Estimating Individual Responses When Tomorrow Matters

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Dynamic Structural Econometrics Summer School

UCL, July 2025

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Dynamic counterfactuals

• Economists are often interested in assessing the effect of a change in the economic environment on individual decisions.

• In dynamic settings, this involves two margins: a contemporaneous change and a change in expectations.

• We introduce *average partial effects* (APE) that account for the joint impact of contemporaneous factors and beliefs.

• We provide conditions under which these APE can be structurally interpreted as counterfactual effects.

• This approach allows us to study dynamic counterfactuals without the need for fully specifying and estimating a structural model.

Application: income, consumption, and income expectations

• Using a standard incomplete markets model as motivation, we focus on a consumption decision rule of the form

$$Consumption_{it} = \phi_i \left(Income_{it}, IncomeBeliefs_{it}, OtherFactors_{it} \right).$$

• We study the impact of a *tax*, which affects consumption through two channels: current income $Income_{it}$, and beliefs about future income $IncomeBeliefs_{it}$.

• Empirically, we make use of subjective expectations data to learn about the individuals' beliefs.

Related literature

• Our approach differs from reduced-form methods that assume the decision rule is invariant under the counterfactual (e.g., Stock, 1989).

• We also differ from structural approaches since we do not specify or estimate a full structural model; e.g., Marschak (1953), Ichimura and Taber (1999, 2002), Keane and Wolpin (2002a,b), Wolpin (2013).

• Structural approaches using beliefs data include Delavande (2008), Van der Klaauw (2012), Wiswall and Zafar (2015), Arcidiacono *et al.* (2020), Attanasio *et al.* (2020), and many others in this conference! Here we focus on expectations about states of nature, not hypothetical choices (Manski, 2004).

• Empirical regressions of outcomes on elicited beliefs are common (e.g., Guiso and Parigui, 1999, Pistaferri, 2001, Dominitz and Manski, 2007, Lochner, 2007).

Outline of the talk

- Average partial effects in dynamic settings
- Structural interpretation
- Example: consumption and (expected) income
- Estimating average partial effects
- Empirical application
- Conclusion

Average partial effects
in dynamic settings

The static case

- Consider an individual outcome y_{it} that depends on some covariates x_{it} and z_{it}.

- Suppose that, for some function g_i,

$$y_{it} = g_i(x_{it}, z_{it}) + \varepsilon_{it},$$

where ε_{it} has zero mean given x_{it} and z_{it}.

- Consider an exogenous change in x_{it}, from $x_{it} = x$ to some other value $x_{it} = x^{(\delta)}$. A standard (static) average partial effect associated with the change in x_{it} is

$$\Delta^{\mathsf{SAPE}}(\delta) = \mathbb{E}\left[g_i(x^{(\delta)}, z) - g_i(x, z)\right].$$

Limitation of the static case

• However, to interpret Δ^{SAPE} as the average change in outcomes when x_{it} changes from x to $x^{(\delta)}$, one needs to assume that the functions g_i remain constant.

• This invariance assumption is often implausible in applications where dynamics matter.

• Indeed, in many settings where the current value of x_{it} changes, beliefs about future x_{it}'s (which are implicitly contained in g_i) are likely to change as well.

• For example, under a tax, both current income and beliefs about future income are generally affected.

Our approach

- Our approach to alleviate this well-known issue is to include beliefs about future x_{it} values as additional determinants of y_{it}.

- Letting π_{it} denote the subjective distribution of $x_{i,t+1}$ at time t, we postulate that, for some function ϕ_i,

$$y_{it} = \phi_i(x_{it}, \pi_{it}, z_{it}) + \varepsilon_{it},$$

where ε_{it} has zero mean given x_{it}, π_{it} and z_{it}.

- We wish to document the effects of a change from $x_{it} = x$ to $x_{it} = x^{(\delta)}$, associated with a change in beliefs from $\pi_{it} = \pi$ to $\pi_{it} = \pi^{(\delta)}$.

- Such a joint change has two distinct effects on outcomes: a contemporaneous one, and a dynamic one associated with the change in beliefs.

Dynamic APE

- We define the total average partial effect, or TAPE, as

$$\Delta^{\mathsf{TAPE}}(\delta) = \mathbb{E}\left[\phi_i(x^{(\delta)}, \pi^{(\delta)}, z) - \phi_i(x, \pi, z)\right].$$

- We then decompose the TAPE as the sum of two terms: a contemporaneous APE, where beliefs are held constant, and a dynamic APE, which solely captures the change in beliefs.

- Formally, we decompose

$$\Delta^{\mathsf{TAPE}}(\delta) = \underbrace{\mathbb{E}\left[\phi_i(x^{(\delta)}, \pi, z) - \phi_i(x, \pi, z)\right]}_{\text{Contemporaneous}} + \underbrace{\mathbb{E}\left[\phi_i(x^{(\delta)}, \pi^{(\delta)}, z) - \phi_i(x^{(\delta)}, \pi, z)\right]}_{\text{Dynamic}}.$$

Interpreting average partial effects

• To interpret Δ^{TAPE} as the average change in outcomes when x_{it} changes from x to $x^{(\delta)}$ and π_{it} changes from π to $\pi^{(\delta)}$, one needs to assume that the functions ϕ_i remain invariant in the counterfactual.

• This invariance is weaker than the assumption that the g_i's (without beliefs) are invariant.

• However, this is still a substantive assumption. In particular, it requires that the law of motion of beliefs remains invariant.

• We now present a structural economic framework that allows us to discuss under which conditions Δ^{TAPE} can be interpreted as a counterfactual effect.

Structural interpretation

A model of intertemporal choice

• Individual i maximizes subjective expected utility. Here we describe an infinite horizon discrete time model, but the framework also applies to finite horizon environments.

• The individual solves

$$(y_{i1}, y_{i2}, ...) = \max_{(y_1, y_2, ...)} \mathbb{E}\left[\sum_{t=1}^{\infty} \beta_i^{t-1} u_i\left(y_t, x_{it}, z_{it}\right)\right].$$

• There are two types of state variables:

-Exogenous: (x_{it}, π_{it}), which are first-order Markov.

-Endogenous: $z_{it} = \gamma_i(z_{i,t-1}, x_{i,t-1}, y_{i,t-1})$.

Beliefs

- We refer to π_{it} as the perceived distribution of $x_{i,t+1}$, or *beliefs*.

- Specifically, letting Ω_{it} be the time-t information set, we denote

$$\left(x_{i,t+1} \,|\, \Omega_{it}\right) \sim \pi_{it}.$$

- Beliefs may also be affected by past actions, although here we omit this dependence for simplicity.

- We assume that x and π are *sufficient* to predict next-period belief, and we denote the belief updating rule as

$$\left(\pi_{i,t+1} \,|\, x_{i,t+1}, \pi_{it}, x_{it}\right) \sim \rho_i.$$

Compatibility of our assumptions with belief formation models

- 1. Adaptive expectations:

$$\mathbb{E}_{\pi_{it}}(x_{i,t+1}) = \mathbb{E}_{\pi_{i,t-1}}(x_{it}) + \lambda_i \Big(x_{it} - \mathbb{E}_{\pi_{i,t-1}}(x_{it})\Big) + \nu_{it}.$$

- 2. Rational expectations with information Ω_{it}:

$$x_{i,t+1} = \eta_{it} + \varepsilon_{it}, \quad \Omega_{it} = \{x_i^t, \eta_i^t\},$$

where η_{it} are first-order Markov independent of ε_{it}.

- 3. Rational expectations with learning:

$x_{it} = \alpha_i + \varepsilon_{it}$, where individuals have a normal prior on α_i,

and $\varepsilon_{it} \sim \mathcal{N}(0, \sigma^2_{\varepsilon_i})$.

- In all these example (x_{it}, π_{it}) is first-order Markov.

Decision rule

- Bellman's principle implies

$$V_i(x_t, z_t, \pi_t) = \max_{y_t} \Big\{ u_i(y_t, x_t, z_t)$$

$$+ \beta_i \iint V_i(x_{t+1}, \gamma_i(z_t, x_t, y_t), \pi_{t+1}) \pi_t(x_{t+1}) \rho_i(\pi_{t+1}; x_{t+1}, \pi_t, x_t) dx_{t+1} d\pi_{t+1} \Big\}.$$

- Under suitable conditions, this implies a decision rule of the form, for some function ϕ,

$$y_{it} = \phi\left(x_{it}, \pi_{it}, z_{it}, u_i, \beta_i, \gamma_i, \rho_i\right).$$

- That is, for $\phi_i(\cdot) = \phi(\cdot, u_i, \beta_i, \gamma_i, \rho_i)$ (notice the absence of a shock ε_{it}; see the paper for a richer model with idiosyncratic shocks):

$$y_{it} = \phi_i\left(x_{it}, \pi_{it}, z_{it}\right).$$

APE as counterfactuals

• A structural interpretation of the TAPE requires that ϕ_i remains invariant in the counterfactual. That is:

• (1) Preferences u_i and discounting β_i remain invariant.

• (2) The law of motion γ_i of z_{it} is invariant. For example: the interest rate or the depreciation rate do not change.

• (3) The belief updating rule ρ_i remains constant. In our setup, we assume that the policy maker can affect beliefs π_{it}, yet that the belief updating rule ρ_i is not affected by the policy.

Example:
consumption and (expected) income

The model

• Consider a standard incomplete markets model of consumption and saving behavior. For simplicity, we focus on an infinite-horizon environment, as in Chamberlain and Wilson (2000).

• Household utility over log consumption is $u_i(y_{it})$. Log income x_{it} and beliefs π_{it} about $x_{i,t+1}$ are jointly first-order Markov.

• Households can self-insure using a risk-free bond with constant interest rate r_i, and assets z_{it} follow (for $w = \exp(x)$ and $c = \exp(y)$):

$$z_{i,t+1} = (1 + r_i)(z_{it} + w_{it}) - c_{it}.$$

• Consumption is then a function of assets, income, and income beliefs

$$y_{it} = \phi\left(x_{it}, \pi_{it}, z_{it}, u_i, \beta_i, r_i, \rho_i\right).$$

An example of income process

• As an example for the income process perceived by the household, consider a permanent-transitory model

$$x_{it} = \eta_{it} + u_{it}, \quad \eta_{it} = \eta_{i,t-1} + v_{it},$$

where $u_{it} \sim \mathcal{N}(0, \sigma_{iu}^2)$ and $v_{it} \sim \mathcal{N}(0, \sigma_{iv}^2)$ are independent over time and independent of each other at all leads and lags.

• Households have rational expectations. At time t, the household observes (x_{it}, η_{it}), but not $(x_{i,t+1}, \eta_{i,t+1})$.

• In this case, we have

$$\pi_{it}(\widetilde{x}) = \frac{1}{\sqrt{\sigma_{iu}^2 + \sigma_{iv}^2}} \varphi\left(\frac{\widetilde{x} - \eta_{it}}{\sqrt{\sigma_{iu}^2 + \sigma_{iv}^2}}\right),$$

where φ is the Gaussian density, and (x_{it}, π_{it}) is first-order Markov.

Tax counterfactual

• Suppose we wish to assess the impact on consumption of a proportional tax $T(w) = (1 - \lambda)w$ at time t.

• Consider the simple permanent-transitory model. Assuming that households fully incorporate the effect of the tax into their beliefs, implementing the tax will lead to

$$\pi'_{it}(\widetilde{x}) = \frac{1}{\sqrt{\sigma_{iu}^2 + \sigma_{iv}^2}} \varphi \left(\frac{\widetilde{x} - \eta_{it} - \ln \lambda}{\sqrt{\sigma_{iu}^2 + \sigma_{iv}^2}} \right).$$

• Hence, the tax affects both current log-income and the perceived mean of future log-income.

• However, in this simple model, ρ_i is not affected by the tax.

Estimating average partial effects

Econometric model

• We study identification and estimation in the model

$$y_{it} = \phi_i\left(x_{it}, \pi_{it}, z_{it}\right) + \varepsilon_{it},$$

where ε_{it} satisfies

$$\mathbb{E}[\varepsilon_{it} \,|\, x_{it}, \pi_{it}, z_{it}] = 0.$$

• If π_{it} were observed and a large T was available, the conditional mean $\phi_i\left(x, \pi, z\right)$ would be nonparametrically identified for all (x, π, z) in the support of $(x_{it}, \pi_{it}, z_{it})$.

• However, π_{it} is unobserved and high-dimensional.

• Moreover, large-T panel data may not be available to the researcher.

Using subjective expectations data

• Eliciting information about beliefs is increasingly common (e.g., Manski, 2004). Responses can often be interpreted as some function $m_{it} = m(\pi_{it})$, such as the mean, variance, or other moment of π_{it}.

• We assume that π_{it} is parametrically specified. That is, there exists a finite-dimensional vector θ_{it} such that

$$\pi_{it} = \pi(\cdot; \theta_{it}),$$

where $\pi(\cdot; \theta)$ is known given θ.

• An example is the analysis of income expectations in the Italian SHIW by Pistaferri (2001) and Kauffmann and Pistaferri (2009).

Specification and estimation in short panels

• In short panels we assume that, for a low-dimensional type α_i,

$$\phi_i\left(x_{it},\pi_{it},z_{it}\right)=\phi\left(x_{it},\pi_{it},z_{it},\alpha_i\right).$$

• Two challenges for estimation are the nonlinearity of ϕ, and the fact that z_{it} is not strictly exogenous.

• The estimates in this talk rely on the additive specification

$$\phi\left(x_{it},\pi_{it},z_{it},\alpha_i\right)=\phi\left(x_{it},\pi_{it},z_{it}\right)+\alpha_i.$$

• If the law of motion of z_{it}, γ_i, is constant across individuals, then one can estimate nonlinear models as if z_{it} was strictly exogenous (B., Dano and Graham, 2023), for example using a discrete-type approach.

Estimation steps

- We first estimate the belief parameters as

$$\widehat{\theta}_{it} = \underset{\theta}{\text{argmin}}\ d\left(m_{it}, m(\pi(\cdot;\theta))\right)$$

- Next, we estimate the parameters of ϕ using, in the additive case,

$$\mathbb{E}\left[y_{it} - y_{i,t-1} - \phi(x_{it}, \pi_{it}, z_{it}) + \phi(x_{i,t-1}, \pi_{i,t-1}, z_{i,t-1}) \,|\, x_i^T, \theta_i^T, z_i^{t-1}\right] = 0.$$

- In the nonlinear case, assuming γ_i is homogeneous and types are discrete we can rely on the likelihood

$$\sum_{\alpha} \Pr\left(\alpha \,|\, x_i^T, \pi_i^T, z_{i1}\right) f_\alpha\left(y_i^T \,|\, x_i^T, \pi_i^T, z_i^T\right).$$

- Given parameter estimates, we finally estimate APE associated with counterfactual changes $x_{it} \mapsto x_{it}^{(\delta)}$ and $\pi_{it} \mapsto \pi_{it}^{(\delta)}$ (for example, complete pass-through of a tax).

Empirical application

Data

- We use the 1989, 1991, 1995 and 1998 waves of the Italian Survey of Household Income and Wealth (SHIW).

- We use expectations questions about income in the following year.

- Our cross-sectional sample has 7,796 household-year observations, and our panel sample has 1,648 household-year observations.

- We assume beliefs about log income growth are normally distributed, and perform robustness checks (see the paper).

Estimates of the consumption function

	(1)	(2)	(3)	(4)	(5)
Mean expected log income		0.235	0.238	0.229	0.231
		(0.094)	(0.095)	(0.093)	(0.093)
(Mean expect. log income)·(Log family income)				0.104	0.104
				(0.061)	(0.061)
Var expected log income			-2.590		-2.613
			(1.876)		(1.941)
(Var expect. log income)·(Log family income)					-1.144
					(3.499)
Log family income	0.584	0.439	0.439	0.439	0.440
	(0.070)	(0.089)	(0.089)	(0.089)	(0.089)
Log family assets	0.010	0.018	0.018	0.019	0.018
	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)
Household fixed effect	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
N observations	1,536	1,536	1,536	1,536	1,536
N households	768	768	768	768	768
R-squared	0.24	0.26	0.26	0.26	0.26
Pvalue F beliefs		0.01	0.03	0.02	0.05

Income tax counterfactuals: setup

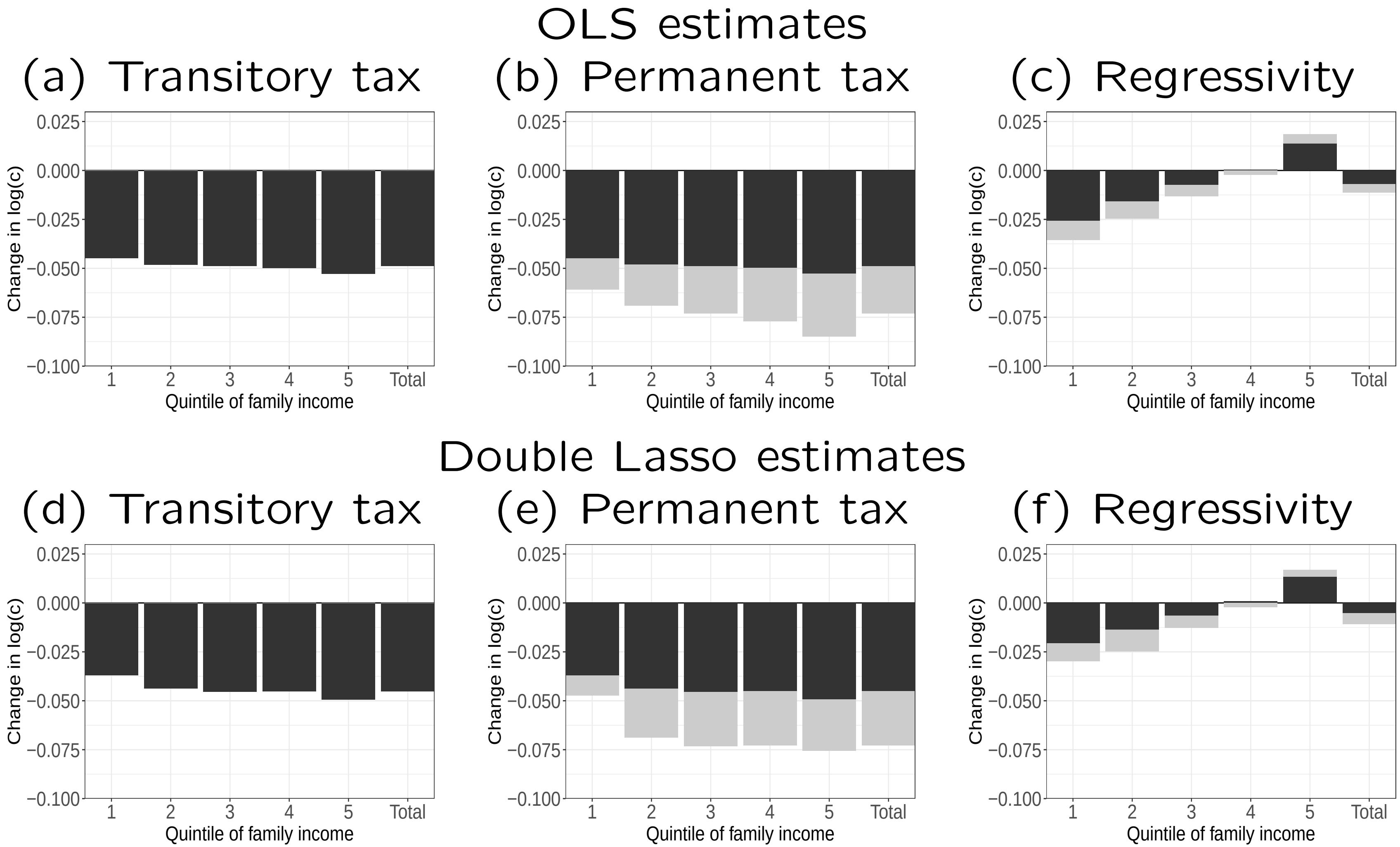
• We use our framework and consumption function estimates to assess the effects of three income tax counterfactuals on consumption.

• We assume that the tax schedule is $T(w) = w - \lambda w^{1-\tau}$, where w is income. In the baseline, we take $\lambda = 0.94, \tau = 0.196$ (Holter *et al.*, 2019).

• In the *transitory tax* and *permanent tax* counterfactuals, we increase the average tax by 10 percentage points, by decreasing λ by 0.10, either in one period only or in all subsequent periods.

• In the *regressivity* counterfactual, we set the parameter τ to its value in the French tax system, which is somewhat less progressive than the Italian one, while at the same time decreasing λ such that the tax change is neutral in terms of total tax revenue.

Income tax counterfactuals



Notes: contemporaneous APE in black, dynamic APE in gray.

Discussion

• The average partial effect of a 10% permanent income tax that does not account for the role of beliefs is -0.065. This is larger than our contemporaneous effect (-0.049), but lower than our total effect (-0.073).

• Beliefs may be measured with error. In the paper, we perform a sensitivity analysis that suggests our estimates are not very sensitive to a particular form of measurement error.

• In the paper we perform other checks, using different functional forms for beliefs, studying variation over time, and varying the assumptions about assets.

• Two important assumptions here are (1) that ρ_i is invariant under the tax, and (2) that individual beliefs respond one-to-one to the tax.

Comparison with a structural life-cycle model

• We simulate a life-cycle model based on Kaplan and Violante (2010), and consider rational and adaptive expectations.

• We compute the effect of a permanent income tax of 10% in the structural model. Then, we compare the structural predictions with those from our semi-structural average partial effects.

	Rational expectations				Adaptive expectations			
	Structural	Semi-structural			Structural	Semi-structural		
		Linear	Quadratic	Spline		Linear	Quadratic	Spline
CAPE	-0.0163	-0.0151	-0.0150	-0.0150	-0.0122	-0.0344	-0.0191	-0.0133
DAPE	-0.0802	-0.0917	-0.0863	-0.0860	-0.0496	-0.0518	-0.0512	-0.0513
TAPE	-0.0965	-0.1068	-0.1013	-0.1010	-0.0618	-0.0863	-0.0704	-0.0646

Notes: linear, quadratic and spline refer to the specification of assets in the consumption regression.

Conclusion

Summary

• We provide a method to account for the role of individual expectations in assessing the impact of policies and other counterfactuals.

• This approach can take advantage of the increasing availability of data on elicited beliefs.

• Our approach is semi-structural, in the sense that it is justified under dynamic structural assumptions, yet implementing the method does not require full specification and estimation of a structural model.

Extensions

• In the absence of belief data, our approach is still applicable provided beliefs can be estimated (e.g., under rational expectations).

• In our approach, long-run beliefs ρ_i are constant in sample and invariant under the counterfactual. This assumption can be relaxed by introducing beliefs over longer horizons.

• Another extension, which we also describe in the paper, is to allow for state-contingent beliefs.

• Our analysis calls for more and improved data collection on (time-varying) individual beliefs.