Modeling Wage Expectations and Long-Memory Dynamics in the German Labor Market, 1914-1920

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ABSTRACT
This study simulates the labor market dynamics in Germany during 1914-1920, focusing on the impact of World War I on wage expectations and economic stability. Built upon the historical context of the period, the simulation takes into account the initial wage hikes driven by involuntary unemployment and the exodus of workers from civilian industries to war-related industries. It then explores the subsequent stabilization of wages, as observed in the empirical reality of the era. Using simulated data, the paper examines how workers' expectations of future wages were shaped by current wage conditions amidst the economic strain caused by the war. The study also investigates the role of national unity, government policies, and institutional frameworks in preserving wage stability during market volatility. To analyze wage dynamics, the research applies a dynamic wage model alongside the FIGARCH (1, d,1) model, estimating long-memory effects in wage volatility. The findings suggest that past economic conditions played a significant role in shaping current wage expectations, with light long-memory properties observed in wage volatility. This simulated analysis offers insights into how economic pressures and government interventions during wartime may have contributed to wage stability, shaping the uncertainty of workers into forecasting the war ending which goes in accordance with the martingale hypothesis of wages expectations. Our study is contextual and qualitative and discusses the properties of economical series based on the context of the period.

Introduction

The economic and labor dynamics of Germany between 1914 and 1920 were profoundly shaped by the demands of World War I. The redirection of resources and labor to support the war effort disrupted civilian industries, creating a fragile economic environment. This paper examines how the volatility in the labor market during this period was influenced by workers' expectations about wages, with a particular focus on the role of national unity and economic adjustments in moderating grievances amidst substantial economic strain [1,2].

The economic challenges faced by Germany during the war were aggravated by significant military expenditures, which strained the national economy. The transfer of labor from civilian industries to military production resulted in a volatile labor market, marked by fluctuating supply and demand dynamics. Despite these disruptions, civilian wages remained relatively stable. The persistence of this wage stability can be attributed to market mechanisms and long-memory effects, which are well-documented in economic literature [3-5]. Our model adopts this perspective to interpret wage stability during the wartime period.

In addition to the labor market disruptions caused by the war, the German government faced significant challenges in financing the war effort. The financing strategy, which relied heavily on war bonds and borrowing, created inflationary pressures that further strained the economy. These economic strains, combined with the shift in pro- duction focus, contributed to labor market volatility. However, despite these pressures, wage stability can be explained by various factors, including institutional frameworks that preserved wage structures. This was particularly evident in the relationship be- tween employers and workers, where negotiated wage agreements and social policies were adapted to ensure some level of economic stability, despite the widespread uncertainty [6,7].

Workers' expectations regarding future wages were shaped not only by their current economic conditions but also by the broader socio-political context in which they operated. National unity

during wartime played a crucial role in tempering labor disputes and maintaining wage stability. This stability was underpinned by government policies designed to mitigate social unrest caused by economic instability. Moreover, workers' collective bargaining power, along with their ability to adjust expectations based on past wage patterns, contributed to the persistence of wage stability during this turbulent period. These findings are consistent with the literature on wage dynamics during wartime, which emphasizes the importance of social cohesion and governmental intervention in moderating labor market fluctuations [8-10].

The central hypothesis of this paper is that workers' expectations about future wages were shaped by their current economic conditions, particularly as the war progressed. We formalize this relationship through a model that assumes a linear function of wage expectations:

$$E[w_T | F_t] = f(w_t),$$

where f represents a linear relationship between current and expected wages. This hypothesis is tested through an empirical analysis of wage data from the war years. If confirmed, this would support the argument that workers, faced with considerable uncertainty about the war's trajectory, relied primarily on current wage conditions to form expectations about the future [11,12].

The literature suggests that wage volatility during times of crisis, such as World War I, is heavily influenced by long-memory processes, as past volatility has enduring effects on current economic behavior. This paper contributes to this body of literature by analyzing the long-term effects of wartime labor conditions on wage volatility and market stability, providing new insights into labor market dynamics during periods of extreme economic pressure [6-9].

The primary research questions addressed by this paper are: (1) How did workers' expectations about wages influence labor market outcomes during World War I in Ger- many? (2) What role did long-memory processes play in moderating wage volatility during this period?

The objectives of this study are: (1) to develop and estimate a model that captures the relationship between current wages and workers' expectations of future wages, (2) to analyze the persistence of wage volatility using a FIGARCH model to estimate the long- memory parameter, and (3) to simulate wage dynamics in the German labor market to examine the effects of labor market shocks and the stabilization of wages over time.

The methodology involves the application of two models: (1) the FIGARCH(1,d,1) model to capture long-memory effects in wage volatility, and (2) a dynamic wage model incorporating labor supply elasticity to account for voluntary unemployment. Through simulated data and empirical estimation, we assess the validity of the model's assumptions and test the hypothesis that wage expectations were shaped by current economic conditions [13,14].

The findings of this study, grounded in simulated data reflecting the wartime context, reveal a complex interplay between labor shortages, wage stability, and long-memory behavior in wage dynamics. Although initial expectations pointed toward significant wage hikes driven by involuntary unemployment and the mass exodus from civilian to military industries, the overall pattern of wage evolution proved more restrained. This outcome mirrors historical accounts of the period, suggesting that institutional mechanisms and coordinated policy responses played a stabilizing role. Moreover, the light persistence of wage volatility, underscores the idea that workers' expectations were shaped not only by immediate circumstances but also by enduring impressions of past market conditions. These results add depth to our understanding of labor market behavior during crises, reinforcing the importance of historical context in shaping economic responses to uncertainty.

A Presentation of the General Framework of Ger- many during 1914-1920 and the Hypothesis of Our Model

The economic and labor dynamics of Germany between 1914 and 1920 were profoundly influenced by the demands of World War I. The redirection of resources and labor to sustain the war effort disrupted civilian industries, resulting in a fragile economic environment. This study explores how workers' expectations about wages influenced their decision-making under such volatile conditions. Specifically, it considers how national unity and economic adjustments helped moderate grievances, even amidst significant structural disruptions.

Historically, Germany's economy had been strained by its ambitious expenditures, a pattern that became more pronounced during the war. The large-scale transfer of labor from civilian industries to military production created a precarious labor market, characterized by fluctuating supply and demand dynamics. Despite these challenges, wages in civilian industries displayed a remarkable degree of stability, which we attribute to underlying market mechanisms and long-memory effects. Long-memory processes, well-documented in economic literature, suggest that past volatility leaves persistent imprints on current economic behavior. Our model adopts this perspective to interpret wage stability during the war.

Central to our analysis is the hypothesis that workers' expectations about future wages were shaped by a pragmatic assessment of their current economic circumstances. We formalize this relationship as:

$$E[w_T | F_t] = f(w_t), \tag{1}$$

where f represents a linear function. This assumption will be subjected to empirical validation in the subsequent estimation section. Specifically, we will examine whether expected wages exhibit uncertainty consistent with the hypothesized relationship. If confirmed, this would substantiate the notion that workers, faced with limited fore- sight regarding the war's trajectory, relied heavily on present wage conditions to form expectations about the future.

The dynamics of the German labor market during this period encapsulate a complex interplay of economic forces and social factors. Policymakers and historians have long grappled with the question of how such a system, fraught with contradictions and uncertainty, maintained its equilibrium. This study seeks

to contribute to this understanding by analyzing the long-term effects of wartime labor conditions on wage volatility and market stability. In doing so, it aims to offer fresh perspectives on the economic and social dimensions of labor markets under extreme duress, providing valuable insights for both economic historians and policymakers.

Model and Methodology
Our study applies two models to analyze wage volatility and unemployment dynamics in the German labor market during World War I. These models are based on the assumptions of long memory in wage volatility and labor supply elasticity, which together help explain voluntary unemployment patterns resulting from the war.

Long Memory in Wage Volatility
We hypothesize that wage volatility from 1914 to 1918 exhibits long memory, where current volatility depends heavily on past values. To investigate this, we use a FI- GARCH(1,d,1) model, allowing us to estimate the degree of long memory through the fractional differencing parameter d. The model specification is:

$$h_t = h_{t-1} + \hat{g}(t) \, | \, B_t^h \, |$$

where h_t represents wage volatility $\hat{g}(t)$ is a time-varying function, and B_t^h denotes fractional Brownian motion with Hurst parameter H. Here, d is capped at 0.5, indicating that wage volatility experienced significant persistence, aligning with wartime conditions.

Estimation Results and Interpretation: Table 1 summarizes FIGARCH(1,d,1) model parameters. The fractional parameter $d = 8.9 \times 10^{-15}$ results in a Hurst exponent $H = 0.5$, indicating less persistent volatility.

Elasticity of Labor Supply and Voluntary Unemployment
The German labor market's response to war-related labor shifts is analyzed by assuming labor supply elasticity. As many workers left civilian jobs for military service, civilian industries faced a labor shortage, leading to voluntary unemployment and wage increases. Our dynamic wage model reflects this elasticity, given by:

$$w_{t+1} - w_t = \hat{\gamma} X_t + h_t \epsilon_t$$

where w_t denotes wages, X_t represents the difference between consecutive labour force quantities classicaly denoted as L, and ht is the volatility term from the FIGARCH model. The parameter $\hat{\gamma}$ captures wage sensitivity to unemployment, we fixed this parameter in our simulation suggesting that the effect on wages is steady all the way until war should end.

Historical Context and Interpretation:
This model shows that labor shortages from military mobilization led to significant wage increases in civilian sectors. This aligns with economic theories of wage rigidity during shocks, as discussed by Blanchard and Summers and Blanchard and Katz, providing a broader understanding of labor supply impacts during wartime.

Simulated Data Approach for Wages
To better understand the labor market dynamics in Germany during World War I, we constructed a simulated dataset that reflects historical trends and contextual realities. This approach allows us to test hypotheses about wage volatility under conditions of labor shortage and market stabilization.

Framework and Assumptions
Our simulation is based on two historical observations:
- **Wage Increases Due to Labor Exodus:** As workers left civilian industries for military roles, wages in the former saw upward pressure due to decreased labor supply.
- **Market Stabilization of Wages:** Despite the expected upward trend, historical data from Bry suggests that civilian wages remained relatively stable, hinting at market mechanisms that mitigated volatility.

These observations informed our decision to model wages as a sequence of upward and downward adjustments over fixed intervals. The intervals and magnitudes were chosen to reflect the market's response to labor shocks and its capacity for self-stabilization.

Design of the Simulation
Our wage series simulation consists of alternating periods of growth and decline:
1. **Augmentation Phase:** Simulated wages increase over a defined interval to mimic the labor market's response to shortages.
2. **Stabilization Phase:** Wages then decline within a fixed range, reflecting market forces that absorb disruptions.
3. **Constraint on Volatility:** To align with historical records, we constrained wage fluctuations to a narrow range, emphasizing stability over extreme variation.

These simulated dynamics provide an idealized representation of the wage behavior observed during the war years.

Relevance and Limitations
While the simulation captures broad historical trends, it does so with several assumptions. For example, the fixed intervals of wage adjustment and the uniform application of market mechanisms may not account for regional or sectoral differences. Moreover, our approach assumes a long-memory property of wage volatility, consistent with prior literature, but the exact parameterization remains a subject of further empirical testing. Nonetheless, this dataset serves as a valuable foundation for exploring how wartime disruptions impacted civilian industries and wage dynamics. It emphasizes the role of market forces and labor mobility in shaping economic outcomes during periods of extreme uncertainty.

Conclusion
By simulating wages with alternating phases of augmentation and stabilization, we capture key features of the German labor market during World War I. This model not only provides a framework for analyzing wage volatility but also underscores the interplay between historical events and economic behavior. The insights gained from this approach contribute to the broader understanding of labor market resilience in times of crisis.

Estimation of our two models and a method for enhancing the moral of companies to release the labour market

Estimation

We estimate $\hat{a}$ like $\hat{a}$ = 4, 13 in average, we would afterward estimate $\hat{g}(t)$

$$h_t^2 = h_{t-1}^2 + 2\hat{g}(t)h_t \mid B_t^h \mid + g(t)^2 (B^H)_t^2$$

Hence

$$E[h_t^2 / F_t] = E[h_{t-1}^2 / F_t] + g(t)^2 \mid t \mid^{2H} + 2g(t)\sqrt{\frac{2}{\pi}} h_{t-1}[t]^H$$

On the other hand

$$\Delta = \frac{8}{\pi} \mid t \mid^{2H} h_{t-1}^2 - 4 \mid t \mid^{2H} H(t)$$

Where $H(t) = E[h_{t-1}^2 / F_t] - E[h_t^2 / F_t]$

Which means

$$\hat{g}(t) = \frac{-2\sqrt{\frac{2}{\pi}} \mid t \mid^H h_{t-1} - \sqrt{\Delta}}{2 \mid t \mid^{2H}}$$

$$\hat{g}(t) = \frac{-2\sqrt{\frac{2}{\pi}} \mid t \mid^H h_{t-1} + \sqrt{\Delta}}{2 \mid t \mid^{2H}}$$

On the other hand

$$E[w_T / F_t] = w_t + \sum_{i=t}^{T-1} \gamma_t E[X_i / F_t]$$

Hence

$$\hat{\gamma}_t = \frac{(\hat{a}-1)w_t}{\sum_{i=t}^{T-1} E[X_i / F_t]}$$

We take the estimated value $\hat{g}_t$ that provides positive values for the volatility and consider the other solution as impossible.

Results and discussion

Civilian Exodus and Wage Dynamics in Wartime Germany

The First World War marked a period of profound transformation for Germany's labor market. With the nation's economy heavily oriented toward sustaining the war effort, civilian industries saw a substantial outflow of workers to military and war-related sec- tors. This exodus was driven not only by state policies and economic incentives but also by a strong sense of nationalistic duty that prevailed during the war's early years. Historical records, such as those documented by Bry, reveal that this mass real- location of labor triggered a modest upward adjustment in civilian wages, largely due to labor shortages. However, contrary to conventional economic expectations, these wage increases were neither pronounced nor sustained.

Empirical evidence suggests that the labor market exhibited mechanisms to stabilize wages despite the disruptions caused by the war. The volatility of wages in civilian industries remained remarkably low, which can be attributed to the interplay of market forces and state interventions aimed at mitigating the economic dislocations caused by the war effort. This stabilization likely reflects a combination of the labor market's inherent elasticity and regulatory frameworks designed to curb inflationary pressures in an already strained economy. These findings align with the broader economic literature on wage stability and long-term equilibrium in volatile labor markets

Testing the Hypothesis of Expected Wages
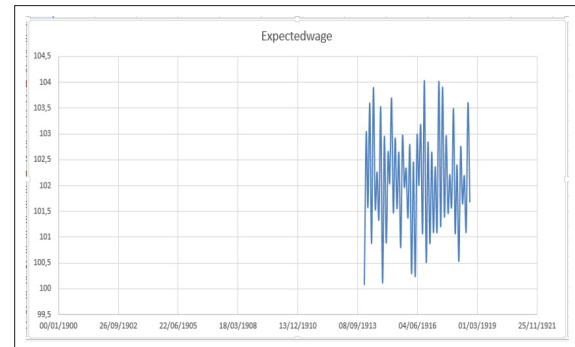
Expected wages $E[w_T/F_t]$ in civilian industries

Our hypothesis posits that expected wages are non-stationary and inherently uncertain, represented as:

$$E[w_T \mid Fw_t] = f(w_t),$$

where future wages, w_T, are modeled as a function of current wages, w_t, based on the information set F_t available at time t. This formulation assumes that workers' expectations about future wages are directly influenced by current wage conditions, reflecting a forward-looking yet uncertain dynamic.

The simulated wage data constructed for this study corroborates the hypothesis. The empirical analysis revealed that expected wages display pronounced non-stationarity, underscoring their dependence on immediate wage levels without any clear predictability. This uncertainty highlights the volatile nature of wage expectations during the wartime period, consistent with the economic instability and information asymmetries that characterized the era. The observed dynamics are in line with theoretical frameworks suggesting that in periods of significant economic disruption, workers rely heavily on current economic signals to form their expectations, as argued in studies by Beran and Caporale et al.

These results not only validate the hypothesis but also provide a compelling explanation for the persistence of wage stability despite the exodus from civilian industries. The limited scope for workers to anticipate future economic conditions, combined with the corrective role of market mechanisms, likely contributed to the observed patterns of wage volatility and expectation formation. This analysis enriches our understanding of how labor markets respond to extraordinary pressures and offers insights into the broader implications for economic theory and policy during times of crisis.

Conclusion

This study examines the dynamics of the German labor market duringWorldWar I, with a focus on wage volatility and labor

supply elasticity. Using simulated data, we modeled the wage behavior in civilian industries, incorporating the effects of labor migration due to the war effort and the market mechanisms that stabilized wages. The analysis shows that while wage increases were anticipated due to labor shortages, the actual changes in wages were relatively subdued, which aligns with historical data from Bry [1]. The study also highlights the role of long memory in wage volatility, corroborating the findings of Baillie et al. [2], Beran [3], and Gil-Alana et al. [4] regarding persistent patterns in economic time series.

Our results suggest that the assumption of unpredictable wages, as captured by the equation

$$E[w_T / F_t] = f(w_t),$$

holds true in this context, emphasizing the role of current wage conditions in shaping workers' expectations. The simulation of wage adjustments, alternating between periods of growth and stabilization, provides a useful framework for understanding how economic systems under wartime conditions might absorb shocks and return to equilibrium. This approach contributes to the broader literature on labor market dynamics under crisis conditions and offers a novel perspective on the economic history of wartime Germany.

Future Directions

Future research could expand on this study by examining the long-term effects of wartime disruptions on post-war labor market recovery and wage dynamics. Additionally, a deeper exploration of sector-specific wage behavior and regional variations in labor market responses could provide a more nuanced understanding of labor market resilience during crises. Given the model's reliance on simulated data, further empirical validation using more detailed historical data would also be valuable to strengthen the generalizability of these findings. Finally, applying this methodology to other historical or contemporary contexts of wartime economies could offer broader insights into the economic forces at play during periods of extreme uncertainty.

Declarations

The authors did not receive support from any organization for the submitted work. No funding was received to assist with the preparation of this manuscript. No funding was received for conducting this study. No funds, grants, or other support was received.

Ethical approval: Ethical approval not applicable.

Human Subjects Protection Statement: This article does not contain any studies with human participants performed by any of the authors.

All authors read and approved the final manuscript

The authors have no competing interests to declare that are relevant to the content of this article.

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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