

# The Role of Wage Expectations in the Labor Market

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## Abstract

The standard search and matching model does not reproduce some key aspects of the US labor market, in particular, the high volatility in vacancies and unemployment and the null contemporaneous correlation between the vacancy-unemployment ratio and labor productivity from 1990-2020. This paper develops a search and matching model applied to the business cycle with internal rational agents. Agents hold subjective wage expectations, a small deviation from rational expectations, and they are rational. The inclusion of learning significantly improves the model's fit with US data compared to its rational expectations counterpart. During expansionary periods, agents underestimate future wages amplifying the effect of productivity shocks on the labor market. The model is consistent with wage forecasts made by professional forecasters. In the light of this model, policymakers relying on rational expectation models may underestimate the costs of unemployment insurance policies on job creation.

**Keywords:** Belief Shock, Internal Rationality, Wage Expectations, Labor Market, Subjective Expectations.

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# 1 Introduction

The Search and Matching Model (DMP) has become the standard equilibrium unemployment theory. However, several studies question the model’s ability to accurately represent labor market fluctuations in the United States.<sup>1</sup> In particular, the standard DMP struggles to replicate observed fluctuations in the labor market and the propagation of productivity shocks. Targeting the ratio of standard deviations between labor market variables and productivity has been the focus of much research. However, the near zero correlation between productivity and labor market tightness post-1990 has been largely neglected in the literature. In this paper, I show that a DMP model is able to reproduce these observations if one allows for small deviations from rational expectations (RE).

I study how to introduce internal rationality (IR) in a DMP model.<sup>2</sup> I relax the standard assumption that agents have perfect knowledge about the wage function obtained from the standard Nash bargaining process. Agents have limited foresight and can not perfectly predict the outcome of wage bargaining instead, workers and firms have subjective beliefs about wages, and they maximize their objective functions subject to their constraints. I call such agents “internal rational” because they know all internal aspects of their problem and maximize their respective objective functions given their knowledge about the wage process. I consider systems of beliefs implying only a small deviation from rational expectations (RE), and that match some aspects of survey wage expectations. The model has a self-referential mechanism: shifts in beliefs about future returns to labor affect current wages, and agents use realized wages to update their beliefs. This generates an additional source of dynamics that helps to match the data. Framing the model under IR provides a microfoundation to previous adaptive learning papers on unemployment.<sup>3</sup>

Moreover, I present a formal econometric test of the null hypothesis that survey evidence is consistent with RE, and demonstrate that the hypothesis of rational wage expectations is rejected by the survey data. The datasets used for this analysis are sourced from the European Commission’s professional forecasters and the New York Federal Reserve’s panel data on workers’ expectations. A notable aspect of this test is its capacity to offer insights into the reasons behind the failure of the RE hypothesis: the failure arises because survey expectations and rational expectations covary differently with the labor productivity. This finding is used to discipline expectations in the model.

To quantitatively evaluate the learning and the RE models, I consider how well they match labor market moments. I use formal structural estimation based on simulated moments (MSM), adapting the results of [Duffie and Singleton \(1990\)](#) to estimate some parameters. Subsequently, I conduct a formal test to determine whether the model statistics significantly deviate from their empirical counterparts.

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<sup>1</sup>See [Shimer \(2005\)](#), [Hall \(2005\)](#), [Fujita and Ramey \(2003\)](#), [Costain and Reiter \(2008\)](#).

<sup>2</sup>See [Adam and Marcet \(2011\)](#).

<sup>3</sup>See [Schaefer and Singleton \(2018\)](#) and [Di Pace et al. \(2021\)](#).

The learning model offers a more accurate representation of U.S. data compared to the rational expectations model. A key finding is the model's capacity to yield a low contemporaneous correlation between labor market tightness and productivity, coupled with elevated relative volatilities in the labor market. For instance, it produces relative volatilities of unemployment and the vacancy-unemployment ratio that are 7.7 and 10.85 times higher than those generated under rational expectations, respectively. This achievement does not necessitate rigid wages. Most models under RE require wages to exhibit minimal responsiveness to productivity variations to achieve such volatility. This results in a wage volatility that is less than that of productivity, a scenario inconsistent with empirical data. In my approach, wages are influenced by both productivity fluctuations and agents' expectations, enabling the model to exhibit a wage volatility that slightly surpasses that of productivity. Additionally, the model generates the positive correlation between wage forecast error and productivity found in surveys, a relationship that is non-existent under rational expectations.

The reduction in the correlation between labor market tightness and labor productivity stems from the additional source of variability introduced by learning, which affects job creation conditions. In a RE framework, labor market tightness solely depends on current productivity, yielding a correlation nearly equal to one. However, with IR, labor market tightness is influenced not only by productivity but also by the time-varying coefficients determining wage expectations, thereby reducing the aforementioned correlation.

Furthermore, learning introduces an endogenous amplification of productivity shocks in the labor market due to the slower adaptation of wage expectations, a result of the constant gain learning algorithm. Hiring decisions are contingent upon firms' projections of future profits per hire, requiring an estimation of the future marginal product and wages over an indefinite horizon. For instance, after a positive productivity shock, the IR firms expect lower future wages compared to the RE firms. Under RE, firms know perfectly how wages correlate with productivity, whereas in the IR model, they do not know exactly how changes in productivity translate into changes in wages instead, they learn about this relationship. The productivity shock generates a negative impact on the forecast error, updating the expectation downwards. In subsequent periods, agents revise their beliefs in response to changes in market opportunities. This causes wage expectations to be lower compared to RE for a while. It will take some periods to adjust its expectations upward, and in the meanwhile, firms will post more jobs.

The quantitative model is next used to assess the welfare implications of the current US unemployment insurance (UI). The UI programs, in United States, become more generous during economic downturns. This issue has gained renewed attention given the recent recession. I focus on quantifying the effects of this policy on job creation. I find that in an economy where agents learn about wages, the welfare costs are significantly higher compared to a model with RE. This is because agents learn how UI impacts wages, and this mechanism amplifies the effect of a negative productivity

shock. Policymakers relying on an RE model might underestimate the costs of UI on job creation and overestimate the total benefits. Implementing a pro-cyclical and symmetric unemployment benefits policy could yield significant welfare gains under IR.

The rest of the paper is organized as follows. Section 2 reviews the literature. Section 3 tests the RE assumption with data from professional forecasters and consumer. Section 4 describes the model. Section 5 presents the calibration of the model and summarizes the main results. Section 6 studies welfare properties of some labor market policies. Section 7 performs some robustness exercises. Lastly, section 8 concludes.

## 2 Related Literature

This model aligns with efforts to solve the Shimer puzzle in the search and matching model literature. Two solutions stand out in the literature. (I) Change in wage formation, in wage formation, as suggested by [Shimer \(2005\)](#), [Hall \(2005\)](#), [Gertler and Trigari \(2009\)](#), , where wages don't fully adjust to productivity shifts, spurring job creation. (II) Calibration changes, as proposed by [Hagedorn and Manovskii \(2008\)](#), enhance firm bargaining power and unemployment benefits, inducing endogenous wage rigidities. Yet, these methods face critiques, and there is no consensus in the literature about how to solve the puzzle.<sup>4</sup> Although these models generate volatility in the labor market, they fall short in explaining the near-zero correlation between labor market metrics and productivity, and the slightly higher wage volatility relative to productivity. Departing slightly from Rational Expectations (RE), I introduce more rigid expectations rather than rigid wages. To the best of my knowledge, this is the first paper to propose a model that is able to generate high volatility in the labor market, a subdued correlation between vacancy-unemployment ratio and labor productivity, flexible wages, and a rationale for wage expectation surveys.

Some recent papers study DMP departing from full information rational expectations (FIRE). For example [Morales-Jiménez \(2022\)](#) and [Menzio \(2022\)](#). In this papers, workers misperceive the true process for productivity. Moreover, workers are assumed to know the mapping from productivity to wages. In these models, agents still require immense knowledge of market behavior. Alternatively, I endow agents with uncertainty regarding how wages are linked to productivity. This fact is tested using wage expectation surveys. My model adeptly addresses the observed correlation between the forecast error of wages and productivity documented in surveys. This is achieved by showcasing a significantly reduced covariance between wage expectations and productivity, as compared to what is implied by rational expectations. In contrast, [Morales-Jiménez \(2022\)](#) and [Menzio \(2022\)](#) do not consider surveys of workers to test the productivity hypothesis.

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<sup>4</sup>These approaches were criticized by [Pissarides \(2009\)](#), [Haefke et al. \(2013\)](#), [Mortensen and Nagypal \(2007\)](#) and [Costain and Reiter \(2008\)](#). There are more solutions to generate volatility in the labor market; see [Costain and Reiter \(2008\)](#), [Silva and Toledo \(2009\)](#), [Reiter \(2007\)](#), [Menzio \(2005\)](#) among others.

This paper extends the adaptive learning literature, with applications outlined in [Evans and Honkapohja \(2012\)](#), [Bullard and Mitra \(2002\)](#) and [Eusepi and Preston \(2011\)](#). Recently, the introduction of a standard adaptive learning approach in the search and matching model has been studied. [Schaefer and Singleton \(2018\)](#) find that when agents make one-step-ahead forecast of labor market tightness, the learning model struggles to capture labor market volatility. Conversely, [Di Pace et al. \(2021\)](#) find that when agents use a misspecified model for wage expectations, while it amplifies labor market dynamics, it overstates wage fluctuations and does not appreciably adjust the correlation between labor market variables and productivity. [Di Pace et al. \(2021\)](#) is the paper most akin to mine. The main difference lies in the way agents form wage expectations. In my paper, agents use productivity directly to form wage expectations, a fact I test with survey data, while in their paper they form wage expectations using an autoregressive model, implying that agents have an inaccurate model to form such expectations. This paper builds on the adaptive learning literature, but maintains the rationality of the agents. Importantly, it is also specific about beliefs system that the agents have in the economy.<sup>5</sup> Both these modelling features are the hallmark of the Internal Rationality framework developed by [Adam and Marcet \(2011\)](#). This approach has not been applied to the search and matching model before and can provide a micro-foundation for adaptive learning models.

A large literature studies the optimality of UI policies including [Fredriksson and Holmlund \(2001\)](#), [Coles and Masters \(2006\)](#), [Lehmann and Van der Linden \(2007\)](#), [Landais et al. \(2010\)](#), [Mitman and Rabinovich \(2015\)](#); among others.<sup>6</sup> I quantify the policy bias in the cost-benefit calculation of unemployment policies that depends on the state of the economy in job creation when using a RE model instead of a learning model. Results show that the cost/benefit of unemployment benefits on job creation is significantly underestimated in rational expectations models.

A vibrant literature has recently developed studying the behavior of expectation surveys. Some papers show that there is a significant discrepancy between the expectations implicit in the macroeconomic model under RE and the expectations coming from the survey data; see [Conlon et al. \(2018\)](#), [Greenwood and Shleifer \(2014\)](#), [Adam et al. \(2017\)](#), [Malmendier and Nagel \(2016\)](#), [Coibion and Gorodnichenko \(2012\)](#), [Coibion and Gorodnichenko \(2015\)](#); among others. I applied the statistical test proposed by [Adam et al. \(2017\)](#) to see whether the data support the rational expectation assumption regarding the formation of future wages. I show that neither workers, firms, nor professional forecasters form wage expectations fol-

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<sup>5</sup>The adaptive learning literature does not specify what agents' views are on the evolution of macro-variables. They only equip them with a recursion, which tracks some moments of the variable. If beliefs are not fully specified in the model, then why, exactly, agents must form expectations according to a given recursion and how this relates to rational behaviour is unclear.

<sup>6</sup>Optimal benefit levels strikes a balance between insurance and incentives, providing insurance against unemployment risk and providing firms with incentives for vacancy creation. I do not address the mention tradeoff, but only highlight the importance of the RE assumption in predicting effects of UI on job creation.

lowing rational expectations. Moreover, the test provides clues about why the RE hypothesis fails, which I used as a guide for modeling expectations.

### 3 Wages and Wage Forecast

Wage expectations play an important role in the labor market decisions. In the search and matching framework, they affect the match surplus and therefore, current wages and also, the hiring decisions made by firms. In the standard DMP model, workers and firms bargain about the wage and the equilibrium wage equation is known by them. More precisely, all agents are assumed to know the mapping from observed productivity shocks to equilibrium wages. This “complete information” assumption is commonly made, although rarely proven, because expectations are very rarely observed.<sup>7</sup>

This section shows that forecast of wages are inconsistent with the notion that agents hold rational wage expectations. I present a formal econometric test following Adam et al. (2017) showing that expectations and RE covary differently with the labor productivity. To run the test, Section 3.1 employs survey data from professional forecasts provided by the European Commission, while Section 3.2 uses data from the Survey of Consumer Expectations (SCE) Labor Market Survey by the New York Fed, which contains workers’ wage expectations. In both datasets, the observed covariance between wage expectations and productivity is significantly lower than the one implied by rational expectations.

#### 3.1 Professional Forecasters

This section conducts a test for rational expectations using survey data that comprises the average forecast of annual wage growth in the United States, reported by the European Commission for the period of 1999 to 2020.<sup>8</sup>

Let  $E_t^S$  denote the agent’s subjective expectation operator based on information up to time  $t$ , which can differ from the rational expectation operator  $E_t$ . Let  $\hat{w}_{t+2}$  denote the two-period ahead realized annual growth of wages, and let  $s_k$  be a measure of agent’s subjective beliefs regarding future growth of wages that are possibly subject to measurement error,  $\nu_t$ , obtained from survey data. Therefore,  $s_{t+2} = E_t^S(\hat{w}_{t+2}) + \nu_t$  represents an estimate of the agents’ subjective beliefs about annual wage growth two semesters ahead. Given the forecast horizon of professional

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<sup>7</sup>Conlon et al. (2018), using the Survey of Consumer Expectations (SCE) Labor Market Survey from the New York FED, found a significant correlation between labor force’s revisions of wage offer forecasts and their forecast errors. This finding supports the existence of information rigidities in forming expectations about future wage offers.

<sup>8</sup>The forecast is reported twice a year in Autumn and Spring. They just report the average forecast. Link reports: [https://ec.europa.eu/economy\\_finance/publications/european\\_economy/forecasts/index-en.htm](https://ec.europa.eu/economy_finance/publications/european_economy/forecasts/index-en.htm)

| Indep. variable | $b^R$             | $b^E$          | P-value           | P-value              |
|-----------------|-------------------|----------------|-------------------|----------------------|
|                 |                   |                | $H_0 : b^R = b^E$ | $H_0 : b^R \geq b^E$ |
| $\hat{y}_t$     | 0,75**<br>(2,35)  | 0.15*<br>(1,9) | 0,0487            | 0,025                |
| $\hat{y}_{t-1}$ | 0,78***<br>(2,71) | 0.12<br>(1,18) | 0,0234            | 0,0202               |

Table 1: RE test

Note: \*\*\*, \*\*, \* denote sig. at 1%, 5% and 10% levels, respectively.  $t$  statistics in parentheses. The Table presents the results of the test  $b^R = b^E$ . The third row shows the results of the test where I include the independent variable with a lag of half a year. The  $p$ -values for the test are constructed using Monte-Carlo simulations. The number of observations is 42.

forecasters,  $t+2$  stands for 2 semesters.

$$\hat{w}_{t+2} = c^R + b^R \hat{y}_t + \nu_t, \quad (1)$$

$$s_{t+2} = c^E + b^E \hat{y}_t + \epsilon_t, \quad (2)$$

where  $\hat{y}$  represents annual productivity growth. Under the null hypothesis of RE ( $H_0 : E_t = E_t^S$ ), if  $\hat{y}_t$  is in the informational set of agents for time period  $t$ , the prediction error must be orthogonal to  $\hat{y}_t$ .  $\hat{b}^R$  and  $\hat{b}^E$  must be estimates of the same regression coefficient because  $b^R = b^E$ . If coefficients across equations are different I reject RE.<sup>9</sup>

Table (1) shows the result of the test. Column 4 shows the  $p$ -values.<sup>10</sup> Additionally, column 5 shows the  $p$ -values for the one-sided test. As a robustness exercise, in the third row, I report the results when the test is performed with annual productivity growth lagged. The results provide evidence against the notion that survey expectations of wages are compatible with RE. This rejection arises because survey expectations and rational expectations covary differently with the labor productivity. Therefore, the forecast error of wages is correlated with productivity growth.

An intriguing observation emerges from the data: during recessions, professional forecasters tend to overestimate wage growth, whereas during expansionary periods, they underestimate it. For instance, amidst the Great Recession, forecasters predicted an average annual wage growth of 0.99%. In contrast, the actual average

<sup>9</sup>Coibion and Gorodnichenko (2012, 2015) bring evidence in favor of information rigidity in expectation formation described by a significant correlation between forecast revisions and forecast error.

$$s_{t+2/t} - s_{t+2/t-1} = c + b(\hat{w}_{t+2} - s_{t+2/t}) + \epsilon_t$$

Using my data,  $b=-0.08$ , the non-significance can be due to the fact that the measurement error of the survey data makes the explanatory variables correlated with the residual and gives a bias  $b$ .

<sup>10</sup>The  $p$ -values are constructed using a small sample correction procedure. To construct the  $p$ -values for the test I rely on Monte-Carlo simulations rather than on asymptotic results. Please refer to Section 2 and Appendix A.3 of Adam et al. (2017) for additional details of the test.

| $b^1$             | $b^2$              | Is $\hat{y}_t$ included? | $R^2$ |
|-------------------|--------------------|--------------------------|-------|
| -                 | 0,094***<br>(2,57) | No                       | 0,09  |
| 0,204**<br>(1,96) | 0,149***<br>(1,97) | Yes                      | 0,16  |

Table 2: RE test

*Note: \*\*\*, \*\*, \* denote sig. at 1%, 5% and 10% levels, respectively. t statistics in parentheses. The Table presents the results of regression 3. The first row shows the results of the regression when I do not include productivity growth as independent variable. The p-values are constructed using Monte-Carlo simulations. The number of observations is 42.*

annual growth for that period experienced a decline of 3.4%. Between Q1-2011 and Q3-2016, a period of economic expansion, the pattern reversed. Forecasts anticipated a growth of 0.76%, yet the actual realization was an impressive 2.51%. Such disparities in wage growth predictions could potentially account for the pronounced fluctuations observed in the labor market. For example, during an expansionary period, a firm that anticipates lower future wages might be inclined to post more job vacancies.

Di Pace et al. (2021) posits that agents rely on an autoregressive models to shape wage expectations.<sup>11</sup> This implies that agents do not use directly productivity to form wage expectations. To test that assumption, I run the following regression:

$$\hat{s}_{t+2} = c + b^1 \hat{y}_t + b^2 \hat{w}_t + \varepsilon_t. \quad (3)$$

Table 2 reveals that productivity remains a significant factor in forecasting wage growth, even after accounting for the realized wage growth.

### 3.2 Consumer Expectations

The survey data on consumer expectations comes from the Survey of Consumer Expectations conducted by the Federal Reserve Bank of New York. To conduct the Rational Expectation test, I use two data sets: (1) the Survey of Consumer Expectations which report information on many demographic variables of the participants, and (2) the Survey of Consumer Expectations (SCE) Labor Market Survey.<sup>12</sup> The participants in the Labor Market Survey are members who participate in an SCE monthly survey in the prior three months. Since respondents are on the SCE panel for a maximum of 12 months, they end up participating in one, two or three labor market surveys during their tenure in the panel.

<sup>11</sup>Di Pace et al. (2021) employ the same survey data up to 2018Q3. However, rather than employing regression (1) and (2) to test Rational Expectations (RE), they examine the correlation between the forecast error,  $\hat{w}_{t+2} - s_{t+2}$ , and GDP growth. While this is a valid approach, as supported by Coibion and Gorodnichenko (2012, 2015), it does not allow for an exploration into the potential association between GDP growth and the forecast of wage growth.

<sup>12</sup>See <https://www.newyorkfed.org/microeconomics/databank.html> for details.



The SCE Labor Market Survey has two main sets of questions: (I) an "Experiences" category that takes data on labor market outcomes, such as wage offers received in the past 4 months, search behavior, reservation wages, job satisfaction and (II) "Expectations" category, which takes data on expectations related to job offer wage expectations, expected job transitions, and retirement.

The panel data enables me to explore how each individual's expectations relate to realizations in the next 4-months period, which allows me to assess the accuracy of expectations and how individuals form their expectations in the labor market. The data from the Labor Market Survey covers the waves from March 2014 to March 2020. The date on which each interview was conducted is represented by the subscript  $t$ . Individuals are surveyed every four months for up to one year, and I will identify each individual with the subscript  $i$ . In the sample, 26,01% took one labor market survey, 33,29% took two surveys, and 40,71% took three surveys. To compute the forecast error for each agent and carry out a statistical test, agents must participate in at least two consecutive surveys. Therefore, I focus on the last two groups.

It is important to clarify the data assumptions that I made. I turn the variables of salary offers and expectations into real terms, the base period of March 2014, using the consumer price index (CPI) for All Urban Consumers from the Federal Reserve Bank of St. Louis.<sup>13</sup> I transform the annual earnings of offers and expectations into hourly earnings, taking into account whether the contract is part-time or full-time. If people work full-time, we divide earnings by 2080 (52 weeks times 40 hours), and if people work part-time, we divide earnings by 1040 (52 weeks, 20 hours). With respect to beliefs, if anyone has received only part-time offers, we assume that her/his beliefs are about part-time work; otherwise, we assume that her/his beliefs are about full-time work. I drop respondents whose revision in beliefs between surveys or the gap between the realizations and the previous period's expectation is greater (lower) than quartile 99 (quartile 1). Finally, I focus on the data from November 2014 onward, when questions about current job offers and expectations about future offers were added to the survey.

The distinction of the rational expectations test conducted in this section, compared to the one proposed by Adam et al. (2017), lies in the nature of the forecast: agents are predicting their own wage offers rather than aggregate economic variables.

Let  $E_t^{S,i}$  denote agent  $i$ 's subjective expectation operator based on information up to time  $t$ , which can differ from the rational expectation operator  $E_t^i$ . Let  $w_{t+1}^i$  denote the realized wage offer that the agent receives four months ahead, and let

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<sup>13</sup>Due to the fact that the survey is four-monthly, I transformed the quarterly data into four-monthly data using interpolation methods. Source: U.S. Bureau of Labor Statistics, Consumer Price Index for All Urban Consumers: All Items in U.S. City Average [CPIAUCSL], retrieved from FRED, Federal Reserve Bank of St. Louis; <https://fred.stlouisfed.org/series/CPIAUCSL>, June 14, 2021.

$s_k^i$  be a measure of agent  $i$ 's subjective beliefs regarding future wage offers that are possibly subject to measurement error,  $\nu^i$  obtained from survey data. Therefore,  $s_{t+1}^i = E_t^{\mathcal{S},i}(w_{t+1}^i) + \nu^i$  represents an estimate of agent  $i$ 's subjective beliefs about his/her wage offer four months ahead. Given the expectation horizon in the Labor Market Survey,  $t+1$  stands for four months.

$$w_{t+1}^i = a + \delta \hat{y}_t + \sum_{n=1}^N \alpha_n X_{i,n} + \epsilon_{i,t}, \quad (4)$$

$$s_{t+1}^i = a^e + \delta^e \hat{y}_t + \sum_{n=1}^N \alpha_n^e X_{i,n} + \mu_{i,t}. \quad (5)$$

Where  $\hat{y}$  represents quarterly productivity growth and  $N$  is the number of control variables such as income, age, race, numeracy, gender, location, education, type of industry, search effort, and employment status (dummies and categorical variables).

Table (3) shows the results of the test under different specifications of the in-

Table 3: RATIONAL EXPECTATIONS TEST,  $H_0 : \delta = \delta^e$

|                           | $\delta$          | $\delta^e$       | $p$ -value<br>$H_0 : \delta = \delta^e$ |
|---------------------------|-------------------|------------------|---|
| Ind. variables: $Y_t$     | 3,24*<br>(1,729)  | 0,208<br>(1,768) | 0,017                                   |
| Ind. variables: $Y_{t-2}$ | 3,62**<br>(1,694) | 0,55<br>(0,532)  | 0,011                                   |
| Ind. variables: $Y_{t-4}$ | 2,85**<br>(1,467) | -0,47<br>(0,195) | 0,009                                   |

*Note:* Robust standard errors in parenthesis. \*\*\*, \*\*, \* denote sig. at 1%, 5% and 10% levels, respectively. The number of observations are 740. The regression in the second row uses productivity growth with two lags (six-month lagged) as an independent variable instead of contemporaneous productivity growth. The regression of the third row uses productivity growth with 4 lags (one year lagged) as independent variable of contemporaneous productivity growth.

dependent variable. The last column presents the  $p$ -values of the test.

The results presented in Table (3) demonstrate that the null hypothesis is rejected in all cases, implying that rational expectations do not find empirical support. Aggregate labor productivity growth correlates with the forecast error of wage offers at a significance level of less than 0.020. Therefore, the forecast error is not orthogonal to productivity growth.

A similar result is evident among professional forecasters. The correlation between

actual wages and productivity surpasses that between wage expectations and productivity. Additionally, it appears that, on average, the labor force does not fully incorporate the impact of productivity when forming their beliefs about future wages.

This empirical observation does not necessarily mean that workers are irrational. One plausible explanation could be that each worker is privy to the time series data of their own wages, but lacks access to the comprehensive panel data that includes wage offers for a broad spectrum of workers. As a result, when a worker conducts a regression of their personal wage offers against aggregate productivity, the derived coefficient may lack statistical significance due to the limited sample size. Consequently, workers might discount aggregate labor productivity as a non-informative factor in predicting their future wages.

The next section spells out the microfoundations of a DMP model under IR where wage expectations are formed using an adaptive approach. Therefore, forecasting errors are not supposed to be necessarily orthogonal to the variables agents observe when making the predictions.

## 4 The Model

I propose a model featuring labor market search and matching friction as in [Mortensen and Pissarides \(1994\)](#) applied to the business cycle. Under the standard setting of RE, agents understand how productivity maps to wages. Instead, I assume the lack of common knowledge of general equilibrium wage mapping and equip agents with a fully specified system of beliefs. Agents form their expectations about the future path of wages based on their respective perceived law of motion (PLM) and update their beliefs as new information becomes available. Given their expectations, agents take optimal decisions. Two shocks can hit the economy: a productivity shock and a shock that affects the agents' beliefs about their expected wages. At the start of a period, shocks occur. Agents forecast future wages, influencing employment surplus of workers, firms' hiring surplus and vacancy decisions. Should a match occur, wages are then bargained over. The period concludes with certain jobs destroyed exogenously.

### 4.1 The Labor Market

Following the standard literature, this economy is characterized by frictions in the labor market. There is a time-consuming and costly process of matching workers and job vacancies, which is captured by a standard constant returns to scale matching function  $m(u, v)$  where  $u$  denotes the unemployment rate and  $v$  is the vacancy rate. I refer to  $\theta_t = \frac{v_t}{u_t}$  as the market tightness at time  $t$ . Hence, the rate at which unemployed workers find a job,  $f(\theta)$ , and vacancies are filled  $q(\theta)$  depend on the vacancy-unemployment ratio, where  $f(\theta) = \theta q(\theta)$  and  $f(\theta)' > 0$ ,  $q(\theta)' < 0$ . The unemployment rate increases when jobs are destroyed at an exogenous rate,  $\lambda$ , and

decreases when workers find jobs. Thus, employment evolves according

$$n_{t+1} = (1 - \lambda)n_t + q(\theta_t)v_t. \quad (6)$$

The labor productivity takes the form of stationary AR(1) in logs:

$$\ln(y_t) = (1 - \rho) \ln(\bar{y}) + \rho \ln(y_{t-1}) + \epsilon_t, \quad 0 < \rho < 1. \quad (7)$$

Where  $\epsilon_t \sim N(0, \sigma^2)$  and  $\rho$  measures the persistence.

## 4.2 Worker's Problem

There is a continuum of identical, risk neutral workers with total measure one and an infinite horizon. These workers can either be employed or unemployed in each period.

An employed worker earns a wage  $w_t$  at  $t$ , and face a probability  $\lambda$  of losing their job in the subsequent period. Conversely, an unemployed worker receives unemployment benefits  $b$  and has a probability  $f(\theta_t)$  of finding a job in the next period. The wage process,  $w_t$ , and the tightness of the labor market,  $\theta_t$ , are given by individual workers. Individual workers have nothing to choose, whether they are employed or not is determined exogenously. Their primary calculation is the net surplus of the match that is used to bargain the wage with the firm if the match is realized. This surplus is the difference between the value of being employed and unemployed.

Deriving the standard surplus of the worker hides many assumptions that I wish to bring out in this section. The worker surplus depend on expectations and that expectations are determine with a probability measure  $\mathcal{P}^w$ . The definition of  $\mathcal{P}^w$  depends on exactly how much workers are assumed to know about the equilibrium process for  $\theta$  and  $w$  and about the properties of these variables. So, I start with a general definition of  $\mathcal{P}^w$  that is consistent with the above setup and that encompasses a number of standard equilibrium concepts that are found in the literature. This will be useful, first, to unveil some assumptions in the standard literature that are often not explicitly stated and it will allow me to extend those equilibrium concepts. Then, I obtain step by step some familiar derivations in the literature and explain how each derivation depends on an increasing amount of assumptions. This provides a clear comparison of the IR equilibrium studied in the paper with RE and with some adaptive learning version of the model.

### 4.2.1 A generic worker problem under Internal Rationality

Consider first the case where I do not make any assumption about the relation between workers' beliefs and actual equilibrium. The next subsection will cover the case of RE as well as the case of Bayesian/RE.

If workers are rational, at the very least, the state space for the measure  $\mathcal{P}^w$  has to contain the payoff relevant variables for individual workers that are beyond the

agent's control, therefore  $\mathcal{P}^w$  puts probabilities on sequences  $\{(w, \theta)^t\}_{t=0}^\infty$ .<sup>14</sup>  $(w, \theta)^t$  is the usual notation describing sequences up to  $t$ , and it is understood that  $E_t^{\mathcal{P}^w}$  responds to the usual definition meaning “conditional expectation given  $(w, \theta)^t$ ”.

Following, I state the first assumption on beliefs

*Assumption 1.* The belief system  $\mathcal{P}^w$  is Markov up to a state vector  $m$ . More precisely,

$$\begin{aligned} Prob^{\mathcal{P}^w}(w_t, \theta_t \mid (w, \theta)^{t-1}) &= \mu(m_{t-1}), \\ m_t &= g(m_{t-1}, y_t, w_t, \theta_t). \end{aligned} \quad (8)$$

For some given functions  $\mu, g$  conformable to their arguments and for a vector  $m_t$  that contains  $\theta_t, w_t$ . In standard IR models,  $m$  will also contain variables that in the workers' mind summarize the best forecast of future wages, as is the case in the main sections of this paper.

Now, I can formulate the value functions for the worker.

The present value of working for an agent is as follows:

$$\mathcal{W}(m_t) = w_t + \beta E_t^{\mathcal{P}^w} [(1 - \lambda)\mathcal{W}(m_{t+1}) + \lambda\mathcal{U}(m_{t+1})]. \quad (9)$$

On the other hand, workers can be unemployed. The present value of unemployment is given by:

$$\mathcal{U}(m_t) = b + \beta E_t^{sw} [f(\theta_t)\mathcal{W}(m_{t+1}) + (1 - f(\theta_t))\mathcal{U}(m_{t+1})]. \quad (10)$$

Where  $N$  and  $U$  are time-invariant functions.

It may seem that this is enough to arrive at a standard equation for worker's surplus,  $\mathcal{W} - \mathcal{U}$ , since I have not given any market knowledge to agents, they still do not necessarily know the equilibrium process of  $\theta$  unless I make the following additional assumption.

*Assumption 2.* Individual workers have a model that forecast correctly the true evolution of  $\theta$ . Formally  $Prob^{\mathcal{P}^w}(\theta_t = \theta_t \mid m_t) = 1$ .

Only under all these assumptions I get the workers' share of the total surplus is:

$$\mathcal{W}(m_t) - \mathcal{U}(m_t) = w_t - b + \beta (1 - \lambda - f(\theta_t)) E_t^{\mathcal{P}^w} (\mathcal{W}(m_{t+1}) - \mathcal{U}(m_{t+1})). \quad (11)$$

This equation would be satisfied when agents learn about wages, as long as Assumptions 1-2 holds. Learning problem remains hidden in the belief structure  $\mathcal{P}^w$ . In section 4.4, I provide an explicit system of beliefs  $\mathcal{P}^w$ .

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<sup>14</sup>From the point of view of probability theory I should also state that the probabilities  $\mathcal{P}^w$  are defined on the sets of a sigma algebra of the mentioned sequence space, but since, it is obvious how to set this up and it does not have an impact on any application to search models we will not mention sigma algebras anywhere else in the paper.

### 4.2.2 The individual problem under RE

Assume now that agents are endowed with the knowledge that wages are a function of the productivity,  $y_t$ , that is I include in (8) an equation giving  $w_t$  as an exact function of  $y_t$ . This is summarize in assumption 3.

*Assumption 3.* The system of equations (8) includes

$$w_t = \mu_w(y_t). \quad (12)$$

In addition, assume that agents know the law of motion of productivity, i.e. they know equation (7). In this paper, I focus on the RE equilibrium that takes the form of the fundamental or minimum state variable solution (MSV).<sup>15</sup> With these additional assumptions then, indeed, we have that  $m_t = (y_t)$ . In this case, market wages carry only redundant information. This allows to exclude wages from the state space without loss of generality.

Additionally, I have to assume the following.

*Assumption 4.* Agents' beliefs are correct, that is, in equilibrium  $\mathbf{w}_t = \mu_w(y_t)$ .

Then workers have RE.

## 4.3 Firms Problem

Consider an economy populated by a mass of infinity firms. Firms' revenues are  $y_t n_t$ , where  $n_t$  and  $y_t$  are exogenous to the firms. The productivity,  $y_t$  follows a AR(1) process (7). Firms pay a total of  $w_t n_t$  at  $t$ , the wage process is taken as given by firms. Each period firms choose the number of vacancies  $v$  to post at a constant ongoing cost  $c$ . Their period- $t$  profits,  $\Pi_t$ , is  $y_t n_t - w_t n_t - cv_t$ .

A key feature of equilibria will be the firms' expected discounted profits from period  $t$  onwards, given by

$$\Pi_t \equiv E_t^{\mathcal{P}^f} \left( \sum_{j=0}^{\infty} \beta^j [y_{t+j} n_{t+j} - w_{t+j} n_{t+j} - cv_{t+j}] \right), \quad (13)$$

where  $\mathcal{P}^f$  is the probability measure about relevant future variables.

To derive the standard job creation condition, it is common in the literature to appeal to dynamic programming to write  $\Pi_t$  in a forward recursive form where  $\Pi_t$  is a function of  $y_t, n_t, w_t$ . In the next subsection, I set out the necessary assumptions to derive this equation. The definition of  $\mathcal{P}^f$  depends on exactly how much firms

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<sup>15</sup>While there may be RE equilibria contradicting this assumption, with added lags in wage determination, Campbell (1994) shows that the RE solution has  $w_t$  as an ARMA(2,1) process. Adhering to McCallum (1983), I select the minimal state variable set that's indispensable for a solution.

are assumed to know about the equilibrium process for  $n, w, y$ , and about the properties of these variables. Therefore, as in the workers problem, I start with a general definition of  $\mathcal{P}^f$  and derive step by step some familiar derivations and explain how each derivation depends on a large amount of assumptions.

#### 4.3.1 A generic firm problem under Internal Rationality

This subsection will cover the case of RE as well as the case of Bayesian/RE for the firms' problem. I do not make any assumption about the process for equilibrium variables nor about the relation between firms' beliefs and actual equilibrium.

The state space for the measure  $\mathcal{P}^f$  has to contain all payoff-relevant variables for individual firms. Hence,  $\mathcal{P}^f$  puts probabilities on sequences  $\{(w, n, y)^t\}_{t=0}^\infty$ .  $(w, n, y)^t$  is the sequences up to  $t$ .  $E_t^{\mathcal{P}^f}$  in (13) represents the “conditional expectation given  $(w, n, y)^{t-1}$ ”.<sup>16</sup>

Since  $\Pi_t$  is still a function of the whole sequence  $(w, n, y)^t$ , to obtain a recursive formulation, I need to add assumptions 1 of the workers' problem, that set that the belief system is a Markov up to a state vector, together with the transversality condition,  $E_t^{\mathcal{P}^f} \beta^j \Pi_{t+j} \rightarrow 0$  as  $j \rightarrow \infty$  almost surely in  $\mathcal{P}^f$ .

Additionally, to set the problem and derive the job creation condition, I have to add the following assumption.

*Assumption 5.* Individual firms know the true evolution of  $n$ .

Taking into account previous assumptions, firms make contingent plans for vacancy posting subject to the evolution of employment (15). Now, I can state the maximization problem of the firms:

$$\Pi(m_t) = \max_{v_t \geq 0} y_t n_t - w_t n_t - c v_t + E_t^{\mathcal{P}^f} \Pi(m_{t+1}) \quad (14)$$

subject to

$$n_{t+1} = (1 - \lambda) n_t + q(\theta_t) v_t. \quad (15)$$

Below, I will specify the probability measure through some perceived law of motion describing the firm's view about the evolution of  $(w_t, y_t)$  over time, together with a prior distribution about the parameters governing this law of motion. Optimal behavior will then entail learning about these parameters, in the sense that agents update their posterior beliefs about the unknown parameters in the line of new wage, and productivity observations. For the moment, this learning problem remains hidden in the belief structure  $\mathcal{P}^f$ .

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<sup>16</sup>Notice that it is incorrect to say that the system of beliefs of workers and firms is the same, since workers take labor market tightness as given and firms choose the labor market tightness through the decision of vacancy posting and their knowledge about the employment. [Di Pace et al. \(2021\)](#) do not specify anything about the agents' belief system.

*Optimality Conditions.* The firm's optimal plan is characterized by the first order condition, together with the envelop condition with respect to  $n_t$ .

$$E_t^{\mathcal{P}^f} \mathcal{J}_{t+1} = \frac{c}{\beta q(\theta_t) \nu}, \quad (16)$$

$$\mathcal{J}_t = y_t - w_t + \beta(1 - \lambda) E_t^{\mathcal{P}^f} \mathcal{J}_{t+1}. \quad (17)$$

where  $\mathcal{J}_t = \frac{\partial \Pi(m_t)}{\partial n_t}$  represents the marginal value of having an additional worker employed at the firm. Therefore, equation (17) gives the surplus of the firm coming from a match. Combining (16) and (17) and iterated forward, I come up with the job creation condition

$$\frac{c}{q(\theta_t) \nu} = E_t^{\mathcal{P}^f} \sum_{j=1}^{\infty} [\beta(1 - \lambda)]^j \left[ \frac{y_{t+j} - w_{t+j}}{1 - \lambda} \right]. \quad (18)$$

This equation would be satisfied when agents learn about wages, as long as all previous assumptions hold. Therefore, in this case I have that the usual job creation condition, but I still need a generic  $m$  in (16) and (17).

#### 4.3.2 The individual firm problem under RE

Analogous to section 4.2.2 of the worker's problem, assume now that firms are endowed with some knowledge of how wages are formed, i.e., assumption 4 holds. Also, firms know the law of motion of  $y$  and firms' beliefs are correct, that is, in equilibrium  $\mathbf{w}_t = \mu_f(y_t)$ .

Then, firms have RE.

### 4.4 Agents' Belief System

Once one departs from rational expectations, beliefs become part of the micro-foundations of the model. In this section, I introduce a fully specified probability measure  $\mathcal{P}$  and derive the optimal belief updating equation it implies. For simplicity, I assume that workers and firms share the probability measures about  $w$  and  $y$ .<sup>17</sup> Nevertheless, agents may not know that this is true prior to wage bargaining. It is important to understand how agents view the wage process to specify an internally consistent rational agent model. The belief system of internally rational agents requires that they do not make obvious mistakes while learning.

Agents have the following perceived law of motion (PLM) which they use to make forecast of wages:

$$\begin{aligned} w_t &= d_t^c + d_t^y y_{t-1} + \epsilon_t, \\ D_t &= D_{t-1} + \nu_t. \end{aligned} \quad (19)$$

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<sup>17</sup>In the section 7.3, I build a version that allow workers and firms have different belief system for wages.



Where  $D_t = [d_t^c \ d_t^y]$ . Shocks  $\epsilon_t \sim \mathcal{N}(0, \sigma_\epsilon^2)$  and  $\nu_t \sim \mathcal{N}(0_{2,1}, \sigma_\nu^2 I_2)$  are independent of each other. This PLM considers a fundamental or minimal state variable solution with unobserved coefficients.

Consider the case where agents' prior beliefs are centered at the REE with the prior variance  $\sigma_{D,0}^2$ :

$$D_0 \sim \mathcal{N}(D^{REE}, \sigma_{D,0}^2 I_2). \quad (20)$$

Where  $\sigma_{D,0}^2$  is set to the steady-state Kalman filter variance. Note that the agents' beliefs (19) encompass the REE of the model. In particular, when agents believe  $\sigma_\nu^2 = 0$  and assign probability 1 to  $D_0 = D^{REE}$ , I have that  $D_t = D^{REE}$  for all  $t \geq 0$  and wages are given by RE equilibrium wages in all periods. Alternatively, if (20) is combined with a belief that  $\sigma_\nu^2$  is small, even though the resulting dynamics of the economy are not going to be precisely given by REE, it will be close to REE.

Agents' posterior beliefs at any time  $t$  are given by

$$D_t \sim \mathcal{N}(\hat{D}_t, \sigma_{D,t}^2 I_2). \quad (21)$$

Given that agents are rational, they update  $\hat{D}_t$  according to the recursive least squares (RLS) algorithm:

$$\begin{aligned} \hat{D}_t &= \hat{D}_{t-1} + \gamma R_t^{-1} z_{t-1} [w_{t-1} - \hat{D}_{t-1}' z_{t-1}] + \epsilon_t^\beta, \\ R_t &= R_{t-1} + \gamma (z_{t-1} z_{t-1}' - R_{t-1}). \end{aligned} \quad (22)$$

Where  $\hat{D}_t = [\hat{d}_t^c \ \hat{d}_t^y]'$  represent the estimated coefficients and  $R_t$  denotes the moment matrix for  $z_{t-1} = [1 \ y_{t-1}]$ .  $\epsilon_t^\beta \sim \mathcal{N}(0_{2,1}, \sigma^{\beta 2} I_2)$  is a shock to wage beliefs and  $\gamma$  denotes the steady state Kalman gain  $\in (0,1)$  that determines the rate at which older observations are discounted.<sup>18</sup> Strictly speaking, given the above information structure the Kalman filter requires  $\sigma^{\beta 2} = 0$ . This shock to beliefs can be interpreted as additional information about  $\nu_t$  available to agents or as a departure from fully rational belief formation.

These beliefs constitute a small deviation from RE beliefs in the limiting case with vanishing innovation to the random walk process. Agents' prior uncertainty then vanishes, and the optimal gain goes to zero. As a result, one recovers the RE equilibrium value for wages.

## 4.5 Wage Bargaining

Wages are negotiated according to a Nash bargaining process. Each agent calculates its respective surplus from its problem, taking into account its system of beliefs of

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<sup>18</sup>The variable  $w_t$  is *not* introduced with a delay in the estimation of  $\hat{D}$ , is a standard assumption in the learning literature. This approach conveniently avoids the simultaneous determination of forecasts and endogenous variables. As proved by [Marcet and Sargent \(1989a\)](#), this does not alter the asymptotic results obtained in the following as compared to the algorithm allowing for simultaneity.

wages, before going to the bargaining process. The wage  $w_t$  maximizes the joint surplus of a match between workers and firms,

$$\max_{w_t} [\mathcal{W} - \mathcal{U}]^\alpha \mathcal{J}_n^{1-\alpha} \quad (23)$$

where  $\alpha$  represents the bargaining power of the worker. The first order condition of this problem gives the standard sharing rule that characterizes the optimal split of the aggregate surplus,

$$(1 - \alpha)(\mathcal{W} - \mathcal{U}) = \alpha(\mathcal{J}_n). \quad (24)$$

Assuming that agents know that (24) holds in expectations, the equilibrium wage is given by

$$\mathbf{w}_t = \alpha(y_t + c\theta_t) + (1 - \alpha)b. \quad (25)$$

The wage equation is the weighted average of the marginal product of employment, the cost of replacing the worker, and the opportunity cost of working,  $b$ . Labor market tightness is a function of expectations; therefore, expectations play an important role in determining wages in equilibrium.

## 4.6 Equilibrium Dynamics under Learning

Under internal rationality, the solution of the model is summarized by (18), (25) and (22). It follows from (19) and (7) that beliefs about wages  $k$  periods ahead are given by

$$E_t^{\mathcal{P}}(w_{t+k}) = \hat{d}_t^c + \hat{d}_t^y((1 - \rho^{k-1}) + \rho^{k-1}y_t). \quad (26)$$

Inserting equation (26) into equation (18) and, then the resulting one into (25), one can write the actual law of motion (ALM) of wages as follows:

$$\mathbf{w}_t = T_c(\hat{d}_t^c, \hat{d}_t^y) + T_y(\hat{d}_t^y)y_{t-1} + T_\epsilon(\hat{d}_t^y)\epsilon_t, \quad (27)$$

where  $T_c$ ,  $T_y$  and  $T_\epsilon$  are functions of the estimated coefficients of the PLM.<sup>19</sup>  $T_c$ ,  $T_y$  and  $T_\epsilon$  represent the coefficients of the the equilibrium wage equation and therefore, implicitly defines the mapping from the PLM to the ALM. The interpretation of the ALM is that describes the stochastic process followed by wages if forecasts are made under the fixed rule given by the PLM. To formulate the T-mapping,  $T(\hat{D}) = (T_c, T_y)$ , I following the method of [Marcet and Sargent \(1989b\)](#) and [Evans and Honkapohja \(2012\)](#). This function maps the agents' perceptions about wage coefficients ( $\hat{D}$ ) to their realized values ( $T(\hat{D})$ ). The T-mapping is not know to agents.

The fixed point of this mapping is the REE of the model.

*Definition:* A rational expectations equilibrium is a matrix  $D = [d^c, d^y]$  that satisfies  $D = T(D)$ . Thus a rational expectations equilibrium is a fixed point of the mapping  $T$ . Let me denote such equilibrium by  $d^{c,RE}$  and  $d^{y,RE}$ .

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<sup>19</sup>For exact formula for  $\Phi^c$ ,  $\Phi^y$  and  $\Phi^\epsilon$  and the derivations see Appendix C.

T-mapping determines the evolution of beliefs in the transition to long-run equilibrium. The fact that agents learn about  $D_t$  introduces a different dynamic behavior. In particular, if firms believe that wages are going to be high tomorrow, this expectation will be transmitted to the actual realized wage through (27), and wages respond to this belief. This is a key feature of self-referential learning models that are absent in Bayesian learning models. Wage expectations affect realized wages, and agents use wages to update their expectations and so on.

Intuitively, the reason learning matters is the following. The higher the wage expectation, the lower the number of vacancies that firms open up, because their expected profits are lower. This makes the labor market tighter, which in turn reduces the probability of finding a job. When firms and workers negotiate wages, -through the bargaining process- in the presence of lower expected profits and a lower probability of finding a job, wages tend to fall. Figures (1) and (2) shows the  $T_y(\hat{d}_t^c \hat{d}_t^{y, RE})$  and  $T_y(\hat{d}_t^y)$ , respectively, represented by the dashed line, which are linear decreasing functions. Values of the coefficient  $\hat{d}_t^c$  and  $\hat{d}_t^y$ , on the right hand side of the fixed point, which is the intersection between the 45 degree line and the T-mapping, indicate that agents expect wages above their realization and vice versa. The negative slopes of the dashed lines reflects the negative relationship between wage expectations and wages present in the model.

Because the agent's equation of wages can differ from the truth, his beliefs evolve over time. To understand the dynamic behavior of  $\hat{D}$ , it helps to analyze whether the learning rule induces instability in the state evolution. Using the theorems of [Sargent and Williams \(2005\)](#), if  $g$  is small enough, to analyze local stability, I need to check the following condition, known as E-stability condition.<sup>20</sup> Accordingly, the stability of the systems (22) is governed by the following ordinary differential equations (o.d.e.):

$$\begin{bmatrix} \dot{\hat{d}}^c \\ \dot{\hat{d}}^y \end{bmatrix} = \begin{bmatrix} T_c(\hat{d}_t^c \hat{d}_t^c) - \hat{d}^c \\ T_y(\hat{d}_t^y) - \hat{d}^y \end{bmatrix}. \quad (28)$$

For local stability, I need all eigenvalues of  $\Omega$  are less than 0 in real part:

$$\Omega = \frac{\partial[T(D) - D]}{\partial D} \Big|_{D=D^{RE}} < 0. \quad (29)$$

The eigenvalues are real and negative, because the derivative of the T-mapping with respect to  $D$  is negative as one can see in figures (1) and (2), so that the condition for local stability of the learning mechanisms is satisfied. Therefore, one may expect constant gain models fluctuate around the REE, and least squared learning would converge.

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<sup>20</sup>If  $g$  is small enough, the local stability conditions are the same than assuming decreasing gain,  $g = \frac{1}{t-1}$ .

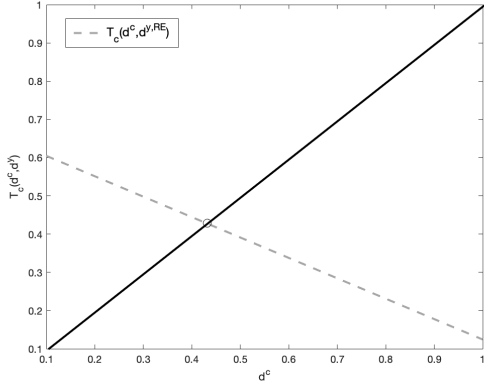


Figure 1: Operator T-mapping for the constant coefficient

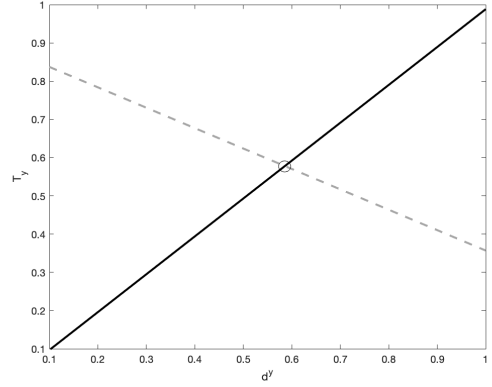


Figure 2: Operator T-mapping for the productivity coefficient

*Note: The dashed line represents the operator, T-mapping for each coefficient. The thick black line represents the 45 degree line. The ellipse represents the RE point -which is the fixed point of the T-mapping. In the first subplot, I assume that the coefficient of the productivity is at its RE point. T-mapping is obtained under the calibration of the learning model specified in section 5.1.*

#### 4.7 Is the structure of Internal Rationality logically inconsistent? An heterogeneous approach

In the context of Internal Rationality (IR), the equilibrium wage function is solely dependent on productivity. This dependency induces a singularity in the objective density across wages and productivity. Given this scenario, a pertinent question arises: would the awareness of this singularity enable internally rational agents to accurately discern the equilibrium wage function through deductive reasoning? In other words, if agents are aware that productivity is the sole source of fundamental disturbances, does internal rationality inherently imply external rationality?

The answer to this question turns out to be ‘no’. In this section, I consider some sources of heterogeneity to highlight that an individual agent would not be able to infer the wage function from observations and her own behavior.

I consider a model in which firms are heterogeneous in some parameter values. Consider the previous RBC search and matching model with firms heterogeneous in the cost of opening a vacancy,  $c^j$  and their discount factor  $\beta^{F,j}$ , but they face the same productivity  $y_t$  that follows an AR(1) process. The values of the pair  $(c^j, \beta^{F,j})$  are drawn from exogenously specified, possibly time-varying distribution. When solving their optimal problem, agents know their own values of  $(c^j, \beta^{F,j})$ . Therefore, the job creation condition for a firm endowed with  $(c^j, \beta^{F,j})$  is as follows:

$$\frac{c^j}{q(\theta_t^j)} = E_t^{sf} \sum_{z=1}^{\infty} [\beta^{F,j}(1-\lambda)]^z \left[ \frac{y_{t+z} - w_{t+z}}{1-\lambda} \right]. \quad (30)$$

Due to the fact that workers are homogeneous and there is no heterogeneity in productivity, there is no dispersion in wages. The equilibrium can be characterized by a degenerate distribution of wages arising from a bilateral bargaining problem between each firm and the average worker. The wage equation is represented by

$$\mathbf{w}_t = \alpha y_t + (1 - \alpha) \left( b + \beta^W m \left( \int_j \frac{v_t^j}{u_t} dj \right) E_t^w \frac{\partial W_{t+1}}{\partial n_{t+1}} \right) \quad (31)$$

Wages are a function of aggregate vacancies. Equivalent, the previous equation can be written as follows

$$\mathbf{w}_t = \int_j \bar{\Phi}^{c,j} dj + \int_j \bar{\Phi}^{y,j} y_{t-1} dj + \int_j \bar{\Phi}^{\epsilon,j} \epsilon_t dj. \quad (32)$$

Assume that firms know that workers know the process of productivity and how to map productivity in their future surplus and the distribution of idiosyncratic parameters across firms. In, this case the firm can perfectly map productivity into the wage.

Instead, firms can know the process of productivity, know that workers form expectations in the right way, and still are not enough to know perfectly how productivity maps to the aggregate level of wages. In addition, I have to assume that firms know the distribution of the vacancy cost and discount factor across firms at each point in time.<sup>21</sup> From this example, I can conclude that it is logically consistent to assume that agents are rational and do not have perfect knowledge of the mapping between productivity onto wages. All I need to assume is that firms do not know the distribution of other firms' vacancy costs and utilities when they have to make the decision of posting vacancies, how the average worker forms its expectations at each point in time, or both.

In fact, section 7.4 extends the model to allow for discrepancies in the way workers and firms form expectations about wages. In that model, I arrive at an equilibrium wage equation that is different from the one obtained in the main paper.

## 5 Quantitative Analysis

In macroeconomics, search and matching models are essential tools for evaluating a range of labor market policies, both existing and prospective. Therefore, it's crucial for the selected model to accurately reflect observed moments in the data. However, the textbook search and matching model is not able to explain the observed fluctuations of unemployment and vacancies in the US economy in response to productivity shocks of plausible magnitude. Additionally, the model demonstrates a lack of propagation, evidenced by an almost 1 contemporaneous correlation between the vacancy-unemployment ratio and productivity, a stark contrast to the near-zero

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<sup>21</sup>In appendix C, you can see the structural form of the parameters  $\Phi$ .  $\bar{\Phi}$  are the parameters  $\Phi$  evaluated at the RE point.

correlation observed in empirical data.

This section evaluates the quantitative performance of the search and matching model with subjective wage beliefs. I formally estimate and test the model using a mixed strategy calibration that includes the Method of Simulated Moments (MSM). Testing helps me to focus on the ability of the model to explain the specific moments of the data described in Table 6.

## 5.1 Estimation of the Model

This section describes the calibration/estimation of the model parameters. The parameterization strategy is threefold. The model has 11 parameters: a subset is selected from the literature, another subset is picked from the US data, and the rest is estimated following the Method of Simulated Moments (MSM).

Specifically, the vector  $\hat{Z} = [\beta, \lambda, \alpha, \bar{y}, \nu]$  is obtained directly from the literature. I normalize time to one-quarter. Following the literature, I assume that the matching function is Cobb-Douglas. Without loss of generality, the steady state of productivity is normalized to 1. The value of the discount factor  $\beta$  is set to generate an annual real interest rate of approximately 5%. The value of the separation rate is set following [Shimer \(2005\)](#), who suggests a quarterly separation rate of 0.10. Hence, on average, jobs last for approximately 2.5 years.

| Parameter         | Description                     | Value  | Source                          |
|-------------------|---------------------------------|--------|---------------------------------|
| $\beta$           | discount factor                 | 0.99   | r=0.05                          |
| $\lambda$         | separation rate                 | 0.10   | <a href="#">Shimer (2005)</a>   |
| $\alpha$          | bargaining power worker         | 0.50   | Hosios rule: $\alpha = 1 - \nu$ |
| $\nu$             | elasticity of matching function | 0.50   | standard                        |
| $\bar{y}$         | steady state productivity       | 1.00   | Normalization                   |
| $\sigma_\epsilon$ | st. dev. of productivity shocks | 0.0058 | Data                            |
| $\rho$            | persistence of productivity     | 0.73   | Data                            |

Table 4: Calibrated quarterly parameters from literature and data

I set the value of the elasticity of the matching function at 0.5 in line with the literature. This value lies within the plausible interval of [0.5 0.7] as surveyed by [Petrongolo and Pissarides \(2001\)](#). Following [Hosios \(1990\)](#), I set the bargaining power of the worker to 0.5. Using US data, I set the standard deviation and persistence of the productivity process to match the empirical behavior of labor productivity from 1990 to 2020. I find a quarterly autocorrelation and standard deviation of 0.7518 and 0.0058, respectively.

Defining  $Z = [c, A, g, \sigma^\beta, b]$  as the vector of parameters to be estimated using an extension of the Simulated Method of Moments. These parameters are estimated to match the first 11 moments reported in table 6, are standardly used in the search

and matching literature to summarize the main features of the labor market.<sup>22</sup> The MSM estimator is given by

$$\min_Z (\hat{\mathcal{S}} - \tilde{\mathcal{S}}(Z))' \hat{\Sigma}_{\mathcal{S}}^{-1} (\hat{\mathcal{S}} - \tilde{\mathcal{S}}(Z)) . \quad (33)$$

where  $\tilde{\mathcal{S}}(Z)$  is the vector of empirical moments to be matched,  $\hat{\mathcal{S}}$  is the model moments counterpart and  $\hat{\Sigma}_{\mathcal{S}}$  is the weighting matrix, which determines the relative importance of each statistic deviation from its target. I use a diagonal weighting matrix whose diagonal is composed of the inverse of the estimated variances of the data statistics.<sup>23</sup> Model-implied statistics are generated through a Montecarlo experiment with 1000 realizations. I formally test the hypothesis that any individual model statistics differ from its empirical counterpart.

The calibrated gain is inside the values found in the literature, which range from 0.002-0.05. Additionally, when compared against wage forecasts from the European Commission, the estimated gain is 0.086.<sup>24</sup> Meanwhile, the standard deviation of the belief shock, introduced in a variant of the learning model, is notably conservative. It is markedly smaller than the empirical standard deviation, which I estimated using the survey of the European Commission, standing at 0.01. These values estimated by survey data can be interpreted as upper bounds.

| Parameter      | Description                    | Values Learning | Values RE |
|----------------|--------------------------------|-----------------|-----------|
| c              | cost of open a vacancy         | 0.45            | 1.30      |
| A              | efficiency matching technology | 0.97            | 1.10      |
| g              | constant gain                  | 0.009           | 0.00      |
| $\sigma^\beta$ | Std. wage belief shocks        | 0.0009          | 0.00      |
| b              | unemployment benefits          | 0.75            | 0.80      |

Table 5: Estimated quarterly parameters from SMM

## 5.2 Statistical Properties

In this section, the estimation results are reported. Table 6 contains statistics from the US labor market data and those implied by the model under rational expectations and learning dynamics.<sup>25</sup> The sample length of one simulation is T=120 quarters. I simulate the model 10,000 times and report the mean values of the

<sup>22</sup>I include functions of moments, instead of pure moments. I target 13 functions of moments. See appendix D for more details.

<sup>23</sup>In practice the estimated variances of the data moments,  $\hat{\mathcal{S}}$  is used. The variances are obtained using a Newey-West estimator and the delta method as in Adam et al. (2016).

<sup>24</sup>Learning in the model is about wage level, therefore I have transformed the annual wage growth forecasts into de-trended levels to estimate the gain, ensuring the forecast generated by the European Commission remains parallel to forecasts implied by the model's learning mechanism. I estimate the gain parameter using a nonlinear least squares to minimize the distance between expectations implied by a constant gain algorithm and the survey expectations.

<sup>25</sup>The sources for the data can be found in Appendix E.

| Moment's Symbol                                | Data   | Learning Model | t-stat | RE model Re-est | t-stat |
|--|--------|----------------|--------|-----------------|--------|
| $\sigma_{\tilde{u}}/\sigma_{\tilde{y}}$        | 11.952 | 8.591          | 1.622  | 0.767           | 5.400  |
| $\sigma_{\tilde{v}}/\sigma_{\tilde{y}}$        | 13.221 | 16.162         | -1.587 | 1.773           | 6.176  |
| $\sigma_{\tilde{\theta}}/\sigma_{\tilde{y}}$   | 24.713 | 22.105         | 0.664  | 2.426           | 5.673  |
| $\sigma_{\tilde{w}}/\sigma_{\tilde{y}}$        | 1.737  | 1.972          | -1.022 | 0.741           | 4.328  |
| $\rho(\tilde{y}_t, \tilde{\theta}_t)$          | -0.040 | 0.145          | -0.429 | 0.991           | -2.400 |
| $\rho(\tilde{v}_t, \tilde{\theta}_t)$          | 0.984  | 0.948          | 3.956  | 0.981           | 0.261  |
| $\rho(\tilde{u}_t, \tilde{\theta}_t)$          | -0.980 | -0.968         | -1.102 | -0.894          | -7.969 |
| $\rho(\tilde{w}_t, \tilde{\theta}_t)$          | 0.780  | 0.949          | -0.480 | 0.991           | -0.600 |
| $\rho(\tilde{\theta}_{t-1}, \tilde{\theta}_t)$ | 0.941  | 0.786          | 2.348  | 0.618           | 4.454  |
| $\rho(\tilde{w}_{t-1}, \tilde{w}_t)$           | 0.826  | 0.785          | 1.302  | 0.703           | 3.840  |
| $\rho(\tilde{u}_t, \tilde{v}_t)$               | -0.927 | -0.844         | -4.134 | -0.791          | -6.771 |
| $b^E$  | 0.15   | 0.39           | -2.14  | 0.62            | -4.20  |
| $b^R$  | 0.75   | 0.85           | 0.35   | 0.74            | 0.035  |

Table 6: Labor Market Statistics

*Note: Data moments are computed over the period 1990Q1: 2020Q1. Moments have been computed as averages over 1000 simulations.  $b^R$  is the coefficients of regression (1) and  $b^E$  is the coefficients of regression (2) running in Section 3. Survey data: European Commission from 1990-2020.  $t$ -ratios are defined as (data moment-model moment)/(estimated standard deviation of the model moment).*

statistics of interest as deviations from the steady state, facilitating comparison to earlier studies.<sup>26</sup> The statistics considered are the relative standard deviation of each labor market variable with respect to the standard deviation of labor productivity, the correlation between each labor variable and labor market tightness, the latter's autocorrelation and wages, and the Beveridge curve represented by the correlation between unemployment and vacancies. Furthermore, the last two rows of Table 6 contrast the non-targeting coefficients from regressions (1) and (2) in Section 3, I employed to test Rational Expectations using forecast data sourced from Professional Forecasters at the European Commission, with those obtained by running the same regressions within the learning and rational expectations models. The second column in Table 6 reports the labor market moments from the data. The third and fourth columns present the moments and  $t$ -statistics of the learning model, respectively, while the fifth and sixth columns provide those of the RE model.

The simplest version of the DMP model with learning performs remarkably well quantitatively. The model statistics pass almost all the  $t$ -tests. It can generate

<sup>26</sup>The initial values of the employment,  $n_t$ , unemployment,  $u_t$ , productivity,  $y_t$  and wages  $w_t$  needed to initialize the algorithm are set to the steady state values. The initial value  $R$  is given by  $R_0 = T^{-1}z'_T z_T$  where  $T$  is 155 quarters that represent a pre-sample period before 1990-Q1. The initial  $D_0$  are set to the RE values, that is  $d^{c,RE} = 0.4359$   $d^{y,RE} = 0.5869$  under the learning calibration.



a low contemporaneous correlation between labor market tightness and productivity, together with the high relative volatilities in the labor market, solving the two puzzles, the propagation and the amplification puzzle. This is achieved without generating rigid wages. This represents a significant success, being problematic for the standard real business cycle model. Job creation is driven by the difference between the expected productivity and the expected cost of labor in new matches. In my model, the learning mechanism makes wage expectations less responsive to changes in productivity, and this generates the amplification. Additionally, the equilibrium wage is now a function not only of productivity but also of expectations. This additional dynamics generated by learning about  $D$  as described in section 4.6, lead to wages fluctuating more extensively than productivity.

Furthermore, the model gives an explanation for the fact that the labor market tightness is not strongly correlated with productivity. This phenomenon occurs because the model introduces a novel source of fluctuations stemming from wage learning. The labor market tightness is not only a function of productivity but also of the estimated coefficients of wage expectations. Additionally, the model also aligns more closely with the coefficient  $b^E$  of regression (2), consistent with the values found in survey data from professional forecasters. This is achieved, even though this coefficient was not directly targeted. The model isn't without its limitations. Large t-ratios of certain moments highlight areas of improvement, though it's important to consider the model's simplicity compared to others within the DMP literature.

I posit a scenario where agents are learning about two coefficients influencing wages and introduce a belief shock. There might be speculations on the specific coefficient driving these results or debates on whether the outcomes are attributed to learning or merely the shock in expectations. In section 7 dedicated to robustness, I demonstrate that the predominant factor is indeed the learning about the coefficient that goes with productivity. This re-calibrated model with just learning about  $d_t^y$ , achieves a relative standard deviation of the vacancy-unemployment ratio and unemployment at 19.9 and 5.22, respectively, and reduces the correlation between the vacancy-unemployment ratio and productivity to 0.39.

The key to understanding where the volatility in the learning model of  $d_t^y$  comes from, lies in the job creation equation (18). This equation is a function of the discounted presented value of profits, the difference of the infinite sums of expected revenues ( $\Theta_y$ ) and expected labor costs ( $\Theta_w$ ). That different can be written as:

$$\Theta_y - \Theta_w = \underbrace{C}_{R1} + \underbrace{\frac{\rho - \hat{d}_t^y}{1 - \beta(1 - \lambda)\rho} y_t}_{R2} + \underbrace{\left( \frac{1}{1 - \beta(1 - \lambda)\rho} - \frac{1}{1 - \beta(1 - \lambda)} \right) \hat{d}_t^y}_{R3}, \quad (34)$$

where  $C = \frac{1 - d^{c, RE}}{1 - \beta(1 - \lambda)} - \frac{\rho}{1 - \beta(1 - \lambda)\rho}$  is a constant.<sup>27</sup> Under RE the volatility in the discounted presented value of profits just come from R2. R3 is constant, so the

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<sup>27</sup>See Appendix B for the details.

volatility of that term is zero under RE,  $var(\Theta_y - \Theta_w)^{RE} = (\frac{\rho - d^{y,RE}}{1 - \beta(1 - \lambda)\rho})^2 var(y_t)$ . The solutions that tries to solve the volatility puzzle keeping RE, try to make the coefficient  $d^{y,RE}$  smaller to increase  $\frac{\rho - \hat{d}_t^y}{1 - \beta(1 - \lambda)\rho} y_t$ . My mechanism does not operate in that way. With a small standard deviation of  $\hat{d}_t^y$ , R3 can add a significant volatility to the discounted presented value of profits, due to the large value of the difference that multiplies  $\hat{d}_t^y$ . Moreover, the small deviations of RE coming from the learning of  $\hat{d}_t^y$  not just make R3 volatile, but also generate a higher volatility in R2. For example, under the proposed calibration R2 is 3 times more volatile than in the RE model.

*The Effects of a Productivity Shock.* To develop more the intuition on the role

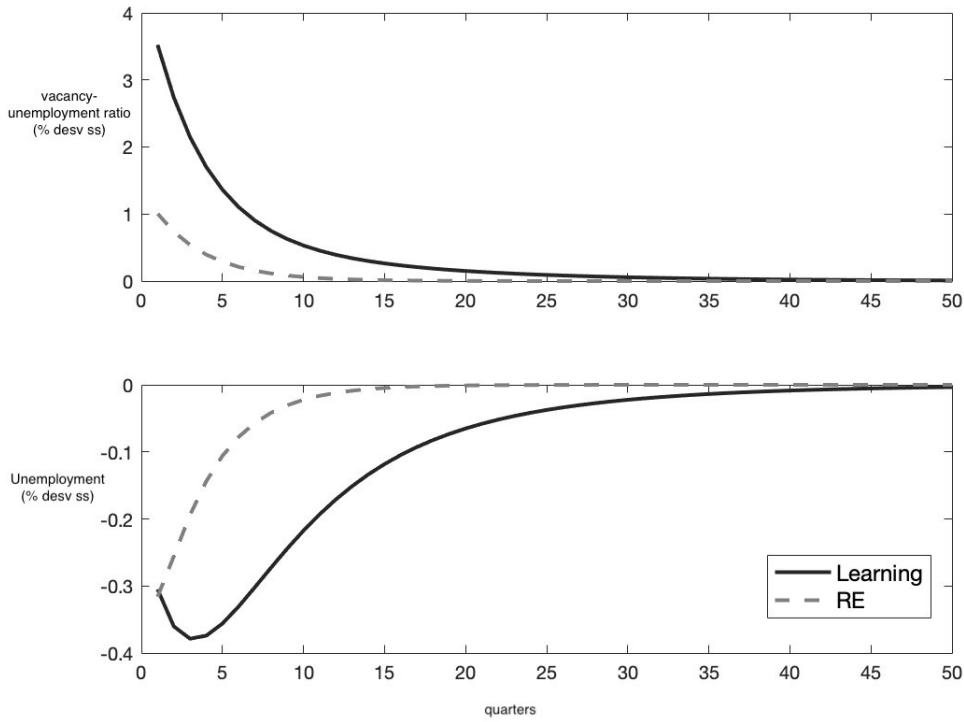


Figure 3: Impulses Responses to a positive Productivity Shock

*Note: Impulse response functions of labor market tightness and unemployment following a one standard deviation positive productivity shock. The dashed line represents the learning model (calibrated under the RE model), while the solid line represents the RE model. The horizontal axis displays the number of quarters after the shock.*

of wage expectations in labor market fluctuations, consider the model's impulse response functions of the labor market tightness, unemployment and the estimated coefficient of wages expectations,  $d_t^y$  to a positive standard deviation productivity shock. The impulse response functions of the labor market tightness and unemployment are expressed in percentage deviations from steady state.

Figure 3 reports the median impulse response functions of the labor market tightness

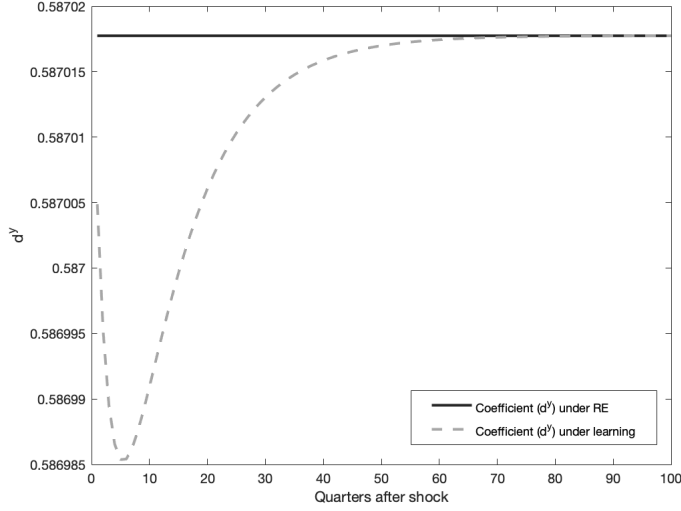


Figure 4: Impulses Responses to a positive Productivity Shock

*Note: Impulse response functions of coefficient  $\hat{d}_t^y$  following a one standard deviation positive productivity shock. The dashed line represents the estimated time-varying coefficient under the learning model (using the RE model calibration), and the solid line represents the constant coefficient  $\hat{d}^{y,RE}$  under the RE model. The horizontal axis displays the number of quarters following the shock.*

and unemployment. It illustrates a pronounced impact of a productivity shock on the labor market under a learning framework compared to Rational Expectations (RE). Figure 4 shows the dynamics following for one of estimated coefficients that determined wage expectations,  $d_t^y$  after a positive productivity shock. Under learning, the productivity shock leads to revisions in wage beliefs that commence the period after the disturbance. Subsequent dynamics are largely driven by revisions to wage beliefs. Particularly, after the shock, firms think that the wages will be lower compared to the RE economy. For a number of periods, the coefficient undergoes a downward adjustment because the forecasting error is negative, i.e.,  $w_{t-1} < d^{c,RE} + \hat{d}_t^y y_{t-1}$ , until some given period. However, after a certain point, economic recovery ensues. Firms start the process of upwardly adjusting their expectations,  $w_{t-1} > d^{c,RE} + \hat{d}_t^y y_{t-1}$  until they align with the RE benchmark. During this adjustment phase, firms' expectations temporarily deviate from the rational expectations framework as they adapt to integrating productivity changes into wage-setting. This adaptive period, where firms anticipate comparatively lower wages than under RE, prompts them to post more vacancies, leading to a decrease in unemployment. Additionally, it takes time to converge to the steady state, so the positive effect of the productivity shock in the labor market is more persistent.

## 6 Labor Market Policies and Welfare

A more realistic microeconomic structure has more reliable and robust macroeconomic implications. However, arguably, an even more important value of the new models lies in their usefulness for analyzing welfare. Given that the learning model reproduces the dynamics in US labor market data, the next step is to analyze the welfare effects of different labor market policies using such model. The goal is to provide policymakers with a more accurate understanding of the potential costs and benefits of these policies and highlight the importance of considering the impact of expectations on labor market outcomes. Learning can amplify the effects of a given policy. If policy makers do not take this effect into account, they may obtain biased estimates and perhaps incur a large cost to the economy after implementation. In the next section, I quantify the biases if policymakers use the RE model to evaluate some policies related to the labor market.

I use the compensating variation method to quantify these welfare effects. This method calculates the number of consumption units that I should give to the representative individual of the economy, uniformly period after period, so that he or she would be indifferent between the economy subject to the base policy and the economy subject to the reform. The welfare measure in these comparisons,  $\lambda$ , is defined from

$$E_0\left[\sum_{t=0}^{\infty} \beta^t (1 + \lambda) c_t\right] = E_0\left[\sum_{t=0}^{\infty} \beta^t c_t^R\right], \quad (35)$$

where  $c_t$  is the consumption under the benchmark case and  $c_t^R$  is the aggregate consumption under a particular experiment. If  $\lambda > 0$  there is a welfare gain; otherwise, there is a welfare loss.

### 6.1 Asymmetric countercyclical UI Policy

In most developed countries, unemployment insurance (UI) is a static program that remains constant regardless of labor market conditions. However, The United States adjusts the generosity of its UI programs during economic downturns. For instance, during the 2007-2011 labor market downturn, the weekly benefit amount increased by \$25. More recently, during the pandemic, interventions such as the FPUC, which offered a weekly supplement in addition to full social security benefits, were implemented. Papers that try to look at the impact of these policies on the economy, for instance [Schwartz \(2013\)](#), they assume that agents have RE. It is important to see whether the fact that agents learn about wages amplifies the effects of such a policy.

To assess the effects of these policies, I consider two rule-based systems that link the level of UI benefits to either GDP or unemployment, and vary the elasticity of the response to changes in these variables. The gdp-based rule is the following:

$$b_t = b - \phi \tilde{y}_{t-1} 1_{\tilde{y}_{t-1} < 0},$$

where  $b$  is the calibrated benchmark UI, and  $\phi$  represents the elasticity of UI with respect to gdp, that is, the percentage increase in UI for each percent drop in

gdp with respect to their steady-state value,  $\tilde{y}$ . The UI is financed using taxes proportional to wages. Alternatively, the rule can be linked to unemployment rather than gdp as follows:

$$b_t = b + \phi \tilde{u}_t 1_{\tilde{u}_t < 0}.$$

Table 7 summarizes the values of  $\lambda$  under the two policy rules compared to the economy in which the UI is constant over the business cycle. In both cases, models predict welfare losses. This is due to the fact that more generous UI benefits lead to higher wages and lower expected profits, which in turn reduce the incentives for firms to create new jobs.

| $\phi$ | GDP rule     |         |                                    | Unemployment rule |         |                                    |
|--------|--------------|---------|------------------------------------|-------------------|---------|------------------------------------|
|        | Learning (%) | RRE (%) | bias $-(\lambda^{RE} - \lambda^L)$ | Learning (%)      | RRE (%) | bias $-(\lambda^{RE} - \lambda^L)$ |
| 0.01   | -0.1         | -0.017  | -0.08                              | -0.27             | -0.0062 | -0.26                              |
| 0.05   | -0.40        | -0.087  | -0.31                              | -1.01             | -0.03   | -0.97                              |
| 0.1    | -0.65        | -0.17   | -0.48                              | -1.61             | -0.08   | -1.53                              |
| 0.2    | -0.97        | -0.33   | -0.64                              | -2.41             | -0.25   | -2.16                              |

Table 7: Values of  $\lambda$ , compared with the benchmark economy where UI is constant over the business cycle

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However, I find that the learning mechanism significantly increases the estimated costs of UI policies on job creation compared with the rational expectations model. In the case of the learning model, by learning about wages, agents learn how the unemployment benefit policy impacts future wages.<sup>28</sup> The increase in unemployment benefits in recessions generates effect on wage expectations. Firms have higher wage expectations than in RE for several periods, as this expectation is gradually updated as agents have new wage data. This results in a greater impact on job creation. Policymakers who use the RE model instead of the learning model significantly underestimate the job creation costs of implementing such policies. Specifically, the learning model predicts higher welfare losses from UI policies than the RE model does, particularly for higher elasticity parameter values. Furthermore, we find that the choice of whether to link UI benefits to GDP or unemployment matters for the estimated costs of UI policies and the choice depends on the model used. In the RE model, linking UI benefits to unemployment leads to slightly lower welfare costs than linking them to GDP, while the opposite is true for the learning model.

Policymakers who rely on the RE model may underestimate the costs of the current UI policies on job creation, and thus overestimate their benefits. Additionally,

<sup>28</sup>In the economy where the reform is implemented, agents' PLM incorporates unemployment benefits:  $w_t = d_t^{f,c} + d_t^{f,y} y_{t-1} + d_t^{f,b} b_{t-1} + \epsilon_t^f$ .

previous findings suggest that the choice of how to link UI benefits to the state of the economy matters for the estimated costs of UI policies and that choice should be informed by the specific model used.

## 6.2 Symmetric procyclical UI Policy

In an economy in which agents learn, the existing US unemployment insurance system generates significant welfare costs coming from their effects on the job creation.<sup>29</sup> Can pro-cyclical unemployment benefits smooth cyclical fluctuations in unemployment and deliver substantial welfare gains? The current section attempts to answer this question.

Unemployment fluctuations are driven by expectations, a combination of learning and belief shocks. Policymakers could, in principle, change the unemployment benefits along the business cycle by responding to unemployment or gdp, and influence the expectations of the firms.

I analyze two rules for such a policy. The first rule that is considered is a standard linear and symmetric response to lagged gdp (rule I in table 8), and the second one is a standard linear and symmetric response to unemployment (rule II in table 8). In order to understand the implications of these rules, I consider three cases: (I) an economy where agents have rational expectations, (II) an economy where agents learn about wages and internalize the UI policy rule implemented by the government, and (III) an economy where agents learn about wages but do not internalize the UI policy rule.

|                              |                                  |
|------------------------------|----------------------------------|
| I. GDP linear rule           | $b_t = b + \phi \tilde{y}_{t-1}$ |
| II. Unemployment linear rule | $b_t = b - \phi \tilde{u}_t$     |

Table 8: Unemployment Benefit Policy rules

*Note:*  $\tilde{y}_{t-1}$  and  $\tilde{u}_t$  represent deviations from the steady state.  $b$  is the unemployment benefits estimated from section 4.1.

The analysis from the previous section has been performed under the assumption that agents fully understand that UI policy responds to unemployment or GDP in recession times. Therefore, when forming expectations of wages, agents would have internalized that the government adjusts the UI level according to the chosen rule. It is reasonable to assume that agents might not internalize the government's reaction to the business cycle. The government may not communicate the policy transparently or agents may believe that the government will not commit to the rule. Therefore, in this section, additionally, I investigate the implications of this

<sup>29</sup>Note that in this simplified model, workers are risk neutral, so I do not take into account the positive effects of unemployment benefit as insurance for workers against the risk of unemployment. The optimal policy of this model without risk adverse workers is zero IU.

lack of information if it is assumed that agents do not consider this rule in their PLM.<sup>30</sup> In reality the government is responding to gdp or unemployment deviations even though agents do not internalize this fact.

Figure 5 plots the welfare benefits implied by the UI rules based on the GDP considered in table 8 for different coefficients regarding the response to GDP. The figures clearly show that when agents internalize such policy while learning about wages, the policy can generate significant welfare improvements. This policy affects not only wages, but also the wage expectations of the agents. When there is an expansion, the government lowers the subsidy to encourage job creation. If there is a recession, raising the UI to cool down the economy. When agents internalize this policy in their expectations, the positive effect of this policy is amplified. However, if agents do not internalize such policy in their wage expectations, welfare gains would be significantly smaller and similar to those generated when agents have rational expectations. The shape of the welfare gain as a function of the gdp has an inverted u-shape: reacting too strongly to gdp can in fact decrease welfare gains because UI is increasing in expansions.

Figure 6 plots the welfare benefits implied by the UI rules based on the unemployment considered in Table 8 for different coefficients of the response to unemployment. If UI responds linear and symmetrically to unemployment might introduce additional volatility in the economy, which might destabilize the system when agents learn and internalize such policy. However, figure 6 shows that this is not the case for a sufficiently small reactions to unemployment. In the area of stability, to the left of the dotted vertical line, the conclusions are in the same line than with the implementation of gdp-based rule. If agents learn and internalize the policy, the welfare gains that we can obtain in the economy are significantly higher compared to the cases where agents have RE or do not internalize the policy.

## 7 Robustness

In this section, I examine the performance of the learning mechanism under alternative assumptions and extensions. All tables I refer to in Section F.1 in the Appendix.

### 7.1 Alternative Calibration

I assess the robustness of the expectation channel proposed in the paper to introducing changes in the calibration of some parameter values. Results are collected in the Table 11.

First, I examine the performance of the baseline model under RE with the solution proposed by Hagedorn and Manovskii (2008) in order to compare both solutions

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<sup>30</sup>In this case, the agents' PLM do not incorporate unemployment benefits, as in the benchmark model:  $w_t = d_t^{f,c} + d_t^{f,y} y_{t-1} + \epsilon_t^f$ .



under the same framework. According to them, the standard DMP model is unable to match the data because of an erroneous parametrization of two parameters: the instantaneous utility of being unemployed and workers' bargaining power. With a higher calibrated value for unemployment benefits closed to the steady-state of wages ( $b = 0.955$ ), and a low bargaining power of the worker, close to zero ( $\alpha = 0.05$ ), the model generates endogenous wage rigidities.<sup>31</sup> This can be seen in the significant drop in the RE value of the coefficient that goes with productivity in the linear wage equation,  $d^{y,RE}$ . Under the learning model 1, that coefficient moves around 0.58, while under the calibration of [Hagedorn and Manovskii \(2008\)](#) it is reduced to 0.11. The rigid wages increase second moment of the vacancy-unemployment ratio. However, the RE model, under [Hagedorn and Manovskii \(2008\)](#) calibration, fails in generating a relative standard deviation between wages and productivity higher than 1. Also, is no able to decrease significantly the correlation between the vacancy-unemployment ratio and productivity.

Second, I simulate the learning model 1 under the calibration of [Shimer \(2005\)](#), keeping the gain parameter equal to their estimated value reported in Table 5, third column. This exercise is running in order to check that the amplification is coming from the learning process instead of an alternative calibration of other parameters such us a higher bargaining power of the worker,  $\alpha = 0.72$  or lower unemployment benefits,  $b = 0.4$ . Column 5 of Table 11 shows that the model still delivers the amplification of the labor market tightness, and a lower correlation between vacancy-unemployment ratio and productivity compared to the RE version of the model.

## 7.2 Learning about the constant

In the core paper, I argue that the primary factor behind labor market fluctuations in the learning model is the learning process about the coefficient governing the relationship between wages and productivity in the wage linear equation, denoted as productivity in the linear equation of wages,  $d^y$ .

Subsequently, I investigate the performance of the learning model when agents are provided with the rational expectations (RE) coefficient  $d_t^y = d^{y,RE} \forall t$ , with their learning focused solely on the constant term of the wage linear equation,  $d^c$ . I also make an assumption that the model environment is devoid of belief shocks to singularly emphasize the impact of learning about the constant. The findings, as presented in Column 7 of Table 11, reveal that the revised model yields a relative standard deviation of labor market tightness, which is 2.3 times higher than what's observed with the RE model. Nevertheless, it is almost 5 times lower compared to learning about  $d_t^y$ . Notably, the model effectively reduces the contemporaneous correlation between labor market tightness and labor productivity.

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<sup>31</sup>The calibration of the remaining parameters follows table 4 and the fifth column of table 5.



### 7.3 Information Assumption

In the baseline model, I assume that agents do not observe period wages at the time they make their forecasts. This is a standard assumption in the learning literature to avoid the simultaneous determination of forecast and endogenous variables. I will move away from that assumption, and I will assume that the forecast of wages, the decision of vacancies and realized wages are determined simultaneously. Consequently, agents beliefs evolve according to the following scheme:

$$\begin{aligned}\hat{D}_t &= \hat{D}_{t-1} + \gamma R_t^{-1} z_{t-1} [w_t - \hat{D}_{t-1}' z_t], \\ R_t &= R_{t-1} + \gamma (z_{t-1} z_{t-1}' - R_{t-1}).\end{aligned}\tag{36}$$

Where  $\hat{D}_t^f = [\hat{d}_t^c \ \hat{d}_t^y]'$  represent the estimated coefficients and  $z_{t-1} = [1 \ y_t]$ . Note that in this case,  $(w_t - \hat{D}_{t-1}' z_t)$  is the most recent forecast error.

As you can see in Table 11, the re-calibrated model still delivers the amplification of the labor market tightness, and a lower correlation between vacancy-unemployment ratio and productivity compared to the RE version of the model. However, this is achieved at the cost of making wages too volatile.

### 7.4 Asymmetric Perceived Law of Motions

I extend the standard search and matching frictions to allow for discrepancies in the way that workers and firms form expectations about future wages. The survey of Consumer Expectations show that on average, workers do not internalize the effect of aggregate labor productivity growth on the formation of such beliefs.<sup>32</sup> In line with that, I assume that firms and workers form wage expectations in different ways. Firms are endowed with a perceived law of motion (PLM) of wages of the minimal state variable (MSV) solution, the one used in this paper. In contrast, workers do not use productivity to form wage expectations in line with the documented fact. Particularly, I assume workers believe that wages follow an unobserved component model of the following form:

$$\begin{aligned}w_t &= d_t^{w,c} + \epsilon_t^w \\ d_t^{w,c} &= d_{t-1}^{w,c} + u_t\end{aligned}\tag{37}$$

Shocks  $\epsilon_t^w \sim \mathcal{N}(0, \sigma_\epsilon^2)$  and  $u_t \sim \mathcal{N}(0, \sigma_u^2)$  are independent of each other. The previous setup defines a filtering problem in which agents need to decompose observed wages into its persistent and transitory elements.

In the model, the worker makes decisions using a misspecified model to form wage expectations, because their PLM differs from the structural form of equilibrium wages. Agents are aware that their peers might interpret the same information differently. In other words, agents reach an agreement for wages because they 'agree to disagree'. Under this assumption, the operator that determines the REE of my model is related to, but distinct from, T-mapping, described in this model. The

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<sup>32</sup>See Section A.2 of the appendix.

restricted perception of one of the agents alters the relevant operator. The long-run equilibrium under this framework is called Restricted Perception rational expectation equilibrium, (RP-REE).

Table 12 shows the statistics coming from the simulation of the models. The learning model with a relative lower gain is able to match very well the moments in the data. It is able to generate fluctuations in the labor market, account for the low correlation between the vacancy-unemployment ratio and productivity, together with flexible wages. Using  $t$ -statistics derived from asymptotic theory, I cannot reject the hypothesis that any of the individual model moments differ from the moments in the data in the estimated earning with asymmetric PLMs.

## 7.5 Sentiment shocks under RE

In this article, I claim that the key model that would solve the puzzle in the labor market is the combination of learning with expectation shocks. A question that may arise is whether the learning mechanism is necessary or whether the same results can be achieved by maintaining rational expectations and adding a sentiment shock.

To address this question, I do two exercise: (1) I simulate the RE model under the same calibrated parameter values than in the main paper and I introduce sentiment shock with the same standard deviation than in the learning model with sentiment shocks. (2) I simulate the RE model and I estimate the standard deviation of the expectation shock to match 2 moments, the amplification and the propagation.

Table 16 reports the results coming from the two exercises. Three things are observed: (I) the model under rational expectations with the same shock as in the learning version generates a volatility almost four times lower than the previous model and a higher correlation. (II) The introduction of this shock in RE generates negative autocorrelations in the labor market variables. (III) To generate the same relative volatility between labor market tightness and productivity as in learning, the volatility of the shock needs to be approximately multiplied by a factor of four. But the higher the volatility of the shock, the higher the negative autocorrelation of the unemployment vacancy ratio.

It seems that this shock does not operate in an economy where agents do not make small mistakes, as it leads to negative autocorrelations in the labor market.

## 8 Conclusions

A simple search and matching model applied to the business cycle is able to quantitatively replicate a number of important labor market facts in US, provided that one slightly relaxes the assumption that agents perfectly know how wages are formed in the market. I assume that agents are internally rational, in the sense that they formulate their doubts about market outcomes using a consistent set of subjective beliefs about wages and behave optimally given this set of beliefs. The system of

beliefs is internally consistent in the sense that it specifies a proper joint distribution of wages and fundamentals at all dates. Moreover, the perceived distribution of wage behavior, although different from the true distribution, is nevertheless close to it and the discrepancies are hard to detect.

In such a setting, optimal behavior implies that agents learn about equilibrium wage process from past wage behavior. This gives rise to a self-referential model of learning about wages. I document that the relation between wage expectations and wages is negative in this model. Higher wage expectations will lead to larger drops in wages.

There are some facts in the labor market that appear puzzling from the RE viewpoint, and many papers question the quantitative consistency of the search and matching models. Sticky wages has gained attention among the literature to solve the puzzling behavior. However as [Pissarides \(2009\)](#) and [Haefke et al. \(2013\)](#) have point out, this mechanisms in matching models is difficult to justify on empirical ground. The learning model performs remarkably well, despite its simplicity. It generates fluctuations in the labor market variables, and it is not subject to the previous critics, in the sense that, the learning approach does not generate rigid wages. Moreover, RE is not supported by survey data in the formation of wage expectations. My result suggest that learning about wage behavior may be a crucial ingredient in understanding labor market volatility.

The finding that large labor market fluctuations can result from optimizing agents with subjective beliefs is also relevant from a policy perspective. As I show in the last part of the paper, If policy makers rely on RE models instead of IR ones, they can get bias estimates for effects of policies related to unemployment benefits. Also, it will be interesting include risk averse agents in the model, and take into account such channel, to get a non-zero optimal policy for unemployment benefits. Therefore, computing the optimal policy of unemployment benefits under internal rationality, and see if such optima policy is time dependent with respect to business cycle, appears to be an interesting avenue for further research.

## References

- Adam, K. and Marcet, A. (2011). Internal rationality, imperfect market knowledge and asset prices. *Journal of Economic Theory*, 146(3):1224–1252.
- Adam, K., Marcet, A., and Beutel, J. (2017). Stock price booms and expected capital gains. *American Economic Review*, 107(8):2352–2408.
- Adam, K., Marcet, A., and Nicolini, J. P. (2016). Stock market volatility and learning. *The Journal of Finance*, 71(1):33–82.
- Bullard, J. and Mitra, K. (2002). Learning about monetary policy rules. *Journal of Monetary Economics*, 49(6):1105–1129.
- Campbell, J. Y. (1994). Inspecting the mechanism: An analytical approach to the stochastic growth model. *Journal of Monetary Economics*, 33(3):463–506.
- Coibion, O. and Gorodnichenko, Y. (2012). What can survey forecasts tell us about information rigidities? *Journal of Political Economy*, 120(1):116–159.
- Coibion, O. and Gorodnichenko, Y. (2015). Information rigidity and the expectations formation process: A simple framework and new facts. *American Economic Review*, 105(8):2644–2678.
- Coles, M. and Masters, A. (2006). Optimal unemployment insurance in a matching equilibrium. *Journal of labor Economics*, 24(1):109–138.
- Conlon, J. J., Pilossoph, L., Wiswall, M., and Zafar, B. (2018). Labor market search with imperfect information and learning. Technical report, National Bureau of Economic Research.
- Costain, J. S. and Reiter, M. (2008). Business cycles, unemployment insurance, and the calibration of matching models. *Journal of Economic Dynamics and Control*, 32(4):1120–1155.
- Di Pace, F., Mitra, K., and Zhang, S. (2021). Adaptive learning and labor market dynamics. *Journal of Money, Credit and Banking*, 53(2-3):441–475.
- Duffie, D. and Singleton, K. J. (1990). Simulated moments estimation of markov models of asset prices.
- Eusepi, S. and Preston, B. (2011). Expectations, learning, and business cycle fluctuations. *American Economic Review*, 101(6):2844–72.
- Evans, G. W. and Honkapohja, S. (2012). *Learning and expectations in macroeconomics*. Princeton University Press.
- Fredriksson, P. and Holmlund, B. (2001). Optimal unemployment insurance in search equilibrium. *Journal of labor economics*, 19(2):370–399.
- Fujita, S. and Ramey, G. (2003). The beveridge curve, job creation and the propagation of shocks. *Unpublished Paper*.

- Gertler, M. and Trigari, A. (2009). Unemployment fluctuations with staggered nash wage bargaining. *Journal of political Economy*, 117(1):38–86.
- Greenwood, R. and Shleifer, A. (2014). Expectations of returns and expected returns. *The Review of Financial Studies*, 27(3):714–746.
- Haefke, C., Sonntag, M., and Van Rens, T. (2013). Wage rigidity and job creation. *Journal of monetary economics*, 60(8):887–899.
- Hagedorn, M. and Manovskii, I. (2008). The cyclical behavior of equilibrium unemployment and vacancies revisited. *American Economic Review*, 98(4):1692–1706.
- Hall, R. E. (2005). Employment fluctuations with equilibrium wage stickiness. *American economic review*, 95(1):50–65.
- Hosios, A. J. (1990). On the efficiency of matching and related models of search and unemployment. *The Review of Economic Studies*, 57(2):279–298.
- Landais, C., Michailat, P., and Saez, E. (2010). Optimal unemployment insurance over the business cycle.
- Lehmann, E. and Van der Linden, B. (2007). On the optimality of search matching equilibrium when workers are risk averse. *Journal of Public Economic Theory*, 9(5):867–884.
- Malmendier, U. and Nagel, S. (2016). Learning from inflation experiences. *The Quarterly Journal of Economics*, 131(1):53–87.
- Marcet, A. and Sargent, T. J. (1989a). Convergence of least-squares learning in environments with hidden state variables and private information. *Journal of Political Economy*, 97(6):1306–1322.
- Marcet, A. and Sargent, T. J. (1989b). Convergence of least squares learning mechanisms in self-referential linear stochastic models. *Journal of Economic theory*, 48(2):337–368.
- McCallum, B. T. (1983). On non-uniqueness in rational expectations models: An attempt at perspective. *Journal of monetary Economics*, 11(2):139–168.
- Menzio, G. (2005). High frequency wage rigidity. *Manuscript. Univ. Pennsylvania*.
- Menzio, G. (2022). Stubborn beliefs in search equilibrium. *National Bureau of Economic Research*.
- Mitman, K. and Rabinovich, S. (2015). Optimal unemployment insurance in an equilibrium business-cycle model. *Journal of Monetary Economics*, 71:99–118.
- Morales-Jiménez, C. (2022). The cyclical behavior of unemployment and wages under information frictions. *American Economic Journal: Macroeconomics*, 14(1):301–31.

- Mortensen, D. and Nagypal, E. (2007). Labor-market volatility in matching models with endogenous separations. *The Scandinavian Journal of Economics*, 109(4):645–665.
- Mortensen, D. T. and Pissarides, C. A. (1994). Job creation and job destruction in the theory of unemployment. *The review of Economic Studies*, 61(3):397–415.
- Petrongolo, B. and Pissarides, C. A. (2001). Looking into the black box: A survey of the matching function. *Journal of Economic literature*, 39(2):390–431.
- Pissarides, C. A. (2009). The unemployment volatility puzzle: Is wage stickiness the answer? *Econometrica*, 77(5):1339–1369.
- Reiter, M. (2007). Embodied technical change and the fluctuations of unemployment and wages. *The Scandinavian Journal of Economics*, 109(4):695–721.
- Sargent, T. J. and Williams, N. (2005). Impacts of priors on convergence and escapes from nash inflation. *Review of Economic Dynamics*, 8(2):360–391.
- Schaefer, D. and Singleton, C. (2018). Unemployment and econometric learning. *Research in Economics*, 72(2):277–296.
- Schwartz, J. (2013). Unemployment insurance and the business cycle: what adjustments are needed? *Southern Economic Journal*, 79(3):680–702.
- Shimer, R. (2005). The cyclical behavior of equilibrium unemployment and vacancies. *American Economic Review*, 95(1):25–49.
- Silva, J. I. and Toledo, M. (2009). Labor turnover costs and the cyclical behavior of vacancies and unemployment. *Macroeconomic Dynamics*, 13(S1):76–96.

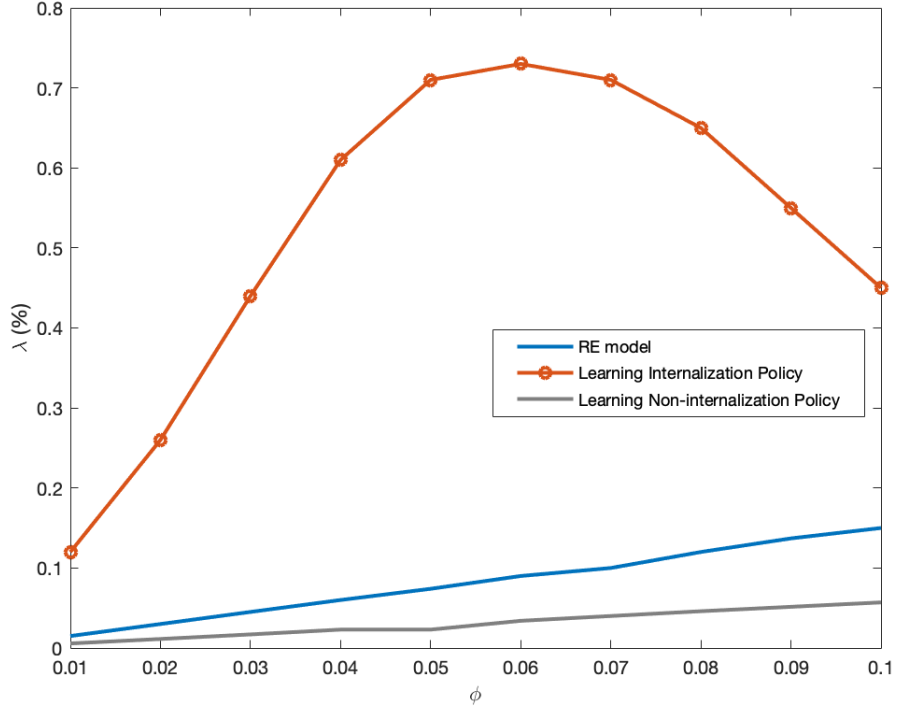


Figure 5: Welfare Implications of UI GDP linear rule

Note: The figure shows the welfare gains  $\lambda$  as defined in equation (31) for different combinations of coefficients for GDP using rule I defined in table (8). Welfare gains were computed as averages over 1000 simulations, each including 120 time periods. Non-internalization implies that although the government changes unemployment benefits based on deviations from GDP, agents do not internalize this fact and form beliefs regarding wages using a misspecified PLM (the same as in the benchmark economy where UI is a parameter).

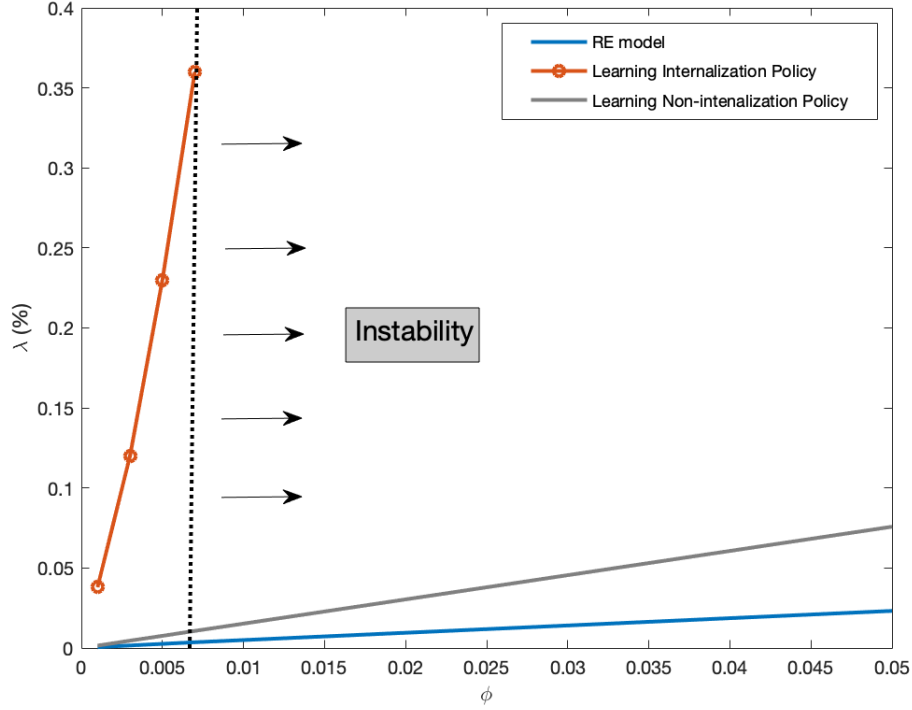


Figure 6: Welfare Implications of UI Unemployment linear rule

Note: The figure shows the welfare gains  $\lambda$  as defined in equation (31) for different combinations of coefficients for unemployment, using rule II defined in table (8). Welfare gains have been computed as averages over 1000 simulations, each one including 120 periods. Non-internalization implies that although the government changes unemployment benefits based on deviations from unemployment, agents do not internalize this fact and form beliefs regarding wages using a misspecified PLM (the same as in the benchmark economy where UI is a parameter). The stability of the system is given by (26).



Figure 7: Operator T-mapping for the constant coefficient

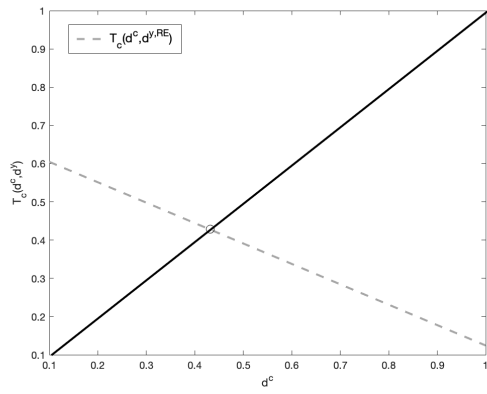
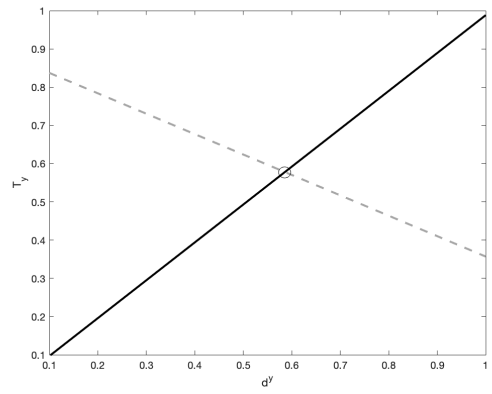
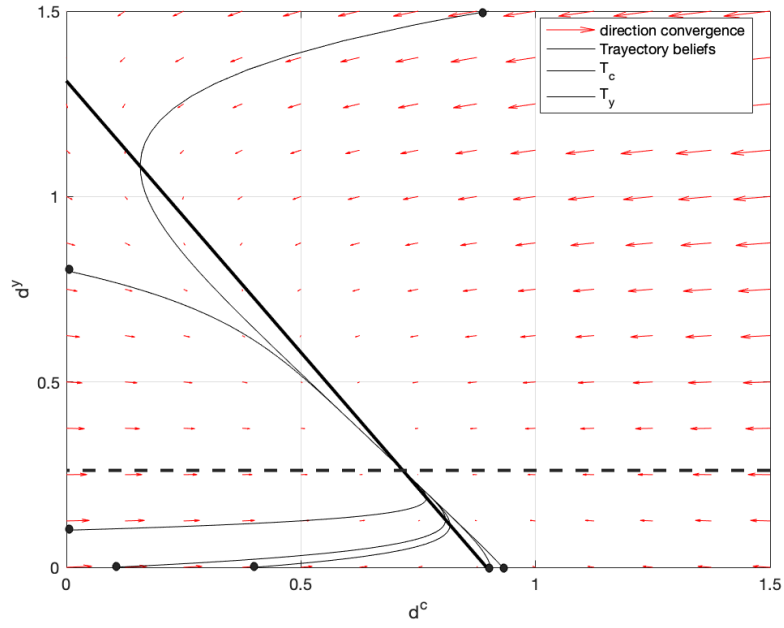


Figure 8: Operator T-mapping for the productivity coefficient



*Note: The dashed line represents the operator, T-mapping for each coefficient . The thick black line represents the 45 degree line. The ellipse represents the RE point -which is the fixed point of the T-mapping. In the first subplot, I assume that the coefficient of the productivity is at its RE point.*

Figure 9: Phase Diagram



The figure plots the trajectories for beliefs about the output gap and its actual realisations given different initial conditions. The thick black line represents the combination of beliefs  $\hat{d}^c$  and  $\hat{d}^y$  such that  $\dot{\hat{d}}^c = 0$ . The dashed line represents the values of  $\hat{d}^y$  such that  $\dot{\hat{d}}^y = 0$ .

## A Survey Data

### A.1 Business Leaders Survey

#### A.1.1 Survey design

In this section, I analyze the expectations of firms about future wages. For that, I use the Business Leaders Survey that is a monthly survey conducted by the Federal Reserve Bank of New York that asks service firms in its district - which includes New York State, upstate New Jersey, and Fairfield County, Connecticut - about recent and expected trends in key business indicators. Service sector participants respond to a questionnaire and report on a range of indicators, both in terms of recent and expected changes.

The survey is sent on the first business day of each month to the same pool of about 150 business executives, usually the president or CEO, in the region's service sector. In a typical month, about 100 responses are received by around the tenth of the month when the survey closes.

#### A.1.2 Questions and description of the data

I am interested in the questions regarding wages paid to the company's average worker. I am focus in two variables: *wpcdina* - current wages - this variable tells me how wages have changed in the last 3 months on average, and *wpfdina* - future wages - lets me know how companies expect wages to change in the next 6 months. Both variables are express in diffusion indexes -the difference between the percentage of firms that report an increase of wages minus the percentage of firms that report a decrease.

Before running the test, I have to deal with a problem of different horizons between the diffusion index of wage realization and the one for wage expectation. To solve this problem and keep things simple, assume that firms have in mind that wages are generated by the following process:

$$w_t = w_t^p + \epsilon_t, \quad (38)$$

$$w_t^p = w_{t-1}^p + \nu_t. \quad (39)$$

Where  $w_t^p$  is a persistent component and  $\epsilon_t$  is a transitory component. Persistent component depends on the past persistent component and on a shock  $\nu_t$ . Both shocks are independently and normally distributed with zero mean. Under this assumption,  $E_t(w_{t+2}) = E_t(w_{t+1})$ .

#### A.1.3 RE test

In this part, I construct a test to verify whether the assumption of RE holds in the data. I test if firms are rational on average when they form expectations about wages. Moreover, this test allow me to know how the firms form their expectations and which variables are important for the determination of them. Particularly, I

| $b^R$              | $b^E$            | p-value<br>$H_0 : b^R = b^E$ | p-value<br>$H_0 : b^R \leq b^E$ |
|--------------------|------------------|------------------------------|---------------------------------|
| 0,0098<br>(0,0882) | 0,16<br>(1,7378) | 0,039                        | 0,00427                         |

Table 9: RE test firms

*Note:  $t$  statistics HAC covariance estimator in parentheses. This table presents the results of the test (41). Monthly data from January 2007 to March 2022.*

want to test if aggregate productivity in New York State, New Jersey, and Connecticut is used by the firms on average, when they form their expectations.

To be rational, expectations have to efficiently use the available information. Forecasting errors, in RE models, have to be orthogonal to all information that was available and relevant to the agents at the moment of making forecasts. The realizations and expectations for each agent should identically incorporate the information contained in his/her past realizations.

Let  $E_t^P$  denote firms' subjective expectations operator based on information up to time  $t$ , which can differ from the rational expectations operator  $E_t$ . Let  $\tilde{w}_{t+1}$  denote the realized wages that the firms paid 3 months ahead, and let  $s_k$  be a measure of firms' subjective beliefs regarding future wages paid to their company's average worker that are possibly subject to measurement error, obtained, from survey data. Therefore,  $s_{t+1} = E_t^P(\tilde{w}_{t+1})$  represents an estimate of firms' subjective beliefs about their wage paid 3 months ahead. Given the expectations horizon in the Business Leaders Survey,  $t+1$  stands for 3 months -quarterly measure-.

$$w_{t+1} = a^R + \delta_t^R Y_{t-1} + \epsilon_t, \quad (40)$$

$$s_{t+1} = a^E + \delta_t^E Y_{t-1} + \nu_t. \quad (41)$$

Where  $Y$  represents the quarterly labor productivity growth in New York State, New Jersey, and Connecticut.

Under the null hypothesis of the information structure of RE ( $H_0 : E_t = E_t^P$ ),  $\hat{\delta}_R = \hat{\delta}_E$  must be estimates of the same regression coefficient, because  $d_E = d_R$  under RE. Under the null hypothesis, the coefficients should equal. If coefficients across equations are different, we reject RE. Under RE, if  $Y_{t-1}$  is in the informational set of the agents for the time period  $t$ , the prediction error must be orthogonal to  $Y_{t-1}$ .

Table 10 shows the result of the test. Column 3 shows the  $p$ -values for the test. Additionally, column 4 shows the  $p$ -values for the one-sided test. The results provide evidence against the notion that firm survey expectations of wages are compatible with RE. The null hypothesis is rejected for the considered period, implying that

rational expectations with respect to real wages do not provide empirical support in that period. The forecast error of wages is correlated with the productivity. It can be seen that firms on average underestimate the effect of productivity in the formation of wage expectations.

## A.2 Survey of Consumer Expectations

### A.2.1 Description of the Data

The survey data on expectations comes from the Survey of Consumer Expectations conducted by the Federal Reserve Bank of New York. To conduct the Rational Expectation test, I use two data sets: (1) the Survey of Consumer Expectations which report information on many demographic variables of the participants, and (2) the Survey of Consumer Expectations (SCE) Labor Market Survey.<sup>33</sup> The participants in the Labor Market Survey are members who participate in an SCE monthly survey in the prior three months. Since respondents are on the SCE panel for a maximum of 12 months, they end up participating in one, two or three labor market surveys during their tenure in the panel.

The SCE Labor Market Survey has two main sets of questions: (I) an "Experiences" category that takes data on labor market outcomes, such as wage offers received in the past 4 months, search behavior, reservation wages, job satisfaction and (II) "Expectations" category, which takes data on expectations related to job offer wage expectations, expected job transitions, and retirement.

The panel data enables me to explore how each individual's expectations relate to realizations in the next 4-months period, which allows me to assess the accuracy of expectations and how individuals form their expectations in the labor market. The data from the Labor Market Survey covers the waves from March 2014 to March 2020. The date on which each interview was conducted is represented by the subscript  $t$ . Individuals are surveyed every four months for up to one year, and I will identify each individual with the subscript  $i$ . In the sample, 26,01% took one labor market survey, 33,29% took two surveys, and 40,71% took three surveys. To compute the forecast error for each agent and carry out a statistical test, agents must participate in at least two consecutive surveys. Therefore, I focus on the last two groups.

It is important to clarify the data assumptions that I made. I turn the variables of salary offers and expectations into real terms, the base period of March 2014, using the consumer price index (CPI) for All Urban Consumers from the Federal Reserve Bank of St. Louis.<sup>34</sup> I transform the annual earnings of offers and expectations into

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<sup>33</sup>See <https://www.newyorkfed.org/microeconomics/databank.html> for details.

<sup>34</sup>Due to the fact that the survey is four-monthly, I transformed the quarterly data into four-monthly data using interpolation methods. Source: U.S. Bureau of Labor Statistics, Consumer Price Index for All Urban Consumers: All Items in U.S. City Average [CPIAUCSL], retrieved from FRED, Federal Reserve Bank of St. Louis; <https://fred.stlouisfed.org/series/CPIAUCSL>, June 14, 2021.

hourly earnings, taking into account whether the contract is part-time or full-time. If people work full-time, we divide earnings by 2080 (52 weeks times 40 hours), and if people work part-time, we divide earnings by 1040 (52 weeks, 20 hours). With respect to beliefs, if anyone has received only part-time offers, we assume that her/his beliefs are about part-time work; otherwise, we assume that her/his beliefs are about full-time work. I drop respondents whose revision in beliefs between surveys or the gap between the realizations and the previous period's expectation is greater (lower) than quartile 99 (quartile 1). Finally, I focus on the data from November 2014 onward, when questions about current job offers and expectations about future offers were added to the survey. <sup>35</sup>

### A.2.2 RE Test

In this section, I construct a test to verify whether the assumption of RE holds in the data, considering the structure of the dataset. The novelty of this paper with respect to the test conducted in the literature (see [Adam et al. \(2017\)](#)); is that agents forecast their own wage offer, instead of aggregate variables in the economy, such as inflation or stock prices. Using this random sample, I test whether the labor force is rational, on average, when they form expectations about wage offers.

To be rational, expectations must use available information efficiently. Forecasting errors in RE models must be orthogonal to all available information and relevant to the agents at the moment of making forecasts. The null hypothesis of the tests presented below encompasses not only the RE model, but also frameworks with limited information that retains the information structure of general equilibrium linkages in the economy.

Let  $E_t^{P,i}$  denote agent  $i$ 's subjective expectation operator based on information up to time  $t$ , which can differ from the rational expectation operator  $E_t^i$ . Let  $w_{t+1}^i$  denote the realized wage offer that the agent receives four months ahead, and let  $s_k^i$  be a measure of agent  $i$ 's subjective beliefs regarding future wage offers that are possibly subject to measurement error obtained from survey data. Therefore,  $s_{t+1}^i = E_t^{P,i}(w_{t+1}^i)$  represents an estimate of agent  $i$ 's subjective beliefs about his/her wage offer four months ahead. Given the expectation horizon in the Labor Market Survey,  $t+1$  stands for four months.

$$w_{t+1}^i = a + \delta \hat{Y}_t + \sum_{n=1}^N \alpha_n X_{i,n} + \epsilon_{i,t}. \quad (42)$$

$$s_{t+1}^i = a^e + \delta^e \hat{Y}_t + \sum_{n=1}^N \alpha_n^e X_{i,n} + \mu_{i,t}. \quad (43)$$

Where  $Y$  represents quarterly productivity growth (growth of real output per person in the non-farm business sector) and  $N$  is the number of control variables such as

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<sup>35</sup>See Appendix ?? to see the questions in detail.

income, age, race, numeracy, gender, location, education, type of industry, search effort, and employment status (dummies and categorical variables).

Under the null hypothesis of the information structure of RE ( $H_0 : E_t^i = E_t^{P,i}, \forall i$ ),  $\hat{\delta}$  and  $\hat{\delta}^e$  must be estimates of the same regression coefficient because  $\delta = \delta^e$  under RE. This is because  $s_{t+1}^i - w_{t+1}^i$  is the prediction error of the true data-generating process. If  $Y_t$  is in the information set for period  $t$  under RE, the prediction error must be orthogonal to  $Y_t$ . Therefore, the null hypothesis of the RE implies  $H_0 : \hat{\delta}^e = \hat{\delta}$ .

Table (10) shows the results of the test under different specifications. The last

Table 10: RATIONAL EXPECTATIONS TEST,  $H_0 : \delta = \delta^e$

|                           | $\delta$          | $\delta^e$       | $p$ -value<br>$H_0 : \delta = \delta^e$ |
|---------------------------|-------------------|------------------|---|
| Ind. variables: $Y_t$     | 3,24*<br>(1,729)  | 0,208<br>(1,768) | 0,017                                   |
| Ind. variables: $Y_{t-2}$ | 3,62**<br>(1,694) | 0,55<br>(0,532)  | 0,011                                   |
| Ind. variables: $Y_{t-4}$ | 2,85**<br>(1,467) | -0,47<br>(0,195) | 0,009                                   |

*Note:* Robust standard errors in parenthesis. \*\*\*, \*\*, \* denote sig. at 1%, 5% and 10% levels, respectively. The number of observations are 740. The regression in the second row uses productivity growth with two lags (six-month lagged) as an independent variable instead of contemporaneous productivity growth. The regression of the third row uses productivity growth with 4 lags (one year lagged) as independent variable of contemporaneous productivity growth.

column presents the  $p$ -values of the test.

The results presented in Table (10) demonstrate that the null hypothesis is rejected in all cases, implying that rational expectations do not provide empirical support. Aggregate labor productivity growth explains the forecast error of wage offers at a significance level of less than 0.020. Therefore, the prediction error is not orthogonal to productivity growth.

This test allow me to understand the drivers of RE rejections. Whereas productivity growth is a variable that significantly affects wage offers, as can be seen in the second column of Table (10), the aggregate labor productivity growth is not used by workers on average to form their expectation about wage offers. As the third column of the table shows, any coefficient ( $\delta^e$ ) in the different regressions is statistically significant.

From these previous results, I conclude that the labor force, on average, does not generally form expectations about wage offers, in accordance with the RE hypothesis. The main reason is that agents do not internalize the effect of fundamental

macroeconomic variables such as productivity on the formation of their beliefs about futures wages. This leads to misspecification in the formation of their beliefs.

This empirical fact does not imply that the workers are irrational. A possible explanation for this behavior is that each worker has the time series of his own wages; they do not see the panel data that contains wage offers of many workers, so when they run a regression of their own wage offers on aggregate productivity, the coefficient they obtain is probably not statistically significant because they only have a small sample. Therefore, the worker simply does not use aggregate labor productivity because he thinks it is not useful for predicting his future wages.

## B Data Source

The time series are presented as seasonally adjusted quarterly series. The period covered is from 1990-Q1 to 2020-Q1, a total of 277 quarters.

**Unemployment:** U.S. Bureau of Labor Statistics, Unemployment Level [UNEMPLOY], retrieved from FRED, Federal Reserve Bank of St. Louis;  
<https://fred.stlouisfed.org/series/UNEMPLOY>, October 20, 2022.

**Vacancies:** To get the vacancy level, I combine two sources. Barnichon, Regis. 2010. “Building a composite Help-Wanted Index”, retrieved from <https://sites.google.com/site/regisbarnichon/data> and U.S. Bureau of Labor Statistics, Job Openings [JTS1000000JOL], retrieved from <https://data.bls.gov/timeseries/JTS1000000JOL>, October 20, 2022.

**Labor productivity:** U.S. Bureau of Labor Statistics, Nonfarm Business Sector: Output per Job for All Employed Persons [PRS85006163], retrieved from FRED, Federal Reserve Bank of St. Louis;  
<https://fred.stlouisfed.org/series/PRS85006163>, October 20, 2022.

**Wages:** U.S. Bureau of Economic Analysis, Gross domestic income: Compensation of employees, paid: Wages and salaries [A4102C1Q027SBEA], retrieved from FRED, Federal Reserve Bank of St. Louis;  
<https://fred.stlouisfed.org/series/A4102C1Q027SBEA>, October 12, 2022.

**Consumer Price Index:** U.S. Bureau of Labor Statistics, Consumer Price Index for All Urban Consumers: All Items in U.S. City Average [CPIAUCSL], retrieved from FRED, Federal Reserve Bank of St. Louis;  
<https://fred.stlouisfed.org/series/CPIAUCSL>, October 12, 2022.



## C Theoretical Model

### C.1 Equilibrium equations

To determine the labor market tightness of the economy, I have to start with the job creation condition:

$$\frac{c}{q(\theta_t)} = E_t^{sf} \sum_{j=1}^{\infty} [\beta(1-\lambda)]^j \left[ \frac{y_{t+j} - w_{t+j}}{1-\lambda} \right] \quad (44)$$

Plugging the expectations of productivity and wages;  $E_t y_{t+j} = (1 - \rho^j) + \rho^j y_t$  and  $E_t w_{t+j} = \hat{d}_t^c + \hat{d}_t^y((1 - \rho^{j-1}) + \rho^{j-1} y_t)$ , the labor market tightness can be write as follows:

$$\theta_t = \left( \frac{A\beta}{c} \right)^{\frac{1}{1-\nu}} [\Theta_y - \Theta_w]^{\frac{1}{1-\nu}}, \quad (45)$$

where  $\Theta_y$  represents the present discount revenues and  $\Theta_w$  the present discount labor costs. These two can be write as

$$\begin{aligned} \Theta_y &= \frac{1}{1 - \beta(1 - \lambda)} + \frac{\rho}{1 - \beta(1 - \lambda)\rho} (y_t - 1) \\ \Theta_w &= \frac{\hat{d}_t^c + \hat{d}_t^y}{1 - \beta(1 - \lambda)} + \frac{\hat{d}_t^y}{1 - \beta(1 - \lambda)\rho} (y_t - 1). \end{aligned} \quad (46)$$

Therefore, vacancies are determine by

$$v_t = u_t \left( \frac{A\beta}{c} \right)^{\frac{1}{1-\nu}} [\Theta_y - \Theta_w]^{\frac{1}{1-\nu}}. \quad (47)$$

### C.2 Wages

Wages are negotiated according to a Nash bargaining process. The wage maximizes the joint surplus of a match between workers and firms. The maximization problem is the following:

$$\max_{w_t} \left[ \frac{\partial W_t(y_t)}{\partial n_t} \right]^{\alpha} \left[ \frac{\partial \Pi_t(y_t)}{\partial n_t} \right]^{1-\alpha}, \quad (48)$$

where  $\alpha$  is the workers' bargaining power. The first order condition is as follows:

$$\begin{aligned} \alpha \left( \frac{\partial W_t(y_t)}{\partial n_t} \right)^{\alpha-1} \left( \frac{\partial \Pi_t(y_t)}{\partial n_t} \right)^{1-\alpha} + \left( \frac{\partial W_t(y_t)}{\partial n_t} \right)^{\alpha} (1-\alpha) \left( \frac{\partial \Pi_t(y_t)}{\partial n_t} \right)^{-\alpha} (-1) &= 0, \\ \alpha \left( \frac{\partial W_t(y_t)}{\partial n_t} \right)^{\alpha-1} \left( \frac{\partial \Pi_t(y_t)}{\partial n_t} \right)^{1-\alpha} &= \left( \frac{\partial W_t(y_t)}{\partial n_t} \right)^{\alpha} (1-\alpha) \left( \frac{\partial \Pi_t(y_t)}{\partial n_t} \right)^{-\alpha}, \\ \alpha \left( \frac{\partial W_t(y_t)}{\partial n_t} \right)^{-1} &= (1-\alpha) \left( \frac{\partial \Pi_t(y_t)}{\partial n_t} \right)^{-1}, \\ \alpha \left( \frac{\partial \Pi_t(y_t)}{\partial n_t} \right) &= (1-\alpha) \left( \frac{\partial W_t(y_t)}{\partial n_t} \right). \end{aligned} \quad (49)$$

Therefore, the following equalities are satisfied:

$$\frac{\partial W_t(y_t)}{\partial n_t} = \alpha S_t, \quad (50)$$

$$\frac{\partial \Pi_t(y_t)}{\partial n_t} = (1 - \alpha) S_t. \quad (51)$$

Where  $S_t$  is the total surplus of the match.

$$S_t = \frac{\partial W_t(y_t)}{\partial n_t} + \frac{\partial \Pi_t(y_t)}{\partial n_t}. \quad (52)$$

Plugging the surpluses into (49), I come up with:

$$\begin{aligned} & \alpha \left[ y_t - w_t + \beta \left[ (1 - \lambda) \frac{\partial E_t^{\mathcal{P}^f} \Pi_{t+1}(y_{t+1})}{\partial n_{t+1}} \right] \right] = \\ & (1 - \alpha) \left[ w_t - b + \beta \left[ (1 - \lambda - f(\theta_t)) \frac{\partial E_t^{\mathcal{P}^w} W_{t+1}(y_{t+1})}{\partial n_{t+1}} \right] \right]. \end{aligned} \quad (53)$$

Assuming that agents belief that (62) and (63) hold in expectations,

$$\begin{aligned} & \alpha \left[ y_t - w_t + \beta E_t^{\mathcal{P}^f} [(1 - \lambda)((1 - \alpha)S_{t+1})] \right] = \\ & (1 - \alpha) \left[ w_t - b + \beta E_t^{\mathcal{P}^w} [(1 - \lambda - f(\theta_t))(\alpha S_{t+1})] \right] \end{aligned} \quad (54)$$

Doing some algebra, I come up with

$$\begin{aligned} & (1 - \alpha)w_t - (1 - \alpha)b + (1 - \alpha)\beta E_t^{\mathcal{P}^w} [(1 - \lambda - f(\theta_t))(\alpha S_{t+1})] = \\ & \alpha y_t - \alpha w_t + \alpha \beta E_t^{\mathcal{P}^f} [(1 - \lambda)((1 - \alpha)S_{t+1})] \end{aligned} \quad (55)$$

Let's assume that  $E_t^{\mathcal{P}^f} = E_t^{\mathcal{P}^w} = E_t^{\mathcal{P}}$ ,

$$w_t = \alpha y_t + (1 - \alpha)b + \beta f(\theta_t) \alpha E_t^{\mathcal{P}}(S_{t+1})(1 - \alpha).$$

Finally, if both agents know that the FOC of firms hold,  $(1 - \alpha)\beta E_t^{\mathcal{P}}(S_{t+1}) = \frac{c\theta_t}{f(\theta_t)}$ , I come up with the following expression:

$$\begin{aligned} w_t &= \alpha y_t + (1 - \alpha)b + f(\theta_t) \alpha \frac{c\theta_t}{f(\theta_t)} \\ &= \alpha(y_t + c\theta_t) + (1 - \alpha)b. \end{aligned} \quad (56)$$

### C.3 T-mapping

First all, I linearize the job creation condition applying a first-order Taylor polynomial of this equation at the steady state  $\theta = \bar{\theta}$ ,  $w = \bar{w}$  and  $y = \bar{y} = 1$ . The job creation condition is represented by the following equation:

$$\frac{c}{\beta q(\theta_t)} = E_t^{\mathcal{P}^f} \sum_{j=1}^{\infty} [\beta(1-\lambda)]^{j-1} [y_{t+j} - w_{t+j}] \quad (57)$$

I take the first-order Taylor polynomial of each component of the previous equation:

$$\frac{c}{\beta q(\theta_t)} = \frac{c}{\beta q(\bar{\theta})} - \frac{c}{\beta q(\bar{\theta})^2} \frac{\partial q(\bar{\theta})}{\partial \theta} (\theta_t - \bar{\theta}) \quad (58)$$

$$E_t^{\mathcal{P}^f} \sum_{j=1}^{\infty} [\beta(1-\lambda)]^{j-1} y_{t+j} = \frac{1}{1-\beta(1-\lambda)} + E_t^{\mathcal{P}^f} \sum_{j=1}^{\infty} [\beta(1-\lambda)]^{j-1} (y_{t+j} - 1) \quad (59)$$

$$E_t^{\mathcal{P}^f} \sum_{j=1}^{\infty} [\beta(1-\lambda)]^{j-1} w_{t+j} = \frac{\bar{w}}{1-\beta(1-\lambda)} + E_t^{\mathcal{P}^f} \sum_{j=1}^{\infty} [\beta(1-\lambda)]^{j-1} (w_{t+j} - \bar{w}) \quad (60)$$

Therefore, I can write equation (57) as

$$\frac{c}{\beta q(\bar{\theta})} - \frac{c}{\beta q(\bar{\theta})^2} \frac{\partial q(\bar{\theta})}{\partial \theta} (\theta_t - \bar{\theta}) = E_t^{\mathcal{P}^f} \sum_{j=1}^{\infty} [\beta(1-\lambda)]^{j-1} [y_{t+j} - w_{t+j}], \quad (61)$$

$$\theta_t = \bar{\theta} + \phi E_t^{\mathcal{P}^f} \sum_{j=1}^{\infty} [\beta(1-\lambda)]^{j-1} [y_{t+j} - w_{t+j}]. \quad (62)$$

where  $\phi = \frac{\beta q(\bar{\theta})^2}{c(q'(\bar{\theta}))}$ . I plug the previous equation into the wage equation, I come up with

$$w_t = \alpha \left( y_t + c \left( \bar{\theta} + \phi E_t^{\mathcal{P}^f} \sum_{j=1}^{\infty} [\beta(1-\lambda)]^{j-1} [y_{t+j} - w_{t+j}] \right) \right) + (1-\alpha)b. \quad (63)$$

Taking into account the expectation;  $E_t^{\mathcal{P}} y_{t+j} = (1-\rho^j) + \rho^j y_t$  and  $E_t^{\mathcal{P}} w_{t+j} = \hat{d}_t^c + \hat{d}_t^y ((1-\rho^{j-1}) + \rho^{j-1} y_t)$ , I come up with:

$$w_t = \Phi^c + \Phi^y y_{t-1} + \Phi^\epsilon \epsilon_t, \quad (64)$$

where

$$\begin{aligned} \Phi^c &= \alpha \left[ c\bar{\theta} + \frac{c\phi}{1-\beta(1-\lambda)} \left[ 1 - (\hat{d}_t^c + \hat{d}_t^y) \right] + (1-\rho) - \rho \left[ \frac{\rho - \hat{d}_t^y}{1-\beta(1-\lambda)\rho} \right] \right] + (1-\alpha)b, \\ \Phi^y &= \rho \left[ \alpha + \phi\alpha c \left[ \frac{\rho - \hat{d}_t^y}{1-\beta(1-\lambda)} \right] \right], \\ \Phi^\epsilon &= \left[ \alpha + \phi\alpha c \left[ \frac{\rho - \hat{d}_t^y}{1-\beta(1-\lambda)} \right] \right]. \end{aligned} \quad (65)$$

## C.4 Method of moments

$$\min_{\theta} (\hat{\mathcal{S}}_i - \tilde{\mathcal{S}}_i(\theta))' \hat{\Sigma}_{\mathcal{S}}^{-1} (\hat{\mathcal{S}}_i - \tilde{\mathcal{S}}_i(\theta)) . \quad (66)$$

Where  $\hat{\Sigma}_{\mathcal{S}}$  is the varianza of the moments.

### C.4.1 The Statistics and Moment Functions

This section gives explicit expressions for the statistics function  $S(\cdot)$  and the moment functions  $h(\cdot)$ .

The undrerlying sample moments needed to construct statistics of interes are:

$$\hat{M}_N = \frac{1}{N} \sum_{t=1}^N h(y_t), \quad (67)$$

where  $h(\cdot)$  is defined as

$$\begin{bmatrix} \tilde{v}_t \\ \tilde{u}_t \\ \tilde{\theta}_t \\ \tilde{y}_t \\ \tilde{w} \\ \tilde{v}_t^2 \\ \tilde{u}_t^2 \\ \tilde{\theta}_t^2 \\ \tilde{y}_t^2 \\ \tilde{w}_t^2 \\ \tilde{v}_t \tilde{\theta}_t \\ \tilde{u}_t \tilde{\theta}_t \\ \tilde{y}_t \tilde{\theta}_t \\ \tilde{w}_t \tilde{\theta}_t \\ \tilde{v}_t \tilde{u}_t \\ \tilde{\theta}_t \tilde{\theta}_{t-1} \\ \tilde{w}_t \tilde{w}_{t-1} \end{bmatrix}$$

The 13 statistics I consider can be expresed as functions of the moments as follows:

$$\mathcal{S}(M) = \begin{bmatrix} \sigma_{\tilde{v}} \\ \sigma_{\tilde{u}} \\ \sigma_{\tilde{\theta}} \\ \sigma_{\tilde{y}} \\ \sigma_{\tilde{w}} \\ \rho(\tilde{v}_t, \tilde{\theta}_t) \\ \rho(\tilde{u}_t, \tilde{\theta}_t) \\ \rho(\tilde{y}_t, \tilde{\theta}_t) \\ \rho(\tilde{w}_t, \tilde{\theta}_t) \\ \rho(\tilde{u}_t, \tilde{v}_t) \\ \rho(\tilde{\theta}_{t-1}, \tilde{\theta}_t) \\ \rho(\tilde{w}_{t-1}, \tilde{w}_t) \end{bmatrix} = \begin{bmatrix} \sqrt{M_6 - M_1^2} \\ \sqrt{M_7 - M_2^2} \\ \sqrt{M_8 - M_3^2} \\ \sqrt{M_9 - M_4^2} \\ \sqrt{M_{10} - M_5^2} \\ \frac{M_{11} - M_1 M_3}{\sqrt{(M_6 - M_1^2)(M_8 - M_3^2)}} \\ \frac{M_{12} - M_2 M_3}{\sqrt{(M_7 - M_2^2)(M_8 - M_3^2)}} \\ \frac{M_{13} - M_4 M_3}{\sqrt{(M_9 - M_4^2)(M_8 - M_3^2)}} \\ \frac{M_{14} - M_5 M_3}{\sqrt{(M_{10} - M_5^2)(M_8 - M_3^2)}} \\ \frac{M_{15} - M_1 M_2}{\sqrt{(M_{10} - M_5^2)(M_8 - M_3^2)}} \\ \frac{M_{16} - M_1^2}{\sqrt{(M_2 - M_1^2)(M_7 - M_2^2)}} \\ \sqrt{M_8 - M_3^2} \\ \sqrt{M_{10} - M_5^2} \\ \frac{M_{17} - M_3^2}{S_{11}^2} \\ \frac{M_{18} - M_5^2}{S_{12}^2} \end{bmatrix}, \quad (68)$$

where  $M_i$  denotes the  $i$ th element of  $M$ .

I compute the  $t$ -statistics for a particular statistic  $i$  as follows:

$$\sqrt{N} \frac{\mathcal{S}_i - \mathcal{S}_i^M}{\hat{\sum}_{\mathcal{S}}}, \quad (69)$$

where  $\mathcal{S}_i$  are the  $i$  statistic of the data and  $\mathcal{S}_i^M$  is the  $i$  statistic coming from the model.  $\hat{\sum}_{\mathcal{S}}$  is the variance for the sample statistics  $\mathcal{S}$ :

$$\hat{\sum}_{\mathcal{S}} = \frac{\partial \mathcal{S}}{\partial M'} \hat{\mathcal{S}}_w \frac{\partial \mathcal{S}'}{\partial M} \quad (70)$$

I can test if the ability of the model to explain individual moments using  $t$ -statistics based on formal asymptotic distribution:

$$\sqrt{N} \frac{\mathcal{S} - \mathcal{S}^M}{\hat{\sum}_{\mathcal{S}}} \rightarrow N(0, 1). \quad (71)$$

## C.5 Tables of Summary Statistics of Robustness

|  | Data   | Learning <sup>1</sup><br>model | RE model <sup>2</sup><br>Hagedorn and Manovskii | Learning <sup>3</sup><br>Shimer | Learning <sup>4</sup><br>Simultaneous (Re-est) | Learning <sup>5</sup><br>Constant (Re-est) |
|--|--------|--------------------------------|---|---------------------------------|--|--|
| $\sigma_{\tilde{\theta}}/\sigma_{\tilde{y}}$ | 24.713 | 19.891<br>(1.228)              | 15.63<br>(2.31)                                 | 16.02<br>(2.21)                 | 19.31<br>(1.37)                                | 4.00<br>(5.27)                             |
| $\sigma_{\tilde{w}}/\sigma_{\tilde{y}}$      | 1.737  | 1.314<br>(1.834)               | 0.10<br>(7.11)                                  | 1.38<br>(1.54)                  | 6.43<br>(-20.42)                               | 0.73<br>(4.37)                             |
| $\rho(\tilde{y}_t, \tilde{\theta}_t)$        | -0.040 | 0.389<br>(-0.998)              | 0.998<br>(-2.42)                                | 0.21<br>(-0.57)                 | 0.11<br>(-0.35)                                | 0.65<br>(-1.60)                            |

Table 11: Summary Statistics: Alternative calibration, learning constant coefficient and infortantion assumption

*Note: 1. Learning model about  $d_t^y$  with productivity shocks,  $d_t^c = d^{c,RE}$ . Calibration follows tables 4 and 5. 2. Calibration follows tables 4 and 5 of the RE model except for parameters  $b = 0.955$  and  $\alpha = 0.05$ . 3. Calibration follows tables 4 and 5 of the learning model 1, expect for parameters  $b = 0.4$  and  $\alpha = 0.72$ . 4. Calibration follows tables 4 and the estimated coefficients coming from SMM are:  $c = 0.9$ ,  $A = 0.6$ ,  $g = 0.051$  and  $b = 0.09$ . 5. Calibration follows tables 4 and the estimated coefficients coming from SMM are:  $c = 0.8105$ ,  $A = 0.5737$ ,  $g = 0.02$  and  $b = 0.75$ . The moments of the data are calculated for the period 1990Q1: 2020Q1. The moments are calculated as averages of 1,000 simulations. The  $t$ -statistics are defined as (data moment-model moment)/E.S. of the data moment.*

|  | Data   | Learning Model | t-stat | RP-RRE model | t-stat |
|--|--------|----------------|--------|--------------|--------|
| $\sigma_{\tilde{u}}/\sigma_{\tilde{y}}$        | 11.952 | 8.814          | 1.515  | 0.310        | 5.621  |
| $\sigma_{\tilde{v}}/\sigma_{\tilde{y}}$        | 13.221 | 13.918         | -0.376 | 0.762        | 6.721  |
| $\sigma_{\tilde{\theta}}/\sigma_{\tilde{y}}$   | 24.713 | 22.360         | 0.599  | 1.026        | 6.030  |
| $\sigma_{\tilde{w}}/\sigma_{\tilde{y}}$        | 1.737  | 1.682          | 0.238  | 1.059        | 2.944  |
| $\rho(\tilde{y}_t, \tilde{\theta}_t)$          | -0.040 | 0.046          | -0.199 | 0.993        | -2.404 |
| $\rho(\tilde{v}_t, \tilde{\theta}_t)$          | 0.984  | 0.989          | -0.594 | 0.983        | 0.072  |
| $\rho(\tilde{u}_t, \tilde{\theta}_t)$          | -0.980 | -0.970         | -0.897 | -0.892       | -8.161 |
| $\rho(\tilde{w}_t, \tilde{\theta}_t)$          | 0.780  | 0.705          | 0.216  | 0.993        | -0.605 |
| $\rho(\tilde{\theta}_{t-1}, \tilde{\theta}_t)$ | 0.941  | 0.907          | -1.747 | 0.999        | -2.653 |
| $\rho(\tilde{w}_{t-1}, \tilde{w}_t)$           | 0.826  | 0.840          | -0.417 | 1.000        | -5.415 |
| $\rho(\tilde{u}_t, \tilde{v}_t)$               | -0.927 | -0.923         | -0.200 | -0.793       | -6.651 |

Table 12: Labor Market Statistics. Asymmetric learning

*Note: The calibration for the two models is described in tables 13 and 14. The moments of the data are calculated for the period 1990Q1: 2020Q1. The moments are calculated as averages of 1,000 simulations. The  $t$ -statistics are defined as (data moment-model moment)/E.S. of the data moment.*

| Variable          | description                     | value  | source                                   |
|-------------------|---------------------------------|--------|--|
| $\beta$           | discount factor                 | 0,95   | Kyndland & Prescott (1982): $r=0,04$ .   |
| $\lambda$         | separation rate                 | 0,1    | Shimer (2005).                           |
| $1-\alpha$        | bargaining power firm           | 0,5    | Standard                                 |
| $\nu$             | elasticity of matching function | 0,5    | Hosios rule (1990): $\alpha = 1 - \nu$ . |
| $b$               | unemployment benefit            | 0,4    | Shimer (2005).                           |
| $\tilde{y}$       | steady state productivity       | 1      | Normalization.                           |
| $\sigma_\epsilon$ | st. dev. of productivity shocks | 0,0058 | Calibrated                               |
| $\rho$            | persistence of productivity     | 0,7318 | Calibrated                               |

Table 13: Calibrated quarterly parameters. Asymmetric Learning

| Variable       | Description                    | Values (Learning)     | Values (RRPE) |
|----------------|--------------------------------|-----------------------|---------------|
| $c$            | cost of open a vacancy         | 0,24                  | 0,195         |
| $A$            | efficiency matching technology | 0,63                  | 0,543         |
| $g$            | constant gain                  | 0,011                 | -             |
| $\sigma^\beta$ | Std. wage belief shocks        | $0,928 \cdot 10^{-3}$ | -             |

Table 14: Estimated quarterly parameters from SMM. Asymmetric Learning

|  | Data   | Learning Model <sup>1</sup> | t-stat | Learning Model <sup>2</sup><br>Productivity (Re-est) | t-stat |
|--|--------|-----------------------------|--------|--|--------|
| $\sigma_{\tilde{u}}/\sigma_{\tilde{y}}$        | 11.952 | 7.461                       | 2.168  | 8.621  | 1.608  |
| $\sigma_{\tilde{v}}/\sigma_{\tilde{y}}$        | 13.221 | 16.850                      | -1.958 | 15.183   | -1.058 |
| $\sigma_{\tilde{\theta}}/\sigma_{\tilde{y}}$   | 24.713 | 23.401                      | 0.334  | 21.569   | 0.801  |
| $\sigma_{\tilde{w}}/\sigma_{\tilde{y}}$        | 1.737  | 1.912                       | -0.765 | 1.958  | -0.963 |
| $\rho(\tilde{y}_t, \tilde{\theta}_t)$          | -0.040 | 0.097                       | -0.319 | 0.152  | -0.447 |
| $\rho(\tilde{v}_t, \tilde{\theta}_t)$          | 0.984  | 0.984                       | -0.018 | 0.950  | 3.719  |
| $\rho(\tilde{u}_t, \tilde{\theta}_t)$          | -0.980 | -0.907                      | -6.743 | -0.980   | 0.051  |
| $\rho(\tilde{w}_t, \tilde{\theta}_t)$          | 0.780  | 0.947                       | -0.475 | 0.954  | -0.495 |
| $\rho(\tilde{\theta}_{t-1}, \tilde{\theta}_t)$ | 0.941  | 0.825                       | -1.217 | 0.830  | 1.713  |
| $\rho(\tilde{w}_{t-1}, \tilde{w}_t)$           | 0.826  | 0.831                       | -0.141 | 0.808  | 0.572  |
| $\rho(\tilde{u}_t, \tilde{v}_t)$               | -0.927 | -0.817                      | -5.460 | -0.873   | -2.720 |

Table 15: Learning about wages and productivity

*Note: 1. Learning model of  $d_t^y$  and  $d_t^c$  with productivity and sentiment shocks. 2. Learning model of  $d_t^y$ ,  $d_t^c$ ,  $a_t^c$  and  $a_t^y$  with productivity and sentiment shocks. Calibration of learning model 1 follows table 4 and the forth column of table 5. Calibration of learning model 2 follows table 4 and the estimated parameters coming from SMM are:  $c = 0.4$ ,  $A = 0.5$ ,  $b = 0.7$ ,  $g = 0.02$  and  $\sigma^\beta = 0.0016$ . The moments of the data are calculated for the period 1990Q1: 2020Q1. The moments are calculated as averages of 1,000 simulations. The  $t$ -statistics are defined as (data moment-model moment)/E.S. of the data moment.*

|  | RE*             | RE (1)       | RE (2)       |
|--|-----------------|--------------|--------------|
|  | No sent. shocks | sent. shocks | sent. shocks |
| $\sigma_{\tilde{\theta}}/\sigma_{\tilde{y}}$   | 1.75            | 6.60         | 24.16        |
| $\rho(\tilde{y}_t, \tilde{\theta}_t)$          | 1.00            | 0.31         | 0.09         |
| $\rho(\tilde{\theta}_{t-1}, \tilde{\theta}_t)$ | 0,70            | -0.27        | -0.35        |

Table 16: Learning model under the calibration of RE model

*\*Calibration follows tables 4 and 5 of the RE model. The moments are calculated as averages of 1,000 simulations. The t-statistics are defined as (data moment-model moment)/E.S. of the data moment.*