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JEL Codes: C73; D91; E71.

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1. Introduction

There is extensive survey evidence for the U.S. and Europe of persistent heterogeneity in workers' unemployment expectations for the near future. These unemployment expectations are generally elicited and reported (yet employing other wording) as ranging ordinally from pessimism to optimism, also including neutral households who expect unemployment to remain about the same (see the motivating Figure 1).[1]

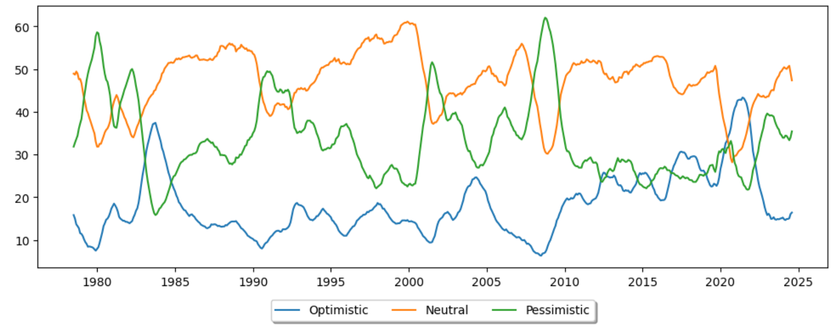
There is also significant evidence coming from both econometric and experimental methods showing that effort on the job and the resulting labor productivity are endogenous to the wage remuneration provided by the employer. In effect, several empirical studies found that a higher wage remuneration is an effective effort-inducing and hence labor productivity-enhancing incentivizing mechanism. As theoretically developed and articulated in the efficiency wage modeling of the labor market, for example, by offering a higher wage remuneration, an individual firm raises the cost of job loss to workers and thereby encourages them to provide more effort on the job.

Following Silveira and Lima (2021), this paper conceives as analytically warranted and fruitful to interpret the two pieces of evidence reported above as causally interrelated, posing the suggestive premise that the perceived risk of job loss and the resulting provision of effort on the job are similarly heterogeneous in the population of workers.

In the novel short-run modeling framework of the labor market set forth in Silveira and Lima (2021), a given firm is unable to perfectly observe and hence monitor whether an individual worker holds a pessimistic unemployment expectation (and therefore provides relatively more effort by having a higher expected

[1] The U.S. Michigan Survey of Consumers monthly asks households: "How about people out of work during the coming 12 months—do you think that there will be more unemployment than now, about the same, or less?" Additional response options include 'don't know' and 'no answer', although these represent only a very small share of total responses (https://data.sca.isr.umich.edu/). In Figures 1 and 2, the proportions for each type of unemployment expectation are calculated excluding the 'don't know' and 'no answer' categories. The main survey of unemployment expectations in the European Union monthly asks households how do they expect the number of people unemployed in the country to change over the next 12 months. Answers include 'increase sharply', 'increase slightly', 'remain the same', 'fall slightly', 'fall sharply', and 'don't know' (https://economy-finance.ec.europa.eu/economic-forecast-and-surveys).

Figure 1: U.S. Michigan Surveys of Consumers: unemployment expectations (1978.01–2024.08) (12-month centered moving average)

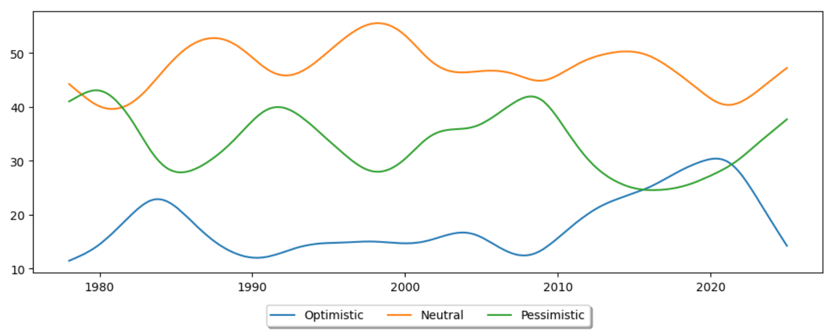


cost of job loss) or an optimistic unemployment expectation (and therefore delivers relatively less effort by having a lower expected cost of job loss). In accordance with survey evidence, the population of workers is also composed of neutral workers who are more optimistic than pessimistic workers, while more pessimistic than optimistic ones. Facing this non-observable behavioral heterogeneity on the part of workers, an individual firm then rationally establishes the uniform wage rate that maximizes its profits by minimizing the cost of labor per unit of average effort. Therefore, optimistic workers are more costly per unit of effort to an individual firm than both neutral and (to a greater extent) pessimistic workers, given that all hired workers are compensated with the same wage rate but neutral and (to a greater extent) pessimistic workers provide more effort on the job than optimistic workers.

In effect, there is robust empirical evidence (relying on both econometric and experimental methods) finding that labor productivity is endogenous to the wage remuneration provided by the employer, with a higher wage remuneration acting as a productivity-enhancing mechanism. Nonetheless, the channels by means of which this endogenous causal determination works are not easily empirically identifiable, not to mention quantifiable. The intuitive reason is that the operation of these channels very likely involve both observable and non-observable intervening factors. Sizeable evidence from laboratory experiments (see, e.g., Fehr et al., 1997; Fehr et al., 1998; Charness, 2004; Charness and Kuhn, 2007; Fehr and Gächter, 2008; Charness and Kuhn, 2011; Sliwka and Werner, 2017) and field experiments (see, e.g., Gneezy and List, 2006; Bellemare and Shearer, 2009; Greiner et al., 2011) reveal that higher wage remuneration incentivizes improved performance of workers on the job. Meanwhile, considerable evidence coming out of surveys (Campbell and Kamlani, 1997) and econometric studies (see, e.g., Cappelli and Chauvin, 1991; Goldsmith et al., 2000; Fleisher and Wang, 2001) show that a higher wage positively impacts on workers' effort on the job and/or labor productivity.

In the novel short-run modeling framework of the labor market developed in Silveira and Lima (2021), the frequency distribution of unemployment expectations across workers is treated as an exogenously given constant. However, as shown in Figure 1, this distribution varies over time—although, as Figure 2 suggests, it is not an unreasonable approximation to consider it roughly constant over extended periods. The novel complementary evidence presented in this paper supports the conclusion that the frequency distribution of unemployment expectations remains roughly constant—or stationary and thus trendless—over long stretches of time, as suggested by Figure 2 and plausibly rationalized by the main result of the dynamic analysis developed here.

Figure 2: U.S. Michigan Surveys of Consumers: unemployment expectations (1978.01–2024.08) (monthly trend – HP filter)



Against the backdrop of evidence that heterogeneity in workers' unemployment expectations varies over time—and the plausible analytical implication that workers' perceived risk of job loss, and thus their effort provision, are similarly heterogeneous and time-varying—this paper proposes a novel evolutionary microdynamic of expectation switching by workers, which is subsequently incorporated into an efficiency wage framework of the labor market. The frequency distribution of unemployment expectations across workers is endogenously time-varying, driven by an expectation-switching protocol grounded in evolutionary dynamics. Workers are assumed to form unemployment expectations under constraints imposed by their limited knowledge of the future. They revise—and may switch—their expectations about future unemployment under conditions of bounded rationality. In this context, heterogeneity in working households' views of unemployment, even in the near future, should not be interpreted as ignorance or irrationality, but rather as a reflection of their reasonably differing perceptions and beliefs regarding an uncertain future.

Our novel evolutionary microdynamic governing the frequency distribution of unemployment expectations across workers draws on two key approaches from behavioral economics. The first is the concept of *satisficing choice*, developed by Herbert Simon in several contributions (see, e.g., Simon, 1955, 1956, 1987). The second is the notion of *reference dependence*, one of the core principles of prospect theory introduced by Daniel Kahneman and Amos Tversky (Kahneman and Tversky, 1979). By combining analytical elements from these two important behavioral approaches, our novel evolutionary expectation-switching protocol centers on the focal concept of a *satisficing reference point*. Under this protocol, the empirically observed persistence of heterogeneity in unemployment expectations across workers emerges as an evolutionary equilibrium.

It is important to emphasize that this paper does not aim to offer a plausible explanation specifically for the U.S. experience depicted in Figures 1 and 2, or for similar experiences in other countries. Rather, these figures serve to motivate the importance of examining the dynamic interplay between time-varying heterogeneity in workers' unemployment expectations and labor market dynamics within an evolutionary framework. As is inevitable in any formal model, we abstract from other determinants of worker effort to focus exclusively on the impact of wage compensation—a factor for which there is substantial empirical support. We also reasonably abstract from alternative channels through which labor effort may increase with wages beyond the expected cost of job loss. In this way, our strategy of isolating a limited set of mechanisms involving unobservable unemployment expectations and imperfectly observable effort is analogous to controlling for other covariates in empirical analyses aimed at identifying causal relationships.

The remainder of the paper is organized as follows. Section 2 presents the heterogeneous expectations-augmented efficiency wage framework and derives its temporary equilibrium, where the frequency distribution of unemployment expectations across workers is taken as predetermined. Section 3 introduces the protocol for expectation formation and switching, grounded in the notion of satisficing reference dependence, and solves for the evolutionary equilibrium. Section 4 concludes.

2. Heterogenous expectations-augmented efficiency wage setting in the short run

The shirking version of the efficiency wage model, formalized by Shapiro and Stiglitz (1984), explains why firms may choose to compensate workers with a wage above the market-clearing level. The central idea is that when monitoring worker effort on the job is imperfect, a higher wage act as a discipline device: it increases the cost of job loss, thereby deterring shirking. Workers who are caught shirking and fired face unemployment, giving them enough incentive to maintain effort. This gives rise to the no-shirking condition, which is the minimum wage needed to ensure that workers choose not to shirk. Firms set wages at or above this threshold to minimize the cost of labor per unit of effort while maintaining labor effort and productivity. A key implication is the existence of involuntary unemployment in equilibrium. Not all willing workers can find jobs at the prevailing wage, because unemployment is necessary to sustain the incentive not to shirk.

Building on this central idea, Silveira and Lima (2021) propose a novel efficiency wage model augmented with heterogeneous unemployment expectations. As this model serves as the foundation for wage-setting behavior in our framework, its structure will be presented in Subsection 2.1.

2.1. Efficiency wage setting with heterogeneous unemployment expectations

The unemployment expectation held by an individual worker and hence her effort performed on the job are not perfectly observed by an individual firm. Nevertheless, an individual worker cares about the possibility of being fired if she is perceived shirking. The resulting cost of job loss for a worker depends on the wage received in the current job and how likely she expects to be re-employed together with the expected alternative wage as determinants of the wage compensation associated with the expected labor market conditions. Drawing on Romer (2019), the worker's effort is specified as follows:

$$\varepsilon_\tau = \begin{cases} \left(\dfrac{w_\tau - \mu_\tau}{\mu_\tau}\right)^\gamma, & \text{for } w_\tau > \mu_\tau, \\ 0, & \text{otherwise,} \end{cases} \tag{1}$$

where ε_τ is the level of effort exerted by the worker of type $\tau = n, o, p$ (which stands for neutral, optimistic, and pessimistic, respectively); $w_\tau \in \mathbb{R}_{++}$ is the wage received by the worker of type $\tau = n, o, p$; μ_τ is an indicator of the wage compensation associated with the expected labor market conditions for a worker of type $\tau = n, o, p$; and the parameter $\gamma \in (0,1) \subset \mathbb{R}$ denotes the measure of the effort-enhancing effect of paying a worker of type $\tau = n, o, p$ a wage compensation that is higher than the wage compensation associated with her expected labor market conditions. The indicator μ_τ is given by:

$$\mu_\tau = (1 - u_\tau^e) w_{a,\tau}, \tag{2}$$

where $u_\tau^e \in (0,1) \subset \mathbb{R}$ is the unemployment rate expected by workers of type $\tau = n, o, p$ and $w_{a,\tau} \in \mathbb{R}_{++}$ is the alternative wage the worker of type $\tau = n, o, p$ would receive in the labor market had she been working for another employer (recall that an individual firm is unable to perfectly observe the unemployment expectation held by a given a worker).

In accordance with the survey data presented in Section 1, such as the one collected by the University of Michigan (see footnote 1), Silveira and Lima (2021) propose the following ordering of the unemployment expectation for each type $\tau = n, o, p$:

$$0 < u_o^e < (u_n^e = u) < u_p^e < 1, \tag{3}$$

where u is the current rate of unemployment.

Each firm is assumed to be small with respect to the economy, and therefore takes workers' expected cost of job loss as given. Moreover, firms are unable to perfectly detect both the type of each worker and her effort level. Thus, the firm will set a homogeneous wage, denoted by w, that minimizes the cost of labor per unit of average effort, denoted by ε. Similarly, the homogeneous wage w and the amount of labor, denoted by L, can be obtained as solution for the following maximization problem:

$$\max_{(w,L)} f(\varepsilon L) - wL, \;\; s.t. \;\; \varepsilon = \varepsilon_n^\eta \varepsilon_o^\theta \varepsilon_p^\rho, \tag{4}$$

where $f(\cdot)$ is a production function featuring $f'(\cdot) > 0$ and $f''(\cdot) < 0$, while ε is the average effort, defined as the weighted geometric mean of the effort levels exerted by workers of type $\tau = n, o, p$, with weights given by the proportions of worker who are neutral (η), optimistic (θ), and pessimistic (ρ). Note that the triple (η, θ, ρ), by construction, belongs to the simplex given by $\Sigma = \{(\eta, \theta, \rho) \in \mathbb{R}_+^3 : \eta + \theta + \rho = 1\}$. Assuming $w > \mu_\tau$, the first-order conditions for an interior solution are the following:

$$\begin{cases} f'(\varepsilon L)L\dfrac{\partial \varepsilon}{\partial w} - L = 0, \\ f'(\varepsilon L)\varepsilon - w = 0. \end{cases} \tag{5}$$

The first-order conditions in (5) can be rearranged to yield the so called Solow condition, as named by Akerlof and Yellen (1986), which states that the profit maximizing pair (w, L) implies a unitary wage-effort elasticity:

$$\frac{\partial \varepsilon}{\partial w}\frac{w}{\varepsilon} = 1. \tag{6}$$

Traditionally, firms face a trade-off between the additional revenue generated by hiring more workers and the higher costs associated with increased wage payments. However, since worker effort appears in the production function (4), and effort is influenced by wages as indicated in (1), the firm now encounters a second trade-off: whether to offer higher wages to employ fewer, more efficient workers, or to offer lower wages to hire more workers who exert less effort. The Solow condition in (6) states that the optimum choice is achieved when the wage-effort elasticity is equal to one.

Employing the definition of ε in (4), Silveira and Lima (2021) obtain what they dub the weighted Solow condition:

$$\eta\frac{\partial \varepsilon_n}{\partial w}\frac{w}{\varepsilon_n} + \theta\frac{\partial \varepsilon_o}{\partial w}\frac{w}{\varepsilon_o} + \rho\frac{\partial \varepsilon_p}{\partial w}\frac{w}{\varepsilon_p} = 1. \tag{7}$$

Thus, by observing the average effort ε and setting a uniform wage w in accordance with (6), the firm automatically fulfills the condition specified in (7).

2.2. *Temporary equilibrium*

The symmetric Nash equilibrium features all firms paying the wage w that satisfies the weighted Solow condition in (7), such that $w_{a,\tau} = w > \mu$ for each $\tau = n, o, p$. Consequently, the wage-effort elasticity for each type of unemployment expectation is given by γ/u^e_τ. Substituting this into the weighted Solow condition in (7) yields the following expression:

$$\gamma\left(\frac{\eta}{u^e_n} + \frac{\theta}{u^e_o} + \frac{\rho}{u^e_p}\right) = 1. \tag{8}$$

Silveira and Lima (2021) assume the following specific form for the well-defined ordering for the unemployment expectations of employed workers of type $\tau = n, o, p$:

$$u_\tau^e = \begin{cases} (1-\delta)u, & \text{for } \tau = o, \\ u, & \text{for } \tau = n, \\ (1+\delta)u, & \text{for } \tau = p, \end{cases} \tag{9}$$

where $\delta \in (0, 1-\gamma) \subset (0,1) \subset \mathbb{R}$ is a dispersion parameter. Since (8) represents the firm's optimality condition, it can be combined with (9) to derive the equilibrium unemployment rate, denoted by u^*, which is given by:

$$u^* = \gamma \left[1 + \left(\frac{\delta}{1-\delta} \right) \theta - \left(\frac{\delta}{1+\delta} \right) \rho \right] \equiv u^*(\theta, \rho, \delta) \in (0,1) \subset \mathbb{R}. \tag{10}$$

At the vertices of the simplex Σ, the equilibrium unemployment rates are given by $u^*|_{\theta=1} = \gamma/(1-\delta)$, $u^*\big|_{\eta=1} = \gamma$, and $u^*\big|_{\rho=1} = \gamma/(1+\delta)$, which establishes the following ordering: $u^*|_{\theta=1} > u^*\big|_{\eta=1} > u^*\big|_{\rho=1}$. In fact, the upper limit $1-\gamma$ of the parameter δ is derived from (10) as the condition ensuring that, even in the extreme case that $\theta = 1$, the equilibrium unemployment u^* remains below one. Moreover, using (9), we find that in equilibrium—and at each vertex of the simplex—the unemployment rate expectations converge to the same value: $u_o^e|_{\theta=1} = u_n^e\big|_{\eta=1} = u_p^e\big|_{\rho=1} = \gamma$. Therefore, among the three monomorphic states—situations in which all workers hold the same type of unemployment expectation (optimistic, neutral, or pessimistic)—the only case in which expectations are confirmed is when all workers hold neutral expectations.

3. Persistence of heterogeneity in unemployment expectations across workers as an evolutionary equilibrium

In light of the evidence on the persistence of heterogeneity in unemployment expectations reported in Section 1, it is reasonable to question whether workers' unemployment expectations—assumed to be exogenous in the short-run model presented by Silveira and Lima (2021) and briefly reviewed in Section 2 through some of its key elements—might, in fact, be endogenous. If individuals are assumed to tailor their expectations to specific decision-making needs based on the economic conditions they experience—following a process aimed at conserving mental resources—it is reasonable to presume that the unemployment conditions workers face influence their expectations about future changes in unemployment. Building on this view of expectation formation, the present paper introduces a dynamic model of workers' unemployment expectations, in which the temporary equilibrium is characterized by the model proposed by Silveira and Lima (2021). To this end, we propose a novel behavioral protocol that governs how workers revise—and possibly switch—their expectations in response to changes in the unemployment rate. As a result, expectations evolve according to an evolutionary dynamic that interacts with the macroeconomic environment (represented by the economy-wide unemployment rate), leading to a coevolution of the macrostate of the economy and the frequency distribution of unemployment expectations across employed workers.

We first demonstrate that no monomorphic microeconomic state—defined as a frequency distribution in which all workers share the same unemployment expectation—constitutes an equilibrium of the corresponding dynamic system. It follows that, if the system admits an equilibrium, it must be characterized by heterogeneity in unemployment expectations within the population of employed workers. Taking a step further, we demonstrate that, if the dynamic system has an equilibrium, it is fully polymorphic—that is, all three types of expectations are held within the population of employed workers. Moreover, we show that such a fully polymorphic equilibrium not only exists but is also unique and asymptotically stable.

3.1. An evolutionary dynamic of unemployment expectations

Let us consider a single-population game in which the agents correspond to the workers in the short-run equilibrium model proposed by Silveira and Lima (2021). Each agent chooses from a set of available strategies denoted by $S = \{o, n, p\}$, representing optimism, neutrality, and pessimism, respectively. Recalling that θ, η, and ρ are the proportions of optimistic, neutral, and pessimistic workers, respectively, the temporary equilibrium unemployment rate given by (10) is parameterized by the frequency distribution of unemployment expectations across workers—that is, by the microstate $(\theta, \eta, \rho) \in \Sigma$.

Since firms set a homogeneous wage and optimistic workers exert the least effort, they receive the highest wage per unit of effort. In this context, one might ask: why would a worker choose to exert a level of effort consistent with either a pessimistic or a neutral expectation of unemployment, given the resulting lower wage per unit of effort? The answer lies in the fact that workers do not determine their effort levels in order to maximize the wage per unit of effort. Rather, effort is a response to the wage offered by the firm, which itself reflects the expected cost of job loss. Because workers hold differing expectations about future unemployment—an observation supported by survey data—the cost of job loss is not the same for everyone. Therefore, the variation in effort reflects optimal responses to the same wage, given heterogeneous perceptions of job insecurity. This leads to the central question: why do workers hold different expectations about unemployment in the first place?

Although all workers face the same actual unemployment rate, some expectations will inevitably be more accurate than others. Given that accuracy is a primary goal in forming expectations, one might assume that workers with inaccurate beliefs would promptly revise them. However, accuracy is never absolute—it is bounded by a cost-benefit calculation. Ultimately, the accuracy of an expectation is not judged by its alignment with aggregate data, but by its usefulness in guiding the decision for which it was formed. As argued by Curtin (2021), it is not surprising that more timely decisions often maximize utility, even if greater accuracy could, in theory, be achieved by allocating more time or cognitive effort. From this perspective, it is reasonable to assume that individuals aim not to optimize but to achieve acceptable outcomes—that is, to seek a solution that yields a context-dependent acceptable level of satisfaction, even if it falls short of the optimal. In such situations, prioritizing acceptability over decimal-point precision is not irrational; rather, it reflects an efficient allocation of limited mental resources.

We specify the evolutionary microdynamic that shapes the distribution of unemployment expectations across workers by drawing on two key approaches from behavioral economics. The first is Herbert Simon's theory of satisficing behavior. According to Simon (1955, 1956), individual decision-making is inherently constrained by limited human capacities for information gathering and processing. As a result, individuals are unable to make optimal decisions based on complete information about all available alternatives. Instead, they rely on bounded rationality, using heuristics, rules of thumb, routines, conventions, and other satisficing procedures and criteria to guide their choices. Therefore, decision-making is a matter of achieving acceptable outcomes rather than selecting the optimal alternative from all possible options.[2] The second behavioral economics approach we draw upon is the concept of reference dependence, a central principle of prospect theory developed by Kahneman and Tversky (1979). In prospect theory, individuals evaluate outcomes involving risk and uncertainty relative to a reference point, rather than in absolute terms. The core insight is that people perceive and experi-

[2] Caplin and Dean (2011) and Hey et al. (2017) provide experimental evidence on satisficing choice behavior as originally defined by Simon (1955, 1956). Artinger et al. (2022) survey subsequent developments in the study of satisficing across economics, psychology, and management, building on Simon's foundational work.

ence outcomes in relation to a reference level.[3] By integrating elements from both this framework and the satisficing approach, our evolutionaty protocol for modeling expectation formation and switching assigns a central role to the concept of a *satisficing reference point*—a term we borrow from Schubert et al. (2018), though they apply it in a different context.

For example, if the actual unemployment rate exceeds a worker's expectation, this discrepancy may not necessarily be interpreted as an error requiring correction and may therefore not prompt a revision of expectations. However, once the difference becomes perceptible or salient in some meaningful way, it may draw conscious attention and lead to reassessment. Suppose each worker holds a *satisficing reference unemployment rate*, which serves as a benchmark for determining whether the actual unemployment rate warrants an expectation switch. If the actual unemployment rate is higher than the worker's expectation but still below the satisficing reference rate, it is perceived as not requiring an expectation switch. In this case, if the worker initially held an optimistic expectation, the gap is not sufficient to trigger a shift. Meanwhile, if the worker held a pessimistic expectation, the fact that the actual unemployment rate lies below the reference rate prompts an expectation switch to either neutrality or even optimism.

To formalize this line of reasoning, let us denote the satisficing reference unemployment rate of worker i by $u_i^\prime$ and assume that this reference rate is determined stochastically according to a cumulative distribution function $F : (0,1) \subset \mathbb{R} \longrightarrow [0,1] \subset \mathbb{R}$, which is continuously differentiable and strictly increasing. Accordingly, the probability that the short-run unemployment rate u^* in (10) exceeds $u_i^\prime$ (that is, the probability that u^* is perceived as—with some abuse of language—*unsatisficing* by worker i) is given by:

$$\text{Prob}(u_i^\prime \leq u^*) = F(u^*). \tag{11}$$

Similarly, the probability that the short-run unemployment rate u^* in (10) lower than $u_i^\prime$ (that is, the probability that u^* is perceived as *satisficing* by worker i) is

[3]Early evidence of such behavior comes from laboratory experiments conducted by Kahneman and Tversky (1979). These experiments have since been replicated and extended in various ways, alongside the development of a substantial theoretical literature aimed at modeling behavior based on reference dependence (see O'Donoghue and Sprenger (2018) for a review). More recent empirical evidence of reference dependence has been observed in contexts including, inter alia, the daily labor supply decisions of taxi drivers (Thakral and Tô (2021) and job search behavior (DellaVigna et al. (2017).

given by:

$$\text{Prob}(u_i' > u^*) = 1 - F(u^*). \tag{12}$$

If we assume that $F(u^*)$ is independent of the distribution of expectations within the population, then the proportion of optimistic workers in the subpopulation for whom the temporary equilibrium unemployment rate is perceived as unsatisficing is equal to the overall proportion of optimists in the population. Therefore, the share of optimistic workers who perceive the temporary equilibrium unemployment rate as unsatisficing is given by the product $\theta F(u^*)$. As discussed earlier, this represents the share of optimistic workers who will switch their expectations—either toward pessimism or neutrality. But to which type of expectation will they transition?

Since a shift from optimism to pessimism represents a more extreme change than a shift from optimism to neutrality—implying a greater adjustment in the provision of effort—it is reasonable to assume that such a transition involves higher perceived risks than a more moderate change to neutrality. Let us therefore assume that the probability a worker is willing to bear these risks is given by $\xi \in [0,1] \subset \mathbb{R}$, and that this probability is independent of both the distribution of expectations across workers and the probability that a worker perceives the temporary equilibrium unemployment rate as either satisficing or unsatisficing. Consequently, if $\xi \in (0, 0.5) \subset \mathbb{R}$, then the likelihood of moderate changes in expectations exceeds that of extreme changes. Similarly, if $\xi \in (0.5, 1) \subset \mathbb{R}$, then the probability of extreme changes in expectations is greater than that of moderate changes. Finally, if $\xi = 0.5$, then extreme and moderate changes are equiprobable. Although the situations we aim to describe are those in which both moderate and extreme changes are possible, it is instructive to consider the limiting cases where $\xi = 0$ (no possibility of extreme changes) and $\xi = 1$ (only extreme changes occur). Therefore, we retain these boundary cases as relevant points for further discussion.

The probabilities in (11) and (12) as well as ξ will perform a key role in the transition flows between expectation types occurring at the end of a given temporary equilibrium, which will result in the proportions of optimistic, neutral, and pessimistic workers featuring as predetermined variables in the next temporary equilibrium. The several transition flows between expectation types are represented diagramatically in Figure 3 and algebraically in Table 1. Per (11), the proportion of optimistic workers who become pessimistic is given by $\theta F(u^*)\xi$ (flow 6), while the proportion of optimistic workers transitioning to neutrality is given by $\theta F(u^*)(1-\xi)$ (flow 5). Similarly, per (12), the proportion of pessimists becoming optimistic or neutral is given by $\rho[1-F(u^*)]\xi$ (flow 4) and

$\rho[1-F(u^*)](1-\xi)$ (flow 3), respectively. Moreover, since neutral workers face no inherent asymmetry in the direction of expectation change—they may revise their expectations toward pessimism or optimism—their switching behavior is not influenced by the parameter ξ. Therefore, according to (12), the proportion of neutral workers transitioning to optimism is given by $\eta[1-F(u^*)]$ (flow 1), while (11) implies that the proportion becoming pessimistic is given by $\eta F(u^*)$ (flow 2).

Figure 3: Diagram of the flows between expectation types held by workers

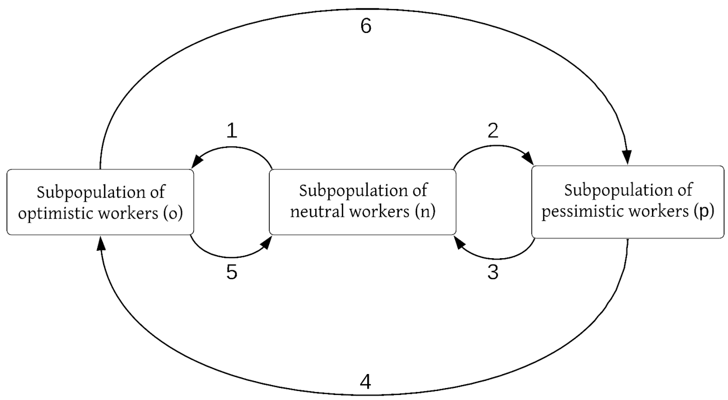


Table 1: Formal expressions of the flows between expectation types held by workers

Identification	**Transition flows between expectation types held by workers**
1	$\eta\left[1-F(u^*)\right]$
2	$\eta F(u^*)$
3	$\rho[1-F(u^*)](1-\xi)$
4	$\rho[1-F(u^*)]\xi$
5	$\theta F(u^*)(1-\xi)$
6	$\theta F(u^*)\xi$

Hence, the rate of change in the proportion of optimists at a given point in time—defined as the difference between the mass of workers transitioning to optimism (that is, the inflow to optimism) and the mass of workers ceasing to be optimists (that is, the outflow from optimism)—is given by:

$$\dot{\theta} = \eta \left[1 - F(u^*)\right] + \rho \left[1 - F(u^*)\right] \xi - \theta F(u^*) \tag{13}$$

Meanwhile, the rate of change in the proportion of pessimists at a given point in time—defined as the difference between the mass of workers transitioning to pessimism (that is, the inflow to pessimism) and the mass of workers ceasing to be pessimists (that is, the outflow from pessimism)—is given by:

$$\dot{\rho} = \eta F(u^*) + \theta F(u^*) \xi - \rho \left[1 - F(u^*)\right]. \tag{14}$$

Considering the temporary equilibrium unemployment rate in (10) and that $\eta = 1 - \theta - \rho$, after some algebraic simplifications in (13) and (14), we obtain the following evolutionary dynamical system:

$$\begin{cases} \dot{\theta} = \left[1 - (1-\xi)\rho\right] \left[1 - F\big(u^*(\theta, \rho, \delta)\big)\right] - \theta, \\ \dot{\rho} = \left[1 - (1-\xi)\theta\right] F\big(u^*(\theta, \rho, \delta)\big) - \rho. \end{cases} \tag{15}$$

The state space of the system in (15) is given by $\Theta = \{(\theta, \rho) \in \mathbb{R}^2_+ : \theta + \rho \leq 1\}$, which represents a projection of the simplex Σ.

3.2. Impossibility of homogeneous unemployment expectations

Let us show that no vertex of the state space Θ constitutes an evolutionary equilibrium of the dynamical system in (15). In other words, we will demonstrate that if the system begins in a microstate where all workers hold the same unemployment expectation (that is, a monomorphic microstate), then the resulting temporary equilibrium unemployment rate will induce an outflow of workers from that expectation type, causing the system to move away from the considered vertex.

Evaluating (15) at the microstate $(\theta, \rho) = (1, 0)$, which consists entirely of optimistic workers, yields:

$$\begin{cases} \dot{\theta}\,|_{\theta=1} = -F(u^*\,|_{\theta=1}), \\ \dot{\rho}\,|_{\theta=1} = F(u^*\,|_{\theta=1})\xi. \end{cases} \tag{16}$$

From (10), we have that $u^*\big|_{\theta=1} = u^*_{\max} = \gamma/(1-\delta)$. Since $F(u^*)$ is strictly increasing and maps into the interval $(0,1) \subset \mathbb{R}$, it follows that $F(u^*\,|_{\theta=1}) = F(u^*_{max}) > 0$. Hence, at the monomorphic microstate $(\theta, \rho) = (1, 0)$, where all workers are optimistic, there exists a positive mass of optimistic workers for whom the corresponding temporary equilibrium unemployment rate (given by $u^* |_{\theta=1}$) exceeds their individual satisficing threshold represented by u', thereby triggering a change in expectations. As a consequence, there will be a net outflow of optimists (that is, $\dot{\theta} < 0$), with a proportion ξ transitioning to pessimism and a proportion $1-\xi$ transitioning to neutrality. In the extreme case where $\xi = 0$, the system moves away from the vertex but remains along the boundary where $\rho = 0$, as illustrated in Panel (a) of Figure 4. However, as the share of optimists decreases and the share of neutrals increases, there will eventually be an outflow of neutral workers becoming pessimists, causing the system to move away from the boundary defined by $\rho = 0$.

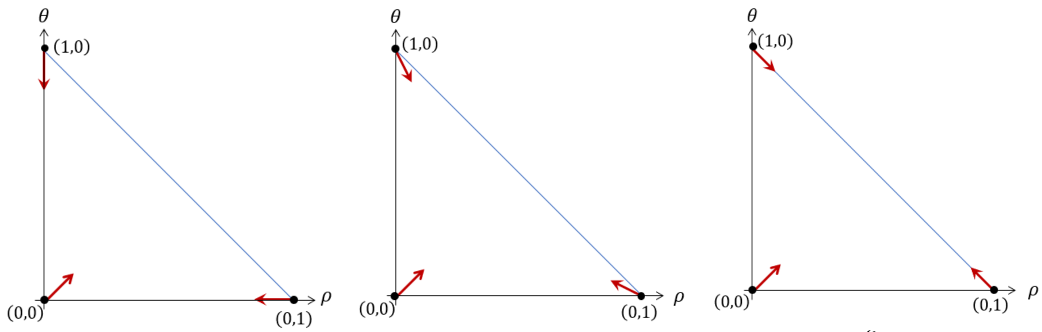
In the opposite extreme case where $\xi = 1$, the outcome is markedly different. Here, the system moves away from the vertex but remains along the boundary where $\eta = 0$, as illustrated in Panel (c) of Figure 4. Since $\xi = 1$ implies that neither pessimists nor optimists ever transition to neutrality, there is no inflow into the neutral group. As a result, the system evolves along the boundary where $\eta = 0$, without moving toward the interior of the state space. For the general case where $\xi \in (0,1) \subset \mathbb{R}$, the vector field generated by the evolutionary dynamics points toward the interior of the state space—away from both the vertex and any boundary—as illustrated in Panel (b) of Figure 4. In other words, the microstate $(\theta, \rho) = (1,0)$ is not an evolutionary equilibrium of the dynamical system described in (15).

Now, let us evaluate (15) at the microstate $(\theta, \rho) = (0,1)$, which consists entirely of pessimistic workers and yields:

$$\begin{cases} \dot{\theta} \,|_{\rho=1} = \left[1 - F(u^* \,|_{\rho=1})\right] \xi, \\ \dot{\rho} \,|_{\rho=1} = -\left[1 - F(u^* \,|_{\rho=1})\right]. \end{cases} \tag{17}$$

From (10), we have that $u^* \big|_{\rho=1} = u^*_{min} = \gamma/(1+\delta)$. Since $F(u^*)$ is strictly increasing and ranges between 0 and 1, $F(u^* \big|_{\rho=1}) = F(u^*_{min}) < 1$. Therefore, at the monomorphic microstate $(\theta, \rho) = (0,1)$, there will be a net outflow of pessimists (that is, $\dot{\rho} < 0$), with a fraction ξ switching to optimism and the remaining $1-\xi$ becoming neutral. The extreme cases where $\xi = 0$ or $\xi = 1$ generate dynamics analogous to those previously discussed for the case $\theta = 1$. Specifically, if $\xi = 0$, the system will initially move along the boundary where $\theta = 0$, but will eventually shift toward the interior of the state space, as shown in Panel (a) of Figure 4. Conversely, if $\xi = 1$, the system will evolve along the frontier where $\eta = 0$, as depicted

Figure 4: Vector field behavior at the vertices of the state space Θ for varying values of ξ.



(a) $\xi = 0$ (b) $\xi \in (0,1) \subset \mathbb{R}$ (c) $\xi = 1$

in Panel (c) of Figure 4. In other words, the microstate $(\theta,\rho) = (0,1)$ is not an evolutionary equilibrium of the dynamical system in (15) either. If $\xi \in (0,1) \subset \mathbb{R}$, then the vector field generated by the evolutionary dynamics will, once again, immediately point toward the interior of the state space, as illustrated in Panel (b) of Figure 4.

Finally, let us evaluate (15) at the monomorphic microstate $(\theta,\rho) = (0,0)$, which consists entirely of neutral workers, and obtain:

$$\begin{cases} \dot{\theta}\,\Big|_{\eta=1} = 1 - F(u^*\,\Big|_{\eta=1}), \\ \dot{\rho}\,\Big|_{\eta=1} = F(u^*\,\Big|_{\eta=1}). \end{cases} \tag{18}$$

From (10), we have that $u^*\,\Big|_{\eta=1} = \gamma$. Since $u^*_{min} < u^*\,\Big|_{\eta=1} < u^*_{max}$, it follows that $0 < F(u^*\,\Big|_{\eta=1}) < 1$. Therefore, at the monomorphic microstate$(\theta,\rho) = (0,0)$, there will be a net outflow of neutral workers, and the vector field generated by the evolutionary dynamics will immediately point toward the interior of the state space for all $\xi \in [0,1] \subset \mathbb{R}$, as illustrated in all panels of Figure 4. In other words, the microstate $(\theta,\rho) = (0,0)$ is not an evolutionary equilibrium of the dynamical system in (15) either.

In light of the results above, we can state the following proposition:

Proposition 1 (**Heterogeneity in unemployment expectations**). *The monomorphic microstates* $(1,0),(0,1)$ *and* $(0,0)$ *are not equilibria of the evolutionary dynamical system in* (15).

3.3. Evolutionary persistence of heterogeneity in unemployment expectations

Even though no evolutionary equilibrium will be a monomorphic microstate, as established in the Proposition 1, it is still possible for only one of the types of unemployment expectations to be extinguished. Let us show that this possibility actually does not exist. To do this, it is enough to show that no boundary points of the state space Θ can be evolutionary equilibria of the dynamical system described in (15). In other words, we will show that if the system begins in a microstate where one of the expectations is not held by any worker, then the resulting temporary equilibrium unemployment rate will induce an inflow of workers into that strategy. Consequently, the system will evolve toward fully polymorphic microstates—states in which all strategies are adopted by at least one worker.

Evaluating (15) at the boundary defined by $\Theta_1 = \{(\theta, \rho) \in \Theta : \theta = 0\}$ yields the dynamics of the system when no workers hold optimistic expectations:

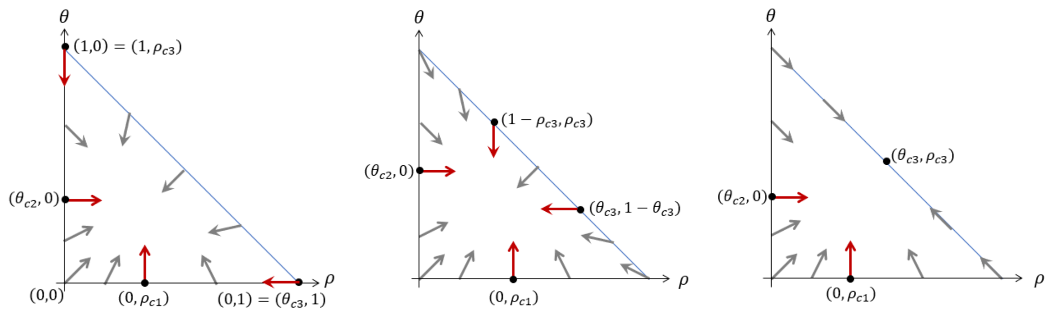
$$\begin{cases} \dot{\theta}\,|_{\theta=0} = \left[1-(1-\xi)\rho\right]\left[1-F(u^*\,|_{\theta=0})\right], \\ \dot{\rho}\,|_{\theta=0} = F(u^*\,|_{\theta=0}) - \rho. \end{cases} \tag{19}$$

From (10), we have that $u^*\big|_{\theta=0} = \gamma - \left[\frac{\gamma\delta}{1+\delta}\right]\rho$. Hence, $u^*_{\min} \leq u^*\big|_{\theta=0} \leq u^*\big|_{\eta=1}$, and, as a consequence, $F\left(u^*\big|_{\theta=0}\right) < 1$. Therefore, $\dot{\theta}\big|_{\theta=0}$ will be equal to zero—and the system will remain on the boundary Θ_1—only in the extreme case where both $\xi = 0$ and $\rho = 1$. However, as derived earlier, at this monomorphic microstate, the system would immediately evolve along the boundary defined by $\theta = 0$. As ρ decreases, θ would begin to increase, thereby moving the system away from the boundary. In the more general case where $\xi \in (0,1) \subset \mathbb{R}$, if the initial microstate describes a situation with both neutrals and pessimists but no optimists, the vector field will direct the system away from the frontier and toward the interior of the state space. In other words, no $(0,\rho) \in \Theta_1$ is an evolutionary equilibrium of the dynamical system in (15). But what about $\dot{\rho}$? At the monomorphic microstate $(\theta,\rho) = (0,0)$, we know that $\dot{\rho} > 0$. On the other hand, at the monomorphic microstate $(\theta,\rho) = (0,1)$, we know that $\dot{\rho} < 0$.[4] Because $u^*\big|_{\theta=0}$ is strictly decreasing in ρ, and $F(u^*\big|_{\theta=0})$ is strictly increasing in u^*, it follows that $F(u^*\big|_{\theta=0})$ is monotonically decreasing in ρ.[5] Thus, by the Intermediate Value Theorem, there

[4]Both results regarding the monomorphic microstates were discussed in the previous subsection.

[5]In fact, note that $\partial u^*\big|_{\theta=0}/\partial\rho = -\gamma\delta/(1+\delta) < 0$ for all $\gamma \in (0,1) \subset \mathbb{R}$ and $\delta \in (0,1-\gamma) \subset \mathbb{R}$.

Figure 5: Vector field behavior at the boundary of the state space Θ for different values of ξ (grey arrows represent auxiliary vectors).



(a) $\xi = 0$ (b) $\xi \in (0,1) \subset \mathbb{R}$ (c) $\xi = 1$

exists a unique critical point $(0, \rho_{c1})$ such that $F(u^*\big|_{\theta=0}) = \rho_{c1}$ and, consequently, $\dot{\rho} = 0$. Simple inspection shows that all points $(0,\rho) \in \Theta_1$ with $\rho > \rho_{c1}$ satisfy $\dot{\rho} < 0$, while all points with $\rho < \rho_{c1}$ satisfy $\dot{\rho} > 0$. This behavior is illustrated in all panels of Figure 5.

Now, if we evaluate (15) at the boundary given by $\Theta_2 = \{(\theta,\rho) \in \Theta : \rho = 0\}$, we have:

$$\begin{cases} \dot{\theta}\,\big|_{\rho=0} = \left[1 - F(u^*\,\big|_{\rho=0})\right] - \theta, \\ \dot{\rho}\,\big|_{\rho=0} = \left[1 - (1-\xi)\theta\right] F(u^*\,\big|_{\rho=0}). \end{cases} \tag{20}$$

From (10), we have that $u^*\big|_{\rho=0} = \gamma + \left[\frac{\gamma\delta}{1-\delta}\right]\theta$. Hence, $u^*\big|_{\eta=1} \leq u^*\big|_{\rho=0} \leq u^*_{\max}$ and, as a consequence, $F(u^*\big|_{\rho=0}) > 0$. It follows that, in the general case where $\xi \in (0,1) \subset \mathbb{R}$, if the initial microstate describes a situation with both neutrals and optimists but no pessimists, the vector field will move away from the boundary and toward the interior of the state space. In other words, no $(\theta, 0) \in \Theta_2$ is an evolutionary equilibrium of the dynamical system in (15). Following the same reasoning used earlier, we find that there exists a unique critical point $(\theta_{c2}, 0) \in \Theta_2$ such that $1 - F(u^*\big|_{\rho=0}) = \theta_{c2}$ and, therefore, $\dot{\theta} = 0$. Simple inspection reveals that all points $(\theta, 0) \in \Theta_2$ with $\theta > \theta_{c2}$ satisfy $\dot{\theta} < 0$, while all points with $\theta < \theta_{c2}$ satisfy $\dot{\theta} > 0$, as illustrated in all panels of Figure 5.

At last, if we evaluate (15) at the boundary given by $\Theta_3 = \{(\theta,\rho) \in \Theta : \theta + \rho = 1\}$, we have:

$$\begin{cases} \dot{\theta}\,\big|_{\eta=0} = \big[1-(1-\xi)(1-\theta)\big]\big[1-F(u^*\,\big|_{\eta=0})\big]-\theta, \\ \dot{\rho}\,\big|_{\eta=0} = \big[1-(1-\xi)(1-\rho)\big]F(u^*\,\big|_{\eta=0})-\rho, \end{cases} \tag{21}$$

alongside with:

$$\dot{\eta} = \theta F(u^*\,\big|_{\eta=0})(1-\xi)+\rho[1-F(u^*\,\big|_{\eta=0})](1-\xi). \tag{22}$$

By simple inspection, we conclude that $\dot{\eta}=0$ at all points on the boundary Θ_3 if $\xi=1$. Consequently, when $\xi=1$, the vector field will not move away from the boundary, and the system will never evolve toward a fully polymorphic microstate. The intuitive reasoning is straightforward: since $\xi=1$ means all pessimists switch directly to optimism (and vice versa), if the system starts in a microstate without neutrals, it will remain without any neutral workers.

For all $\xi \in [0,1) \subset \mathbb{R}$, we know from our previous discussion that $\dot{\eta}$ is positive at the vertices $(\theta,\rho)=(1,0)$ and $(\theta,\rho)=(0,1)$. Let us now analyze $\dot{\eta}$ at points other than these vertices for all $\xi \in [0,1) \subset \mathbb{R}$. Since:

$$u^*\,\big|_{\eta=0} = \gamma\left[1+\left(\frac{\delta}{1-\delta}\right)(1-\rho)-\left(\frac{\delta}{1+\delta}\right)\rho\right], \tag{23}$$

it then follows that $u^*_{\min} < u^*\big|_{\eta=0} < u^*_{\max}$ for all $(\theta,\rho)\in\Theta_3$ that are not vertices and, as a consequence, $0 < F(u^*\big|_{\eta=0}) < 1$. Therefore, both in the general case where $\xi \in (0,1) \subset \mathbb{R}$ and the extreme case where $\xi=0$, if the initial microstate describes a situation with both optimists and pessimists (outside the vertices), but no neutrals, the vector field will move away from the boundary and toward the interior of the state space. In other words, if $\xi \in [0,1) \subset \mathbb{R}$, then no $(\theta,\rho)\in\Theta_3$ is an evolutionary equilibrium of the dynamical system in (15). But what about $\dot{\theta}$ and $\dot{\rho}$? Let us first analyze the extreme cases of ξ before considering the general case where $\xi \in (0,1) \subset \mathbb{R}$.

If $\xi=1$, then the dynamical system in (21) becomes:

$$\begin{cases} \dot{\theta}\,\big|_{\eta=0} = (1-\theta)-F(u^*\,\big|_{\eta=0}), \\ \dot{\rho}\,\big|_{\eta=0} = F(u^*\,\big|_{\eta=0})-\rho. \end{cases} \tag{24}$$

Thus, if $\xi=1$, both $\dot{\theta}$ and $\dot{\rho}$ will be equal to zero at the point $(\theta_{c3}, 1-\theta_{c3}) = (1-\rho_{c3},\rho_{c3}) \in \Theta_3$, where $\rho_{c3}=F(u^*\big|_{\eta=0})$ and $\theta_{c3}=1-F(u^*\big|_{\eta=0})$. Therefore, in this extreme case, we have an evolutionary equilibrium on the boundary where $\eta = 0$. Simple inspection of (24) reveals that for any $(\theta, \rho) \in \Theta_3$ with $\rho > \rho_c$, we have $\dot{\theta} > 0$ and $\dot{\rho} < 0$. Similarly, for any $(\theta, \rho) \in \Theta_3$ with $\rho < \rho_c$, we have $\dot{\theta} < 0$ and $\dot{\rho} > 0$, as illustrated in panel (c) of Figure 5.

Now, let us consider the opposite extreme case where $\xi = 0$. The dynamical system in (15) becomes:

$$\begin{cases} \dot{\theta}\,\big|_{\eta=0} = -\theta F(u^*\,\big|_{\eta=0}), \\ \dot{\rho}\,\big|_{\eta=0} = -\rho\left[1 - F(u^*\,\big|_{\eta=0})\right]. \end{cases} \tag{25}$$

Since $\theta = 0$ implies $u^*\big|_{\eta=0} = u^*_{\text{min}}$ and, consequently, $F(u^*\big|_{\eta=0}) = F(u^*_{\text{min}}) = 0$, we have that $\dot{\theta} = 0$ on the boundary where $\eta = 0$ only at the vertex $(0, 1) \in \Theta_3$. For any pair $(\theta, \rho) \in \Theta_3$ such that $\theta < 1$, we have $\dot{\theta} < 0$. Conversely, since $\rho = 0$ implies $u^*\big|_{\eta=0} = u^*_{\text{max}}$ and therefore $F(u^*\big|_{\eta=0}) = F(u^*_{\text{max}}) = 1$, we have $\dot{\rho} = 0$ on the boundary where $\eta = 0$ only at the vertex $(\theta, \rho) = (1, 0) \in \Theta_3$. For any $(\theta, \rho) \in \Theta_3$ such that $\rho < 1$, we have $\dot{\rho} < 0$. This behavior is illustrated in Panel (a) of Figure 5.

Finally, let us consider the general case where $\xi \in (0, 1) \subset \mathbb{R}$. The dynamical system in (15) becomes:

$$\begin{cases} \dot{\theta}\,\big|_{\eta=0} = \left[1 - (1-\xi)\rho\right]\left[1 - F(u^*\,\big|_{\eta=0})\right] - (1-\rho), \\ \dot{\rho}\,\big|_{\eta=0} = \left[1 - (1-\xi)\theta\right] F(u^*\,\big|_{\eta=0}) - (1-\theta), \end{cases} \tag{26}$$

The condition for $\dot{\theta}\,\big|_{\eta=0} = 0$ is given by:

$$F(u^*\,\big|_{\eta=0}) = \frac{\xi(1-\theta)}{1 - (1-\xi)(1-\theta)}. \tag{27}$$

From (23), we know that $u^*\big|_{\eta=0}$ is strictly increasing in θ. Hence, the left-hand side of (27) is strictly increasing in θ. Conversely, the right-hand side of (27) is strictly decreasing in θ. Since $\dot{\theta} > 0$ at $(\theta, \rho) = (0, 1)$ and $\dot{\theta} < 0$ at $(\theta, \rho) = (1, 0)$, the Intermediate Value Theorem guarantees the existence of a unique critical point $(\theta_{c3}, 1 - \theta_{c3}) \in \Theta_3$ where $\dot{\theta} = 0$.

Similarly, the condition for $\dot{\rho}\,\big|_{\eta=0} = 0$ is given by:

$$F(u^*\,\big|_{\eta=0}) = \frac{\rho}{1 - (1-\xi)(1-\rho)}. \tag{28}$$

From (23), we know that $u^*\big|_{\eta=0}$ is strictly decreasing in ρ. Hence, the left-hand side of (28) is strictly decreasing in ρ. Conversely, the right-hand side of (28) is strictly increasing in ρ. Since $\dot{\rho} > 0$ at $(\theta,\rho) = (1,0)$ and $\dot{\rho} < 0$ at $(\theta,\rho) = (0,1)$, the Intermediate Value Theorem ensures the existence of a unique critical point $(1-\rho_{c3},\rho_{c3}) \in \Theta_3$ such that $\dot{\rho} = 0$. Both critical points are illustrated in panel (b) of Figure 5.

In summary, when $\xi = 0$, the critical points occur at $(\theta,\rho_{c3}) = (0,1)$ and $(\theta_{c3},\rho) = (1,0)$. As ξ increases, both ρ_{c3} and θ_{c3} decrease. Finally, as ξ approaches 1, we have $\rho_{c3} \to (1-\theta_{c3})$ and $\theta_{c3} \to (1-\rho_{c3})$.

In light of the results above, we can state the following proposition:

Proposition 2 (Partial heterogeneity in unemployment expectations). *The evolutionary dynamics described by* (15) *has an evolutionary equilibrium featuring coexistence of both optimistic and pessimistic unemployment expectations only in the particular case in which the economy begins without neutral workers (*$\eta = 1$*) and all workers only make extreme expectation switches (*$\xi = 1$*).*

It follows from Proposition 2 that, if $\xi \in (0,1) \subset \mathbb{R}$, then the vector field points toward the interior of the state space. However, this alone does not imply that the system will converge to an evolutionary equilibrium in the interior. For instance, the trajectory could be cyclical or even chaotic. Now that we have established that no evolutionary equilibrium exists on the boundary of the state space, we turn to proving that there exists an interior evolutionary equilibrium—corresponding to a fully polymorphic microstate—which is both unique and asymptotically stable.

Let $\left(\overline{\theta},\overline{\rho}\right) \in \Theta$ be the pair such that $\dot{\theta} = \dot{\rho} = 0$, and let $u^*\left(\overline{\theta},\overline{\rho}\right) = \overline{u}$. Then, the dynamical system in (15) becomes:

$$\begin{cases} \left[1-(1-\xi)\overline{\rho}\right]\left[1-F(\overline{u})\right] - \overline{\theta} = 0, \\ \left[1-(1-\xi)\overline{\theta}\right]F(\overline{u}) - \overline{\rho} = 0. \end{cases} \tag{29}$$

From the first equation of the system in (29), we have:

$$1 - F(\overline{u}) = \frac{\overline{\theta}}{1-(1-\xi)\overline{\rho}}, \tag{30}$$

and from the second equation of the system in (29), we have:

$$F(\overline{u}) = \frac{\overline{\rho}}{1-(1-\xi)\overline{\theta}}. \tag{31}$$

Thus, the pair $\left(\overline{\theta},\overline{\rho}\right)$ is an evolutionary equilibrium of the dynamical system in (15) if and only if it satisfies both (30) and (31) simultaneously.

Proposition 3 (Existence and uniqueness of a full polymorphic evolutionary equilibrium). *The evolutionary dynamics described by* (15) *features a unique equilibrium* $\left(\overline{\theta},\overline{\rho}\right)\in\Theta$*, which is a full polymorphic evolutionary one, that is, an evolutionary equilibrium characterized by* $\overline{\theta}>0,\overline{\rho}>0$ *and* $\overline{\theta}+\overline{\rho}<1$.

***Proof*.** See Appendix A.

Having established the existence and uniqueness of the evolutionary equilibrium $\left(\overline{\theta},\overline{\rho}\right)$, and that this equilibrium is fully polymorphic for the general case where $\xi\in(0,1)\subset\mathbb{R}$, we now turn to the analysis of its stability. Since (15) is a nonlinear system, we analyze local stability using a first-order (linear) approximation. Specifically, the evolutionary equilibrium $\left(\overline{\theta},\overline{\rho}\right)$ will be asymptotically stable in the linearized system if the eigenvalues of the Jacobian matrix evaluated at the equilibrium have negative real parts. If this condition is satisfied, the Hartman–Grobman Theorem implies that $\left(\overline{\theta},\overline{\rho}\right)$ is a locally asymptotically stable equilibrium of the original nonlinear dynamical system in (15). This leads to the following proposition:

Proposition 4 (Stability). *The unique full polymorphic evolutionary equilibrium* $\left(\overline{\theta},\overline{\rho}\right)\in\Theta$ *is locally asymptotically stable for any* $\xi\in(0,1)\subset\mathbb{R}$.

***Proof*.** See Appendix B.

Therefore, the model developed in this paper implies the existence of a fully polymorphic evolutionary equilibrium of the dynamical system in (15) that is both unique and locally asymptotically stable. In other words, the model predicts that full heterogeneity in workers' unemployment expectations constitutes a stable evolutionary equilibrium configuration—an outcome consistent with the empirical evidence presented in Section 1, which shows that heterogeneity in unemployment expectations across workers is persistent, with all types of expectations being held by workers, as illustrated by Figure 1. In fact, the novel complementary evidence provided in Appendix C warrants the conclusion that the frequency distribution of unemployment expectations remains roughly constant—or stationary and thus trendless—over long stretches of time, as suggested by Figure 2 and rationalized by the main result of this paper.

4. Concluding remarks

This paper is motivated by substantial survey evidence of enduring heterogeneity in workers' unemployment expectations, alongside econometric and experimental findings indicating that labor productivity is endogenous to the wage compensation offered by employers, with higher compensation functioning as a mechanism that enhances productivity. These two strands of evidence are treated as causally linked, based on the plausible premise that the perceived risk of job displacement—and the corresponding effort exerted on the job—are likewise heterogeneous across the workforce.

The paper develops a novel evolutionary microdynamic of expectation formation and switching, embedded in a heterogeneous expectations-augmented efficiency wage modeling of the labor market. This evolutionary microdynamic builds upon two foundational contributions to behavioral economics: Herbert Simon's concept of satisficing choice behavior and the theory of reference-dependent choice introduced by Daniel Kahneman and Amos Tversky. Central to the evolutionary protocol governing expectation formation and switching is the key notion of a satisficing reference point.

The distribution of unemployment expectations—and, by extension, of effort levels on the job—across employed workers evolves endogenously over time, shaped by an evolutionary protocol grounded in the idea of satisficing reference dependence, and co-evolves with the aggregate unemployment rate. The model exhibits a fully polymorphic evolutionary equilibrium that is both unique and locally asymptotically stable, consistent with the novel motivating evidence offered in this paper that the frequency distribution of unemployment expectations across workers is stationary over extended time horizons.

Appendix A. Existence and uniqueness of a fully polymorphic evolutionary equilibrium

Existence: If we isolate $F(\overline{u})$ in (30) and equate it to the expression in (31), we obtain the following equation:

$$\frac{\overline{\rho}}{1-(1-\xi)\overline{\theta}} = \frac{1-(1-\xi)\overline{\rho}-\overline{\theta}}{1-(1-\xi)\overline{\rho}}. \tag{A.1}$$

Rearranging the terms yields the following quadratic equation in $\overline{\rho}$:

$$(1-\xi)\overline{\rho}^2 - \overline{\rho}\left[(2-\xi)-(1-\xi)^2\overline{\theta}\right] + \overline{\theta}^2(1-\xi) - \overline{\theta}(2-\xi) + 1 = 0, \tag{A.2}$$

the solution of which is:

$$\overline{\rho}(\overline{\theta};\xi) \equiv \frac{(2-\xi)-(1-\xi)^2\overline{\theta}-\sqrt{\left[(2-\xi)-(1-\xi)^2\overline{\theta}\right]^2-4(1-\xi)\left[(1-\xi)\overline{\theta}^2-(2-\xi)\overline{\theta}+1\right]}}{2(1-\xi)}, \tag{A.3}$$

which is well defined for all $\xi \in (0,1) \subset \mathbb{R}$.[6]

Let us define the following expression by substituting both $\overline{\theta}$ and $\overline{\rho}(\overline{\theta};\xi)$ into equation (10):

$$\overline{u}(\overline{\theta};\xi) \equiv \gamma\left[1+\left(\frac{\delta}{1-\delta}\right)\overline{\theta}-\left(\frac{\delta}{1+\delta}\right)\overline{\rho}(\overline{\theta};\xi)\right]. \tag{A.4}$$

Therefore, substituting $\overline{\rho}(\overline{\theta};\xi)$ into either (30) or (31) yields the following condition:

$$F\left(\overline{u}(\overline{\theta};\xi)\right) = \frac{\overline{\rho}(\overline{\theta};\xi)}{1-(1-\xi)\overline{\theta}}. \tag{A.5}$$

It follows that all that remains to be shown is that there exists some $\overline{\theta} \in (0,1) \subset \mathbb{R}$ that solves equation (A.5) for some feasible value of the parameter ξ. To this end, let us consider the following function:

$$\varphi(\overline{\theta};\xi) = F\left(\overline{u}(\overline{\theta};\xi)\right) - g(\overline{\theta};\xi), \tag{A.6}$$

where $g(\overline{\theta};\xi)$ denotes the right-hand side of (A.5). Consequently, if there exists some $\overline{\theta} \in (0,1) \subset \mathbb{R}$ such that $\varphi(\overline{\theta};\xi) = 0$ for feasible values of ξ, then condition (A.5) is satisfied, and the pair $\left(\overline{\theta},\overline{\rho}\right)$ constitutes an evolutionary equilibrium of the dynamical system in (15).

First, note that:

$$\overline{\rho}(0;\xi) = \frac{2-\xi-\sqrt{(2-\xi)^2-4(1-\xi)}}{2(1-\xi)} = 1. \tag{A.7}$$

Thus, $g(0;\xi) = 1$ for all $\xi \in (0,1) \subset \mathbb{R}$. Since $\overline{u}(0;\xi) = \gamma/(1+\delta)$, it follows that $F\left(\overline{u}(0;\xi)\right) < 1$, and consequently, $\varphi(0;\xi) < 0$ for all $\xi \in (0,1) \subset \mathbb{R}$. Now,

[6] The solution corresponding to the addition of the square root term in (A.3) leads to values outside the simplex and must therefore be excluded.

note that:

$$\overline{\rho}(1;\xi) = \frac{1+\xi-\xi^2-\sqrt{(1+\xi-\xi^2)^2}}{2(1-\xi)} = 0. \tag{A.8}$$

It then follows that $g(1;\xi) = 0$ for all $\xi \in (0,1) \subset \mathbb{R}$. Since $\overline{u}(1;\xi) = \gamma/(1-\delta)$, we have $F\big(\overline{u}(1;\xi)\big) > 0$, and consequently, $\varphi(1;\xi) > 0$ for all $\xi \in (0,1) \subset \mathbb{R}$. Therefore, since $\varphi(\overline{\theta};\xi)$ is continuous on its entire domain, the Intermediate Value Theorem implies that there exists some $\overline{\theta} \in (0,1) \subset \mathbb{R}$ such that $\varphi(\overline{\theta};\xi) = 0$, which completes the proof.

Uniqueness: To prove that $\big(\overline{\theta},\overline{\rho}\big)$ is the unique evolutionary equilibrium, it suffices to show that there is one, and only one, $\overline{\theta}$ such that $\varphi(\overline{\theta};\xi) = 0$. Since $\varphi(\overline{\theta};\xi)$ is continuous over its entire domain, with $\varphi(0;\xi) < 0$ and $\varphi(1;\xi) > 0$, uniqueness will hold if $\varphi(\overline{\theta};\xi)$ is strictly monotonically increasing; that is, if $\frac{\partial \varphi(\overline{\theta};\xi)}{\partial \overline{\theta}} > 0$ for all $\xi \in (0,1) \subset \mathbb{R}$.

Given that:

$$\frac{\partial \varphi(\overline{\theta};\xi)}{\partial \overline{\theta}} = F'(\overline{u})\frac{\partial \overline{u}(\overline{\theta};\xi)}{\partial \overline{\theta}} - \frac{\partial g(\overline{\theta};\xi)}{\partial \overline{\theta}}, \tag{A.9}$$

let us analyse each term on the right-hand side of (A.9) separately. Since $F'(\overline{u}) > 0$ by definition and

$$\frac{\partial \overline{u}(\overline{\theta};\xi)}{\partial \overline{\theta}} = \gamma\left[\left(\frac{\delta}{1-\delta}\right) - \left(\frac{\delta}{1+\delta}\right)\frac{\partial \overline{\rho}(\overline{\theta};\xi)}{\partial \overline{\theta}}\right], \tag{A.10}$$

we conclude that the first term on the right-hand side of (A.9) will be positive if, and only if, $\partial \overline{\rho}(\overline{\theta};\xi)/\partial \overline{\theta} < 0$. Evaluating this partial derivative using the `Reduce[]` command from Wolfram Mathematica, we find that $\partial \overline{\rho}(\overline{\theta};\xi)/\partial \overline{\theta} < 0$ for all $\overline{\theta} \in (0,1) \subset \mathbb{R}$ and $\xi \in (0,1) \subset \mathbb{R}$. Therefore, the first term on the right-hand side of (A.9) is positive.

Meanwhile, if we apply the same procedure to the second term on the right-hand side of (A.9)—that is, calculate the partial derivative of $g(\overline{\theta};\xi)$ with respect to $\overline{\theta}$ and evaluate it using the `Reduce[]` command in Wolfram Mathematica—we find that this partial derivative is strictly negative for all $\overline{\theta} \in (0,1) \subset \mathbb{R}$ and $\xi \in (0,1) \subset \mathbb{R}$. It follows that the second term on the right-hand side of (A.9) is also positive. Consequently, we have shown that $\varphi(\overline{\theta};\xi)$ is strictly monotonically increasing; that is, $\frac{\partial \varphi(\overline{\theta};\xi)}{\partial \overline{\theta}} > 0$ for all $\overline{\theta} \in (0,1) \subset \mathbb{R}$ and $\xi \in (0,1) \subset \mathbb{R}$. It follows that the second term on the right-hand side of (A.9) will also be positive. As a consequence, we have proved that $\varphi(\overline{\theta};\xi)$ is strictly monotonically increasing (that is, $\partial\varphi(\overline{\theta};\xi)/\partial\overline{\theta} > 0$ for all values of $\overline{\theta} \in (0,1) \subset \mathbb{R}$ and $\xi \in (0,1) \subset \mathbb{R}$). We can then finally conclude that the evolutionary equilibrium $\left(\overline{\theta},\overline{\rho}\right)$ not only exists and is fully polymorphic, but it is also unique, which was to be demonstrated.

Appendix B. Global stability of the fully polymorphic evolutionary equilibrium

The partial derivatives of the Jacobian matrix, denoted by $J(\theta,\rho)$, of the dynamical system in (15), evaluated at any point $(\theta,\rho) \in \Theta$, are given by:

$$\frac{\partial\dot{\theta}}{\partial\theta} = -\left[1-(1-\xi)\rho\right]F'(u^*)\left(\frac{\gamma\delta}{1-\delta}\right) - 1 < 0, \tag{B.1}$$

$$\frac{\partial\dot{\theta}}{\partial\rho} = -(1-\xi)\left[1-F(u^*)\right] + \left[1-(1-\xi)\rho\right]F'(u^*)\left(\frac{\gamma\delta}{1+\delta}\right), \tag{B.2}$$

$$\frac{\partial\dot{\rho}}{\partial\theta} = -(1-\xi)F(u^*) + \left[1-(1-\xi)\theta\right]F'(u^*)\left(\frac{\gamma\delta}{1-\delta}\right), \tag{B.3}$$

$$\frac{\partial\dot{\rho}}{\partial\rho} = -\left[1-(1-\xi)\theta\right]F'(u^*)\left(\frac{\gamma\delta}{1+\delta}\right) - 1 < 0. \tag{B.4}$$

Note that the partial derivatives in (B.1) and (B.4) are strictly negative for any microstate $(\theta,\rho) \in \Theta$ because $\gamma \in (0,1) \subset \mathbb{R}$, $\delta \in (0,1-\gamma) \subset (0,1) \subset \mathbb{R}$, $\xi \in [0,1] \subset \mathbb{R}$, and $F'(u^*) > 0$ for any u^* defined in (10). As a result, we are able to conclude that:

$$\mathrm{tr}J(\theta,\rho) = \frac{\partial\dot{\theta}}{\partial\theta} + \frac{\partial\dot{\rho}}{\partial\rho} < 0, \text{for all } (\theta,\rho) \in \Theta, \tag{B.5}$$

and

$$\frac{\partial\dot{\theta}}{\partial\theta}\frac{\partial\dot{\rho}}{\partial\rho} > 0, \text{for all } (\theta,\rho) \in \Theta, \tag{B.6}$$

Meanwhile, the determinant of Jacobian matrix, evaluated at any point $(\theta,\rho) \in \Theta$, is strictly positive, that is:

$$\begin{aligned}\det(J(\theta,\rho)) = \;& F'(u^*)\gamma\delta\left\{\tfrac{1-(1-\xi)\theta}{1+\delta} + \tfrac{1-(1-\xi)\rho}{1-\delta} + (1-\xi)F(u^*)\tfrac{[1-(1-\xi)\overline{\rho}]}{1+\delta}\right.\\ &\left. +(1-\xi)[1-F(u^*)]\tfrac{[1-(1-\xi)\theta]}{1-\delta}\right\}\\ & -(1-\xi)^2F(u^*)\left[1-F(u^*)\right] + 1 > 0.\end{aligned} \tag{B.7}$$

Recalling that $\gamma \in (0,1) \subset \mathbb{R}$, $\delta \in (0,1-\gamma) \subset (0,1) \subset \mathbb{R}$, $\xi \in [0,1] \subset \mathbb{R}$, $F(u^*) \in [0,1] \subset \mathbb{R}$, and $F'(u^*) > 0$ for any u^* defined in (10), we know that the term inside the curly brackets in (B.7) is strictly positive, as well as the multiplying factor $F'(u^*)\gamma\delta$, and $0 \leq (1-\xi)^2 F(u^*)\left[1-F(u^*)\right] < 1$, such that the determinant in (B.7) is, in fact, strictly positive.

Considering the conditions (B.5), (B.6), and (B.7), we can conclude, based on Theorem 3 in Olech (1963), that the fully polymorphic equilibrium $\left(\overline{\theta},\overline{\rho}\right) \in \Theta$ is globally asymptotically stable.

Appendix C. Evidence on the stationarity of unemployment expectations in the U.S. Michigan Survey of Consumers

This appendix provides motivating and complementary evidence on the time-series properties of households' unemployment expectations, as leveraged from the U.S. Michigan Survey of Consumers and displayed in Figure 2 in the text. These properties indicate that such expectations are largely stationary in the long run, fluctuating around an equilibrium level rather than following a deterministic trend.

The novel evidence reported below corroborates the main analytical result of the model set forth in this paper. Namely, the existence of a fully polymorphic evolutionary equilibrium—where all types of expectations (optimistic, pessimistic, and neutral) coexist—that is both unique and locally asymptotically stable, implying that the frequency distribution of workers' unemployment expectations is largely trendless over long stretches of time.

We performed stationarity tests for the workers' unemployment expectations provided by the U.S. Michigan Survey of Consumers. As an additional robustness check, we decomposed each series into unobserved components, in order to verify whether any series has any time-varying trend. All econometric estimations were performed in Python using the statsmodels package (Seabold and Perktold, 2010), version 0.15.0.

Stationarity was assessed using two complementary procedures: the Dickey and Fuller (1979) (ADF) test, which evaluates the null hypothesis of a unit root (non-stationarity), and the Kwiatkowski et al. (1992) (KPSS) test, which evaluates the null of stationarity. Tests were applied to the series in levels. All specifications included an intercept whenever it was statistically significant. The results, shown in Table C.2, indicate that the ADF null is rejected, implying that all series are stationary. The KPSS null, in turn, is not rejected for either the pessimistic or optimistic series (also implying stationarity), but it is rejected for the neutral expectations series. Overall, this novel evidence suggests that pessimistic and optimistic expectations behave as stationary processes—their means and variances remain stable over time—and shocks tend to dissipate rather than persist. Nevertheless, the evidence for the neutral expectations series is mixed, as the respective tests yield opposite conclusions, indicating that the stationarity implied by the ADF test should be interpreted with caution.

Table C.2: Unit root and stationarity tests for unemployment expectations

	ADF Test		KPSS Test	
	Statistic	5% Crit. Value	Statistic	5% Crit. Value
Pessimistic	−5.398	−2.867	0.212	0.463
Neutral	−4.271	−2.867	0.792	0.463
Optimistic	−3.762	−2.867	0.242	0.463

Notes: Lag length for ADF selected by Akaike Information Criterion (AIC) and for KPSS is calculated using the data-dependent method of Hobijn et al. (2004).

To further improve our analysis, we estimated an Unobserved Components Model (UCM) following Harvey and Jaeger (1993) to decompose each series y_t into four components:

$$y_t = \mu_t + \gamma_t + c_t + \varepsilon_t, \tag{C.1}$$

where μ_t denotes the trend, γ_t the stochastic seasonal component, c_t the stochastic cyclical component, and ε_t the irregular component.[7] The trend component is modeled as a smooth trend (or integrated random walk), represented by equations (C.2) and (C.3) below. In this specification, the first difference of the trend—its slope—is given by ν_t, which is time-varying whenever σ^2_ζ is statistically different from zero. Thus, we only need to verify that ν_t is statistically different from zero for all t.

$$\mu_{t+1} = \mu_t + \nu_t, \tag{C.2}$$

$$\nu_{t+1} = \nu_t + \zeta_{t+1}, \qquad \zeta_{t+1} \sim N(0, \sigma^2_\zeta). \tag{C.3}$$

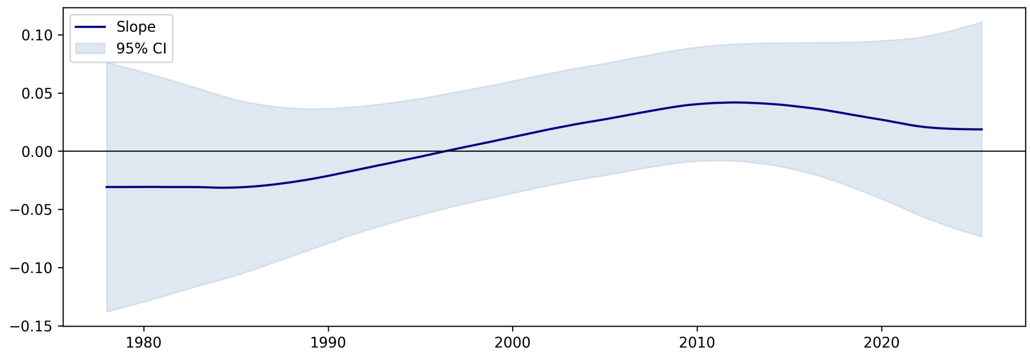
The model was estimated by maximum likelihood using the two-sided Kalman

[7]The cyclical component has a damping factor between 0 and 1.

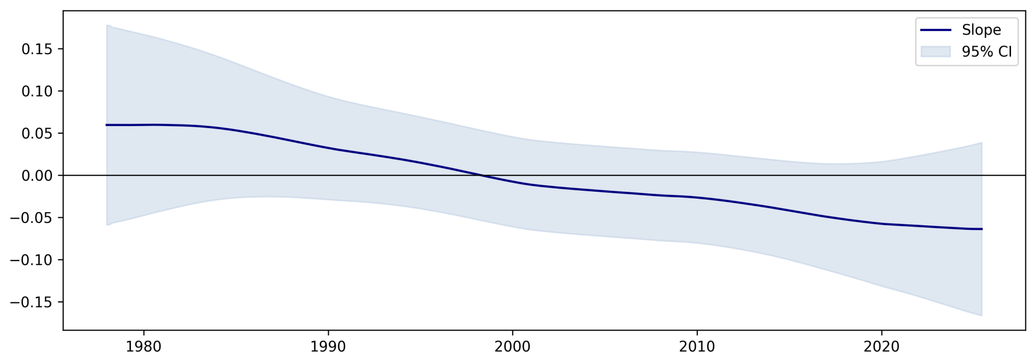
filter (Kalman smoother). As shown in panels C.6a and C.6b, both the optimistic and neutral series display trends that are statistically time-invariant (i.e., their slopes are statistically zero), meaning that these series fluctuate around relatively constant values. The pessimistic series, in turn, exhibits periods of statistically negative slope (between May 1980 and May 1983) and positive slope (between April 2022 and April 2024), as shown in panel C.6c. Although these patterns may partly reflect end-of-sample bias or diffuse initialization, the trend of the pessimistic series remains largely constant over time.

These additional findings are consistent with the ADF and KPSS tests, supporting the interpretation that unemployment expectations in the U.S. Michigan Survey of Consumers do not exhibit a persistent deterministic trend and can therefore be treated as stationary processes. Accordingly, the key analytical result derived in this paper—the existence of a fully polymorphic evolutionary equilibrium in which optimistic, pessimistic, and neutral expectations coexist, and that is both unique and locally asymptotically stable—provides a plausible rationalization for the observed evidence that these expectations fluctuate around a steady-state level.

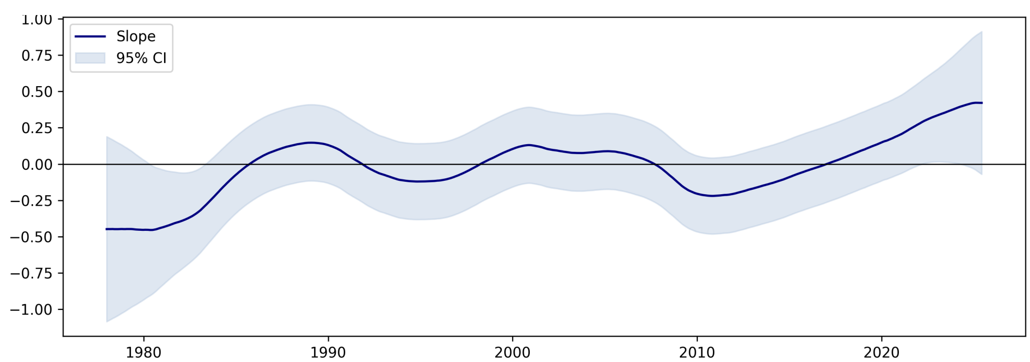
Figure C.6: Slope component of each workers' expectation's trend.



(a) Optimistic expectations.



(b) Neutral expectations.



(c) Pessimistic expectations.

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