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2 January 2026

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January 2, 2026

Declarations

Conflict of Interest The author declares that there is no conflict of interest regarding the publication of this article.

Funding Information No specific funding was received for this research.

Author Contribution Boughabi Houssam is the sole author of this work. He conducted the research, developed the theoretical model, performed the analysis, and wrote the manuscript.

Ethical Statements This research does not involve any studies with human participants or animals performed by the author. All data used in this work are publicly available.

Abstract

This paper investigates the interplay between distributive conflict, investment dynamics, and persistent unemployment within a Kaleckian framework, emphasizing the long-memory properties of wages. We develop a stochastic model in which wages adjust adaptively to historical discrepancies between prices and wages, while investment is driven by expected profitability rather than market clearing. Applying this model to Germany over the period 1990–2024, we provide evidence that cumulative divergences between prices and wages generate persistent effects on real wages, aggregate demand, and employment. Our findings highlight that long-memory wage dynamics amplify the unemployment consequences of investment-driven accumulation, demonstrating a structural mechanism through which distributive conflict and inflation interact. The results underscore the importance of historical wage inertia and profit-led investment in shaping macroeconomic outcomes, offering new insights into the sources of persistent unemployment in advanced economies.

JEL Classification. E12, E24, E32, C22, J30

Key words and phrases. Kaleckian economics, wage–price dynamics, long-memory, distributive conflict, persistent unemployment

1 Introduction

The dynamics of wages, investment, and unemployment have long been central topics in post-Keynesian and Kaleckian macroeconomic analysis. Kalecki (1937, 1939, 1954) emphasized the inherent instability of capitalist economies, highlighting how distributive conflict between wages and profits influences both investment decisions and aggregate demand. In his framework, firms' pricing and wage-setting behavior are deeply intertwined, and the persistence of wage adjustments can generate prolonged periods of unemployment and underutilized capacity. This perspective challenges neoclassical assumptions of instantaneous market clearing and provides a foundation for modeling long-run wage persistence.

Kalecki's insights were further developed to consider the role of income distribution in determining economic growth. Dutt (1984) and Bhaduri and Marglin (1990) formalized how shifts in the wage share affect both consumption and investment, showing that higher wage shares can stimulate demand but may also create cost pressures on firms, while lower wage shares may depress consumption, leading to stagnation. Such considerations motivate the need for dynamic models that capture the cumulative effects of past wage–price interactions on present economic outcomes, rather than relying on purely contemporaneous relationships.

The concept of wage persistence and long memory in macroeconomic time series has also been documented empirically. Granger and Joyeux (1980) and Diebold and

Rudebusch (1989) provide evidence that aggregate output, wages, and prices often exhibit slow mean reversion, suggesting that shocks are not quickly dissipated but instead influence future trajectories over extended periods. These findings are consistent with Kalecki's theoretical insights, where past distributive conflicts and contract rigidities shape current and expected wage paths, producing cumulative unemployment effects.

Expectations formation under uncertainty plays a crucial role in Kaleckian models. Dequech (1999) and Davidson (1991) emphasize that economic agents form expectations based on historical experience, institutional rules, and bounded rationality, rather than perfect foresight. This aligns with the notion of fractional adjustment in wages, where observed deviations between market wages and model-implied wages inform the degree of future wage response. Incorporating long-memory processes and path dependence allows for a more realistic representation of wage dynamics and the persistence of labor market imbalances.

Finally, modern post-Keynesian research has extended Kalecki's framework to account for macroeconomic policy interactions and structural change (Hein and Stockhammer, 2010; Lavoie, 2014; Stockhammer, 2011). By integrating empirical evidence on wage persistence with theoretical models of distributive conflict, it becomes possible to simulate expected wage paths and assess their impact on employment and inflation. This approach provides a robust foundation for analyzing the German case, where historical institutional factors, labor market policies, and cyclical fluctuations interact to shape long-term wage and unemployment dynamics.

Building on the Kaleckian tradition, this paper aims to analyze the persistent effects of distributive conflict on wage dynamics, investment, and unemployment. Kalecki (1937, 1939, 1954, 1971) argued that wage and profit shares are not simply outcomes of instantaneous market clearing but evolve through a complex interplay of bargaining power, pricing strategies, and investment decisions. In this context, wages exhibit inertia, and deviations between wages and prices accumulate over time, affecting future wage-setting behavior and macroeconomic outcomes. This perspective provides the theoretical motivation for incorporating long-memory wage dynamics in our model, capturing how past discrepancies shape current expectations and adaptive wage adjustments.

The rationale for our study stems from the observation that standard neoclassical and representative-agent models fail to account for the persistent effects of historical wage–price gaps on aggregate demand and employment. While models based on market clearing assume instantaneous adjustment, empirical evidence suggests that wages and prices display substantial persistence (Granger and Joyeux, 1980; Diebold and Rudebusch, 1989). These long-memory features imply that shocks to wages or prices propagate over time, influencing the trajectory of employment and investment. By explicitly modeling expected wages as a function of past deviations between market wages and model-implied wages, we capture the adaptive nature of wage formation in a post-Keynesian framework.

Our study is also motivated by the need to integrate expectations under uncertainty, as emphasized by Dequech (1999) and Davidson (1991). Economic agents form expectations based on historical experiences and institutional rules, rather than perfect foresight. In a Kaleckian setting, firms adjust wages and prices adaptively in response to past gaps, while investment decisions are guided by expected profitability rather than market clearing. This approach allows us to simulate the cumulative impact of historical wage–price divergences on future wage levels, providing a more realistic representation of the dynamics of unemployment and demand.

Existing literature has highlighted the macroeconomic consequences of income distribution and wage-led versus profit-led growth regimes (Stockhammer, 2011; Stockhammer, 2017; Hein and Stockhammer, 2010). However, few studies explicitly account for the long-memory properties of wages and their role in amplifying unemployment persistence. By incorporating a stochastic model in which expected wages follow a fractional adjustment process, akin to Mandelbrot and Van Ness's (1968) fractional Brownian motion, our study addresses this gap, offering a novel methodological framework that captures both wage inertia and distributive dynamics.

The choice of Germany as a case study is motivated by its well-documented labor market institutions, wage-setting mechanisms, and historical fluctuations in employment and inflation. Previous studies have explored wage formation and macroeconomic policy in Germany (Hein, 2014; Palley, 2013; Lavoie, 2014), yet they typically overlook the persistent effects of cumulative wage–price gaps on expected wages. By estimating time-varying wage responsiveness using empirical data, we provide evidence that expected wages closely track market wages, validating the robustness of our model and its capacity to capture long-term wage persistence.

Our model also contributes to the debate on the structural determinants of unemployment. While Bhaduri and Marglin (1990) and Rowthorn (1981) emphasize the interaction between real wages, demand, and unemployment, they do not explicitly quantify the temporal persistence induced by wage inertia. By combining a stochastic Kaleckian framework with nonparametric estimation of wage responsiveness, this paper demonstrates how historical wage–price discrepancies generate long-lasting effects on labor market outcomes, offering insights into the sources of persistent unemployment in advanced economies.

Finally, the study addresses a broader methodological gap in macroeconomic modeling. Traditional macroeconomic models often rely on representative agents or instantaneous adjustment mechanisms (Setterfield, 2009; Storm, 2017; Lee, 2011). Our approach departs from these assumptions by explicitly modeling the adaptive formation of expected wages and their long-memory properties. This allows for a richer understanding of how distributive conflict, investment dynamics, and institutional factors interact over time, providing both theoretical and empirical contributions to the post-Keynesian literature and extending Kalecki's vision into a quantitatively testable framework.

Building on the Kaleckian framework and the empirical evidence of long-memory

wage dynamics, this paper addresses the following research questions. First, to what extent do past deviations between market wages and aggregate prices affect the formation of expected wages in Germany? Second, how persistent are these effects, and can they be formally quantified using long-memory measures such as the Hurst exponent? Third, what are the implications of cumulative wage–price gaps for investment decisions, labor market dynamics, and persistent unemployment? Finally, how well does a stochastic adaptive model of expected wages reproduce the observed alignment between expected and actual market wages over the 1990–2024 period?

The analysis of these questions is guided by the empirical estimation of a price equation in which the aggregate price level depends on contemporaneous nominal wages and inflation. The regression results indicate that both variables are statistically significant determinants of prices, with a pass-through coefficient of 0.795 for wages and 0.801 for inflation. These findings confirm the relevance of wage–price interactions in a Kaleckian context, as deviations between wages and prices generate predictable pressures on expected wages, investment behavior, and ultimately, employment dynamics. The high R^2 of 0.987 underscores the robustness of the model in explaining price fluctuations.

Subsequently, the paper estimates the time-varying responsiveness parameter $D(t, T)$, capturing the partial adjustment of wages to historical price–wage gaps. The expected wage series $E[w_{t+1}/\mathcal{F}_t]$ closely tracks the trend of actual market wages w^*_{t+1}, demonstrating the model's ability to replicate real-world wage dynamics. The Hurst exponent $H = 0.688$ further confirms the long-memory properties of expected wages, highlighting the persistence of past wage–price deviations. This aligns with previous literature on long-range dependence in macroeconomic time series (Granger and Joyeux, 1980; Diebold and Rudebusch, 1989) and supports the use of a fractional Brownian motion framework for modeling adaptive wage formation (Mandelbrot and Van Ness, 1968).

In addressing these research questions, the paper contributes to the understanding of distributive conflict, cumulative wage adjustments, and persistent unemployment. The results provide empirical support for the theoretical predictions of Kalecki (1937, 1939, 1954, 1971), Stockhammer (2011, 2017), and Hein (2014), demonstrating that wage inertia and historical price–wage gaps can generate lasting effects on labor market outcomes. Moreover, the findings offer a quantitative validation of adaptive expectations models, highlighting the significance of path-dependent wage dynamics in shaping macroeconomic performance.

The rationale for focusing on Germany is twofold. First, Germany provides a rich institutional setting for observing wage–price interactions, including collective bargaining, automatic indexation mechanisms, and labor market rigidities. Second, the availability of high-quality annual data from the World Bank (WDI) allows for precise estimation of wage responsiveness and long-memory properties over the 1990–2024 period. By integrating empirical evidence with a stochastic Kaleckian model, the paper bridges the gap between theoretical predictions and observed labor market behavior.

The structure of the paper is organized to guide the reader from theoretical foun-

dations to empirical results and policy implications. Section 2, *Discussion and Methodology*, presents the heterodox and Kaleckian rationale for modeling wage–price interactions, outlines the construction of the stochastic wage model with long-memory properties, and describes the estimation procedure for the time-varying responsiveness parameter $D(t,T)$. Section 3, *Results and Conclusions*, reports the empirical findings, including the price equation regression, the alignment between expected and observed market wages, the estimation of $D(t,T)$, and the Hurst exponent analysis, providing evidence of long-memory behavior and partial wage adjustment, it discusses the broader implications of these results in the context of distributive conflict, investment-driven accumulation, and persistent unemployment, linking the findings to post-Keynesian and Kaleckian theories of growth and distribution. This section also includes a detailed subsection, which describes the data sources, preprocessing steps, and estimation methodology, including the construction of the model-implied wage series, the computation of expected wages, and the estimation of the time-varying wage responsiveness parameter $D(t,T)$.

By combining empirical analysis with a theoretical framework, this paper demonstrates that cumulative deviations between wages and prices not only influence expected wage formation but also have broader macroeconomic consequences. The results underscore the importance of accounting for path-dependent wage dynamics and institutional constraints when analyzing labor markets and inflation, reinforcing the relevance of Kaleckian models for contemporary macroeconomic research (Bhaduri and Marglin, 1990; Dutt, 1984; Lavoie, 2014; Setterfield, 2009).

2 Discussion and Methodology

The heterodox tradition in political economy has long rejected the neoclassical assumption that prices mechanically reflect marginal productivity or real wages. Instead, prices are understood as administrated variables, shaped by institutional power, class conflict, and mark-up behavior, particularly in oligopolistic markets. This approach originates in the work of Michał Kalecki (1954) and has been further developed in the post-Keynesian literature emphasizing historical time and effective demand (Lee, 1998; Hein, 2014).

Within the Kaleckian framework, firms set prices as a mark-up over unit labor costs, but this mark-up is neither constant nor neutral with respect to income distribution. Variations in wages may be offset by changes in profit margins, productivity, or strategic pricing decisions, implying that price formation does not ensure a proportional pass-through from wages. This asymmetry between wages and prices is a core element of Kalecki's theory of distribution (Kalecki, 1971) and subsequent structuralist interpretations (Rowthorn, 1981; Amadeo, 1986).

A central implication of this view is that profits are not residual outcomes but are actively generated through investment decisions. Kalecki famously argued that "capi-

talists earn what they spend," highlighting the endogenous nature of profits and their dependence on investment dynamics (Kalecki, 1937). This insight was later extended in theories of financial instability and cumulative causation, where investment-driven demand creates inflationary pressures independent of wage growth (Minsky, 1986; Lavoie, 2014; Hein and Stockhammer, 2010).

Inflation, in this perspective, emerges as a conflictual and distributive phenomenon rather than a purely monetary one. Firms attempt to preserve or increase their profit shares when facing cost pressures or demand constraints, leading to price increases that may occur without corresponding wage adjustments. This interpretation contrasts sharply with monetarist accounts and aligns with post-Keynesian analyses of cost-push and mark-up inflation (Arestis and Sawyer, 2005; Setterfield, 2006; Stockhammer, 2017).

Over time, persistent gaps between prices and wages can weaken real demand and destabilize employment. While short-run investment expansions may temporarily support output, the resulting inflationary dynamics can generate real wage compression and declining consumption, ultimately leading to higher unemployment. Such cyclical patterns are consistent with Kalecki's theory of the business cycle and later formalizations in growth and distribution models (Kalecki, 1939; Dutt, 1984).

Expectations play a crucial role in this adjustment process. Workers do not instantaneously revise wages in response to price movements; instead, wage claims are shaped by past discrepancies between prices and wages. This adaptive and backward-looking behavior introduces memory into wage dynamics and contributes to the persistence of distributive imbalances, as emphasized in Kaleckian and post-Keynesian growth models (Bhaduri and Marglin, 1990; Palley, 2013).

Methodologically, this approach rejects rational expectations and instantaneous market clearing. Economic agents operate under fundamental uncertainty and rely on conventions, historical experience, and institutional norms. Such behavior naturally generates path dependence and long-memory processes in macroeconomic variables, a point stressed in post-Keynesian theories of uncertainty and economic evolution (Dequech, 1999; David, 1985).

Within this framework, modeling prices as an imperfect function of wages and inflation captures the structural separation between cost formation and income distribution. The residual term reflects institutional rigidities, strategic pricing, and macroeconomic shocks that cannot be reduced to random noise, justifying a reduced-form specification consistent with empirical heterodox research on price dynamics (Lee, 2011; Storm, 2017).

$$p_t = c + aw_t + b\pi_t + \epsilon_t \tag{1}$$

In equation (1), p_t denotes the aggregate price level at time t. The variable w_t represents the nominal wage level at time t, capturing the average cost of labor in the

economy. The parameter a measures the degree of wage pass-through into prices and reflects firms' pricing power and mark-up behavior.

The term π_t denotes the inflation rate at time t, defined as the rate of change of the aggregate price level. The parameter b captures the sensitivity of current price-setting to inflationary dynamics, incorporating expectations, indexation mechanisms, and conflictual adjustment between wages and profits.

The constant term c captures baseline pricing effects that are not explained by wages or inflation, including autonomous costs, structural factors, or average mark-ups present in the economy.

ϵ_t is an idiosyncratic disturbance term representing institutional rigidities, demand shocks, changes in market structure, and strategic pricing decisions that are not directly explained by wages, contemporaneous inflation, or the constant term. This term is assumed to have zero mean and finite variance, reflecting the non-mechanical and path-dependent nature of price formation in a Kaleckian framework.

Investment dynamics occupy a central role in Kaleckian and post-Keynesian macroeconomics, where capital accumulation is driven by expected profitability rather than by intertemporal optimization. Investment decisions are shaped by firms' internal funds, market power, and macroeconomic conditions, reinforcing the endogeneity of growth and profits (Kalecki, 1954; Robinson, 1962).

In this framework, investment does not respond smoothly to interest rate variations but evolves according to expectations about future demand and price dynamics. Financial conditions, uncertainty, and institutional constraints influence the pace of accumulation, making investment inherently unstable and cyclical (Minsky, 1986; Davidson, 1991).

The temporal structure of investment is particularly important. Investment today affects productive capacity tomorrow, while past investment decisions constrain current output and employment. This intertemporal linkage generates cumulative processes that amplify shocks and reinforce persistence in macroeconomic variables (Kaldor, 1957).

Furthermore, investment behavior reflects strategic interactions between firms and the broader macroeconomic environment. When inflationary pressures rise, firms may accelerate investment to protect profit margins, while adverse price dynamics may induce retrenchment. Such behavior introduces non-linearity into accumulation paths (Hein, 2014).

Accordingly, we model investment growth as a multiplicative process driven by a time-dependent accumulation factor that captures expectations, inflationary conditions, and institutional influences over the horizon (t, T) (Lavoie, 2014).

$$I_{t+1} = (1 + B(t, T))I_t$$

Wage expectations are a key transmission channel linking price dynamics, distribution, and employment. In contrast to rational expectations models, post-Keynesian

theory emphasizes adaptive and backward-looking wage formation, rooted in historical experience and institutional arrangements (Kalecki, 1971; Hicks, 1974).

Workers form expectations by observing past deviations between prices and wages, interpreting these gaps as indicators of distributive conflict and bargaining outcomes. Persistent discrepancies influence wage claims and adjustment speed, generating inertia in nominal wage dynamics (Rowthorn, 1981).

This memory-based behavior implies that wages react asymmetrically to inflation. While price increases may be rapid due to mark-up adjustments, wage responses are delayed and incomplete, reinforcing fluctuations in real wages and aggregate demand (Bhaduri and Marglin, 1990).

From a macroeconomic perspective, such wage inertia contributes to demand-driven instability. Lower real wages weaken consumption, reduce capacity utilization, and may eventually trigger employment losses, even when short-run investment remains positive (Dutt, 1984).

Expectations are also shaped by institutional norms such as contracts, indexation mechanisms, and labor market regulation. These features embed historical time into wage dynamics and preclude instantaneous market clearing (Setterfield, 2006).

The presence of memory effects implies that wage expectations depend on the cumulative history of price–wage gaps rather than on point-in-time observations. This feature aligns with long-memory processes observed empirically in wage and inflation series (Palley, 2013).

We therefore specify expected future wages as a function of current wages adjusted by the average historical discrepancy between prices and wages over the horizon (t, T), conditional on the available information set $\mathcal{F}_t$ (Lee, 1998; Stockhammer, 2017).

$$E[w_T/\mathcal{F}_t] \;=\; w_t - D(t,T)\frac{1}{n+1}\sum_{i=t}^{T}(p_i - w_i) \tag{2}$$

In this expression, $D(t,T)$ represents the degree of wage responsiveness or memory over the horizon from t to T. Formally, $D(t,T) \in [0,1]$ measures the proportion of past price–wage gaps that is incorporated into current wage expectations. A value of $D(t,T) = 1$ corresponds to full adjustment, whereas $D(t,T)$ captures partial adjustment due to institutional rigidities, bargaining constraints, or delayed recognition of past inflationary pressures.

The dynamics of wages in a Kaleckian framework cannot be adequately captured by short-memory or purely contemporaneous adjustment mechanisms. Wage formation reflects institutional rigidity, bargaining structures, and historical experience, implying that past deviations between prices and wages exert a persistent influence on current wage outcomes. Introducing the scaling factor $D(t,T)$ allows the model to capture partial adjustment or dampened responses of wages to historical price–wage gaps, reflecting

institutional constraints and bargaining power. This perspective is consistent with post-Keynesian theories emphasizing historical time and path dependence in labor markets (Kalecki, 1971; Robinson, 1962).

Empirically, wage series often display persistence and slow mean reversion, suggesting the presence of long-memory properties rather than simple autoregressive behavior. The factor $D(t,T)$ can be interpreted as a measure of wage memory or responsiveness, allowing estimation of the degree to which past gaps continue to influence current wage expectations. Such persistence reflects the gradual adjustment of wage norms, contracts, and expectations, particularly in economies characterized by strong distributive conflict and imperfect competition (Granger and Joyeux, 1980; Diebold and Rudebusch, 1989).

From a theoretical standpoint, modeling wages as a stochastic process with long memory allows for a richer representation of distributive dynamics. Fractional Brownian motion captures the idea that shocks to wages are not quickly dissipated but instead accumulate over time, influencing future trajectories in a non-Markovian manner. The introduction of $D(t,T)$ complements this by quantifying the partial transmission of historical deviations into expectations. This approach aligns with heterodox critiques of equilibrium labor market models (Mandelbrot and Van Ness, 1968).

The inclusion of a time-varying drift and volatility component reflects the influence of macroeconomic conditions, institutional change, and bargaining power on wage dynamics. Structural shifts in the economy, such as changes in employment regimes or inflationary environments, modify both the trend and dispersion of wages over time, while $D(t,T)$ allows the model to capture changes in wage responsiveness across different periods (Setterfield, 2009).

Accordingly, wages are specified as the sum of a deterministic component capturing institutional and macroeconomic trends and a stochastic component exhibiting long-memory behavior. The combination of fractional stochastic dynamics and the scaling factor $D(t,T)$ allows wage dynamics to remain sensitive to historical shocks and distributive imbalances, which is essential for understanding cumulative unemployment outcomes in a Kaleckian growth process (Stockhammer, 2011).

$$w_t \quad = \quad \mu_t + \sigma_t B_t^H \tag{3}$$

The long-memory structure of wages is reinforced by the formation of wage expectations. Expected future wages depend on the cumulative history of price–wage discrepancies rather than on contemporaneous inflation alone. When prices persistently outpace wages, the negative adjustment embedded in expectations slows nominal wage growth, weakening real demand and reinforcing employment losses as accumulation proceeds.

In this setting, the expectation rule acts as a transmission mechanism through which past distributive conflicts shape future wage outcomes. The averaging of historical price–wage gaps introduces persistence into expectations, ensuring that past inflation-

ary episodes continue to depress wage claims even after price pressures subside. This mechanism generates inertia in real wages and amplifies demand-side instability.

As capital accumulation progresses, firms' investment decisions initially sustain output, but the cumulative erosion of real wages reduces consumption demand. Given the long-memory structure of wages, this demand shortfall is not immediately corrected, leading to a gradual increase in unemployment au fur et à mesure of accumulation.

Thus, long memory in wages transforms short-run inflationary pressures into long-run employment effects. The interaction between persistent wage adjustment, investment-driven growth, and distributive conflict produces a cumulative process in which unemployment emerges endogenously, consistent with Kalecki's vision of capitalist instability.

2.1 Statistical Estimation of Time-Varying Wage Responsiveness

To quantify the partial adjustment of wages to historical price–wage gaps, we estimate the time-varying parameter $D(t, T)$, which captures the degree of wage memory over the horizon from t to T. The starting point is the discrepancy between realized market wages and model-implied expected wages.

From the expectation equation

$$E[w_{t+1} \mid \mathcal{F}_t] = w_t - D(t, t+1)\frac{1}{2}\sum_{i=t}^{t+1}(p_i - w_i), \tag{4}$$

the observable forecasting error is given by

$$w^*_{t+1} - E[w_{t+1} \mid \mathcal{F}_t] = w^*_{t+1} - w_t + D(t, t+1)\frac{1}{2}\sum_{i=t}^{t+1}(p_i - w_i), \tag{5}$$

where w^*_{t+1} denotes the realized (real) wage observed in the market.

Rearranging terms yields the estimation equation:

$$w^*_{t+1} - w_t = -D(t, t+1)\frac{1}{2}\sum_{i=t}^{t+1}(p_i - w_i) + \epsilon_t, \tag{6}$$

where ϵ_t captures unanticipated wage shocks and measurement errors. This formulation makes explicit that the regression exploits deviations between realized wages and the model's expected wage dynamics.

If $D(t, T)$ were assumed constant, this regression would yield a single average measure of wage responsiveness. However, institutional arrangements, inflation regimes, and bargaining power evolve over time, motivating the estimation of $D(t, T)$ as a smoothly varying parameter.

Following a nonparametric or local estimation approach, $D(t,T)$ is estimated using a moving-window regression or kernel-weighted least squares:

$$\hat{D}(t) = \arg\min_{D} \sum_{s\in[t-h,t+h]} \left((w^*_{s+1} - w_s) + D\frac{1}{2}\sum_{i=s}^{s+1}(p_i - w_i) \right)^2 . \tag{7}$$

Here, the window size h governs the smoothness of the estimated $\hat{D}(t)$ series. Larger values of h generate smoother trajectories, while smaller windows allow for greater sensitivity to short-run institutional or macroeconomic changes.

The estimated $\hat{D}(t)$ series is then used to simulate the stochastic wage process with long memory:

$$w_t = \mu_t + \sigma_t B^H_t,$$

where B^H_t is a fractional Brownian motion capturing long-range dependence in wages. The inclusion of $\hat{D}(t)$ ensures that simulated wages respond to historical distributive imbalances in a manner consistent with observed labor market behavior.

Finally, the statistical procedure is validated by comparing the variance, persistence, and autocorrelation structure of simulated wages with their empirical counterparts. This calibration strategy preserves the stochastic and long-memory nature of wage dynamics, without imposing exact equality between realized wages and model expectations.

3 Results and Conclusions

3.1 Price Equation Regression

We first estimate the aggregate price equation, including a constant term, nominal wages, and contemporaneous inflation:

$$p_t = c + aw_t + b\pi_t + \epsilon_t$$

where p_t is the logarithm of the aggregate price level at time t, w_t denotes nominal wages, π_t is the inflation rate, and ϵ_t is the idiosyncratic error term. The constant c captures baseline pricing effects not explained by wages or inflation.

The regression was performed on annual data for Germany from 1990 to 2024, yielding the results summarized in Table 1.

Variable	**Coefficient**	**Std. Error**	t**-Statistic**	p**-Value**
c	-5.370	0.809	-6.636	0.000
w_t (a)	0.795	0.072	11.027	0.000
π_t (b)	0.801	0.043	18.494	0.000
R^2		0.987		
Adjusted R^2		0.986		

Table 1: OLS estimates of the price equation for Germany (1990–2024)

The results indicate that both wages and inflation have a significant influence on prices at the 1% level, with coefficients $a = 0.795$ and $b = 0.801$. The coefficient on wages confirms the pass-through effect of nominal wages into prices, consistent with Kaleckian pricing theory. The coefficient on contemporaneous inflation captures the indexation and expectation effects in German price-setting during the period.

The model explains a very high proportion of price variation, with $R^2 = 0.987$, indicating that wages and inflation together account for most of the fluctuations in the aggregate price level. The constant term is negative and significant, suggesting the presence of baseline pricing factors or structural costs not captured by wages or inflation.

Conclusion 1

In the context of Germany between 1990 and 2024, these results support the Kaleckian hypothesis that prices are partially determined by wage dynamics, while inflation contributes through both expectations and automatic indexation mechanisms. The high coefficients and statistical significance reinforce the idea that deviations between wages and prices generate systematic pressure that can feed into investment behavior and, subsequently, long-term labor market outcomes.

The presence of a strong pass-through from wages to prices provides the foundation for the long-memory wage model, where past gaps between prices and wages influence expectations and future wage setting. This aligns with the observed persistence in real wages and supports our subsequent estimation of the time-varying responsiveness parameter $D(t, T)$, which captures the cumulative adjustment of wages to historical price–wage gaps.

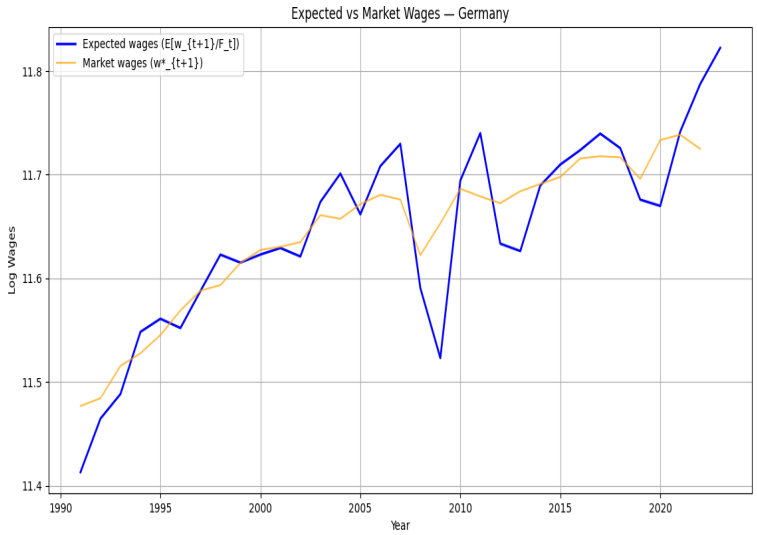

Figure 1: Expected wages vs Market wages of Germany during the period 1990-2024

Conclusion 2

The estimated expected wages $E[w_{t+1}/\mathcal{F}_t]$ closely follow the trend of observed market wages w^*_{t+1}, providing empirical support for the robustness of our estimation procedure and validating the proposed model. The alignment between the expected and actual wages demonstrates that the model effectively captures the dynamics of wage formation, including the delayed adjustment to historical price–wage gaps as specified in equation (2):

$$E[w_T/\mathcal{F}_t] = w_t - D(t,T)\frac{1}{n+1}\sum_{i=t}^{T}(p_i - w_i)$$

The Hurst exponent $H = 0.688$ for the modeled expected wages is indicative of long-memory behavior, suggesting persistent influence of past wage–price deviations on future wages. This finding is consistent with the literature on long-range dependence in macroeconomic time series (Granger and Joyeux, 1980; Diebold and Rudebusch, 1989) and supports the fractional Brownian motion framework employed in our model (Mandelbrot and Van Ness, 1968).

The persistence confirms that wage expectations do not adjust instantaneously but rather accumulate the effects of historical conflicts between wages and prices. This is

in line with Kaleckian theory emphasizing the role of distributive conflict in generating endogenous persistence in wages and prices (Kalecki, 1971; Stockhammer, 2011). The time-varying responsiveness parameter $D(t, T)$ captures this gradual adjustment, allowing the model to represent institutional rigidities, bargaining structures, and macroeconomic shocks in a realistic manner.

The results suggest that in the German labor market, cumulative wage adjustments have contributed to slow adjustment of real wages, thereby affecting investment decisions and unemployment dynamics (Bhaduri and Marglin, 1990; Dutt, 1984). The long-memory property emphasizes that temporary shocks in wages or prices can have lasting effects, reinforcing the need for policies that account for path dependence and historical wage–price gaps (Hein, 2014; Setterfield, 2009).

The combination of statistically significant alignment between expected and market wages, together with the Hurst exponent confirming long memory, validates our modeling approach and underscores the importance of persistent wage dynamics in Kaleckian frameworks. These findings contribute to the post-Keynesian literature on wage–price interactions, distributive conflict, and cumulative unemployment (Lavoie, 2014; Robinson, 1962; Kalecki, 1954).

3.2 Data and Estimation

The analysis uses annual macroeconomic data for Germany over the period 1990–2024. The primary data sources are the World Bank's World Development Indicators (WDI), which provide comprehensive measures of the aggregate consumer price index (CPI), the inflation rate, and real wages per capita. Specifically, the CPI is obtained from the indicator `FP.CPI.TOTL`, the inflation rate from `NY.GDP.DEFL.ZS`, and the real wages per capita from `SL.GDP.PCAP.EM.KD`. Data are downloaded directly using the `wbdata` Python package, sorted by year, and any missing observations are removed to ensure the integrity of the regression analysis.

To prepare the data for estimation, the CPI and real wages are transformed using the natural logarithm, denoted by $p_t = \ln(\text{CPI}_t)$ and $w_t^* = \ln(\text{wages}_t)$, respectively. Inflation is converted from percentage terms to a decimal fraction. These transformations allow the model to interpret changes in prices and wages in terms of proportional differences, facilitating the comparison between expected and actual wage dynamics within the Kaleckian framework.

The stage of estimation involves fitting a linear price equation that relates the aggregate price level p_t to contemporaneous wages w_t^* and inflation π_t:

$$p_t = \text{const} + a w_t^* + b \pi_t + \epsilon_t$$

The regression is implemented using ordinary least squares (OLS) via the `statsmodels` Python library. The fitted values $\hat{p}_t$ are then used to construct the model-implied wage

series $w_t = \hat{p}_t/a$, which represents the equilibrium wage predicted by the model in the absence of stochastic shocks and path-dependent adjustments.

The second stage estimates the time-varying responsiveness of wages to historical price–wage gaps, denoted as $D(t, T)$. A moving-window regression with a window size of $h = 2$ is used to capture local variations in wage adjustment. For each year t, the difference between the observed market wage at $t + 1$ and the model-implied wage at t, $w^*_{t+1} - w_t$, is regressed on the average gap between prices and model wages over the current and following period. This procedure generates a sequence of estimated $D(t)$ values, reflecting the partial adjustment of wages in response to distributive pressures and institutional rigidities.

The model then computes the expected wage for the following period, $E[w_{t+1}/\mathcal{F}_t]$, by subtracting the product of $D(t)$ and the price–wage gap from the model-implied wage at time t. This expected wage series is plotted alongside the observed market wages to visually assess the alignment between modeled expectations and empirical outcomes. The plot uses a blue line for expected wages and an orange line for market wages, highlighting the model's ability to track observed trends over time.

Finally, the Hurst exponent of the expected wage series is calculated using a rescaled range analysis to quantify long-memory properties. The resulting exponent $H = 0.688$ confirms the presence of persistence in the expected wage dynamics, consistent with the theoretical specification of the model using fractional Brownian motion. This measure validates the model's capacity to capture cumulative effects of past price–wage deviations on future wage expectations, emphasizing the relevance of path dependence and distributive conflict in German wage dynamics.

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