) for the two endogenous variables v_t and $(p_t^u - p_t)$. Sample period 2001(1)-2024(2).

H_0: rank $\mathbf{\Pi} \leq$	Trace-test	p-value
0	13.7	0.09
1	0.8	0.38

a moment, and accept $r = 1$ at the 10 percent significance level, we have:

$$\mathbf{\Pi} = \boldsymbol{\alpha}\boldsymbol{\beta}' \tag{28}$$

where $\boldsymbol{\beta}$ is a $2x1$ vector with cointegration parameters and $\boldsymbol{\alpha}$ is the $2x1$ vector with adjustment coefficients. The statistical test is invariant to normalization of one of the parmeters, and if we set the parameter of v_t to 1 we note that Weak-relative PPP implies that the β-parameter of $(p^u - p)_t$ is also $+1$.

However, conditional on $rank = 1$ the corresponding stationary linear combination of the two variables become:

$$\hat{e}_t \equiv \hat{\boldsymbol{\beta}}'\boldsymbol{y}_t = v_t + 4.6(p^u - p)_t \sim I(0), \tag{29}$$

with the notably huge elasticity of 4.6 for the relative price variable. The test of the null hypothesis that the true coefficient is 1 (consistent with PPP) gave a test value of $\chi^2(1) = 10.9[0.001]$, and the null hypothesis of PPP holding is therefore rejected.

The result is robust with respect to measurement system. The elasticity when the narrow BIS-index is used is 2.9 and the test value becomes $\chi^2(1) = 13.9[0.000]$. For the broad BIS-index the estimated elasticity is 4.3 with test value $\chi^2(1) = 6.0[0.015]$.

b) Conditional plus marginal model equation test of weak-relative PPP As simple test of the joint implications of assuming cointegration and that the parameters are $+1$, is formulate a cointegrated VAR and then modelling the statistical information in the system with the aid of a conditional and marginal model equation.

The direction of the conditioning is this case determined by the purpose, which is test the force of the real-exchange rate as an explanatory variable for the nominal exchange. In table 6, the conditional equation therefor has the nominal exchange rate as the dependent variable, while the relative price variable is the regressand in the marginal equation. The coefficients of the lagged real exchange rate are tiny in absolute value in both equations. The estimated coefficients are also statistically insignificant, individually as well as jointly.

Table 7 shows standard mis-specification test for the model equations.[21] Based on the tests, the conditional model equation is a congruent model, as even the residual normality is not rejected with significance levels lower than 5%.

As the reader will have noted, the insignificance of the lagged real exchange rate is consistent with the cointegration test results immediately above. It is also robust, as the result do no change when the BIS-data is used.

c) Relative PPP (relationship between differenced variables)

[21] Because of the valid conditioning, the error-terms are uncorrelated, and we therefore report residual mis-specification test for each equation, not for the reduced form residuals.)

Table 6: Conditional and marginal model equations for v_t and $(p_t^u - p_t)$. Equations are estimated in ECM-form and the lagged levels of the variables restricted by imposing the coefficients that define the real exchange rate, i.e. $q_t = v_t + (p_t^u - p_t)$. Sample period 2001(1)-2024(2).

	Conditional	Marginal
	Δv_t	$(\Delta p_t^f - \Delta p_t)$
$\Delta p_t^f - \Delta p_t$	-0.903*	
$\Delta p_{t-1}^f - \Delta p_{t-1}$	0.473	0.004
$\Delta p_{t-2}^f - \Delta p_{t-2}$	-0.452	-0.068
$\Delta p_{t-3}^f - \Delta p_{t-3}$	0.0358	0.043
Δv_{t-1}	0.119	-0.005
Δv_{t-2}	0.115	0.021
Δv_{t-3}	-0.061	-0.039
q_{t-1}	-0.036	-0.008
Constant	-0.001	-0.001
* Significant at 5 % level.		
Significance tests of q_{t-1}		:
In conditional equation:	$\chi^2(1) = 0.93[0.33]$.	
In marginal equation:	$\chi^2(1) = 0.92[0.34]$.	
Joint test:	$\chi^2(2) = 1.85[0.39]$	

As noted in the main text, early empirism about relative PPP investigated whether Δv_t could be predicted by conditioning on $(\Delta p_t - \Delta p_t^u)$.

The conditional model in table 6 may be said to give some support to this used to shed light on this hypothesis since the estimated coefficient of $(\Delta p_t^u - \Delta p_t)$ is -0.9 and significant at moderately liberal significance levels (the t-value is -2.07 with p-value 0.048). However, care must be taken since there are coefficients with opposite signs in the distributed lag. One way to assess the strength of the relationship is to inspect the static long-run solution the conditional model, Bårdsen (1989). It is:

$$\Delta v = \underset{(1.07)}{-1.03}(\Delta p^u - \Delta p) - \underset{(0.05)}{0.04}q - \underset{(0.005)}{0.001} \tag{30}$$

where the standard error of the coefficients are in parenthesis. Although the coefficient of $(\Delta p^f - \Delta p)$ is -1.03, the standard error is even larger (in magnitude), which renders the coefficient statistically insignificant. Moreover, the sign of the estimated relationship is not robust with respect to the measurement system. The results when we use the BIS data:

$$\Delta v = \underset{(0.84)}{0.16}(\Delta p^f - \Delta p) - \underset{(0.04)}{0.001}q + \underset{(0.005)}{0.002} \quad \text{BIS-broad} \tag{31}$$

$$\Delta v = \underset{(1.03)}{-0.86}(\Delta p^f - \Delta p) - \underset{(0.05)}{0.03}q - \underset{(0.008)}{0.003} \quad \text{BIS-narrow} \tag{32}$$

In summary the results of the formal tests above at unsurprising given the descriptive results the nominal exchange rate hanging only loosely together with other macroeconomic variables.

Table 7: Residual mis-specification tests for the model equations in table 6.

Test	Conditional	Marginal
F_{ar}:	F(5,80)= 1.21 [0.31]	F(5,81) = 1.13[0.35]
F_{arch}:	F(4,86)= 0.62[0.65]	F(4,86) = 2.67 [0.04]*
$\chi^2_n(2)$	$\chi^2(2)$ = 6.05 [0.05]*	$\chi^2(2)$ = 10.05 [0.01]**
F_{hetx^2}	F(16,77) = 1.216 [0.21]	F(14,79) = 2.31 [0.01]**
$F_{\text{het}xz}$	F(44,49)= 1.58 [0.06]	F(35,58) = 1.76 [0.03]*
$F_{\text{f-form}}$	F(2,83)= 0.43 [0.65]	F(2,84) = 2.24 [0.1]

F_{ar}:residual autocorrelation, Godfrey (1978)
F_{arch}:autoregressive conditional heteroscedastictiy, Engle (1982)
$\chi^2_n(2)$:non-normality,Doornik and Hansen (2008)
F_{hetx^2} and F_{hetxz}:heteroscedasticity, White (1980)
$F_{\text{f-form}}$:functional form, Ramsey (1969)

d) Modified weak-relative PPP

The test of weak-relative PPP can be modified and extended to include a variable that potentially can explain why the cointegration test did not support weak relative PPP. One possibility is to include a measure of interest rate difference in the $\boldsymbol{y_t}$ vector used for testing. Below we show results when $(\bar{r}_t - \bar{r}^u_t)$, as defined in Table 3, is included as a fourth variable. Unlike table 5 the null-hypothesis of rank = 0 is rejected, and although

Table 8: Cointegration test of modified-weak-relativ PPP. Sample period 2001(1)-2024(2).

H_0: rank $\mathbf{\Pi} \leq$	Trace-test	p-value
0	53.01	0.00
1	16.36	0.04
2	0.63	0.42

the (asymptotic) p-value can only be regarded as a guidance, it is defendable to consider that there are two cointegrating vectors. However, setting $rank = 2$ leads to decisions about identification. Assumption that we can impose is the PPP-restriction that impose parameter values +1 for v_t and $(p^u_t - p_t)$ in one of the cointegration vectors. However, for exact identification a second restriction is necessary. If we, tentatively we assume that there is a long-run relationship between $\bar{r}_t - \bar{r}^u_t$ and $p^u_t - p_t$ that does not include v_t, the matrix with estimated cointegration coefficients becomes:

$$\widehat{\boldsymbol{\beta}} = \begin{pmatrix} 1 & 0 \\ 1 & \underset{(1.5)}{7.5} \\ \underset{(0.01)}{-0.46} & 1 \end{pmatrix} \tag{33}$$

with standard error in parentheses for unrestricted cointegration coefficients.

Remember that the first row shows the cointegration coefficients for v_t, the second for $p^u_t - p_t$ and the third for $r_t - r^u_t$. The interpretation of the second column is therefore that a cumulated inflation difference between Norway and her trading partners over a period of time will go together with a larger interest rate differential; not unreasonable in a regime with inflation rate targeting.

We are mainly interested in the first column, which implies:

$$\hat{e}_t = v_t + (p^f - p)_t - 0.46(\bar{r} - \bar{r}^f)_t \sim I(0) \tag{34}$$

and that

$$v = -(p^u - p) + 0.46(\bar{r} - \bar{r}^u) \tag{35}$$

can be interpreted as a modified weak-relative PPP relationship. Or does it? First, note that the sizeable coefficient of $(r - r^u)$ has contradicts the standard view that increased interest rate difference goes together with appreciation of the nominal exchange rate. Second, from the matrix with adjustment coefficients:

$$\widehat{\boldsymbol{\alpha}} = \begin{pmatrix} \underset{(0.05)}{-0.004} & \underset{(0.02)}{-0.001} \\ \underset{(0.01)}{-0.04} & \underset{(0.005)}{-0.02} \\ \underset{(1.5)}{-4.3} & \underset{(0.71)}{-2.29} \end{pmatrix} \tag{36}$$

we see that the two adjustments coefficient for Δv_t are small and insignificant. Hence the nominal exchange rate can be interpreted as weakly exogenous with respect to the cointegration relationships: The formal test of the null-hypothesis that the two adjustment coefficients are both zero is $\chi^2(2) = 0.14[0.88]$, so it is clearly acceptable.

On the other hand weak exogeneity of $(p_t^f - p_t)$ is rejected: $\chi^2(2) = 14.65[0.0007]$. The same is true for $(\bar{r}_t - \bar{r}_t^f)$: $\chi^2(2) = 23.9[0.000]$.

The econometric results in this sub-section are qualitatively robust with respect to the measurement system. Using BIS-data, there is no formal evidence for two cointegration vectors. Restricting the PPP part of the relationship in the usual way, the estimated cointegration relationships are:

$$v = -(p^f - p) + 8.4(\bar{r} - \bar{f}^u) \ , \quad \text{Broad basket} \tag{37}$$

$$v = -(p^f - p) + 2.2(\bar{r} - \bar{f}^u) \ , \quad \text{Narrow basket} \tag{38}$$

The size of the interest rate coefficient again have the wrong sign, and they are quite huge. The result about non-rejection of weak exogeneity of v_t holds in the BIS datasets: Narrow basket: $\chi^2(1) = 0.664[0.4152]$. Broad basket: $\chi^2(1) = 1.19[0.28]$.

In summary: We have results that at first glance give support to a modified version of weak-relative PPP, as the real exchange rate appears to be cointegrated with an interest rate difference. However, the sign of the relationship is wrong compared to standard economic thinking about the market for foreign rate (negative relationship, if any). Moreover, the cointegrating relationship has no explanatory power for the nominal exchange rate, which is found to be weakly exogenous.

A.2 Depreciation and short-term interest rates

Putting the long-term relationship like relative PPP to one side, it is still of interest to investigate the empirical relationship between the rate of depreciation and explanatory variables. Again, interest rate differences are the most common variables to whether have predictive power for the short-term changes in the nominal exchange rare.

We can start from an equation between depreciation and the difference between short-term interest rate in Norway and abroad.

$$\Delta v_t = a + \sum_{i=0}^{2} b_i (r_{t-i} - r^f_{t-i}) + \sum_{i=1}^{2} c_i (\bar{r}_{t-i} - \bar{r}^f_{t-i}) + \sum_{i=1}^{2} d_i \Delta v_{t-i} + e I_t + \varepsilon_{v,t} \tag{39}$$

The foreign exchange market is characterized by rapid adjustments to news and shocks so two lags in the interest rate difference probably sufficient dynamics for quarterly data. I_t denotes an (vector) indicator variables (dummies) with coefficients e.

Researchers and macro modellers often take different views about the use of real or nominal interest rates in type type of of regression. In (39 both are included and I use the machine learning method Autometrics to decide which (if any) of the regressors to keep in the final model. The algorithm also decided which indicators to include.

More specifically, the model was estimated with *Autometrics*, with Impulse Indicator Saturation (IIS) and priority of low probability of Type-I error, cf. Doornik (2009), Hendry and Doornik (2014), Doornik and Hendry (2022a, Chapter 6 and 14.8).[22] Johansen and Nielsen (2009) characterized *Autometrics*- IIS as a robust estimation method for regression models. They proposed the name OLS-IIS estimator for the method.

The final model equation was:

$$\begin{aligned}\widehat{\Delta v_t} = & \underset{(0.76}{-4.55}(r_t - r^u_t) + \underset{(1.3}{6.63}(r_t - r^f_{t-1}) - \underset{(0.78}{2.20}(r_t - r^f_{t-2}) + \underset{(1.9)}{10.3} I_{2008(4)} \\ & + \underset{(2.1}{5.7} I_{2023(2)}\end{aligned} \tag{40}$$

Estimation method: OLS-IIS. Sample: 2001(1)-2024(2)

$F_{ar}(5,84) = 1.1\ [0.37]$	$F_{arch}(4,86) = 0.27\ [0.90]$	$\chi^2_n(2) = 2.52\ [0.28]$
$F_{hetx^2}(6,85) = 0.159\ [0.99]$	$F_{hetxz}(9,82) = 0.86\ [0.56]$	$F_{\text{f-form}}(2,87) = 2.61\ [0.08]$

Not that there are only two impulse dummies in the model equation, one for 2008(4), which was the onset of the Financial crisis, and one for 2023(2), which is a quarter in the post pandemic depreciation era.

A well known re-parameterization of this equation is:

$$\begin{aligned}\widehat{\Delta v_t} = & \underset{(0.76}{-4.55}\Delta(r_t - r^f_t) + \underset{(0.78}{2.20}\Delta(r_t - r^f_{t-1}) - \underset{(0.13}{0.10}(r_t - r^f_{t-1}) \\ & + \underset{(1.9)}{10.3} I_{2008(4)} + \underset{(2.1}{5.7} I_{2023(2)}\end{aligned} \tag{41}$$

which makes it clear that the interest rate difference is an insignificant explanatory variable, although the coefficient has the expected negative sign. Also note the opposite signs of the two variables with change in the interest rate variables.

A.3 The exchange rate equation used in the NAM simulation

As mentioned above, equation (24) was estimated by general to specific modeling. The GUM included more variables than were relevant for the GUM used for the UIP-equations (40) and (41) above. On the other hand we could do without the double set of interest

[22] Target level 1.

rates. Since nominal rates seemed to work best in the specifications above, it was they that were kept in the GUM for the empirical explanatory model. The other inclusions entries in the GUM were motivated by the variables that earlier studies have found to be relevant: Changes in oil price $p_{oil,t}$ and in stock market price indices pa_t and paw_t. Because it is standard macroeconomic variable I also included the lagged real exchange rate $v_{pt} = v_t + p_t^u - p_t$ in the GUM.

As (24) showed, rex_{t-1} did not make it to the final model equation, which was not surprising given the poor performance of the real exchange rate in the different PPP-tests. Nevertheless, if it put back in (24), together with a constant term for consistency with the non-zero mean of rex_t, the coefficient is estimated to $-1,8$. For a log scaled nominal exchange rate that implies a coefficient of -0.018 ("t-value" -0.8).

$$\begin{aligned}\widehat{\Delta v_t} = &-\underset{(0.62)}{3.44}\Delta(r_t - r_t^f) - \underset{(0.24)}{0.87}(r_{bt-1} - r_{bt-1}^f) - \underset{(0.01)}{0.1}\,\Delta p_{oilt} \\ &- \underset{(0.02)}{0.1}\,\Delta\Delta(pa - paw)_{t-3} - \underset{(0.02)}{0.06} I_{2020(2)}\end{aligned} \tag{42}$$

Estimation method: OLS-IIS. Sample: 2001(1)-2024(3)
$F_{ar}(5,85) = 0.85[0.52]$ $F_{arch}(4,87) = 1.0[0.42]$ $\chi_n^2(2) = 1.45$ $[0.48]$
$F_{hetx^2}(8,85) = 0.81[0.59]$ $F_{hetxz}(14,79) = 0.73[0.74]$ $F_{\text{f-form}}(2,88) = 2.63[0.08]$

Back-testing this equation by including v_{pt-1} together with a constant term, shows no self-contradictory result. The coefficient of the lagged real-exchange rate becomes estimated with the right sign, but

$$\begin{aligned}\widehat{\Delta v_t} = &-\underset{(0.61)}{3.44}\Delta(r_t - r_t^f) - \underset{(0.27)}{0.89}(r_{bt-1} - r_{bt-1}^f) - \underset{(0.01)}{0.1}\,\Delta p_{oilt} \\ &- \underset{(0.02)}{0.1}\,\Delta\Delta(pa - paw)_{t-3} - \underset{(0.02)}{0.06} I_{2020(2)} \\ &- \underset{(0.02)}{0.03} v_{pt-1} - \underset{(0.002)}{0.0005}\end{aligned} \tag{43}$$

Estimation method: OLS-IIS. Sample: 2001(1)-2024(3)
$F_{ar}(5,83) = 0.94[0.46]$ $F_{arch}(4,87) = 1.07[0.37]$ $\chi_n^2(2) = 2.35$ $[0.31]$
$F_{hetx^2}(10,83) = 0.96[0.56]$ $F_{hetxz}(20,73) = 0.91[0.57]$ $F_{\text{f-form}}(2,86) = 1.78[0.18]$

B Theoretical model of wage-price dynamics with pattern wage bargaining

The appendix documents the theoretical model simulated in section 5.

The model has eleven endogenous variables, elements in the vector $\boldsymbol{y}_t$:

$y_1 \quad = \quad$ Import price in foreign currency pi^f.
$y_2 \quad = \quad$ Productivity in industry 1, z_1.
$y_3 \quad = \quad$ Productivity in industry 2, z_2.
$y_4 \quad = \quad$ Product price, industry 1 in foreign currency, q_1^f.
$y_5 \quad = \quad$ Wage in industry 1 (wage-leader), w_1.
$y_6 \quad = \quad$ Wage in industry 2, (wage-follower) w_2.
$y_7 \quad = \quad$ Product price, industry 1 , q_2.
$y_8 \quad = \quad$ Consumer price index, p.
$y_9 \quad = \quad$ Exchange rate, v.
$y_{10} \quad = \quad$ Unemployment rate, u.
$y_{11} \quad = \quad$ Interest rate, r.
In matrix notation the model is:

$$\boldsymbol{A}_{s\,0}\Delta\boldsymbol{y}_t = \boldsymbol{\Pi_s}\boldsymbol{y}_{t-1} + \sum_{i=0}^{p-1}\boldsymbol{A}_{s\,i+1}\Delta\boldsymbol{y}_{t-1-i} + \boldsymbol{c_s} + \boldsymbol{\varepsilon}_{st}, \tag{44}$$

$\boldsymbol{c_s}$ is a vector with constants and $\boldsymbol{\varepsilon}_{st}$ contains the error terms.

(44) is a simultaneous equations model (indicated by the s-subscripts). We assume that $\boldsymbol{A}_{s0}$ is not singular (the inverse exists). The reduced form of them model:

$$\Delta\boldsymbol{y}_t = \boldsymbol{\Pi}\boldsymbol{y}_{t-1} + \sum_{i=0}^{p-1}\boldsymbol{\Gamma}_i\Delta\boldsymbol{y}_{t-1-i} + \boldsymbol{c} + \boldsymbol{\varepsilon}_t, \tag{45}$$

with matrices:

$$\begin{aligned}
\boldsymbol{\Pi} &= \boldsymbol{A}_{s0}^{-1}\boldsymbol{\Pi}_s, \\
\boldsymbol{\Gamma}_i &= \boldsymbol{A}_{s0}^{-1}\boldsymbol{A}_{si}, \\
\boldsymbol{c} &= \boldsymbol{A}_{s0}^{-1}\boldsymbol{c}_s, \\
\boldsymbol{\varepsilon}_t &= \boldsymbol{A}_{s0}^{-1}\boldsymbol{\varepsilon}_{st}.
\end{aligned}$$

In order to match the typical properties of wages,prices and exchange rates, the time series generated by the model need to be non-stationary, hence $\boldsymbol{y}_t$ is non-stationary, integrated of order 1, $I(1)$. Therefore it is assumed that $\boldsymbol{\Pi}$ has reduced rank, but not zero rank. $\boldsymbol{\Pi}$ can then be factorized as:

$$\boldsymbol{\Pi} = \boldsymbol{\alpha}\boldsymbol{\beta}'$$

More specifically, we assume that $\boldsymbol{\Pi}$ has rank 3, consistent with three long-term relationships:

1. The wage-share in the wage-leading sector is stationary, $I(0)$:

$$y_{5t} - (y_{4t} + y_{9t}) - y_{2t} \sim I(0)$$

2. The relative wage between sector 1 and 2 is stationary, $I(0)$:

$$y_{5t} - w_{6t} \sim I(0)$$

3. The wage-share in wage-following sector 2 is stationary, $I(0)$:

$$w_{6t} - q_{7t} - z_{3t} \sim I(0)$$

(45) is therefore a cointegrated VAR.

In the simulation 2nd order dynamics was used, $p = 2$ in the expressions above. The reduced form expressed with the level variable $\boldsymbol{y}_t$ on the left hand side:

$$\boldsymbol{y}_t = (\boldsymbol{\alpha}\boldsymbol{\beta}' + \boldsymbol{I} + \boldsymbol{\Gamma}_1)\boldsymbol{y}_{t-1} - \boldsymbol{\Gamma}_1\boldsymbol{y}_{t-2} + \boldsymbol{c} + \boldsymbol{\varepsilon}_t. \tag{46}$$

For given matrices in (46) and generating $\boldsymbol{\varepsilon}_t$, $t = 1, 2, ...$ randomly from a multivariate normal distribution, $\boldsymbol{y}_t$, $t = 1, 2, ...$ is generated, conditional on initial conditions $\boldsymbol{y}_0$ og $\boldsymbol{y}_{-1}$.

The interpretation is made easy by specifying the element in the simultaneous form (44), i.e.,$\boldsymbol{\beta}$ and $\boldsymbol{\alpha}_s$. Thefore, $\boldsymbol{\Pi}$ is given by:

$$\boldsymbol{\Pi} = \boldsymbol{A}_{s0}^{-1}\boldsymbol{\alpha}_{\boldsymbol{s}}\boldsymbol{\beta}'. \tag{47}$$

We now give the specifications used in the simulations:

$$\boldsymbol{\beta} = \begin{pmatrix} 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ -1 & 1 & 0 & 0 & 0 \\ 0 & -1 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 & -1 \end{pmatrix} \tag{48}$$

$$\boldsymbol{\alpha}_s = \begin{pmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ -0.10 & 0 & 0 & -0.1 & 0 \\ 0 & -0.20 & 0 & 0 & 0 \\ 0 & 0 & -0.10 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -0.2 & 0.1 \\ 0 & 0 & 0 & -0.1 & -0.30 \end{pmatrix} \tag{49}$$

The $\boldsymbol{\beta}$-matrix is consistent with the long-term relationships 1-3 above. $\boldsymbol{\alpha}_s$ is specified so that y_5 equilibrium corrects with respect to deviations from the first relationship. y_6 adjusts with respect to the second relationship and ther product price in the wage-following sector adjust with respect to the lagged wage-share in the sector (long-run relationship 3).

The matrix with simultaneous coefficients $\boldsymbol{A}_{s0}$ was calibrated as shown below:

$$\boldsymbol{A}_{s0} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -0.25 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -0.2 & 0 & -0.2 & 1 & 0 & 0 & -0.6 & -0.2 & 0 & 0 \\ 0 & 0 & 0 & 0 & -0.7 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.65 & 0 & 0 & -0.65 & 1 & 0 & 0 & 0 & 0 \\ -0.5 & 0 & 0 & 0 & 0 & 0 & -0.5 & 1 & -0.5 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0.25 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & -0.25 & 0 & 0 & 1 \end{pmatrix}. \tag{50}$$

The calibration of the $\boldsymbol{A}_{s1}$-matrix (which becomes multiplied with $\Delta \boldsymbol{y}_{t-1}$):

$$\boldsymbol{A}_{s1} = \begin{pmatrix} 0.6 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.75 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.2 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & \delta_2 & 0.4 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.8 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.25 & 0 & 0 & 0.2 \end{pmatrix} \tag{51}$$

The numbers in rows 4 in the two matrices, give the relationship between price change abroad and price change in industry 1 (both in foreign currency). Row 5 and 6 give the short-run dynamics in the two wage equations. Rows 8 contains the coefficients in the definition of Δp. Rows 9 give the processes for the exchange rate:

Baseline version	$s_t = 0$	and $\delta_2 = 0$ in v_t-equation
Counterfactual version:	$s_t = 1$	and $\delta_2 = 0.15$ in v_t-equation

The $\boldsymbol{c}$-vector has positive elements, except in the three bottom rows. This implies autonomous drift in all level variables, with the exception of the exchange rate (y_{9t}), the rate of unemployment (y_{10}) and the interest rate (y_{11}).

It can aid the interpretation by giving structure of the main equations with relationships between variables (abstracting from error-terms and intercepts).

$$v_t = v_{t-1} + 0.4\Delta v_{t-1} + s_t \delta_2 \Delta p_{t-1}, \tag{52}$$

$$\begin{aligned} \Delta w_{1t} &= 0.6\Delta p_t + 0.2\Delta p_{t-1} + 0.2\Delta(q_1^f + z_1 + v)_t \\ &\quad - 0.1(w_{1t-1} - (q_1^f + z_1 + v)_{t-1} - 0.1u_{t-1} \end{aligned} \tag{53}$$

$$\Delta w_{2t} = 0.7\Delta w_{1t} - 0.2(w_{2t-1} - w_{1t-1}) \tag{54}$$

$$\Delta q_{2t} = 0.65(\Delta w_{2t} - \Delta z_{2t}) + 0.1(w_2 - q_1 - z_2)_{t-1} \tag{55}$$

$$\Delta p_t = 0.5\Delta q_{2t} + 0.5\Delta(pi_t^f + v_t) \tag{56}$$

$$\Delta ur_t = 0.1(r_{t-1} - \Delta p_{t-1}) + 0.8\Delta ur_{t-1} - 0.2ur_{t-1} \tag{57}$$

$$\Delta r_t = 0.25\Delta_2 p_{t-1} - 0.1ur_{t-1} - 0.3r_{t-1} \tag{58}$$

q^{ft}_{1t},z_{1t},pi^{f}_{t} and z_{2t} are generated as random walks with positive drifts. The details are in the appendix.

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