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Adaptive Risk-Taking

A dissertation submitted in partial satisfaction of the
requirements for the degree Doctor of Philosophy

in

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by

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The Dissertation of Remy Levin is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

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Chapter 1 is currently being prepared for submission for publication of the material. It is sole authored by the dissertation author.

Chapter 2 is currently being prepared for submission for publication of the material, and is coauthored with Daniela Vidart. The dissertation author was a primary investigator of this material.

Chapter 3 is currently being prepared for submission for publication of the material, is coauthored with Wesley Howden. The dissertation author was a primary investigator of this material.

All errors are my own.

VITA

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ABSTRACT OF THE DISSERTATION

Adaptive Risk-Taking

by

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Doctor of Philosophy in Economics

University of California San Diego, 2020

Professor Simone Galperti, Co-Chair
Professor David Lagakos, Co-Chair

I study how attitudes towards risk and risky behavior adapt over the long-run to changes in risk in individuals' environments. In the first chapter I build a dynamic model of choice in which agents' endogenous foreground risk-taking adapts to evolving beliefs about exogenous background risk. The key features of this model are that foreground and background risk are substitutes, and that the agent learns about both the mean and variance of the background risk from observing its realizations over their lifetime. My model makes sharp predictions about the dynamics of risk-taking, the three most important being that (1) risk aversion increases monotonically in variance increases relative to the prior variance, and is (2) decreasing and (3)

convex in mean increases about the prior mean.

In the subsequent two chapters I test the predictions of my model for two sources of background risk, using large-scale panel surveys from Indonesia and Mexico containing repeat elicited measures of risk aversion for the same subjects years apart. In chapter two, coauthored with Daniela Vidart, we link changes in measured risk aversion to state-level real GDP growth time series capturing subjects' lifetime macroeconomic experiences. In line with the model's predictions we find that measured risk aversion increases in growth volatility and decreases in mean growth. These findings are robust to controlling for changes in subjects' personal economic circumstances and experiences of violence and natural disasters. Decreases in measured risk aversion correlate with substantial increases in risky behavior in the domains of health, migration, and occupational choice.

In chapter three, coauthored with Wesley Howden, we link changes in measured risk aversion to state-level temperature and precipitation time series measuring subjects' lifetime experiences of climate change. We find that measured risk aversion increases in the volatility of temperature in Indonesia and precipitation in Mexico, that it decreases in the mean of temperature in both countries and precipitation in Mexico, and that it is convex in the mean of temperature in Indonesia. These findings are robust to the inclusion of controls. Decreases in measured risk aversion correlate with large changes in migration, occupational choice, and agricultural investment behavior.

Introduction

How individuals make decisions in the presence of uncertainty is arguably *the* central question of microeconomic theory. The corpus of literature in this area is vast, and its greatest hits well-known: von Neumann and Morgenstern's foundational work on expected utility theory (EUT); its extension to subjective expected utility theory (SEUT) starting with Ramsey and de Finetti, and actualized in the work of Savage, Anscombe, and Aumann; the seminal contributions to EUT of Arrow, Pratt, Stieglitz, and Rothchild; the parallel challenges to EUT and SEUT by Allais and Ellsberg; Kahneman and Tversky's response in the form of prospect theory, which spawned behavioral economics; and the most prominent modern incarnation of that theory, Kőszegi and Rabin's expectations-based reference dependence.

A common thread running throughout this corpus, and a motif it shares with microeconomic theory more generally, is that in it the subject of choice, mathematically formalized as the agent's utility function, is assumed to be exogenous. In other words the agent's preferences, here over risk, are thought of as given by the theoretician. The question of where these preferences come from exactly is thus outside the scope of the model.[1] A corollary of this received wisdom is that utility is assumed to be stable over time.[2] After all, if we allowed utility functions to change we might be compelled to ask *why* they change.

In this dissertation I gently tug on this thread. The animating spirit of this research is

[1]Adopting this posture towards the study of human behavior is a habit that goes back at least as far as Hume. Its most ardent expression, however, is undoubtedly in the famous paper by Becker and Stigler (1977), who argue that the very thing that separates Economics from the lesser beasts of the social sciences is the exogeneity of preferences.

[2]Luckily, this has proven to be no impediment to the analysis of dynamic behavior in Economics. All one needs to do to make their model dynamic while still coloring within the lines is to redefine the domain of the static utility function to be over all possible outcomes in all periods under consideration. Presto!

the question of where individual risk preferences come from, and how and why do they change, particularly in the long-run. My answer is that risk preferences adapt to changes in risk in individuals' environments in particular ways. I explore some of the theoretical implications and empirical consequences of this answer below.

Chapter 1

A Model of Adaptive Risk-Taking

We develop a dynamic model of risky choice in which an agent's endogenous risk-taking adapts to evolving beliefs about unknown background risk in their environment. We link changes in the agent's history of experienced shocks to changes in their risky decision-making in two steps. First, we model how changes in the agent's beliefs about the environment affect their decision-making using a static background risk framework. The key feature of this model of utility is that background risk in the environment and foreground risk in the agent's choice problem are substitutes. Second, we model how experienced shocks affect the agent's beliefs about risk using a Bayesian updating process over structural uncertainty. The central aspect of this model of learning is that the agent directly forms beliefs about risk in the environment, meaning that they learn about both the mean and the variance of the background risk from its realizations over their lifetime.

1.1 Model

The choice environment. Consider an agent born at time 0. In each period, indexed by $t \in \{1,2,...,T\}$, the agent receives a fixed wealth endowment w and is exposed to two sources of risk. First, the agent must choose an income lottery $\tilde{x}$ from a menu of lotteries $\mathscr{X}$. We call $\tilde{x}$ the *endogenous* or *foreground* risk, and denote its cdf $F_{\tilde{x}}(x)$ and its pdf $f_{\tilde{x}}(x)$. The menu $\mathscr{X}$ is identical in each period, and consists of a safe lottery x^s, and a risky lottery x^r, such that

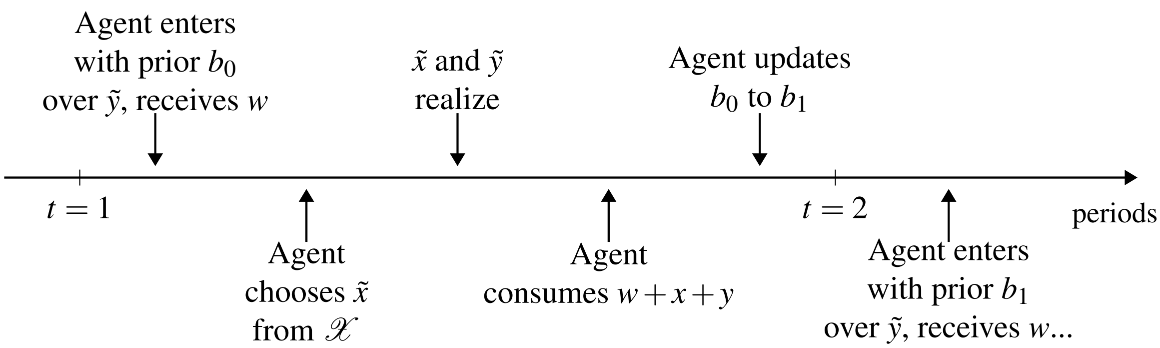


Figure 1.1. Timing of events in the model

$\mathbb{E}[x^s] < \mathbb{E}[x^r]$ and $Var[x^s] < Var[x^r]$. To fix ideas, we think of the lotteries in $\mathscr{X}$ as objective gambles for which the agent knows the odds, though $\mathscr{X}$ could also, without loss of generality, consist of several insurance or investment options over which the agent has subjective beliefs, so long as those beliefs do not change over time.

In addition to the endogenous lottery $\tilde{x}$ the agent is exposed in each period to an exogenous *background* income risk $\tilde{y}$, which is a random variable with stationary cdf $F_{\tilde{y}}(y)$. Background risk $\tilde{y}$ is statistically independent of all $\tilde{x} \in \mathscr{X}$ in all t, and is unavoidable by the agent. The agent does not know the parameters of $F_{\tilde{y}}(y)$ but rather has beliefs over them, which she updates each period as she experiences a new realization of $\tilde{y}$. Denote with $B_t(y)$ and $b_t(y)$ the cdf and the pdf, respectively, of the agent's beliefs distribution about the outcomes of $\tilde{y}$ at time t.

Timing. The timing of events in the model is shown in Figure 1.1. The agent enters period t with income endowment w and prior beliefs b_{t-1} about the background risk $\tilde{y}$. They then chooses $\tilde{x}$ *before* $\tilde{y}$ is realized, given their beliefs. We assume that the agent does not have access to a savings technology, so once $\tilde{x}$ and $\tilde{y}$ realize the agent consumes their period endowment and the combined realization $w + x + y$. At the end of the period the agent updates their prior b_{t-1} to posterior b_t, which forms their prior in the next period.

Utility and risk. We assume that the agent is a subjective expected utility maximizer and has a four-times-differentiable utility function u for which $u' > 0$ and $u'' < 0$. u is defined over the wealth endowment, the foreground risk, and the background risk:

$$\begin{aligned}
\mathbb{E}u(w+\tilde{x}+\tilde{y}) &= \int\int u(w+x+y) f_{\tilde{x}}(x) b_t(y)\, dx dy \\
&= \int \Big[\int u(w+x+y) b_t(y) dy\Big] f_{\tilde{x}}(x) dx \\
&= \mathbb{E}u(w+\tilde{x}|\tilde{y}) \\
&= \mathbb{E}u(w+\tilde{x}|B_t(y)),
\end{aligned}$$

where the second equality follows from the law of iterated expectations. To simplify notation we will use $\tilde{y}_t = \tilde{y}|B_t(y)$ to refer to the background risk that the agent believes they face at time t.

Our measure of risk-taking is the *coefficient of absolute risk aversion* $r_t(w)$, here written to depend on the agent's beliefs about $\tilde{y}$, which vary over time:

$$r_t(w) = r(w|B_t(y)) \equiv -\frac{u''(w|B_t(y))}{u'(w|B_t(y))}.$$

The coefficient $r_t(w)$ has a well-known behavioral interpretation as the agent's risk premium, or local price for trading off the mean and variance of a risky prospect. Given a choice between a safe and a risky investment option, as in the choice of $\tilde{x}$, an agent with higher $r_t(w)$ will invest a lower amount in (or be less probable to choose, in the discrete case) the risky option.

It is also useful to define two higher-order analogues of $r_t(w)$, the *coefficient of absolute prudence* $p_t(w) = -u'''(w|B_t(y))/u''(w|B_t(y))$ and the *coefficient of absolute temperance* $q_t(w) = -u''''(w|B_t(y))/u'''(w|B_t(y))$. These allow us to identify conditions on the third and fourth moments of u that are collectively termed *risk vulnerability*.[1]

Definition 1.1. (*Risk-vulnerable utility*) An expected utility maximizer with $u' > 0$ and $u'' < 0$ is risk-vulnerable at time t if $p_t(w) \geq r_t(w)$ and $q_t(w) \geq r_t(w)$.

Risk vulnerability is the feature of the utility function that ensures that background and

[1] Gollier and Pratt (1996).

foreground risks are substitutes for the agent. Intuitively it corresponds to higher-order concavity in the agent's utility function. Note that all HARA utility functions exhibit risk vulnerability. We will assume in the analysis below that the agent is risk vulnerable at all t.

Learning. The agent in our model is a Bayesian who uses personally observed realizations of the background risk to update their belief distribution $B_t(y)$. We make two structural assumptions about the agent's updating process. First, we assume that the agent believes that the realizations, or *signals*, are drawn from a stationary Gaussian random variable with unknown mean and unknown variance. Second, we assume that the agent's *prior* over the mean and variance takes the form of a normal-inverse-chi-squared distribution. We call this learning process Bayesian updating over structural uncertainty, and describe it formally in the following definition:

Definition 1.2. (*Bayesian updating over structural uncertainty*) We say that a Bayesian agent is updating over structural uncertainty if:

1. The agent' perceived likelihood function over the background risk is a stationary Gaussian random variable:

$$\tilde{y} \sim \mathcal{N}(M, \Sigma^2) \ \ \forall t,$$

   where M and Σ^2 are both scalars that are unknown to the agent.

2. The agent's prior over the mean and variance $p(M, \Sigma^2)$ is a $NI\chi^{-2}$ distribution, that is

$$\begin{aligned} p(M, \Sigma^2) &= NI\chi^{-2}(\mu_0, \kappa_0, \sigma_0^2, \nu_0) \\ &= \mathcal{N}(M|\mu_0, \Sigma^2/\kappa_0) \times \chi^{-2}(\Sigma^2|\nu_0, \sigma_0^2) \end{aligned}$$

   where μ_0 and σ_0^2 are the agent's point priors over the mean and variance of $\tilde{y}$, and $\kappa_0 > 0$ and $\nu_0 > 2$ are hyper-parameters capturing the agent's confidence or precision over the prior mean and variance, respectively.

Given the above prior it is straightforward to show that the agent's expected values for M and Σ^2 at time 0 are

$$\mathbb{E}_0[M] = \mu_0 \tag{1.1}$$
$$\mathbb{E}_0[\Sigma^2] = \frac{\nu_0}{\nu_0 - 2}\sigma_0^2. \tag{1.2}$$

The $NI\chi^{-2}$ distribution is the unique *conjugate prior* of the Gaussian with unknown mean and unknown variance likelihood. This means that the Bayesian agent's posterior distribution upon receiving signals will also be in the $NI\chi^{-2}$ family, with updated hyperparameters. Consequently, the agent's posterior mean and variance have closed form expressions. Let $\mathscr{D}_t = \{y_1, ..., y_t\}$ be a set of t iid draws from $\tilde{y}$. Then these posteriors will be:[2]

$$\mathbb{E}_t[M|\mathscr{D}_t] = \mu_t = \mu_0 + \frac{t}{\kappa_0 + t}(\bar{y}_t - \mu_0) \tag{1.3}$$
$$\mathbb{E}_t[\Sigma^2|\mathscr{D}_t] = \frac{\nu_t}{\nu_t - 2}\sigma_t^2 = \frac{1}{\nu_0 + t - 2}\left[\nu_0\sigma_0^2 + \sum_{i=1}^{t}(y_i - \bar{y}_t)^2 + \frac{t\kappa_0}{\kappa_0 + t}(\bar{y}_t - \mu_0)^2\right], \tag{1.4}$$

where $\bar{y}_t = 1/t\sum_{i=1}^{t} y_i$ is the sample mean of $\mathscr{D}_t$. It will also be useful to refer to the sample variance of $\mathscr{D}_t$, $s_t^2 = 1/t\sum_{i=1}^{t}(y_i - \bar{y}_t)^2$.

We will denote the *total* change in the agent's beliefs about the mean at time t, relative to their prior, as $\Delta_t M = \mathbb{E}_t[M|\mathscr{D}_t] - \mathbb{E}_0[M]$, and about the variance $\Delta_t\Sigma^2 = \mathbb{E}_t[\Sigma^2|\mathscr{D}_t] - \mathbb{E}_0[\Sigma^2]$. These will be distinct quantities in our model from the comparisons that the agent makes between the mean of the data and their prior mean, which we label $\delta_t^m = \bar{y}_t - \mu_0$, and the difference between the sample variance and their prior variance, which we label $\delta_t^v = s_t^2 - \frac{\nu_0}{\nu_0 - 2}\sigma_0^2$.

[2] Degroot (1970) [pg.169] proves this for the parameterization of the normal in terms of mean and precision. Here we use the alternative parameterization for the normal in terms of the mean and variance. This form of the posterior variance follows trivially from replacing the Gamma prior marginal distribution of the precision in Degroot (1970) with an inverse chi squared prior marginal distribution for the variance (Murphy (2007)).

1.2 Discussion of the model

Models of background risk, and their use in analyzing choice under multiple sources of risk, have a long tradition in economics, stemming from their introduction in Pratt and Zeckhauser (1987). Foundational work in this area identified conditions on the higher moments of the agent's von-Neumann Morgenstern utility function that guarantee "natural" behavioral responses of risk-taking to independent sources of risk (Kimball (1990), Kimball (1993), Gollier and Pratt (1996), Caballé and Pomansky (1996)). These conditions, often termed prudence and temperance, generally imply that more risk in the environment will lead to lower endogenous risk-taking by the agent, as they do in our model, even if the two sources of risk are statistically independent. Substantial empirical evidence from experimental studies exists for these conditions (Noussair and Trautmann (2014), Deck and Schlesinger (2014), Ebert and Wiesen (2014)).

The theoretical literature on background risk has generally assumed that the odds and payoffs of these risks are known to the agent when they are making decisions. In reality, however, individuals often make high-stakes risky choices in the presence of substantial background risk over which they have limited information and considerable uncertainty. A wage worker deciding whether to start their own business must contend with the possibility of an economic downturn over the medium-term; a renter choosing whether to buy a house (and how much of it to buy) needs to consider the likely path of the housing market over the next few years; a farmer choosing between planting a risky cash crop and a relatively safe food crop has to confront the possibility of droughts, heatwaves, and price fluctuations that could spell riches or ruins. These risks are substantial, largely outside of individuals' control, and often difficult or impossible to forecast even for experts with access to sophisticated models and the best data.

We contribute to the background risk literature by building and studying a model of individual risky choice where the exact parameters of the background risk are unknown to the agent. Rather the agent in our model has priors over these parameters, observes realizations of the background risk over time, and updates as a Bayesian in the face of new information. While "risk" has many definitions, in its most classical formulation it involves a trade-off between the mean and variance of a gamble (Pratt (1964), Arrow (1970)). Since we are interested in the consequences of uncertainty and updating over the background risk, we model the agent as having beliefs over *both* its mean and variance that evolve over time.

The result is a model in which the history of shocks an agent experiences shapes their risk-taking over time. The theoretical literature on history-dependent risk attitudes is markedly scant, with the notable exception of Dillenberger and Rozen (2015). In that paper the authors construct a model where an agent recursively evaluates compound lotteries to classify experienced realizations as disappointing or elating relative to some threshold. The authors show that assuming choice consistency, the agent in their model exhibits a "reinforcement effect," where risk-taking will always increase after an elation and decrease after a disappointment. Importantly, the agent in Dillenberger and Rozen (2015) does not consider how big the realizations they observe are, but only whether they are good or bad. We contribute to this nascent literature by building the first model, to our knowledge, wherein the *magnitude* of an experienced realization affects risk attitudes. As we show below, because of the variance beliefs channel in our model, the magnitude of a realization can matter just as much as its sign for the risk-taking of the agent. This means that our model can be used to think about the relative effects of large and small shocks, and not just the relative effects of positive and negative realizations.

This model also contributes to a growing literature on fat-tailed distributions in economics. Fat-tailed distributions have generated renewed interest in the last few years across several fields, including macroeconomics (Gabaix et al. (2006), Morris and Yildiz (2016)), finance (Gabaix et al. (2003), Kelly and Jiang (2014)), and the economics of climate change (Weitzman (2007), Weitzman (2009))[3]. Recent evidence suggests that macroeconomic variables, in particular GDP, are likely distributed with fat tails (Acemoglu, Ozdaglar and Tahbaz-Salehi (2017)). An interesting feature of our model is that while the conditional marginal distribution of the agent's

[3] We adopt the term "structural uncertainty" from Weitzman's work, who used a related updating framework to model societal uncertainty over the tail-risk of climate change.

mean is normal, its unconditional marginal distribution is in fact a student's-t[4], which is fat-tailed. Our model can therefore be interpreted as examining the dynamics of risk-taking under updating over a fat-tailed mean distribution.

1.3 The effect of mean-preserving changes in variance on risk-taking

We first examine the effect of mean-preserving changes in the variance of the background risk on the agent's risk-taking. These are, in a sense, the "purest" changes in risk that the agent experiences. We use *mean-preserving* here to refer to an aspect of the data, or signals, when compared to the agent's prior. Since this usage is slightly different than that commonly employed, we define it below:

Definition 1.3. (*Mean-preserving dataset*) Let $\mathscr{D}_t = \{y_1, ..., y_t\}$ be a set of t iid draws from $\tilde{y}$. We say D_t is a mean-preserving dataset for the agent if $\bar{y}_t = \mu_0$.

With this definition in hand we can now state and prove our first result:

Proposition 1. (Monotonicity in mean-preserving variance changes) *Suppose an agent is a risk-vulnerable subjective expected utility maximizer who is updating as a Bayesian over structural uncertainty in background risk $\tilde{y}$. Suppose further that the agent observes a mean-preserving dataset of signals $\mathscr{D}_t$. Then $r_t(w) > (\leq)\ r_0(w)$ iff $\delta_t^v > (\leq)\ 0$.*

Proof. Since $\mathscr{D}_t$ is a mean-preserving dataset, the agent's posterior mean equals their prior mean μ_0, and $\Delta_t M = 0$. The agent's posterior variance, meanwhile, reduces to the term $\frac{1}{v_0+t-2}\left[v_0\sigma_0^2 + \sum_{i=1}^{t}(y_i - \bar{y}_t)^2\right]$. Therefore, $\Delta_t\Sigma^2 > (\leq)\ 0$ iff $\delta_t^v > (\leq)\ 0$. This results in a mean-preserving spread (scrunch) in the agent's belief distribution $B_t(y)$, represented by $\tilde{y}_t$. Consider the effect of

[4] A $t_{v_t}(M|\mu_t, \sigma_t^2/\kappa_t)$ distribution, to be precise.

$\tilde{y}_t$ on the agent's absolute risk aversion:

$$
\begin{aligned}
\left.\frac{r_t(w)-r_0(w)}{r_0(w)}\right|_{\Delta_t\Sigma^2|\tilde{y}_t} &= [r_0(w)]^{-1}\left[\frac{-\mathbb{E}u''(w+\tilde{y}_t)}{\mathbb{E}u'(w+\tilde{y}_t)} - r_0(w)\right] \\
&= [r_0(w)]^{-1}\left[\frac{-\mathbb{E}[u''(w)+\tilde{y}_t u'''(w)+0.5\tilde{y}_t^2 u''''(w)]}{\mathbb{E}[u'(w)+\tilde{y}_t u''(w)+0.5\tilde{y}_t^2 u'''(w)]} - r_0(w)\right] \\
&= \frac{1+\frac{tp_0(w)q_0(w)}{2(v_0+t-2)}\delta_t^v}{1+\frac{tr_0(w)p_0(w)}{2(v_0+t-2)}\delta_t^v} - 1 \\
&= \frac{\frac{tp_0(w)\left(q_0(w)-r_0(w)\right)}{2(v_0+t-2)}\delta_t^v}{1+\frac{tr_0(w)p_0(w)}{2(v_0+t-2)}\delta_t^v},
\end{aligned}
$$

where the second equality follows from the normality of $\tilde{y}_t$.[5] For a small change in variance the change in $r_t(w)$ is well approximated by

$$
\left. r_t(w)-r_0(w)\right|_{\Delta_t\Sigma^2|\tilde{y}_t} \approx \frac{tr_0(w)p_0(w)\left(q_0(w)-r_0(w)\right)}{2(v_0+t-2)}\delta_t^v. \tag{1.5}
$$

Since the agent is risk averse $r_0(w) > 0$. By risk vulnerability $p_0(w) \geq r_0(w)$ and $q_0(w) \geq r_0(w)$, so the sign of $r_t(w)-r_0(w)$ is the same as the sign of δ_t^v.[6] $\square$

Proposition 1 has a straightforward interpretation. Holding mean changes constant, our agent compares the sample variance of the realizations of the background risk that they observe to their prior beliefs about its variance. If this sample variance is larger than their prior variance they reduce their endogenous risk-taking, while if it is smaller they increase their risk-taking. In

[5] If $\tilde{y}_t$ was not normal, we could derive this equality approximately from a second order Taylor approximation of the relevant derivatives of $u(w+\tilde{y}_t)$ about w, provided that all moments of $F_{\tilde{y}}$ of third degree or higher are $o(\tilde{y}^2)$.

[6] Note that the logic in this proof is valid for any second order stochastic change in $B_t(y)$, though the form of risk vulnerability required is somewhat stronger, as shown by Eeckhoudt, Gollier and Schlesinger (1996):

1. there exists a scalar c such that $p_t(w+(x+y)) \geq c \geq r_t(w+(x+y)')$ $\forall w$ and $\forall (x+y), (x+y)'$ in t.
2. there exists a scalar d such that $q_t(w+(x+y)) \geq d \geq r_t(w+(x+y)')$ $\forall w$ and $\forall (x+y), (x+y)'$ in t.

These conditions were first articulated by Ross (1981) to accommodate an ordering of individuals by risk aversion when all objects of choice are risky lotteries.

other words, the agent's changing beliefs about pure risk in the environment monotonically drive their own risk-taking, even though this background risk is statistically independent of the returns on the foreground risk that is their object of choice.

1.4 The effects of variance-preserving mean changes on risk-taking

We next turn our attention to the effects of small mean changes on risk-taking, by which we refer to the effects of deviations of the sample mean of background risk signals $\tilde{y}_t$ from the agent's prior μ_0. From equation 1.3 we can see that δ_t^m shifts the agent's posterior mean. A shift in mean beliefs functions as a deterministic shift in wealth for the agent, so that

$$r_t(w) - r_0(w)\Big|_{\Delta_t M|\delta_t^m} \approx (\Delta_t M|\delta_t^m) r_0'(w) = -\frac{t r_0(w)\big(p_0(w) - r_0(w)\big)}{\kappa_0 + t}\delta_t^m. \tag{1.6}$$

Given decreasing absolute risk aversion (the first condition in risk vulnerability) we can sign this effect consistently: $\delta_t^m > 0$ implies that $r_t(w) - r_0(w) < 0$. However, as can be seen from equation 1.4, δ_t^m also enters the agent's posterior variance as a quadratic term. Assuming that the sample variance is at the posterior-neutral point ($\delta_t^v = 0$, or $s_t^2 = \mathbb{E}_0[\Sigma^2]$), the effect of the mean via the variance on risk-taking is

$$r_t(w) - r_0(w)\Big|_{\Delta_t \Sigma^2|\delta_t^m} \approx \frac{t\kappa_0 r_0(w) p_0(w)\big(q_0(w) - r_0(w)\big)}{2(\nu_0 + t - 2)(\kappa_0 + t)}(\delta_t^m)^2 \tag{1.7}$$

Given risk vulnerability we can also sign this effect—if $(\delta_t^m)^2$ increases $r_t(w) - r_0(w)$ increases. Combining these two effects yields

$$r_t(w) - r_0(w)\Big|_\delta \approx -\frac{t r_0(w)\big(p_0(w) - r_0(w)\big)}{\kappa_0 + t}\delta_t^m + \frac{t\kappa_0 r_0(w) p_0(w)\big(q_0(w) - r_0(w)\big)}{2(\nu_0 + t - 2)(\kappa_0 + t)}(\delta_t^m)^2 \tag{1.8}$$

This leads us to our next result:

Proposition 2. (Local convexity in mean changes) *Suppose an agent is a risk-vulnerable subjective expected utility maximizer who is updating as a Bayesian over structural uncertainty in background risk $\tilde{y}$. Suppose further that the agent observes a dataset of signals $\mathscr{D}_t$ for which $\delta_t^v = 0$ and δ_t^m is small. Then $r_t(w) - r_0(w)$ is a decreasing and convex function of δ_t^m.*

Proof. The proposition follows directly from the quadratic functional form of $r_t(w) - r_0(w)$ in δ_t^m in equation 1.8. □

Proposition 2 is a significant departure from the mean-only model. Even if the agent observes no change in variance, and even for small deviations of the data mean from the prior mean, $r_t(w) - r_0(w)$ is convex (and decreasing), rather than linear in δ_t^m. **This means that the marginal effect on risk-taking in absolute terms for negative shocks will be larger for the agent than for equal-sized positive shocks.** This asymmetry of positive and negative shocks is driven not by assumptions on the utility function, as in, for instance, the case of loss aversion in prospect theory, but rather by the interdependence of the agent's posterior mean and variance in our learning model.

1.5 The combined effects of mean and variance

We are now ready to examine the combined effects of mean and variance changes on the agent's risk-taking. The overarching theme of the results in this section is that unlike in the mean-only model, in our model risk-taking is non-monotonic in the mean displacement from the prior.

Assume that $\tilde{y}_t$ is a background risk involving a small change in the agent's mean plus a small mean preserving-spread in the agent's variance relative to the agent's prior. Let $\delta_t^v = (s_t^2 - \frac{\nu_0}{\nu_0 - 2}\sigma_0^2)$. Then the change in the agent's risk-taking due to his posterior variance is:

$$r_t(w) - r_0(w)\Big|_{\Delta_t\Sigma^2|\tilde{y}_t} \approx \frac{t r_0(w) p_0(w)\big(q_0(w) - r_0(w)\big)}{2(\nu_0 + t - 2)}\Big(\delta_t^v + \frac{\kappa_0}{t + \kappa_0}(\delta_t^m)^2\Big), \tag{1.9}$$

which we obtain from (equation 5) by including the appropriate terms for $\Delta_t\Sigma^2$, given non-zero δ_t^v and δ_t^m. This results in a total change in risk-taking for the agent, given both mean and variance, of

$$\begin{aligned} r_t(w) - r_0(w)\Big|_{\tilde{y}_t} \approx -\frac{t r_0(w)\big(p_0(w) - r_0(w)\big)}{\kappa_0 + t}\delta_t^m + \frac{t\kappa_0 r_0(w) p_0(w)\big(q_0(w) - r_0(w)\big)}{2(\nu_0 + t - 2)(\kappa_0 + t)}(\delta_t^m)^2 \\ + \frac{t r_0(w) p_0(w)\big(q_0(w) - r_0(w)\big)}{2(\nu_0 + t - 2)}\delta_t^v \end{aligned}$$

We will next assume that the agent has a CRRA utility function ($u(w) = (w^{1-\eta} - 1)/(1-\eta)$). This will allow us to maximize intuition in the following results. Note, however, that our results would be qualitatively similar for any utility function, so long as it exhibits risk vulnerability.

Given CRRA utility we have that $r_0(w) = \eta/w$, $p_0(w) = (\eta+1)/w$, and $q_0(w) = (2+\eta)/w$. The above equation simplifies to:

$$r_t(w) - r_0(w)\Big|_{\tilde{y}_t} \approx -\frac{t\eta}{(\kappa_0 + t)w^2}\delta_t^m + \frac{t\kappa_0\eta(\eta+1)}{(\nu_0 + t - 2)(\kappa_0 + t)w^3}(\delta_t^m)^2 + \frac{t\eta(\eta+1)}{(\nu_0 + t - 2)w^3}\delta_t^v \tag{1.10}$$

The next two propositions relate to this function:

Proposition 3. (Variance dominating threshold) *Suppose an agent is a risk-vulnerable subjec-*

tive expected utility maximizer who is updating as a Bayesian over structural uncertainty in background risk $\tilde{y}$. Then there exists a threshold value $\delta_t^{v*} > 0$ such that for small $\tilde{y}_t$, if $\delta_t^v > \delta_t^{v*}$, then $r_t(w) - r_0(w) > 0$ for all δ_t^m. If the agent's utility function is CRRA this threshold is:

$$\delta_t^{v*} = \Big(\frac{\nu_0 + t - 2}{2\kappa_0}\Big)^2 \Big(\frac{\kappa_0 + t}{\kappa_0}\Big)^{-1} \Big(\frac{\eta + 1}{w}\Big)^{-2} \tag{1.11}$$

Proof. As can be see from equation 1.10, $r_t(w) - r_0(w)$ is a quadratic function in δ_t^m, where the coefficient of the δ_t^m term is negative, the coefficient of the $(\delta_t^m)^2$ term is positive, and the coefficient of the δ_t^v term is positive (these signs are the same for any risk-vulnerable utility function). Since δ_t^v is unbounded above, δ_t^{v*} must exist. The form of δ_t^{v*} in 1.11 follows directly from solving for the discriminant in equation 1.10. □

Proposition 3 states that for an agent who is updating beliefs about both the mean and variance of the background risk, there exist high enough realizations of the variance so as to entirely overwhelm the effects of the mean, and make the agent more risk averse regardless of its realization. This is in stark contrast to a mean only model of updating, which typically implies strong monotonicity on the part of the mean, with increases leading to lower risk aversion and decreases leading to higher risk aversion (Dillenberger and Rozen (2015)). This is a direct consequence of the local convexity of the mean established in the previous proposition. Without the countervailing effect of $(\delta_t^m)^2$ no such threshold on δ_t^v would exist. Thus, although this result is written as a threshold on the variance, it is the consequence more strictly of the interdependence via the mean of the posterior mean and variance in our model.

The form of δ_t^{v*} in 1.11 provides instructive intuition for how the agent's utility and beliefs interact in our model. δ_t^{v*} is composed of three terms. The first is, to a scale factor, the ratio of the agent's posterior confidence about the variance and their prior confidence about the mean. δ_t^{v*} is increasing in this term. The second is the ratio of the agent's posterior confidence about the mean and their prior confidence about the mean. The third is the agent's coefficient of absolute prudence. δ_t^{v*} is decreasing in the latter two terms. Intuitively, higher values of δ_t^{v*}

correspond to lower sensitivity of the agent's risk-taking to the variance relative to the mean. Thus, 1.11 tells us that in our model the agent is relatively *more* sensitive to the variance when they are *less* confident about its value ex post relative to the value of the mean ex ante; and relatively *more* sensitive to the variance when they are *more* confident about the value of the mean ex post relative to the value of the mean ex ante. In other words, **the agent is more sensitive to the moment for which uncertainty declines relatively less in their posterior**. The agent is also relatively *more* sensitive to the variance the *more* prudent they are.

Proposition 3 identifies an upper bound on δ_t^v beyond which the agent becomes more risk averse for every value of δ_t^m. In the next proposition we examine how the combined effects of the mean and variance when the variance is below this critical value.

Proposition 4. (Combined effects of mean and variance changes) *Suppose an agent is a risk-vulnerable subjective expected utility maximizer who is updating as a Bayesian over structural uncertainty in a small background risk $\tilde{y}$ and has a CRRA utility function. Suppose further that $\delta_t^v < \delta_t^{v*}$. Then there exists a threshold mean value*

$$\delta_t^{m*} = \frac{\nu_0 + t - 2}{2\kappa_0}\left(\frac{\eta+1}{w}\right)^{-1} - \sqrt{\left(\frac{\nu_0+t-2}{2\kappa_0}\right)^2\left(\frac{\eta+1}{w}\right)^{-2} - \frac{\kappa_0+t}{\kappa_0}\delta_t^v} \tag{1.12}$$

and we have the following cases:

1. $\delta_t^v = 0$*: then* $\delta_t^{m*} = 0$*, and* $r_t(w) - r_0(w) > 0$ *iff* $\delta_t^m < 0$.

2. $0 < \delta_t^v < \delta_t^{v*}$*: then* $\delta_t^{m*} > 0$*, and* $r_t(w) - r_0(w) > 0$ *iff* $\delta_t^m < \delta_t^{m*}$.

3. $-\frac{\nu_0}{\nu_0 - 2}\sigma_0^2 \leq \delta_t^v < 0$*: then* $\delta_t^{m*} < 0$*, and* $r_t(w) - r_0(w) < 0$ *iff* $\delta_t^m > 0$

Proof. The proposition follows directly from solving for the smaller root of δ_t^m in equation 1.10. □

Proposition 4 illustrates that the simple monotonic relationship between changes in mean and the agent's risk-taking in the mean-only model is an edge case in the mean-variance model, and breaks down even for moderate changes in variance. In particular, when the agent experiences an increase in variance relative to their prior, their risk-taking may decrease even under small increases in the mean. Conversely, agents who experience decreases in their variance relative to the prior may exhibit increases in risk-taking even under negative mean changes.

Note that here, as in the previous proposition, the threshold value that determines in which direction the agent's risk-taking changes under the countervailing effects of the experienced mean and variance depends both on the agent's information and on their utility. Under both cases 2 and 3 the absolute value of δ_t^{m*} captures the size of interval over which the variance effect dominates the mean. Aside from increasing in the absolute value of δ_t^v, in both cases it also increases in the ratio of the agent's posterior mean confidence to their prior mean confidence, and decreases in the ratio of variance posterior confidence to mean prior confidence and in the agent's absolute prudence.

Unlike in the previous proposition, however, the current result does not hinge on the quadratic form of δ_t^m in the $r_t(w) - r_0(w)$ function. Even under linearity in the mean a threshold δ_t^{m*} with similar properties would exist. This fact will prove important when we consider the effects of time in the next section.

1.6 Limiting behavior

Up to now we have assumed that the time period t is fixed for the agent. In the next proposition we examine how the change in risk-taking function is affected by t. To do this we could take a derivative in t, but the intuition of the result is clearer if we examine the limiting behavior of the function instead, as we do in the next proposition:

Proposition 5. (Limit in time) *Suppose an agent is a risk-vulnerable subjective expected utility maximizer who is updating as a Bayesian over structural uncertainty in a small background risk*

$\tilde{y}$, and has a CRRA utility function. Then

$$\lim_{t\to\infty}\left(r_t(w)-r_0(w)\right)\Big|_{\tilde{y}_t} = -\frac{\eta}{w^2}\delta_t^m + \frac{\eta(\eta+1)}{w^3}\delta_t^v \tag{1.13}$$

Proof. The proposition follows from applying L'Hôpital's rule once to equation 1.10 before taking its limit in t. □

Given a fixed frequency of realizations we can think of t as being the age of the agent. Proposition 5 can then be interpreted as speaking to the role of mean and variance changes to affect the agent's risk-taking when they are old. Two points can be seen from the form of the limit. First, the effect of the quadratic term in δ_t^m declines faster in time than that of the linear terms on the mean and variance. This is in line with the intuition in the previous section that the agent is affected more by quantities over which they have higher posterior uncertainty. Intuitively, the agent learns about the quadratic term from both the posterior mean and the posterior variance. Functionally, this would mean that we would expect younger individuals to exhibit a more asymmetric marginal response to the mean than older individuals.

The second point is that at the limit our learning model converges to a fully deterministic functional form, with the agent's utility function alone driving their response to new realizations of the background risk.[7] This is due to the stationarity of the underlying data generating process. Behaviorally, this corresponds to declining learning and increasing stability of risk-taking in the face of background risk as individuals age.

1.7 Discussion of the results

Our model paints a comprehensive picture of how risk-taking adapts to learning about unknown background risk. We reach several conclusions. Risk-taking monotonically increases in mean-preserving spreads in the data. Risk-taking is convex in mean changes, even for small

[7] In fact, this is exactly the functional form of the marginal effects of mean and variance in Gollier and Pratt (1996), as can be seen from converting the CRRA representations of the coefficients of absolute risk aversion, prudence, and temperance back to their original forms.

shocks, and declining across the prior mean boundary. This means that the marginal effect of small negative shocks on risk-taking is larger than the marginal effect of small positive shocks. This asymmetry in response declines in the agent's age. The relative sensitivity of the agent to the two moments depends both on their information and their utility, with the moment containing more posterior uncertainty having a proportionally larger effect on risk-taking. When the effects of both the mean and the variance are taken into account, the simple monotonic link posited in prior work between mean changes and changes in risk-taking breaks down. Increases in risk-taking are sometimes associated with an increasing mean and decreases in risk-taking are sometimes associated with an decreasing mean, depending on the value of the variance and the agent's relative sensitivity to the two moments.

In order to reach these conclusions we have made several strong simplifying assumptions. First, we have completely abstracted from any savings, insurance, or hedging decision that the agent might pursue, through our assumption of the non-existence of a savings technology and hand-to-mouth consumption. This assumption considerably simplifies our analysis, since it reduces both the choices that the agent makes and their beliefs function to essentially a static problem. This assumption means, however, that the results of our current analysis are likely to be more applicable to settings with missing insurance markets and significant barriers to savings, as is the case in much of the developing world today and was the case in developed countries in the not-too-distant past. How savings behavior and insurance choices interact with learning over background risk is important for extending our results to a broader class of settings and is a key direction for future work in this area.

A second set of important simplifying assumptions we make are on the agent's learning process. In our model learning is entirely passive, meaning that the agent makes no decisions that affect the information they receive. Understanding how adaptive risk-taking interacts with information search is important if we are to extend our analysis to examine risky decisions that also involve information gathering, like migration. Furthermore, we assume in the model that the agent's only source of information is personally-observed realizations of the background risk.

This abstracts from processes of social learning. By relaxing this assumption we should be able to study important margins in the long-run dynamics of risk-taking, particularly intergenerational transmission of risk attitudes and the consequent effect of shocks on the cultural evolution of risk-taking.

Finally, we make strong assumptions about the underlying data generating process, in particular its normality and stationarity. These may or may not be appropriate depending on the real-world application of the model. The normality assumption would likely be difficult to relax while maintaining analytical tractability. It is worth noting, however, that since we assume an unknown mean and unknown variance for the agent, the overall updating process is more general than the standard normal likelihood with unknown mean might imply. In particular our model of updating can be thought of as one where the agent updates their beliefs about the mean for a fat-tailed distribution, which many natural processes follow. Of course, many natural processes are also non-stationary, so examining the consequences of relaxing this assumption is a priority for future work.

1.8 Acknowledgements

Chapter 1 is currently being prepared for submission for publication of the material, and is sole authored by the dissertation author.

Chapter 2

Empirical Evidence of Risk-Taking Adaptation to Macroeconomic Experiences

Our model of adaptive risk-taking makes strong predictions about the effects of changes in background risk on individual risk-taking over time. In this chapter we test these predictions for macroeconomic risk using two large panel survey data sets from two large and diverse developing countries, Indonesia and Mexico. Both surveys contain repeated measures of absolute risk aversion for the same individuals several years apart. We link within-person changes in these measures to changes in real GDP growth statistics in individuals' state of birth over their lifetime.

Let R_{it} be our empirical measure of individual risk aversion, with higher values indicating lower propensity to take risks. We term the experienced mean of real GDP growth A_{it}, and the experienced volatility V_{it}. Our model makes three testable predictions for the correlation of growth experiences with individual measured risk aversion: (1) R_{it} **is increasing in** V_{it}; (2) R_{it} **is decreasing in** A_{it}; (3) R_{it} **is increasing in** A_{it}^2. The focus of this chapter is on testing these three predictions empirically, examining their behavioral consequences, and establishing whether they represent causal relationships.

2.1 Data and Methodology

We perform our empirical analysis using data from Indonesia and Mexico. These two countries are advantageous settings for our purposes, for two reasons. The first is their similarity. Both countries share a recent history of rapid and volatile economic change. since both are low- to middle-income, they exhibit significant missing markets in insurance, credit, and risk-sharing. This means that the average individual in both countries is likely to have experienced substantial and unavoidable changes in background risk over their lifetime, which in turn means that we are more likely to detect effects in line with our theoretical predictions in these settings.

The second reason is their differences. Indonesia and Mexico offer a distinct contrast along many plausibly important dimensions, including geography, level of development, language, culture, religion, institutions, and other aspects of their history.[1] This aids in establishing the both the internal validity and external validity of our results. If we detect common effects in both countries we can be more confident that they are not driven by idiosyncratic characteristics of either setting, and more comfortable in predicting that they will generalize to other settings.

For the Indonesian analysis our source of micro data is the Indonesian Family Life Survey (IFLS) (Strauss et al. (2009), Strauss, Witoelar and Bondan (2016)). The IFLS is a longitudinal study administered by the RAND corporation in 13 provinces in Indonesia in five waves, starting in 1993. For the Mexican analysis our source of micro data is the Mexican Family Life Survey (MXFLS), a longitudinal study administered in 16 states in three waves starting in 2002. The MXFLS was piloted by the RAND corporation, and is now managed by the Iberoamerican University (UIA) and the Center for Economic Research and Teaching (CIDE). Both surveys exhibit high recontact rates (>90%), and contain a wealth of economic and demographic covariates, allowing for a near-complete accounting of the balance sheet

[1]To make a few of these differences concrete: (1) Indonesia straddles the world's largest archipelago, spread out in equatorial waters in south-east Asia, while Mexico comprises a solid landmass in the North American continent; (2) Mexico is about 55% richer in per-capita GDP (PPP) terms than Indonesia as of 2018 ($20,602 vs. $13,230); (3) Indonesia is the world's largest Muslim country in the world, while Mexico is overwhelmingly Christian, primarily Roman-Catholic.

for subjects, including household income, assets, savings and borrowing. Both also contain residence and migration histories, allowing us to link place-based variables like GDP growth to subjects. Crucially for our purposes, the two most recent waves of both the IFLS and the MXFLS (IFLS4 (2007 - 2008), IFLS5 (2014), MXFLS2 (2005-2006), and MXFLS3 (2009-2012)) include modules for measuring subject financial risk aversion using hypothetical, high-stakes monetary gambles. We use measures from these modules to construct our primary dependent variables, which we describe in detail in Subsection 2.1.1.

We use sub-national measures of real GDP growth to construct measures capturing subject lifetime macroeconomic experiences, which are the primary independent variables in our analysis. Our data on GDP growth at the province level in Indonesia (equivalent to the state level in the United States) comes from the Indonesian Bureau of statistics (BPS) via the World Bank's INDO-DAPOER database, and from the BPS's statistical yearbooks for the years 2012-2015. These data exist at the province level starting in 1977. For Mexico, we obtain state level growth data from German-Soto (2005), who construct the GDP series using historical data from the National Institute on Statistics and Geography (INEGI). These data are available starting in 1941. We describe how we construct macroeconomic experience variables and assign them to subjects in detail in Subsection 2.1.2.

The sample for our main analysis is subjects who completed the risk aversion module in both waves of each survey. Focusing on subjects who appear in both waves of each survey allows us to estimate a model with individual fixed effects, which eliminates substantial amounts of noise due to idiosyncratic variation. This results in a primary sample of 17,302 subjects for Indonesia and 8,187 subjects for Mexico, each appearing twice in our data. In some analyses we do not include individual fixed effects, which allows us to expand the sample to all subjects who responded to the risk module in either wave of each survey, for a total of 55,820 subject-year observations in Indonesia and 25,005 subject-year observations in Mexico. Summary statistics for the complete survey samples and the primary samples are available in Section A.1. The geographic distributions of our samples in Indonesia and Mexico are available in Section A.2.

2.1.1 Risk Aversion Measures

Both surveys include modules for measuring financial risk aversion, from which our main dependent variables are constructed. These modules employ "staircase" instruments, similar to those used in Falk et al. (2018). Staircase instruments have been shown to generate high-quality measures of risk aversion with low subject response burden, which makes them ideal for field applications. In a staircase risk aversion instrument subjects are given a series of hypothetical high-stakes choices between a safe lottery (often a sure amount of money) and a riskier lottery (which generally has a higher mean and a higher variance than the safe option). Lotteries are commonly in the form of fair coin flips. Based on the subject's choice in the first question they are sorted into one of two other questions with different amounts of money for the lotteries. If the subject previously chose the safe (risky) option, risk in the coin flip is reduced (increased) in their subsequent question. This process can then be repeated as many times as necessary to yield as fine a measure of risk aversion as desired. The result is an ordinal binned measure of absolute risk aversion for each subject. Our process for constructing the risk aversion measures from the IFLS and MXFLS data is displayed in Section A.3.

In IFLS4 and IFLS5 subjects answered between two and three questions each, which resulted in measure with five bins. Each question offered the same fixed safe amount of money, while the amounts of the risky lottery varied between questions. The same module with the exact same amounts per question was used in both waves of the survey. We code the resulting measure with higher numbers (1-5) indicating more risk aversion. One complicating factor with the IFLS risk aversion module is that the first question offered subjects a choice between a sure amount and a coin flip over two higher amounts. Between 28% and 40% of the sample chose the dominated, certain option, even after being prompted to reconsider a second time (see Section A.4 for the sample distribution of the risk aversion measure). It is unclear whether these "gamble averse" subjects are extremely risk averse (or certainty seeking), or whether another factor, like subject misunderstanding or aversion to gambling generally is driving these choices.

In our main analysis we include these subjects and code them as having the highest rate of risk aversion. In Section 2.4 we test the robustness of our results to excluding these subjects from the sample. Reassuringly, our main results are qualitatively similar for the effect of the variance, though the sign of the mean effect changes when excluding these individuals.

In MXFLS2 subjects answered between two and five questions each, which resulted in a measure with five bins. Questions offered subjects a choice between a safe coin flip and a riskier coin flip, with the amounts of the riskier coin flips generally changing between questions. We code the resulting measure with higher numbers (1-5) indicating more risk aversion. The staircase instrument was changed for MXFLS3 to align more closely with the instrument in the IFLS. In MXFLS3 subjects answered between two and five questions each, resulting in a measure with six bins. Each question offered the same fixed safe amount of money, while the amounts of the risky lottery varied between questions. A "gamble averse" option was offered in this instrument. Since gamble aversion only appears in one wave of the MXFLS we drop subjects who chose this option in MXFLS3 from our sample. We code the resulting measure (1-5) in the same way as the other measures.

A pervasive concern with all elicited measures of financial risk aversion is the high degree of noise that they exhibit, which often means their predictive power for real-world risky behavior quite low (Yariv, Gillen and Snowberg (2019)). This raises the possibility that any detected effects on measured risk aversion will be due to noise, and won't translate to real changes in risk-taking behavior by the subjects. We address this concern head on in Subsection 2.3.3, where we show that subjects who became more risk averse by our measures also became less risk-taking in their economic behavior. We can also examine the predictive capacity of our measures in the cross-section. In Section A.5 we present the results of regressing our measures of risk aversion on a host of demographic covariates and economic variables capturing risk-taking behavior in our samples, without including individual fixed effects in the regression. For subjects for whom we have complete data for all covariates our IFLS risk aversion measure, unlike many in the literature, exhibits significant correlations with risk-taking behavior like self employment and migration, and demographic measures like age and gender in expected ways, both in primary (panel) sample and in the broader sample. Our measure of risk aversion from the MXFLS is noisier than that in the IFLS, and consequently only exhibits significant correlations with smoking and age.

2.1.2 Macroeconomic Experience Variables

As a broad-based measure of macroeconomic conditions we use real GDP growth at the lowest administrative unit for which all pertinent data is available, the Indonesian province and Mexican state (both roughly equivalent to US states). Our data contain time series from 25 Indonesian provinces spread out over 9 major islands, and all 32 Mexican states, corresponding to the birth provinces reported by subjects in the IFLS and MXFLS.

Two complications with the growth data are worth noting. First, the boundaries of administrative units in Indonesia have not remained constant over our period of measurement. Following the 1998 collapse of the Suharto regime, Indonesia underwent a rapid (and still ongoing) process of decentralization. As a consequence, many administrative units at all levels of the state split, with the number of provinces increasing from 27 to 34 from 1993 to 2015. Since our analysis requires a consistent definition of administrative units, we mapped back all province-level variables (including GDP, population, and inflation) to provinces as they were defined in 1993. This is possible to do because in all cases a larger province split into multiple provinces, and in no cases did they recombine into novel provinces. Thus, every province in 2015 has exactly one corresponding ancestor province in 1993. To avoid confusion we refer to Indonesian provinces throughout by their names in 1993. Second, measurement error for sub-national macroeconomic variables in both countries is likely to be substantial. To reduce the effects of noise due to measurement error on our results we winsorize the province- and state-level GDP measures at the 5-95 level.

To construct our macroeconomic experience variables, we first assign to each individual the province/state real GDP growth time series in their birth province. Subjects who are born after 1976 in Indonesia and 1940 in Mexico, the first years for which subnational GDP data is available in each country, respectively, are assigned time series starting in their year of birth. Subjects born before these years are assigned time series starting in these initial years for their province of birth.

Once the time series are assigned we calculate for each individual the mean (A_{it}) and the standard deviation (V_{it}) of their time series from birth to year of measurement in the corresponding survey. Thus an individual born in East Java in 1981, for instance, will be assigned the statistics for the East Java time series from 1981 to 2007 (the year of IFLS4) and from 1981 to 2014 (the year of IFLS5). Let g_{is} be the growth rate assigned to person i in year s. Then for year of measurement t these statistics are:

$$A_{it} = \frac{1}{t-b_i} \sum_{s=b_i+1}^{t} g_{is} \tag{2.1}$$

$$V_{it} = \sqrt{\frac{1}{t-b_i-1} \sum_{s=b_i+1}^{t} (g_{is} - A_{it})^2} \tag{2.2}$$

where

$$b_i = \begin{cases} \text{BirthYear}_i & \text{if BirthYear}_i > B \\ B & \text{if BirthYear}_i \leq B, \end{cases}$$

and

$$B = \begin{cases} 1976 & \text{if Country}_i = \text{Indonesia} \\ 1940 & \text{if Country}_i = \text{Mexico}. \end{cases}$$

To estimate the effects of experienced growth an alternative approach we might have employed, rather than calculating the above statistics, is to regress our measure of risk-taking on growth in each year for each individual. We elect to use the above method for three reasons. First, the year-by-year analysis would result in an unbalanced panel structure for our data, with all the attendant difficulties. Second, we would likely be under-powered to estimate the large number of parameters in such an analysis (Malmendier and Nagel (2011)). Third, the statistics we calculate correspond closely to relevant quantities in our model, allowing for direct tests of the theoretical predictions in our data.

2.1.3 Empirical Specification

Our baseline empirical specification is a two-way fixed effects model where we regress the individual risk aversion measure R_{it} on A_{it}, A_{it}^2, and V_{it}, as well as a constant α_{FE} and individual and time fixed effects:

$$R_{it} = \alpha_{FE} + \alpha_i + \alpha_t + \beta_1 A_{it} + \beta_2 A_{it}^2 + \beta_3 V_{it} + \gamma_1 PriceLevel_p + \gamma_2 X_{it} + \varepsilon_{it}. \tag{2.3}$$

The individual fixed effect α_i absorbs variation due to time-invariant idiosyncratic heterogeneity, whereas the time fixed effect α_t nets out the effect of aggregate time trends.

A salient concern about regressing R_{it} on the macroeconomic experience variables is that inflation could bias the estimates of the effects, for two reasons. First, since R_{it} is measured off of nominal hypothetical lotteries, the real value of the prizes offered in these lotteries can change between waves. This means that inflation, even at the national level, can introduce noise into the repeated measurement of risk aversion using these survey instruments. The second concern is that inflation can introduce bias into the analysis if it varies significantly at the subnational level, as we in fact observe in the data. This is because subnational inflation might correlate with province-level growth and growth volatility, as well as R_{it}, creating a potential omitted variable bias problem. To address these concerns we include a measure of the price level subnational for administrative unit p as a control variable in all baseline specifications. This takes the form of a consumer price index normalized to 100 during the year of the first wave (IFLS4 and MXFLS2) of the respective survey. In Indonesia p is the province level, whereas in Mexico, due to data constraints, p is region.

Our baseline specifications, which are meant to yield as close to a clean estimate of the causal effect of macroeconomic experiences on risk-taking, include no additional controls. This is due to concerns about the endogeneity of variables like income or assets with risk-taking, which could affect identification. In Subsection 2.3.2 we demonstrate the robustness of our results to including additional time-varying controls, which are represented by X_{it} above. The errors ε_{it} are clustered at the province of birth by birth year level in our baseline specification, which is the level of treatment in our analysis.

Since we have two periods in our analysis (the first and second waves of each survey), our two-way fixed effects specification is econometrically equivalent to a first-difference specification:

$$\Delta R_{it} = \alpha_{FD} + \beta_1 \Delta A_{it} + \beta_2 \Delta A_{it}^2 + \beta_3 \Delta V_{it} + \gamma_1 Inflation_p + \gamma_2 \Delta X_{it} + \varepsilon_{it}. \tag{2.4}$$

For expositional reasons we present the results below for the first-difference specification.

2.2 Identification

The goal of our empirical analysis is to yield clean causal estimates of the effects of lifetime experiences of growth dynamics on individuals' attitudes towards risk. This aim is complicated by several econometric issues. We discuss these issues and our solutions to them in this section.

The **first** issue arises from the nature of the data used to estimate individuals' risk-taking in economics. By definition, subjects' propensity to take risks is a mental process, which we have not yet figured out how to observe directly. Rather, we observe choices that an individual makes and infer something about the underlying attitudes that are driving them. In the case of risk-taking a vast array of different instruments are used in the literature, ranging from real-world behaviors like portfolio, employment, or crop choices, to experimental instruments using monetary lotteries, to surveys of self-reported attitudes.

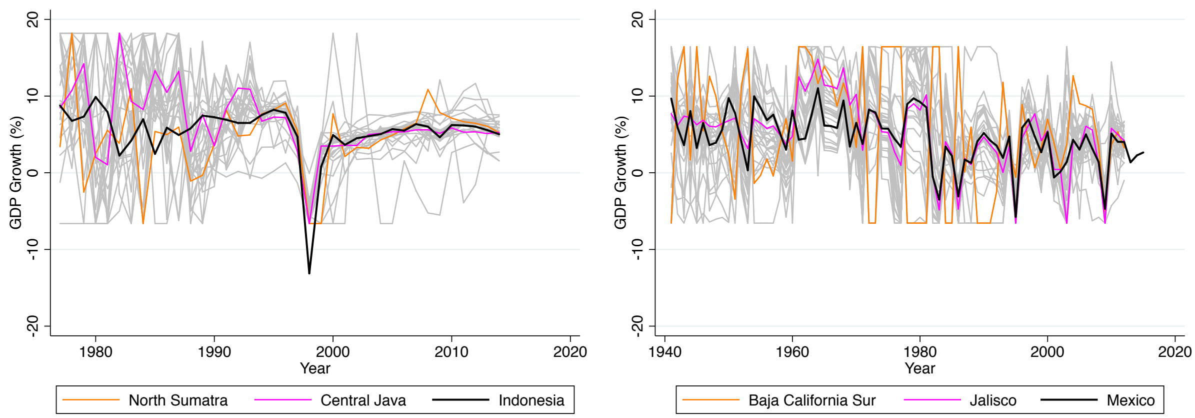
In order to be able to identify changes in attitudes towards risk from data on changes in risky choice one confound we must account for is that observed changes in choices might reflect changes in the properties of the good over which the choices are being made, rather than the attitudes themselves. A second, related concern is that since we are linking changes in choices to changes in the agent's environment, changes in the choices might reflect changes in the relationship between the object of choice and the environment, rather than the effect of the environment on the underlying attitudes.

As an illustration of these points consider the potential use of portfolio choice as a measure of risk-taking in our setting. Imagine that we observe a subject investing 100% of their wealth in stocks in period one, and 100% of their wealth in (safer) bonds in period two. We know that macroeconomic volatility increased from period one to period two. Can we say that this increase in volatility made the agent more risk averse? Maybe. But something else that could be happening is that the characteristics of the stocks in the agent's portfolio have independently changed over time–perhaps the companies issuing them came out with negative earnings statements between period one and two. Another possibility is that the relationship between macroeconomic volatility and stock returns has changed between the two periods, as it is known to do over the business cycle. In either one of these cases we might think that the agent's attitudes towards risk have changed, when in reality the properties of the choice we use to measure risk-taking have changed instead.

Our empirical measure of risk-taking is uniquely suited to overcoming these issues. The hypothetical lotteries offered the subjects have known odds and prizes in both surveys, and are fixed between the waves of the survey in the IFLS. This means that changes in subject choice are unlikely to be driven by changes in the characteristics of the lotteries, especially once we control for inflation. Furthermore, the prizes in the lotteries are statistically independent and exogenous of the growth experiences of the subjects, meaning that observed changes in choice are unlikely to be driven by changes in the relationship of the object of choice to the environment.

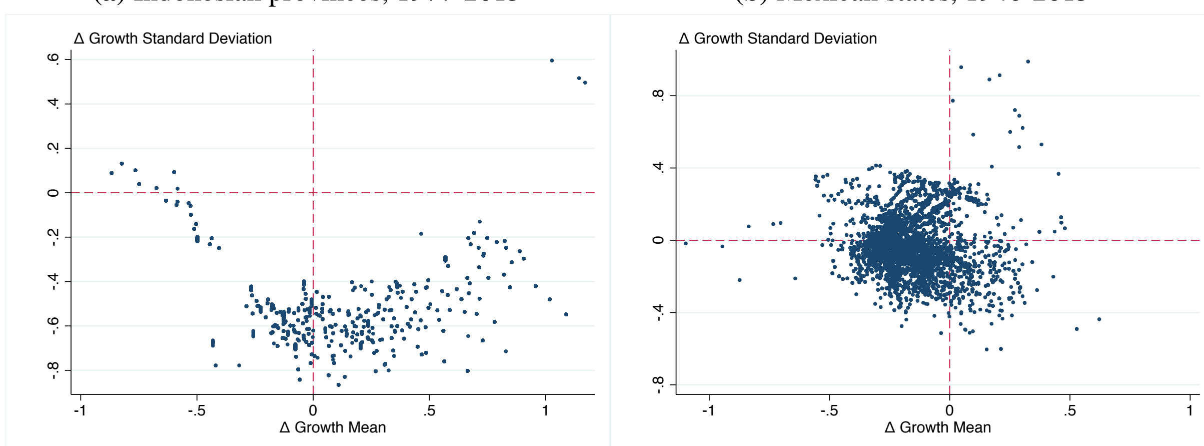
A **second** concern for identification is the possibility of reverse causality, where changes in subjects' propensity to take risks changes the macroeconomic environment to which they are exposed, instead of the other way around. The primary channel through which this might occur in our setting is endogenous migration, as migration could lead to exposure to different macroeconomic conditions, and is thought to be a risky choice itself (Bryan, Chowdhury and Mobarak (2014)). For instance, it might be the case that individuals whose propensity to take risks increases differentially migrate to provinces experiencing increases in growth. To address this concern in our baseline analysis we use macroeconomic conditions in an individual's province or state of birth over their lifetime, rather than their province or state of residence. By doing so we are, in essence, instrumenting for presence in a given location with their location of birth, which is exogenous under the assumption that location of birth does not correlate with later in life risk-taking dynamics or growth dynamics.

A **third** possible threat to identification is macro-level omitted variable bias, or the existence of an unobserved aggregate variable that could be correlated with growth dynamics and driving changes in individual risk attitudes. One might imagine, for instance, that instances of natural disasters or the outbreak of violence could increase risk aversion (Cameron and Shah (2015), Callen et al. (2014)) and be correlated with growth volatility. We employ a three-pronged approach to deal with this issue. First, our inclusion of a time fixed effect in the regression ensures that aggregate trends at the national level do not contaminate our estimates. Second, we employ subnational variation in macroeconomic conditions within two countries over time. This means that any potential omitted macro variable driving the results would have to correlate with growth dynamics over both space and time in order to generate our estimated effects. While this is possible, we believe that it is unlikely given the substantial variation that exists in our data (see Figure 2.1). This identifying variation comes from three sources: heterogeneity in growth experiences between cohorts, within cohorts over time, and within cohort in the cross-section. Third, we control directly for some of the most likely suspects, particularly exposure to violence and natural disasters, in Subsection 2.3.2 and see no meaningful change in the results.



(a) Indonesian provinces, 1977-2015

(b) Mexican states, 1940-2015



(c) Indonesia birth-province cohorts

(d) Mexican birth-state cohorts

Figure 2.1. Variation in Macroeconomic Data

Notes: This figure displays our macroeconomic data in two ways. The top two panels display the real GDP growth time series for all 25 Indonesian provinces (1993 definitions) and 32 Mexican states in our data (winsorized at the 5-95 level to reduce measurement error), as well as the national GDP time series. As can be seen these time series exhibit substantial variation both in the cross section and over time. The bottom two panels display the raw distributions of our main explanatory variables ΔA_{it} and ΔV_{it} graphed against each other in each country. These scatterplots demonstrate that substantial variation exists not only in macroeconomic conditions across provinces/states, but also in the dynamics of macroeconomic experiences at the individual level.

A **fourth** and final concern is micro-level omitted variable bias, or the possibility that an unobserved individual-level covariate is erroneously driving the correlation we observe between growth dynamics and measured risk aversion. Since our outcome variable is within-person changes in measured risk aversion, we can rest easy that static individual-level covariates, like subjects' income level, are not likely to be driving our results. Nevertheless it is possible that changes in individual-level variables could be driving the result. The most likely culprits, according to theory, are household-level economic variables like changes in income and assets. In Subsection 2.3.2 we control for these directly and find that our results are robust to their inclusion.

To our knowledge, ours is the first paper in the empirical experience effects literature to include data from multiple countries, subnational variation in each, and repeat observations of the outcome of interest for the same individuals. Malmendier and Nagel (2011) use the national-level time series of stock market returns and examine stock market participation and elicited risk aversion in a repeated cross-section specification. Shigeoka (2019) exploits within-country variation in macroeconomic conditions in Japan, but its empirical analysis does not include individual fixed effects or cross-country data. Malmendier and Shen (2019) and Ampudia and Ehrmann (2017) use cross-country data from 13 Eurozone countries in their estimates of the effects of economic shocks on risk taking, but do not include individual fixed effects or subnational macroeconomic data in their analyses. A number of papers in the development literature present data containing repeat measures of risk aversion for the same individuals, and exploit fine-grained subnational variation in the occurrence of violence (Jakiela and Ozier (2019), Brown et al. (2019)) or a natural disaster (Cameron and Shah (2015), Hanaoka, Shigeoka and Watanabe (2018)), but these studies generally focus on a discrete set of events rather than cumulative lifetime experiences of risk, and none contains evidence from multiple countries.

2.3 Results

This section contains the findings from our three primary empirical analyses. In Subsection 2.3.1 we present the results from regressing within-subject changes in measured risk aversion on subjects' experienced mean real GDP growth (linear and squared) and growth volatility. These regressions, which include no controls aside from subnational inflation, are the most direct tests of the three model-generated hypotheses discussed at the beginning of this chapter. In Subsection 2.3.2 we demonstrate the robustness of these findings to the inclusion of controls for changes in subjects' economic constraints and experiences of violence and natural disasters. In Subsection 2.3.3 we display the correlation between changes in several kinds of risky behaviors and predicted change in risk-taking based on the model we estimated in Subsection 2.3.1.

2.3.1 Effects of macroeconomic experiences on measured risk aversion

Our main empirical findings are presented in Table 2.1. Column 1 displays the result of regressing changes in measured risk aversion on mean changes in experienced growth in subjects' province or state of birth. In line with hypothesis 2, the estimated effect of the mean in both countries is negative and highly significant.[2] In column 2 we show the results of regressing changes in measured risk aversion on changes in the standard deviation of growth. In line with hypothesis 1 the estimated effect of changes in volatility is positive and highly significant in both settings. These findings hold when we regress changes in measured risk aversion on both mean and volatility, as can be seen in column 3.

In column 4 we display the results of adding the change in squared mean term to the previous specification. As before, the coefficient of the volatility term remains highly significant and positive in both settings. In the Mexican data the coefficient of the linear mean term remains negative, highly significant, and its magnitude increases by approximately 75%, while the coefficient of the mean squared term is positive and marginally significant, in line with hypothesis 3. In the Indonesian data in this specification the coefficient of the linear mean term becomes statistically insignificant, while the coefficient of the mean squared is actually marginally significant and negative.

[2]This is the specification most closely analogous in our main analysis to Malmendier and Nagel (2011), who examine the differential effects of mean changes in macroeconomic conditions (like stock market returns) on stock market participation and elicited risk aversion. Our first result here is broadly consistent with their findings.

Overall our results provide strong evidence for hypotheses 1 and 2, but only weak or mixed evidence for hypothesis 3. While the coefficient of the mean squared term is of the correct sign in Mexican data, it is only marginally significant, and the corresponding coefficient in the Indonesian data is actually of the opposite sign (though also marginally significant). It is possible that these results (or lack thereof) are driven by the stronger dependence of the mean squared on the subjects' age, as the theory suggests. Notably, however, the magnitude of the linear mean term in both settings changes considerably once the mean squared term is introduced. This suggests that the square of the mean might play an important role in the overall effect of the mean on measured risk aversion, though ultimately our data are too noisy to reliably estimate this effect consistently.

It is also notable that the magnitude of the volatility term is .9 (Mexico) to 4.3 (Indonesia) times as large as the linear mean term in specification 3, where their magnitudes are most directly comparable. This tells us that the marginal effect of changes in variance are not second-order relative to that of the mean, but are rather as important if not significantly more so for driving changes in subjects' measured risk aversion.

Table 2.1. Main results

Dep. Var: Δ Meas. Risk Av.	(1)	(2)	(3)	(4)
Indonesia				
Δ Growth Mean	-0.35***		-0.30***	0.42
	(0.08)		(0.07)	(0.46)
Δ Growth Mean^2				-0.07*
				(0.04)
Δ Growth Volatility		1.36***	1.30***	1.21***
		(0.17)	(0.16)	(0.18)
Observations	17302	17302	17302	17302
Mexico				
Δ Growth Mean	-1.02***		-0.97***	-1.69***
	(0.20)		(0.19)	(0.44)
Δ Growth Mean^2				0.10*
				(0.05)
Δ Growth Volatility		0.91***	0.87***	0.86***
		(0.17)	(0.17)	(0.17)
Observations	8187	8187	8187	8187

Notes: *Measured Risk Aversion*: 1-5, 5 highest measured risk aversion. Province (Indonesia) and regional (Mexico) inflation included in all regressions. Standard errors clustered at the cohort by province/state of birth level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

2.3.2 Additional controls

Our main results are estimated without the inclusion of any additional controls aside from subnational inflation, though there are well-founded reasons to include additional covariates. Theoretically, changes in subjects' income, wealth, buffer stocks of savings, or other economic circumstances might be expected to influence their measured risk aversion. Empirically, previous studies have shown that exposure to traumatic experiences like natural disasters and violence can change measured risk aversion.

We do not include these controls in our main analysis because they are endogenous to risk aversion itself. This means that their inclusion could threaten the causal interpretation of our results. Nevertheless, we would like to know whether we can interpret the changes we observe in measured risk aversion as representing changes in underlying risk attitudes, or merely as driven by changes in personal economic circumstances. Further, it would be useful to directly test whether macroeconomic experiences are in fact driving the observed changes or whether other kinds of experiences whose incidence may be correlated with growth dynamics are in fact playing a central role.

We provide some evidence on these points in Table 2.2, where we progressively add in additional controls to the specification for the last column in Table 2.1. These include time-varying demographics, like marital status, educational attainment, and household size; changes in income, assets, and savings; and self-reported exposure to violence and natural disasters (full details on the controls are available in Section A.6). In both countries our results are highly robust to the inclusion of this rich set of covariates, suggesting that the changes we estimate in measured risk aversion are driven by experienced growth dynamics and represent changes in underlying attitudes towards risk.

2.3.3 Changes in Risky Behavior

Another issue of interpretation of our results is the question of whether changes in measured risk aversion capture changes in actual risk-taking behavior for subjects. We study this question by constructing a variable measuring predicted change in risk aversion ($\widehat{\Delta R_{it}}$) using our preferred specification (column 4 of Table 2.1), and examining its correlation with changes in downstream risky behaviors in our data. We focus on behaviors commonly examined in relation to risk-taking in the literature, and for which we have data: smoking, having ever migrated across province or state lines, self-employment status, and, in Indonesia, whether subjects report that their land is planted in at least one cash crop.[3] This last measure captures risky investment

[3] Cash crops asked about in the IFLS include coconut, coffee, cloves, rubber, and other hard stem plants.

Table 2.2. Additional controls

Dep. Var: Δ Meas. Risk Av.	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Indonesia							
Δ Growth Mean	0.42	0.33	0.32	0.33	0.34	0.34	0.42
	(0.43)	(0.44)	(0.45)	(0.44)	(0.45)	(0.44)	(0.44)
Δ Growth Mean^2	-0.07*	-0.06	-0.06	-0.06	-0.06	-0.06	-0.07*
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Δ Growth Volatility	1.21***	1.24***	1.24***	1.24***	1.24***	1.23***	1.22***
	(0.18)	(0.19)	(0.19)	(0.19)	(0.19)	(0.18)	(0.18)
Observations	17,302	16,086	16,082	16,082	16,082	16,082	16,082
Mexico							
Δ Growth Mean	-1.69***	-1.78***	-1.77***	-1.75***	-1.74***	-1.79***	-1.71***
	(0.44)	(0.45)	(0.45)	(0.45)	(0.45)	(0.46)	(0.45)
Δ Growth Mean^2	0.10*	0.11*	0.11*	0.10*	0.10*	0.10*	0.09*
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.06)	(0.05)
Δ Growth Volatility	0.86***	0.85***	0.86***	0.86***	0.86***	0.82***	0.80***
	(0.17)	(0.17)	(0.17)	(0.17)	(0.17)	(0.17)	(0.17)
Observations	8,187	8,046	8,046	8,046	8,046	7,996	7,996
Inflation	X	X	X	X	X	X	X
Δ Demographics		X	X	X	X	X	X
Δ Income			X	X	X	X	X
Δ Assets				X	X	X	X
Δ Savings					X	X	X
Δ Violence						X	X
Δ Natural Disasters							X

Notes: *Measured Risk Aversion*: 1-5, 5 highest measured risk aversion. Province (Indonesia) or regional (Mexico) inflation included in all regressions. Demographics include marital status, household size, household size squared, and educational attainment. Violence and natural disasters variables from self-reported exposure. Standard errors clustered at the cohort by province of birth level in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

behavior in our data.

Results for this analysis are presented in Figure 2.2, which displays the average value of each downstream variable for each quartile of the $\widehat{\Delta R_{it}}$ distribution. Here light blue bars represent subjects who are predicted to become measurably less risk averse by our model, while dark blue bars represent subjects who are predicted to become measurably more risk averse. 95% confidence intervals are indicated for each quartile. We use the first to fourth interquartile range as an empirical benchmark and run a two-sided t-test to check if the difference between the average values of the outcome in these quartiles is statistically significant.

Our results provide strong evidence that increases in measured risk aversion predicted by experienced growth dynamics are associated with decreases in risk-taking behavior in Indonesia, and moderate and somewhat conflicting evidence of the same in Mexico. Increases in predicted risk aversion are associated with decreases in risk-taking behavior for six out of the seven variables examined. Three of these declines are significant at conventional levels, all in Indonesia: Smoking (4.3 percentage point increase to 1.2 percentage point emphdecrease ($p = .0001$)), Ever Migrated across Province Lines (+1.3pp $\rightarrow$ +0.2pp, ($p = .0001$)), and Self Employed (+7.3pp $\rightarrow$ +4.7pp, ($p = .053$)). Three decreases are not significant at conventional levels: planting of cash crops in Indonesia (+2.1pp $\rightarrow$ +1.5pp, ($p = .3$)), smoking in Mexico (+2pp $\rightarrow$ +0.9pp, ($p = .236$)), and Ever Migrated across State Lines in Mexico (+0.5pp $\rightarrow$ +0.3pp, ($p = .274$)). One outcome, self-employment in Mexico, exhibits a marginally significant increase (+0.9pp $\rightarrow$ +4.6pp, ($p = .087$)).

The decreases in risk-taking behavior predicted by increases in measured risk aversion are large and economically significant. In Indonesia, the first to fourth interquartile range of $\widehat{\Delta R_{it}}$ for smoking represents a 17.5 percent decline relative to the IFLS4 baseline, for migration an 8.1% decline, for self employment a 6.5% decline, and for cash crop planting a 7.4% decline. In Mexico the interquartile range for smoking represents a 14.1% decline relative to the MXFLS2 baseline, for migration a 1.3% decline, and for self employment a 17% increase.

We can also quantify the magnitudes of lifetime changes in mean growth and growth volatility associated with changes in risky behavior. In Indonesia the first to fourth interquartile range represents a .32 percentage point decrease in mean growth (+.13pp $\rightarrow$ $-$.19pp) and a .27pp increase in the standard deviation of growth ($-$.61pp $\rightarrow$ $-$.34pp). In Mexico the first to fourth interquartile range represents a .22pp decrease in mean growth ($-$.01pp $\rightarrow$ $-$.23pp) and a .29pp increase in the standard deviation of growth ($-$.16pp $\rightarrow$ +.13pp).

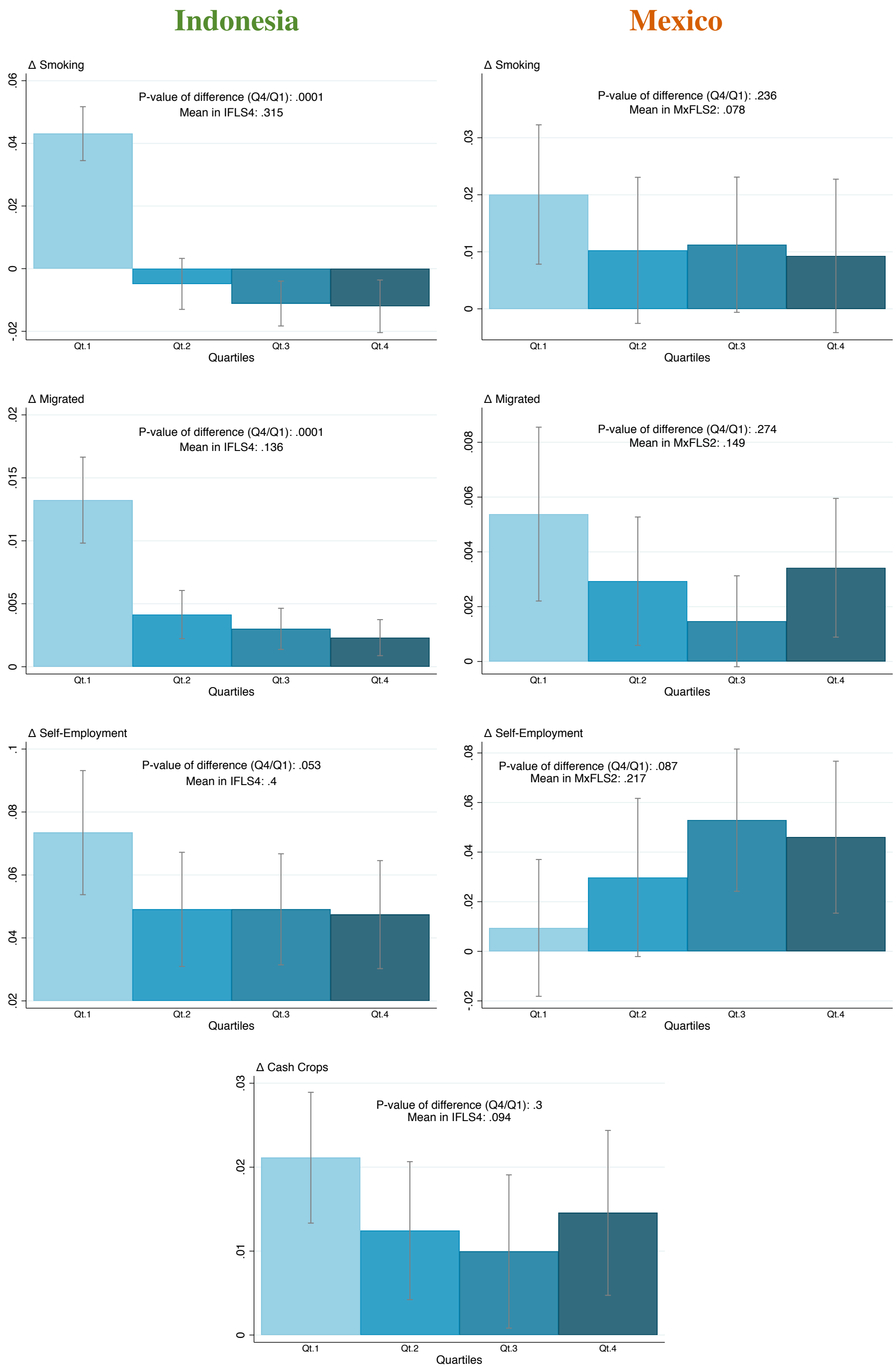


Figure 2.2. Correlations of changes in risky behaviors with predicted increase in risk aversion

Notes: Bars represent quartiles of the predicted change in risk aversion distribution. Light blue is the bottom quartile of this distribution, representing the agents who are predicted to experience a decrease in risk aversion. Bottom panel is from the Indonesian data.

2.4 Robustness

We test the robustness of our main results to varying methodological choices in our analysis. First, in Section A.7 we present the results of running our main analysis with **alternate sample compositions**. In particular, we (1) limit the analysis to individuals born after 1976 in Indonesia and 1940 in Mexico (for whom we have full lifetime macroeconomic histories); (2) include only individuals born after 1976 in Mexico (to compare with the parallel sample from Indonesia); and (3) exclude the "gamble averse" from our analysis in Indonesia (see Subsection 2.1.1). The results are qualitatively quite similar for each of these samples, though the sign of the linear mean term in Indonesia becomes positive when the gamble averse are excluded.

In Section A.8 we present the results of our main analysis for **alternate specifications of measured risk aversion**. For both Indonesia and Mexico, we repeat the analysis with (1) a binarized measure of risk aversion (instead of using the 5 buckets of measured risk aversion, we set buckets 1 and 2 to be 0, and buckets 3, 4 and 5 to be 1); and (2) using an ordered probit specification. The latter specification accounts explicitly for the ordinal nature of our risk aversion measure, though its results should be interpreted with care as the ordered probit with two way fixed effects estimator is known to be biased. For both specifications results are qualitatively quite similar to the baseline.

In Section A.9 we present the results of our main analysis using data on **macroeconomic conditions in subjects' province or state of residence**, rather than their province or state of birth. Here we use the migration histories for subjects and assign them growth time series based on their actual location in every given year. These data more closely match the intuitive notion of macroeconomic experiences, but, as discussed above, suffer from a potential identification problem due to endogenous migration. Results are again qualitatively similar to the main analysis, with the magnitudes of the mean coefficients in specification 4 in both countries increasing by 40%-80% and becoming more significant.

Malmendier and Nagel (2011) estimate a non-linear single parameter weighting function for the effects of mean stock market returns on later in life stock market participation and elicited risk aversion. Malmendier and Nagel (2016) extend this analysis to the context of inflation experiences. This **temporal weighting function** is meant to flexibly estimate higher relative weights on early, formative experiences or on recent experiences due to recency bias. In Section A.10 we extend their method to the context of lifetime volatility experiences. Our results are qualitatively similar to those in our baseline model. We estimate substantial recency effects across all specifications using this method.

In Section A.11 we present the results of our main analysis with **standard errors clustered at the province/state of birth level**, using the wild bootstrap method of Cameron, Gelbach and Miller (2008). Estimates of our coefficients are mostly not significant at conventional levels under this scheme, though the coefficient of the mean and the volatility terms in Mexico are significant in some specifications.

In Section A.12 we conduct our main analysis using a **repeated cross-section specification** that drops the individual fixed effects from the regression. We perform this analysis both restricting to our primary sample and extending the sample to any individuals who respond to the risk instrument in one of the waves of the surveys. The msgnitude of the estimated coefficients drops considerably in both settings under this specification. While the estimates for Mexico are no longer significant, estimates for our Indonesian sample remain consistent and significant.

2.5 Conclusions

Our analysis provides significant evidence that lifetime experiences of growth dynamics do indeed shape risk-taking for individuals in developing countries. Using micro data from two different countries, linked to subnational growth statistics capturing subjects' macroeconomic experiences, we find strong support for the hypotheses of our model regarding the effects of mean and variance of background risk. These findings are robust to the inclusion of a rich set of controls for changes in economic circumstances and other categories of experiences. Changes in measured risk aversion correlate with substantial changes risk-taking health, migration, and economic behavior.

2.6 Acknowledgements

Chapter 2 is currently being prepared for submission for publication of the material, and is coauthored with Daniela Vidart. The dissertation author was a primary investigator of this material.

Chapter 3

Empirical Evidence of Risk-Taking Adaptation to Climate Change

In the previous chapter we examined the adaptation of risk-taking by individuals in Indonesia and Mexico to lifetime experiences of GDP growth dynamics. In this chapter we apply the same methodology to a different source of environmental risk—climate change. As in the previous chapter, we will focus on testing the three key predictions of our model: (1) R_{it} **is increasing in** V_{it}; (2) R_{it} **is decreasing in** A_{it}; (3) R_{it} **is increasing in** A_{it}^2. Here, however, the mean and variance examined will be of time series of temperature and precipitation, rather than economic growth.

3.1 Data and methodology

Our primary source of microdata are the Indonesian family life survey (IFLS) and Mexican family life survey (MXFLS). Descriptions of these data and our measures of risk aversion are available in Section 2.1. For the climate change variables in Indonesia we use the universe of available ground station temperature data, reported by the National Climate Data Center (NOAA-CDO (2020)). In Mexico we use the gridded weather data for North America compiled by Livneh et al. (2015), which contains information on temperature and precipitation. In the next section we describe the construction of our climate change experience variables using these data.

3.1.1 Climate experience variables

To construct our main independent variables for the analysis we begin by constructing province/state-month time series for temperature in Indonesia and temperature and precipitation in Mexico. In Indonesia, we use the universe of available ground station data, reported by the National Climate Data Center (NOAA-CDO (2020)). Following concerns about measurement error due to entry and exit of stations as detailed in Dell, Jones and Olken (2014), we restrict the set of stations in our baseline specification to 61 stations that do not exit during the extent of our panel, from 1972 to 2014. These stations report daily mean temperatures in degrees Celsius (following convention, this daily mean is the mean of the daily maximum and minimum readings). To reduce the incidence of measurement noise we winsorize this station-day data set at the 1-99 level over the universe of station-day observations. We take the median of these station-day means over all stations in a province to get province-day observations. We then average the province-day observations over days of a month to yield province-month time series.

Some measurement error exists in earlier data in Indonesia due to stations going offline. Reassuringly, for earlier years in the data less than 1% of province-month observations are missing. We demonstrate robustness to alternate specifications of the Indonesia temperature data in Section 3.3.

In Mexico we use data from the gridded weather product for North America created by Livneh et al. (2015). These data contain meteorological variables at a 6 kilometer-pixel resolution at the daily frequency from 1950-2013. As is the convention with this type of data in the literature, we construct daily mean temperatures for each pixel by averaging the highest and lowest daily reading for that pixel. We then construct pixel-month time series by averaging daily pixel means within each month. We match pixels to Mexican states using the GIS layer of Mexican administrative state boundaries from the Department of the Interior DOI (2020) (in Section 3.3 we show robustness to a different state matching procedure using inverse distance weighting of pixels from the state centroid). With these matched pixels we construct state-month level time series by averaging the pixel-month values of temperature and precipitation for each pixel that falls within a state's administrative boundary, following a similar procedure to Auffhammer and Rubin (2018).

Once we obtain province/state-month time series for climatic variables we match them to subjects in our data by their state and year of birth. Subjects born in a given year are matched with a time series for their province/state of birth starting in January of the next year. Once the time series are assigned we calculate for each individual the mean (A_{it}) and the standard deviation (V_{it}) of their climatic time series from birth to year of measurement in the corresponding survey. Thus an individual born in East Java in 1981, for instance, will be assigned the statistics for the East Java temperature time series from January 1982 to 2007 (the year of IFLS4) and from 1982 to 2014 (the year of IFLS5). In Mexico, since MXFLS2 was administered between 2005 and 2007, and MXFLS3 was administered between 2009 and 2013, subjects are assigned time series that extend from birth to their exact measurement year. Let c_{is} be the climatic variable assigned to person i in year s (with $c \in \{\text{temperature, precipitation}\}$). Then for month of measurement t (with $t = 1$ for January of the subject's birth) these statistics are:

$$A_{it} = \frac{1}{t - b_i} \sum_{s=b_i+1}^{t} c_{is} \tag{3.1}$$

$$V_{it} = \sqrt{\frac{1}{t - b_i - 1} \sum_{s=b_i+1}^{t} (c_{is} - A_{it})^2} \tag{3.2}$$

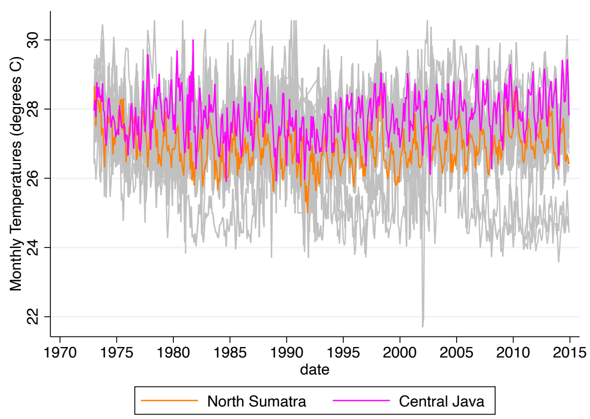
where

$$b_i = \begin{cases} \text{BirthYear}_i & \text{if } \text{BirthYear}_i > B \\ B & \text{if } \text{BirthYear}_i \leq B, \end{cases}$$

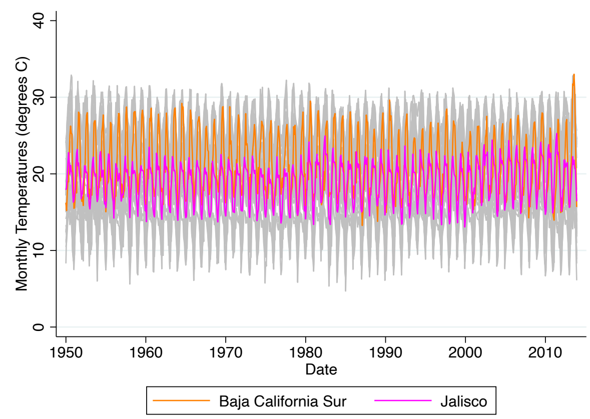
and

$$B = \begin{cases} 1972 & \text{if Country}_i = \text{Indonesia} \\ 1950 & \text{if Country}_i = \text{Mexico.} \end{cases}$$

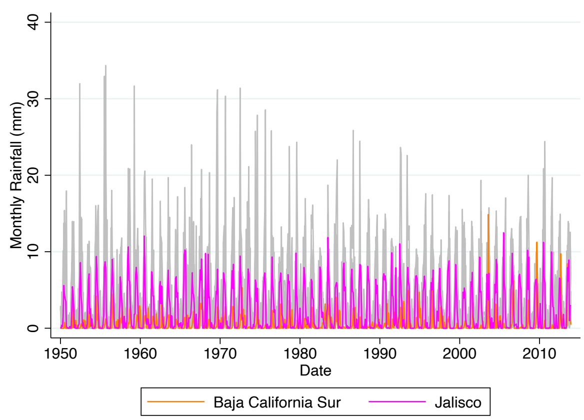
Significant variation exists in these experienced climate variables, as can be seen from Figure 3.1 and Figure 3.2.



(a) Temperature, Indonesia



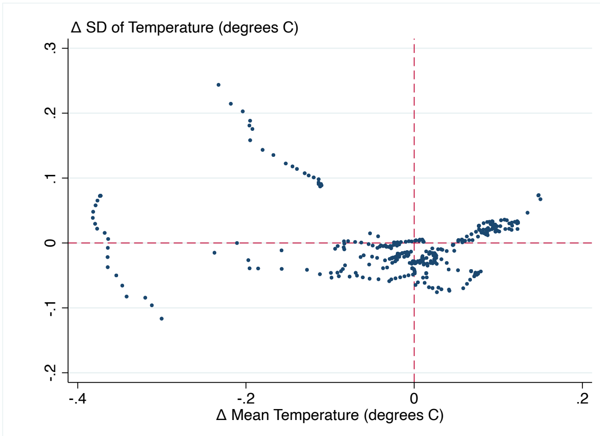
(b) Temperature, Mexico



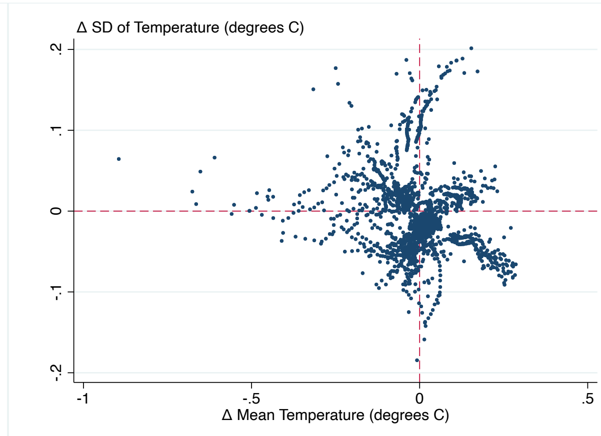
(c) Precipitation, Mexico

Figure 3.1. Province/state level time series of climate variables. monthly

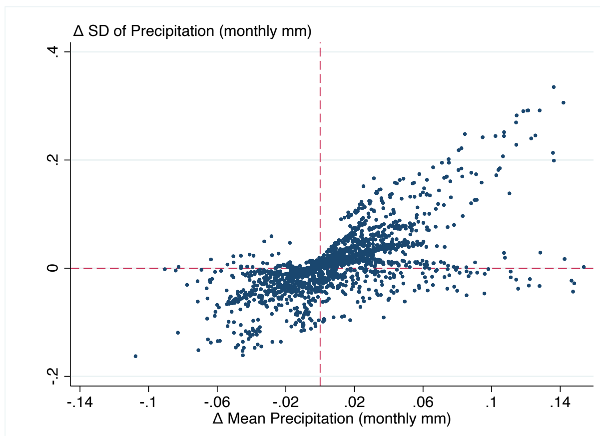
Notes: This figure displays the monthly temperature and precipitation (the latter only in Mexico) time series for all 25 Indonesian provinces (1993 definitions) and 32 Mexican states in our data. As can be seen these time series exhibit substantial variation both in the cross section and over time.



(a) Temperature, Indonesia



(b) Temperature, Mexico



(c) Precipitation, Mexico

Figure 3.2. Moment correlations for birth-province/state cohorts

Notes: This figure displays the raw distributions of our main explanatory variables ΔA_{it} and ΔV_{it} graphed against each other in each country for each independent variable. These scatterplots demonstrate that substantial variation exists not only in climate conditions across provinces/states, but also in the dynamics of climate experiences at the individual level.

3.1.2 Empirical specification

As in the case of growth, our baseline empirical specification is a two-way fixed effects model where we regress the individual risk aversion measure R_{it} on A_{it}, A_{it}^2, and V_{it}, as well as a constant α_{FE} and individual and time fixed effects:

$$R_{it} = \alpha_{FE} + \alpha_i + \alpha_t + \beta_1 A_{it} + \beta_2 A_{it}^2 + \beta_3 V_{it} + \gamma_1 PriceLevel_p + \gamma_2 X_{it} + \varepsilon_{it}. \tag{3.3}$$

The individual fixed effect α_i absorbs variation due to time-invariant idiosyncratic heterogeneity, whereas the time fixed effect α_t nets out the effect of aggregate time trends.

Since we have two periods in our analysis (the first and second waves of each survey), our two-way fixed effects specification is econometrically equivalent to a first-difference specification:

$$\Delta R_{it} = \alpha_{FD} + \beta_1 \Delta A_{it} + \beta_2 \Delta A_{it}^2 + \beta_3 \Delta V_{it} + \gamma_1 Inflation_p + \gamma_2 \Delta X_{it} + \varepsilon_{it}. \tag{3.4}$$

For expositional reasons we present the results below for the first-difference specification.

3.2 Results

This section contains the findings from our three primary empirical analyses. In Subsection 3.2.1 we present the results from regressing within-subject changes in measured risk aversion on subjects' experienced mean temperature change (linear and squared) and temperature volatility change in Indonesia and Mexico, as well as the corresponding variables for precipitation in Mexico. These regressions, which include no controls aside from subnational inflation, are the most direct tests of the three model-generated hypotheses discussed at the beginning of this chapter. In Subsection 3.2.2 we demonstrate the robustness of these findings to the inclusion of controls for changes in subjects' economic constraints and experiences of violence, natural disasters, and macroeconomic growth. In Subsection 3.2.3 we display the correlation between changes in several kinds of risky behaviors and predicted change in risk-taking based on the model we estimated in Subsection 3.2.1.

3.2.1 Effects of climate experiences on measured risk aversion

Our main empirical findings are presented in Table 3.1. Column 1 displays the result of regressing changes in measured risk aversion on mean changes in experienced growth in subjects' province or state of birth. In line with hypothesis 2, the estimated effect of mean changes in temperature in both countries is negative and highly significant. Mean changes in precipitation in Mexico are not significant in this specification. In column 2 we show the results of regressing changes in measured risk aversion on changes in the standard deviation of temperature and precipitation. In line with hypothesis 1 the estimated effect of changes in temperature volatility in Indonesia and precipitation volatility in Mexico are positive and highly significant, though the coefficient of temperature volatility in Mexico is not significant in this specification. In column 3 we regress changes in measured risk aversion on both mean and volatility changes in the climatic variables. Almost all coefficients are highly significant and signed in line with our model, including the mean term for precipitation in Mexico which is now significant. The exception is the coefficient of changes in temperature volatility in Mexico, which remains not significant in this specification.

In column 4 we display the results of adding the change in squared mean term to the previous specification. As before, the coefficients of the volatility terms for temperature in Indonesia and precipitation in Mexico remain highly significant and positive. The coefficient of the linear mean term now increases by two orders of magnitude in absolute terms for temperature in Indonesia, while becoming not significant in both Mexican specifications. In line with hypothesis 3, the squared mean term for temperature in Indonesia is positive and highly significant in this specification. The respective coefficients in both Mexico specifications are not significant.

Overall our results provide strong evidence for hypotheses 1 and 2, and moderate evidence for hypothesis 3. The sign of the linear mean term and the variance term are in line with the theory and strongly significant across most specifications. The squared mean term is highly significant in Indonesia, and even in those specifications where it is not significant, is associated with substantial changes in the linear mean term, suggesting that it plays an important role in driving the measured changes in risk aversion.

It is also notable that the magnitude of the volatility term is .65 (Mexico precipitation)

Table 3.1. Main results

Dep. Var: Δ Meas. Risk Av.	(1)	(2)	(3)	(4)
Indonesia				
Δ Mean temp	-1.13***		-0.91***	-58.09***
	(0.13)		(0.16)	(8.85)
Δ Mean temp^2				1.08***
				(0.17)
Δ Temp volatility		3.28***	1.99***	3.61***
		(0.64)	(0.63)	(0.60)
Observations	16267	16267	16267	16267
Mexico				
Δ Mean temp	-1.17***		-1.19***	1.69
	(0.22)		(0.22)	(2.27)
Δ Mean temp^2				-0.07
				(0.06)
Δ Temp volatility		-0.10	-0.35	-0.44
		(0.48)	(0.50)	(0.52)
Observations	8126	8126	8126	8126
Mexico				
Δ Mean precip	-1.14		-3.99***	-2.87
	(0.93)		(1.15)	(2.54)
Δ Mean precip^2				-0.21
				(0.45)
Δ Precip volatility		1.17**	2.58***	2.57***
		(0.55)	(0.69)	(0.69)
Observations	8126	8126	8126	8126

Measured Risk aversion: 1-5, 5 highest measured risk aversion. Province (Indonesia) or regional (Mexico) inflation included in all regressions. Standard errors clustered at the cohort by province/state of birth level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

to 2.2 (Indonesia temperature) times as large as the linear mean term in specification 3, where their magnitudes are most directly comparable. This tells us that the marginal effect of changes in variance are not second-order relative to that of the mean, but are rather as important if not significantly more so for driving changes in subjects' measured risk aversion.

3.2.2 Additional controls

Our main results are estimated without the inclusion of any additional controls aside from subnational inflation, though there are well-founded reasons to include additional covariates. Theoretically, changes in subjects' income, wealth, buffer stocks of savings, or other economic circumstances might be expected to influence their measured risk aversion. Empirically, previous studies have shown that exposure to traumatic experiences like natural disasters and violence can change measured risk aversion. Our own results in the previous chapter show that macroeconomic experiences significantly change measured risk aversion.

We do not include these controls in our main analysis because they are endogenous to risk aversion itself. This means that their inclusion could threaten the causal interpretation of our results. Nevertheless, we would like to know whether we can interpret the changes we observe in measured risk aversion as representing changes in underlying risk attitudes, or merely as driven by changes in personal economic circumstances. Further, it would be useful to directly test whether experiences of climate change are in fact driving the observed changes or whether other kinds of experiences whose incidence may be correlated with climate dynamics are in fact playing a central role.

We provide some evidence on these points in Table 3.2, where we progressively add in additional controls to the specification for the last column in Table 3.1. These include time-varying demographics, like marital status, educational attainment, and household size; changes in income, assets, and savings; self-reported exposure to violence and natural disasters; and measured GDP growth experiences from our own data (full details on the controls are available in Section A.6). In both countries our results are highly robust to the inclusion of this rich set of covariates. The only covariate which substantially attenuates the measured effect are our macroeconomic experience variables, whose inclusion reduces the magnitude of the estimated volatility coefficient by 33 to 61 percent. This suggests that the changes we estimate in measured risk aversion represent changes in underlying attitudes towards risk, and are substantially driven by lifetime experiences of climate change.

Table 3.2. Additional controls

Dep. Var: ΔR_{it}	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Indonesia								
Δ Mean temp	-58.09***	-59.02***	-58.77***	-59.77***	-59.77***	-59.29***	-58.53***	-55.88***
	(8.85)	(8.72)	(8.71)	(8.71)	(8.71)	(8.69)	(8.79)	(9.83)
Δ Mean temp^2	1.08***	1.10***	1.10***	1.11***	1.11***	1.10***	1.09***	1.03***
	(0.17)	(0.17)	(0.17)	(0.17)	(0.17)	(0.17)	(0.17)	(0.19)
Δ Temp volatility	3.61***	3.57***	3.56***	3.56***	3.56***	3.54***	3.44***	1.35***
	(0.60)	(0.60)	(0.60)	(0.60)	(0.60)	(0.59)	(0.60)	(0.64)
Observations	16267	16267	16263	16263	16263	16263	16263	16263
Mexico								
Δ Mean temp	1.69	1.63	1.57	1.52	1.49	1.51	1.14	2.05
	(2.27)	(2.27)	(2.27)	(2.27)	(2.27)	(2.27)	(2.28)	(2.29)
Δ Mean temp^2	-0.07	-0.07	-0.07	-0.07	-0.07	-0.07	-0.06	-0.14*
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
Δ Temp volatility	-0.44	-0.47	-0.48	-0.48	-0.46	-0.46	-0.48	-0.35
	(0.52)	(0.51)	(0.51)	(0.51)	(0.51)	(0.51)	(0.51)	(0.53)
Observations	8126	8126	8126	8126	8126	8126	8126	8126
Mexico								
Δ Mean precip	-2.87	-3.00	-3.03	-3.06	-2.99	-2.97	-3.48	-3.73
	(2.54)	(2.54)	(2.54)	(2.54)	(2.54)	(2.55)	(2.53)	(2.48)
Δ Mean precip^2	-0.21	-0.21	-0.21	-0.20	-0.21	-0.21	-0.19	0.17
	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)	(0.45)	(0.44)	(0.43)
Δ Precip volatility	2.57***	2.58***	2.58***	2.58***	2.57***	2.57***	2.68***	1.80***
	(0.69)	(0.69)	(0.69)	(0.69)	(0.69)	(0.69)	(0.69)	(0.68)
Observations	8126	8126	8126	8126	8126	8126	8126	8126
Inflation	X	X	X	X	X	X	X	X
Δ Demographics		X	X	X	X	X	X	X
Δ Income			X	X	X	X	X	X
Δ Assets				X	X	X	X	X
Δ Savings					X	X	X	X
Δ Violence						X	X	X
Δ Natural Disasters							X	X
Δ Growth experiences								X

Measured Risk aversion: 1-5, 5 highest measured risk aversion. Province (Indonesia) or regional (Mexico) inflation included in all regressions. Demographics include marital status, household size, household size squared, and educational attainment. Violence and natural disasters variables from self-reported exposure. Growth experiences include the mean, mean squared, and standard deviation of province/state level real GDP growth in subjects' province/state of birth. Standard errors clustered at the cohort by province of birth level in parenthesis. *** p<0.01, ** p<0.05, * p<0.1.

3.2.3 Changes in risky behavior

Another issue of interpretation of our results is the question of whether changes in measured risk aversion capture changes in actual risk-taking behavior for subjects. We study this question by constructing a variable measuring predicted change in risk aversion ($\widehat{\Delta R_{it}}$) using our preferred specifications (column 4 of Table 3.1), and examining its correlation with changes in downstream risky behaviors in our data. We focus on behaviors commonly examined in relation to risk-taking in the literature, and for which we have data: smoking, having ever migrated across province or state lines, self-employment status, and, in Indonesia, whether subjects report that their land is planted in at least one cash crop.[1] This last measure captures risky investment behavior in our data. In Mexico we examine the correlation of changes in each of the first three variables with changes in risk aversion predicted by lifetime experiences of temperature and precipitation.

Results for this analysis for temperature in Indonesia are presented in Figure 3.3, and for temperature and precipitation in Mexico in Figure 3.4. These figures display the average value of each downstream variable for each quartile of the $\widehat{\Delta R_{it}}$ distribution. Here light blue bars represent subjects who are predicted to become measurably less risk averse by our model, while dark blue bars represent subjects who are predicted to become measurably more risk averse. 95% confidence intervals are indicated for each quartile. We use the first to fourth interquartile range as an empirical benchmark and run a two-sided t-test to check if the difference between the average values of the outcome in these quartiles is statistically significant.

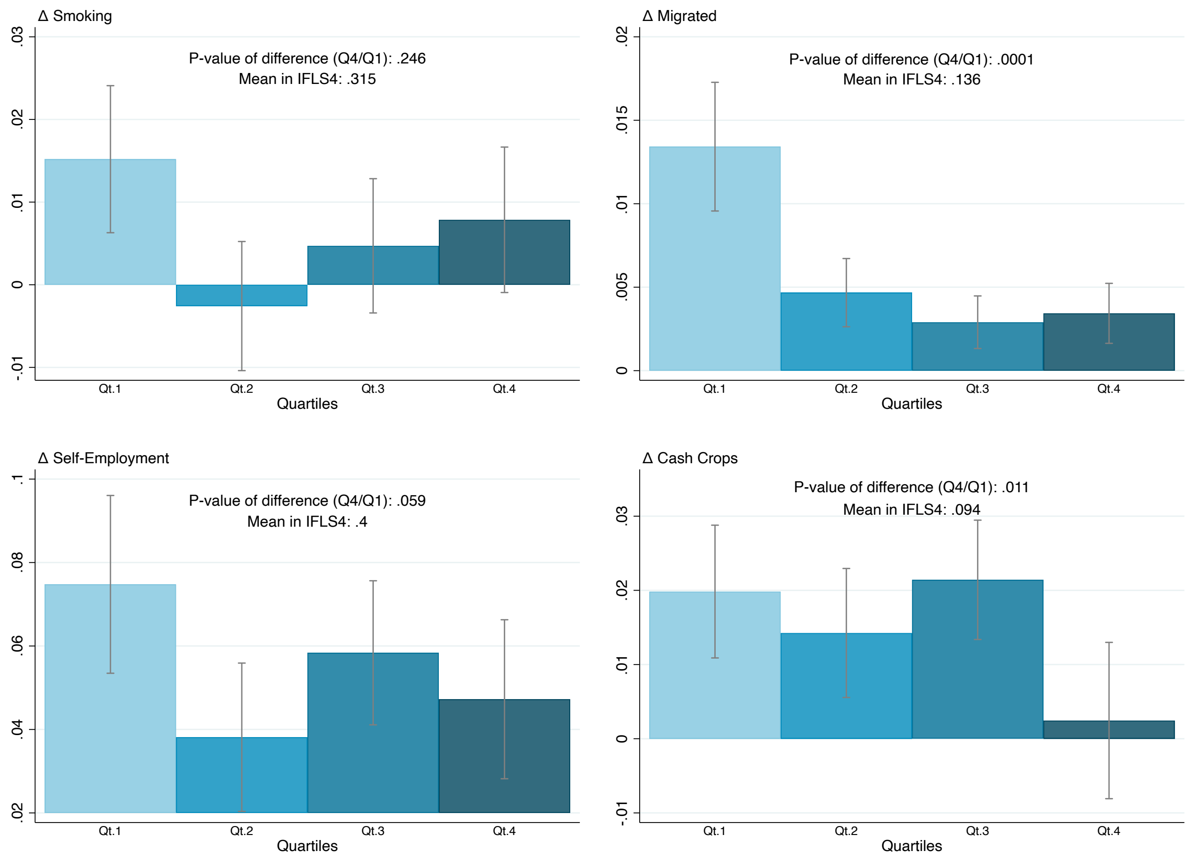
Our results provide strong evidence that increases in measured risk aversion predicted by climate change experiences are associated with decreases in risk-taking behavior in Indonesia, and moderate and somewhat conflicting evidence of the same in Mexico. Increases in predicted risk aversion are correlated with decreases in risk-taking behavior for seven out of the ten variables examined. Three of these declines are significant at conventional levels, all

[1] Cash crops asked about in the IFLS include coconut, coffee, cloves, rubber, and other hard stem plants.

in Indonesia: ever migrated across province lines (1.3 percentage point increase to 0.3 percentage point increase ($p = .0001$)), self employed ($+7.5$pp $\rightarrow +4.7$pp, ($p = .059$)), and planted in cash crops ($+2.0$pp $\rightarrow +0.2$pp, ($p = .011$)). Four decreases are not significant at conventional levels: smoking in Indonesia ($+1.5$pp $\rightarrow +0.8$pp, ($p = .246$)), smoking in Mexico by temperature ($+1.7$pp $\rightarrow +1.5$pp, ($p = .785$)), ever migrated in Mexico by temperature ($+0.5$pp $\rightarrow +0.3$pp, ($p = .274$)), and ever migrated in Mexico by precipitation ($+0.5$pp $\rightarrow +0.3$pp, ($p = .409$)). Three outcomes, all in Mexico, exhibit increases. Two of these are not significant at conventional level: smoking in Mexico by precipitation ($+1.2$pp $\rightarrow +1.7$pp, ($p = .591$)), and self employed in Mexico by temperature ($+3.4$pp $\rightarrow +4.3$pp, ($p = .68$)). One outcome, self employed in Mexico by precipitation, exhibits a statistically significant increase ($+1.0$pp $\rightarrow +5.3$pp, ($p = .039$)).

The decreases in risk-taking behavior predicted by increases in measured risk aversion are large and economically significant. In Indonesia, the first to fourth interquartile range of $\widehat{\Delta R_{it}}$ for migration represents a 7.3 percent decline relative to the IFLS4 baseline, for self employment a 7% decline, for cash crop planting a 19.2% decline, and for smoking a 0.7% decline. In Mexico, for the temperature predicted outcomes, the change in migration represents a 1.3% decline relative to the MXFLS2 baseline, in self employment a 4.2% increase, and for smoking a 2.6% decrease. For the precipitation predicted outcomes in Mexico, the change in migration represents a 1.3% decline, in self employment a 19.8% increase, and in smoking a 6.4% increase.

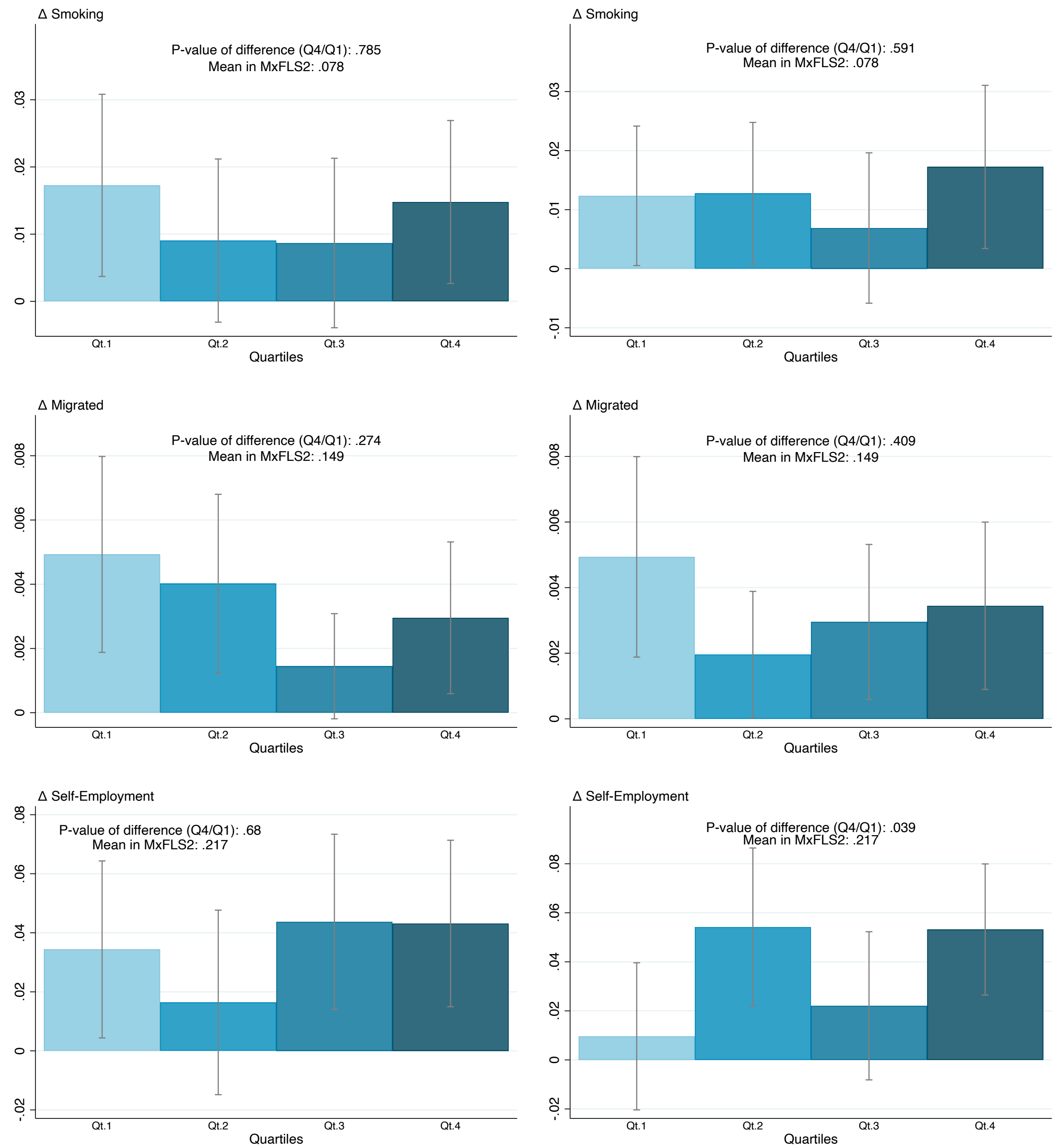
We can also quantify the magnitudes of lifetime changes in mean temperature and precipitation associated with changes in risky behavior. In Indonesia the first to fourth interquartile range for temperature represents a .065 degree Celsius decrease in mean temperature ($+0.040 \rightarrow -0.025$) and a .004 ncrease in the standard deviation of temperature ($-0.005 \rightarrow -0.001$). In Mexico this same IQR represents a .18 ecrease in mean temperature ($+0.082 \rightarrow -0.098$) and a .022 ecrease in the standard deviation of temperature ($+0.082 \rightarrow -0.098$). For precipitation in Mexico the first to fourth quartile IQR represents a .012 millimeters per month decrease in mean precipitation ($+0.013$mm/mth $\rightarrow +0.001$mm/mth) and a .066 mm/month increase in the standard deviation of precipitation (-0.039mm/mth $\rightarrow +0.025$mm/mth).



Indonesia - Temperature

Figure 3.3. Correlations of changes in risky behaviors with predicted increase in risk aversion

Notes: Bars represent quartiles of the predicted change in risk aversion distribution. Light blue is the bottom quartile of this distribution, representing the agents who are predicted to experience a decrease (or smaller increase) in risk aversion.



Mexico - Temperature　　　　**Mexico** - Precipitation

Figure 3.4. Correlations of changes in risky behaviors with predicted increase in risk aversion

Notes: Bars represent quartiles of the predicted change in risk aversion distribution. Light blue is the bottom quartile of this distribution, representing the agents who are predicted to experience a decrease (or smaller increase) in risk aversion.

3.3 Robustness

We test the robustness of our main results to varying methodological choices in our analysis. First, in Section B.1 we present the results of running our main analysis with **alternate sample compositions**. In particular, we (1) limit the analysis to individuals born after 1972 in Indonesia and 1950 in Mexico (for whom we have full lifetime climate histories); and (2) exclude the "gamble averse" from our analysis in Indonesia (see Subsection 2.1.1). The results are qualitatively very similar for each of these samples, though the linear mean term in the Mexico precipitation regression becomes marginally significant when the sample is restricted to those born after 1950.

In Section B.2 we present the results of our main analysis for **alternate specifications of measured risk aversion**. For both Indonesia and Mexico, we repeat the analysis with (1) a binarized measure of risk aversion (instead of using the 5 buckets of measured risk aversion, we set buckets 1 and 2 to be 0, and buckets 3, 4 and 5 to be 1); and (2) using an ordered probit specification. The latter specification accounts explicitly for the ordinal nature of our risk aversion measure, though its results should be interpreted with care as the ordered probit with two way fixed effects estimator is known to be biased. For both specifications results are qualitatively quite similar to the baseline.

In Section B.3 we present the results of our main analysis using data on **climate conditions in subjects' province or state of residence** at the time of the first survey, rather than their province or state of birth. These data more closely match the intuitive notion of climate change experiences, but, as discussed above, suffer from a potential identification problem due to endogenous migration. Results are again qualitatively similar to the main analysis.

In Section B.4 we present the results for **alternative specifications of the climate variables** in each country. Specifically, for the Indonesian ground station data we calculate the province-daily observation by taking the mean rather than the median of the station-daily observations. For the Mexican gridded data we examine the robustness of the results to matching pixels to states using inverse distance weighting for all pixels within 100 kilometers of the state centroid. Results are qualitatively similar to the baseline specification.

In Section B.5 we present the results of our main analysis with **standard errors clustered at the province/state of birth level**, using the wild bootstrap method of Cameron, Gelbach and Miller (2008). Estimates of our coefficients are mostly not significant at conventional levels under this scheme, though the coefficient of the mean coefficient in Mexico and the volatility coefficient in Indonesia are significant in some specifications.

In Section B.6 we conduct our main analysis using a **repeated cross-section specification** that drops the individual fixed effects from the regression. We perform this analysis restricting to our primary sample. The magnitude of the estimated coefficients drops considerably in both settings under this specification. In Indonesia the mean and mean squared coefficients remain the same sign and highly significant. In Mexico the volatility coefficient for temperature now becomes significant and negative, while the mean coefficient loses significance. In Mexico for precipitation the mean coefficient now becomes positive and significant, and the other coefficients lose significance.

3.4 Conclusions

Our analysis provides significant evidence that lifetime experiences of climate change shape risk-taking for individuals in Indonesia and Mexico. Using micro data containing elicited risk aversion for the same subjects years apart, linked to subnational climate statistics capturing subjects' climate experiences, we find strong support for the hypotheses of our model about the adaptation of risk-taking to changes in the mean and variance of background risk. These findings are robust to the inclusion of a rich set of controls for changes in economic circumstances and other categories of experiences. Changes in measured risk aversion correlate with substantial changes risk-taking in the domains of health, migration, and investment behavior.

3.5 Acknowledgements

Chapter 3 is currently being prepared for submission for publication of the material, and is coauthored with Wesley Howden. The dissertation author was a primary investigator of this material.

Appendix A

Appendix for Chapter 2

A.1 Summary statistics

Table A.1. Summary Statistics (sample mean)

	Indonesia		Mexico	
Sample:	Primary sample	Full sample	Primary sample	Full sample
Measured Risk aversion	3.55	3.52	2.43	2.41
Woman	0.55	0.53	0.58	0.59
Age	40.27	37.32	42.80	42.02
Married	0.89	0.81	0.66	0.65
Household Size	5.20	5.21	5.64	5.65
Comp. Elementary	0.41	0.35	0.51	0.50
Comp. Junior High	0.19	0.20	0.25	0.25
Comp. High School	0.28	0.32	0.13	0.13
Above High School	0.13	0.14	0.11	0.11
Self-employed	0.42	0.39	0.23	0.22
Currently smoke	0.32	0.32	0.08	0.08
Ever migrated	0.14	0.17	0.15	0.15
Income/month	9.20	8.868	2,420	2,420
Consumption/month	2.35	2.45	2,088	1,768
Savings	8.09	8.76	9,677	9,522
Borrowing	2.64	2.68	4,734	4,707
Observations	35,292	55,820	19,769	25,005

A.2 Geographic distribution of survey samples in our data

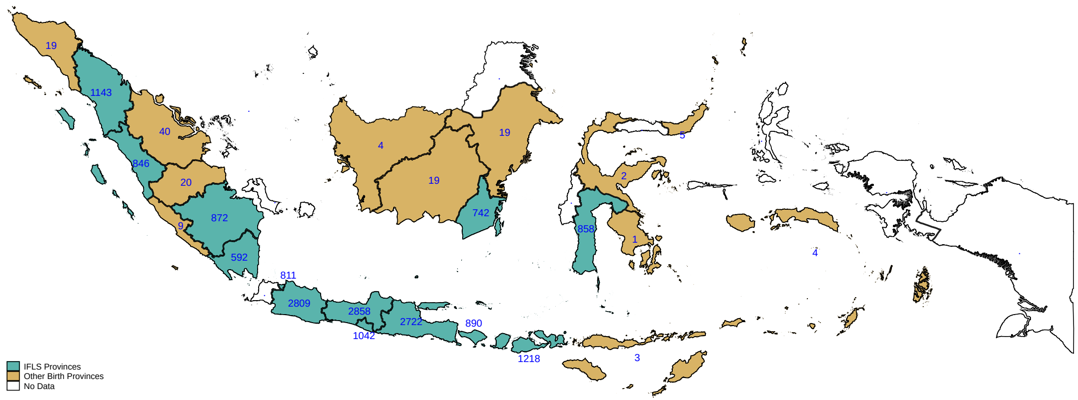


Figure A.1. Distribution of the Primary Sample in Indonesia by Province of Birth

Notes: Provinces in blue are ones in which the IFLS has been deployed. Provinces in brown are non-IFLS provinces in which some subjects in our primary sample were born.

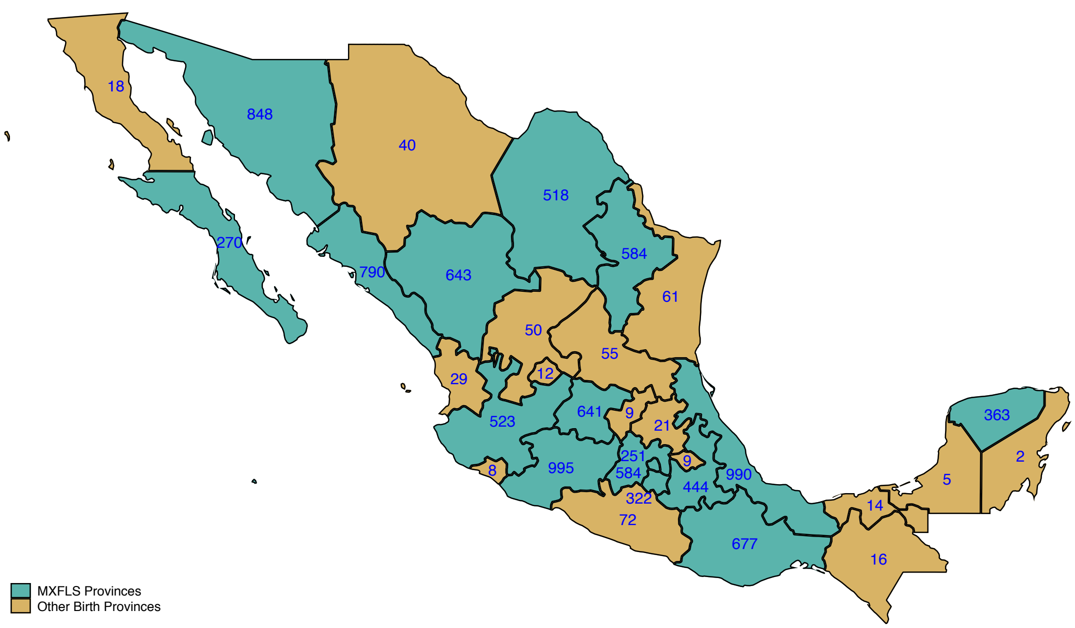


Figure A.2. Distribution of the Primary Sample in Mexico by Province of Birth

Notes: States in blue are ones in which the MXFLS has been deployed. States in brown are non-MXFLS states in which some subjects in our primary sample were born.

A.3 Construction of Risk aversion measures

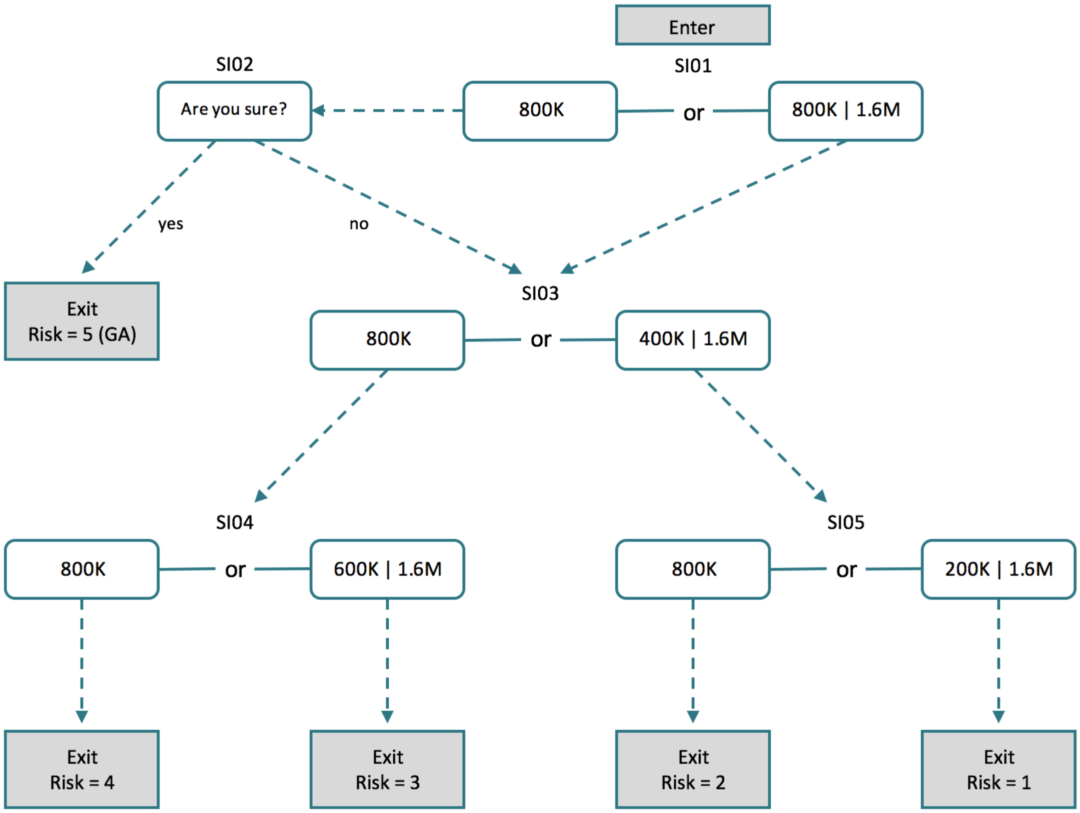


Figure A.3. Construction of risk aversion measure in IFLS2 and IFLS3

Notes: Higher numbers for "Risk" indicate a higher rate of measured risk aversion. Values are in Indonesian Rupiah.

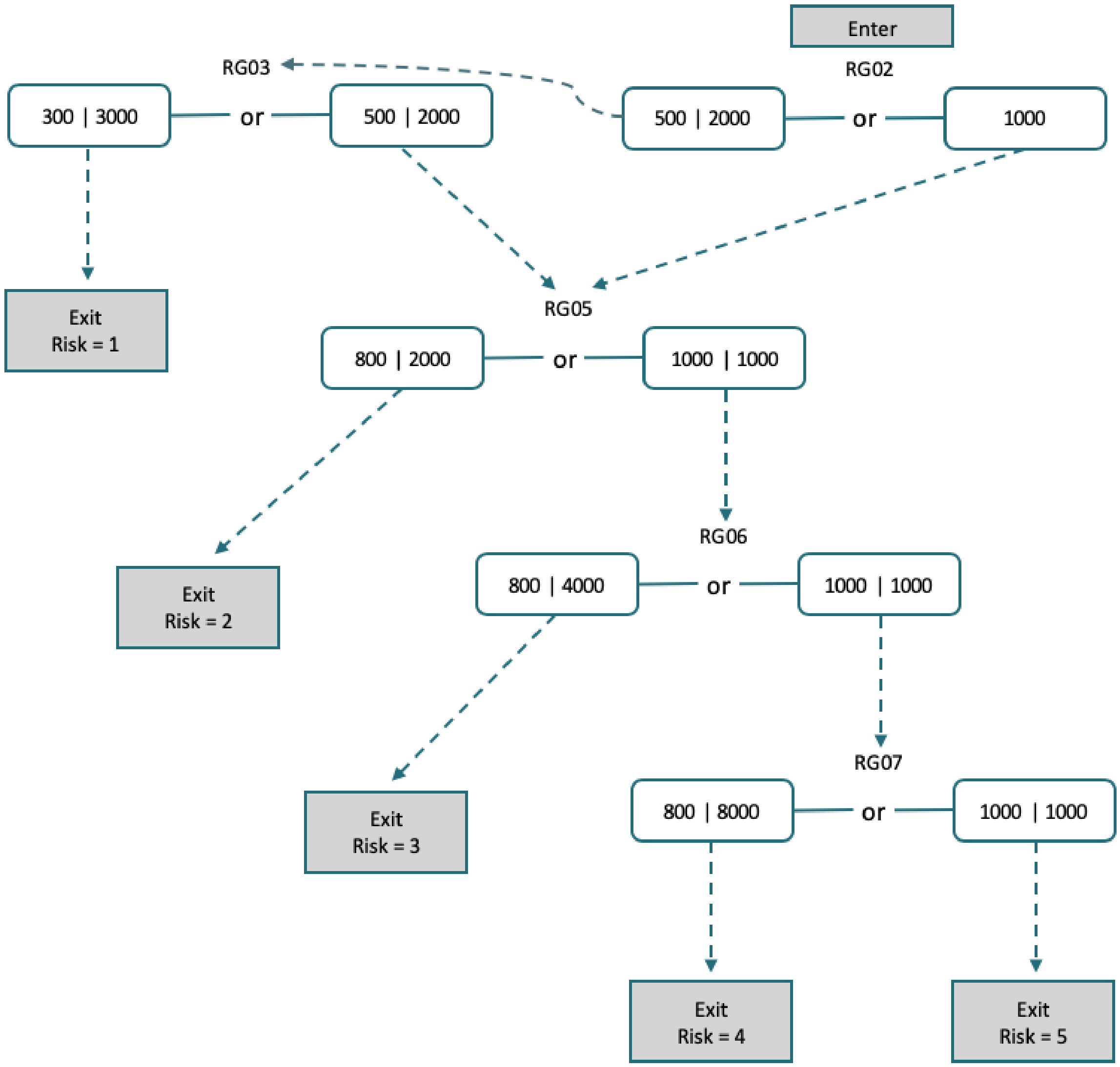


Figure A.4. Construction of risk aversion measure in MXFLS2

Notes: Higher numbers for "Risk" indicate a higher rate of measured risk aversion. Values are in Mexican Pesos.

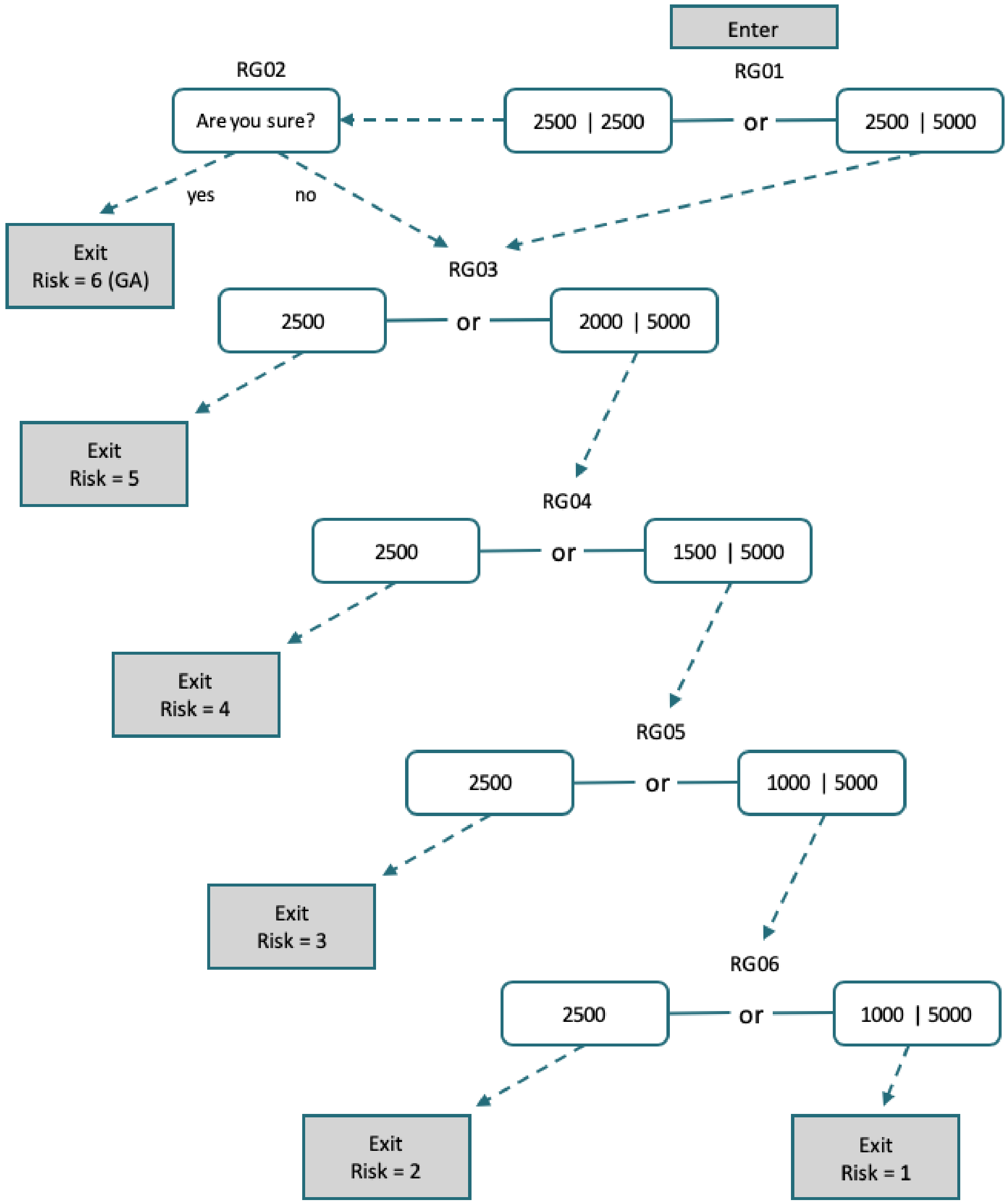


Figure A.5. Construction of risk aversion measure in MXFLS3

Notes: Higher numbers for "Risk" indicate a higher rate of measured risk aversion. Values are in Mexican Pesos.

A.4 Sample distribution for risk aversion measures

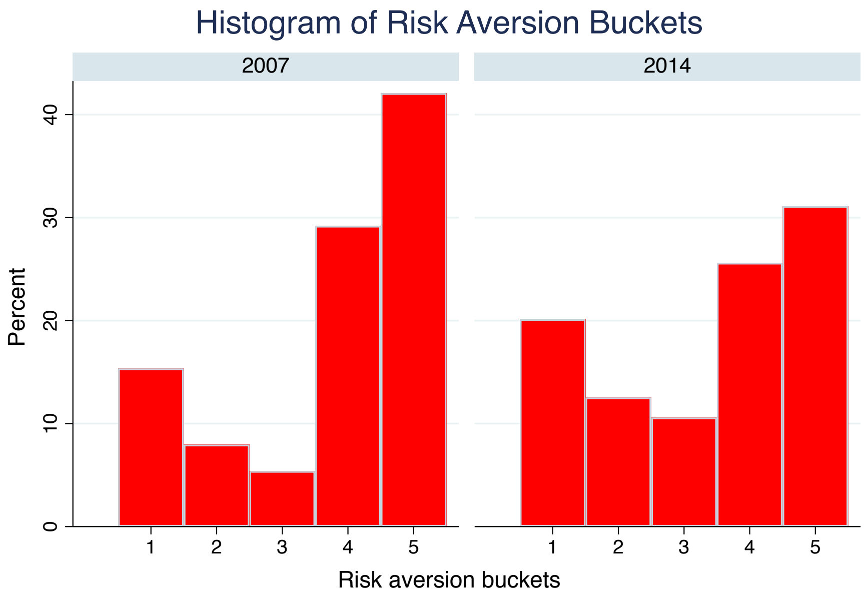


Figure A.6. Histogram of Measured Risk Aversion buckets in IFLS4 and IFLS5

Notes: *Measured Risk Aversion*: 1-5, 5 highest measured risk aversion. Distributions for individuals in main regressions: present in both 2007 and 2014 surveys.

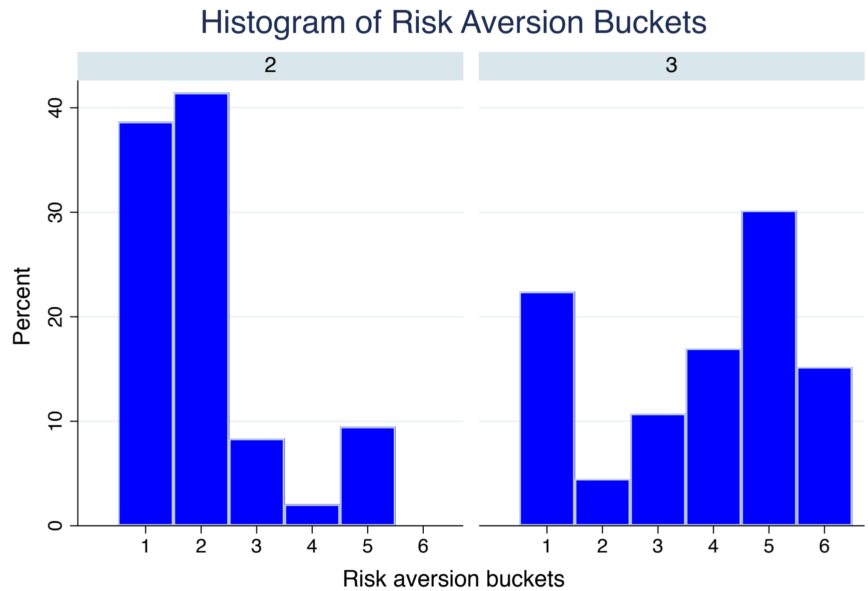


Figure A.7. Histogram of Measured Risk Aversion buckets in MXFLS2 and MXFLS3

Notes: *Measured Risk Aversion*: 1-6, 6 highest measured risk aversion. Distributions for individuals in main regressions: present in both 2005 and 2009 surveys.

A.5 Correlates of risk aversion measures in the cross-section

Table A.2. Correlates of risk preference measures

	Indonesia		Mexico	
Dep. Var:	Measured Risk Aversion		Measured Risk Aversion	
Sample:	X-Sec	Panel	X-Sec	Panel
Self-employed	-0.11***	-0.10***	0.01	0.03
	(0.018)	(0.021)	(0.03)	(0.04)
Migrated	-0.10***	-0.08**	0.02	0.03
	(0.023)	(0.033)	(0.034)	(0.039)
Income	1.52e-06***	1.75e-06***	0.07	0.08*
	(3.39e-07)	(3.86e-07)	(0.05)	(0.04)
Consumption	-0.015***	-0.018***	-0.16	-0.05
	(0.004)	(0.005)	(0.24)	(0.26)
Total assets	-3.47e-05	-3.39e-05	0.009	0.01
	(3.04e-05)	(3.82e-05)	(0.01)	(0.01)
Borrowing	-0.001**	-0.001**	-0.07	-0.1
	(0.0004)	(0.0005)	(0.21)	(0.23)
Savings	-0.0003	-0.0002	0.06	0.18
	(0.0002)	(0.0003)	(0.32)	(0.33)
Smoker	0.09***	0.07*	-0.17***	-0.15***
	(0.0 30)	(0.038)	(0.05)	(0.06)
Cigs/day	-0.06***	-0.04**	0.001	0.001
	(0.02)	(0.02)	(0.0007)	(0.0008)
Woman	0.28***	0.26***	0.04	0.02
	(0.023)	(0.028)	(0.03)	(0.03)
Age	-0.015***	-0.014***	-0.012**	-0.012**
	(0.004)	(0.005)	(0.005)	(0.006)
Age^2	0.002***	0.002***	0.0001**	0.0001**
	(4.25e-05)	(5.64e-05)	(5.55e-05)	(6.22e-05)
Observations	35,848	23,995	11,740	9,335
R-squared	0.052	0.055	0.18	0.168

Table Notes: Coefficients from regressions of dependent variables on all covariates. Monthly income and consumption. Income, consumption, assets, borrowing, and savings at household level. Standard errors clustered at the cohort by province of birth in parenthesis. Observations are at the individual by year level. Controls: Time FE, Province FE, HH size, marital status education dummies, and religiosity dummies (religiosity dummies only for Indonesia). Monetary variables in millions of rupiah and pesos. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. "X-SEC" refers to subjects appearing in at least one wave; "Panel" refers to those who appear in both. Note that the sample size for this analysis is smaller than in the baseline results, due to missing data in variables of interest for some subjects.

A.6 Details of additional controls

Table A.3. Description of controls included in Table 2.2

Category	Variables Included
Demographics (**Indonesia** and **Mexico**)	Married Household Size Household Size Squared Educational Attainment
Income, Assets and Savings (**Indonesia** and **Mexico**)	Total household income Total value of household assets* Net Households Savings (Savings-Borrowing)
Violence (**Indonesia**)	Perceived safety level of village Perceived safety of walking in village alone at night Occurrence of civil strife in household's region of residence in last 5 years Civil strife severe enough to cause death, major injury, direct financial loss, or relocation of any member of HH
Violence (**Mexico**)	Perceived safety level of village Feels safe at home Fear of assault during the day Fear of assault at night No. of times robbed, assaulted, kidnapped Experienced family/friend robbed, assaulted, kidnapped in last 12 month
Natural Disasters (**Indonesia**)	Occurrence of natural disaster in household's region of residence in last 5 years Natural disaster severe enough to cause death, major injury, direct financial loss, or relocation of any member of HH
Natural Disasters (**Mexico**)	Household/business lost due to natural disaster

A.7 Results for alternate samples

A.7.1 Restricting sample by birth year

Table A.4. Alternate samples

Dep. Var: Δ Meas. Risk Av.	(1)	(2)	(3)	(4)
Indonesia (born post-1976)				
Δ Growth Mean	-0.42***		-0.37***	0.99*
	(0.12)		(0.10)	(0.56)
Δ Growth Mean^2				-0.14**
				(0.06)
Δ Growth Volatility		1.48***	1.41***	1.19***
		(0.25)	(0.22)	(0.25)
Observations	6374	6374	6374	6374
Mexico (born post-1940)				
Δ Growth Mean	-0.97***		-0.94***	-1.67***
	(0.20)		(0.19)	(0.47)
Δ Growth Mean^2				0.10*
				(0.06)
Δ Growth Volatility		0.85***	0.83***	0.81***
		(0.17)	(0.17)	(0.17)
Observations	7420	7420	7420	7420

Mexico (born post-1976)				
Δ Growth Mean	-0.84***		-0.80***	-1.73
	(0.31)		(0.30)	(1.06)
Δ Growth Mean^2				0.18
				(0.19)
Δ Growth Volatility		0.49**	0.44*	0.44*
		(0.24)	(0.24)	(0.24)
Observations	2284	2284	2284	2284

Notes: *Measured Risk Aversion*: 1-5, 5 highest measured risk aversion. Province (Indonesia) and regional (Mexico) inflation included in all regressions. Standard errors clustered at the cohort by province/state of birth level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

A.7.2 Excluding Gamble Averse Individuals in Indonesia

Table A.5. Excluding Gamble Averse Individuals

Dep. Var: Δ Meas. Risk Av.	(1)	(2)	(3)	(4)
Indonesia (excluding gamble averse)				
Δ Growth Mean	0.10		0.13*	1.50***
	(0.07)		(0.07)	(0.50)
Δ Growth Mean^2				-0.13***
				(0.05)
Δ Growth Volatility		0.48***	0.52***	0.31*
		(0.16)	(0.16)	(0.18)
Observations	7193	7193	7193	7193

Notes: *Measured Risk Aversion*: 1-4, 4 highest measured risk aversion. Province (Indonesia) and regional (Mexico) inflation included in all regressions. Standard errors clustered at the cohort by province/state of birth level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

A.8 Alternate Specifications of Measured Risk Aversion

Table A.6. Ordered Probit with two-way fixed effects

Dep. Var: Δ Meas. Risk Av.	(1)	(2)	(3)	(4)
Indonesia				
Δ Growth Mean	-0.18*		-0.16*	0.13
	(0.04)		(0.04)	(0.23)
Δ Growth Mean^2				-0.03
				(0.02)
Δ Growth Volatility		0.71*	0.69*	0.65*
		(0.09)	(0.08)	(0.09)
Observations	16083	16083	16083	16083
Mexico				
Δ Growth Mean	-0.49***		-0.47***	-0.78***
	(0.10)		(0.10)	(0.23)
Δ Growth Mean^2				0.04
				(0.03)
Δ Growth Volatility		0.44***	0.42***	0.42***
		(0.09)	(0.09)	(0.09)
Observations	8046	8046	8046	8046

Notes: *Measured Risk Aversion*: 1-5, 5 highest measured risk aversion. Province (Indonesia) and regional (Mexico) inflation included in all regressions. Standard errors clustered at the cohort by province/state of birth level in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A.7. Binarized measure of risk aversion

Dep. Var: Δ Meas. Risk Av.	(1)	(2)	(3)	(4)
Indonesia				
Δ Growth Mean	-0.08*		-0.06*	0.22
	(0.02)		(0.02)	(0.13)
Δ Growth Mean^2				-0.03**
				(0.01)
Δ Growth Volatility		0.33*	0.32*	0.29*
		(0.05)	(0.05)	(0.05)
Observations	16083	16083	16083	16083
Mexico				
Δ Growth Mean	-0.32***		-0.31***	-0.58***
	(0.06)		(0.06)	(0.13)
Δ Growth Mean^2				0.04**
				(0.02)
Δ Growth Volatility		0.26***	0.25***	0.24***
		(0.05)	(0.05)	(0.05)
Observations	8046	8046	8046	8046

Notes: *Binarized Measured Risk Aversion*: Measured Risk Aversion buckets 1 and 2 are set to 0, and buckets 3, 4, and 5 to 1. Province (Indonesia) and regional (Mexico) inflation included in all regressions. Standard errors clustered at the cohort by province/state of birth level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

A.9 Results for province of residence macroeconomic conditions

Table A.8. Province of Residence Macroeconomic Experiences

Dep. Var: Δ Meas. Risk Av.	(1)	(2)	(3)	(4)
Indonesia				
Δ Growth Mean	-0.36***		-0.31***	0.77*
	(0.08)		(0.07)	(0.42)
Δ Growth Mean^2				-0.10***
				(0.04)
Δ Growth Volatility		1.26***	1.19***	1.06***
		(0.17)	(0.16)	(0.17)
Observations	17394	17394	17394	17394
Mexico				
Δ Growth Mean	-1.25***		-1.26***	-2.39***
	(0.19)		(0.18)	(0.41)
Δ Growth Mean^2				0.15***
				(0.05)
Δ Growth Volatility		0.78***	0.80***	0.82***
		(0.17)	(0.17)	(0.17)
Observations	7971	7971	7971	7971

Notes: *Measured Risk Aversion*: 1-5, 5 highest measured risk aversion. Province (Indonesia) and regional (Mexico) inflation included in all regressions. Standard errors clustered at the cohort by province/state of birth level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

A.10 Results using non-linear weighting based on Malmendier and Nagel (2011)

Malmendier and Nagel (2011) estimate a non-linear single parameter weighting function for the effects of mean stock market returns on later in life stock market participation and elicited risk aversion. We extend this method to the context of lifetime experiences of growth volatility. For individual i measured at time t, with experienced growth g_t occurring s years before t, our weighting function is:

$$w_{it}(s,\lambda) = \frac{(age_{it} - s)^{\lambda}}{\sum_{s=1}^{age_{it}-1}(age_{it} - s)^{\lambda}}.$$

This weighting function yields a set of monotonic weights for experiences that always add up to unity, regardless of the age of the individual at measurement. Figure A.8 illustrates this weighting scheme for different values of λ for a 30 year old subject. For all ages, higher values of λ mean placing more relative weight on recent experiences, $\lambda = 0$ implies a flat weighting scheme like the one used in our baseline analysis, and negative values of λ indicate placing more relative weight on early life experiences.

Using this weighting scheme we construct a measure of average experienced lifetime growth as follows:

$$A_{it}(\lambda) = \sum_{s=1}^{age_{it}-1} w_{it}(s,\lambda) g_{t-s}.$$

We also construct an analogous measure of experienced lifetime growth volatility using the weighted standard deviations of experienced growth:

$$V_{it}(\lambda) = \sqrt{\frac{\sum_{s=1}^{age_{it}-1} w_{it}(s,\lambda)(g_{t-s} - A_{it}(\lambda))^2}{\frac{age_{it}-2}{age_{it}-1}\sum_{s=1}^{age_{it}-1} w_{it}(s,\lambda)}}$$

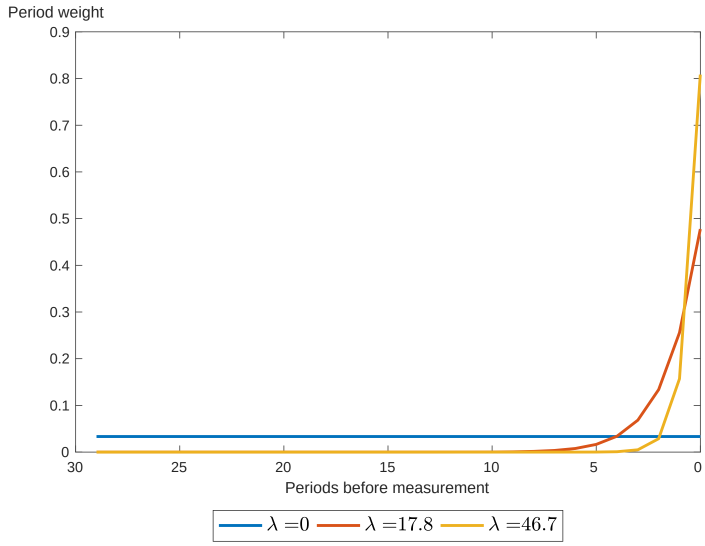


Figure A.8. Relative weights placed on years of growth for individual aged 30 at different levels of λ

Table A.9. Non-linear temporal λ weighting

Dep. Var: Δ Meas. Risk Av.	(1)	(2)	(3)	(4)
Indonesia				
Δ Growth Mean	-0.35***		0.06**	0.49***
	(0.04)		(0.03)	(0.11)
Δ Growth Mean^2				-0.04***
				(0.009)
Δ Growth Volatility		0.89***	0.93***	0.97***
		(0.09)	(0.09)	(0.09)
λ	5.1***	46.1***	46.7***	46.8***
	(0.20)	(3.5)	(13.1)	(2.7)
Observations	17299	17299	17299	17299
Mexico				
Δ Growth Mean	-0.12		-0.32***	-0.06**
	(0.08)		(0.08)	(0.02)
Δ Growth Mean^2				0.03***
				(0.003)
Δ Growth Volatility		0.30***	0.32***	0.02
		(0.10)	(0.09)	(0.02)
λ	-0.2***	0.1***	-0.1***	17.78***
	(0.03)	(0.01)	(0.01)	(2.05)
Observations	8187	8187	8187	8187

Notes: *Measured Risk Aversion*: 1-5, 5 highest measured risk aversion. Regressions estimated via NLLS. Province (Indonesia) and regional (Mexico) inflation included in all regressions. Standard errors clustered at the cohort by province/state of birth level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

We estimate the marginal effects of these weighted macroeconomic experiences variables on measured risk aversion by estimating Equation A.1 using non-linear least squares. This allows us to simultaneously estimate the marginal coefficients of mean growth, squared mean growth and growth volatility (β_1, β_2 and β_3), and the value of the non-linear weighting parameter λ:

$$\Delta R_{it} = \alpha + \beta_1 \Delta A_{it}(\lambda) + \beta_2 \Delta (A(\lambda)_{it})^2 + \beta_3 \Delta V_{it}(\lambda) + \gamma Inflation_p + \varepsilon_{it}. \tag{A.1}$$

Since non-linear estimation methods are known to be sensitive to initial seed values, we choose the initial value of λ that maximizes the likelihood in a linear specification of our model. Specifically, we build a fine grid of λ values, and generate our macroeconomic variables of interest using each of these values. We then use maximum likelihood estimation on these linearized versions of the model considering for each value of λ, and choose as the initial seed for the nonlinear estimation the value of λ that maximizes the likelihood. Results of this estimation are below.

A.11 Results with birth-province/state level clustering

Table A.10. Birth-province/state level clustering

Dep. Var: Δ Meas. Risk Av.	(1)	(2)	(3)	(4)
Indonesia				
Δ Growth Mean	-0.35		-0.30	0.42
	(0.52)		(0.39)	(0.82)
Δ Growth Mean^2				-0.07
				(0.65)
Δ Growth Volatility		1.36	1.30	1.21
		(0.25)	(0.14)	(0.18)
Observations	17302	17302	17302	17302
Mexico				
Δ Growth Mean	-1.02		-0.97	-1.69**
	(0.19)		(0.12)	(0.05)
Δ Growth Mean^2				0.10
				(0.31)
Δ Growth Volatility		0.91*	0.87	0.86
		(0.10)	(0.13)	(0.14)
Observations	8187	8187	8187	8187

Notes: *Measured Risk Aversion*: 1-5, 5 highest measured risk aversion. Province (Indonesia) and regional (Mexico) inflation included in all regressions. Standard errors clustered at the province level using the wild bootstrap procedure in Cameron, Gelbach and Miller (2008). P-values from 1000 repetitions in parenthesis. *** p <0.01, ** p <0.05, * p <0.1.

A.12 Results for repeated cross-section specifications

The empirical specification for these regressions, including age, time, and province of birth fixed effects, is

$$R_{it} = \alpha + \alpha_t + \beta_{Age}Age_{it} + \beta_{Prov}Province_i + \beta_1 A_{it} + \beta_2 A_{it}^2 + \beta_3 V_{it} + \gamma ProvInf_{it} + \delta X_{it} + \varepsilon_{it}$$

Where X_{it} in this case are controls for gender and ethnicity.

Table A.11. Repeated Cross-Section (with panel sample only)

Dep. Var: Δ Meas. Risk Av.	(1)	(2)	(3)	(4)
Indonesia				
Δ Growth Mean	-0.07*		-0.09*	-0.14
	(0.03)		(0.03)	(0.18)
Δ Growth Mean^2				0.00
				(0.02)
Δ Growth Volatility		0.04	0.07*	0.07*
		(0.03)	(0.03)	(0.03)
Observations	34851	34851	34851	34851
Mexico				
Δ Growth Mean	-0.00		-0.01	0.04
	(0.03)		(0.03)	(0.07)
Δ Growth Mean^2				-0.01
				(0.01)
Δ Growth Volatility		0.01	0.01	0.01
		(0.02)	(0.02)	(0.02)
Observations	18015	18015	18015	18015

Notes: *Measured Risk Aversion*: 1-5, 5 highest measured risk aversion. Province (Indonesia) and regional (Mexico) inflation included in all regressions. Standard errors clustered at the cohort by province/state of birth level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A.12. Repeated Cross-Section

Dep. Var: Δ Meas. Risk Av.	(1)	(2)	(3)	(4)
Indonesia				
Δ Growth Mean	-0.05*		-0.05**	-0.15
	(0.02)		(0.02)	(0.11)
Δ Growth Mean^2				0.01
				(0.01)
Δ Growth Volatility		0.05**	0.05**	0.05**
		(0.02)	(0.02)	(0.02)
Observations	55111	55111	55111	55111
Mexico				
Δ Growth Mean	-0.00		-0.01	0.08
	(0.02)		(0.02)	(0.06)
Δ Growth Mean^2				-0.01
				(0.01)
Δ Growth Volatility		0.02	0.02	0.02
		(0.02)	(0.02)	(0.02)
Observations	20976	20976	20976	20976

Notes: *Measured Risk Aversion*: 1-5, 5 highest measured risk aversion. Province (Indonesia) and regional (Mexico) inflation included in all regressions. Standard errors clustered at the cohort by province/state of birth level in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Appendix B

Appendix for Chapter 3

B.1 Results for alternate samples

Table B.1. Restricting the sample by birth year

Dep. Var: Δ Meas. Risk Av.	(1)	(3)	(5)	(7)
Indonesia (Born post-1970)				
Δ Mean temp	-1.21***		-1.12***	-51.23***
	(0.17)		(0.19)	(11.11)
Δ Mean temp^2				0.95***
				(0.21)
Δ Temp volatility		2.32***	1.49**	3.07***
		(0.77)	(0.69)	(0.73)
Observations	9158	9158	9158	9158
Mexico (Born post-1950)				
Δ Mean temp	-1.23***		-1.26***	0.58
	(0.23)		(0.23)	(2.39)
Δ Mean temp^2				-0.05
				(0.06)
Δ Temp volatility		-0.32	-0.56	-0.61
		(0.53)	(0.55)	(0.57)
Observations	6617	6617	6617	6617

Mexico (Born post-1950)				
Δ Mean precip	-0.48		-3.54***	-5.17*
	(1.00)		(1.18)	(2.67)
Δ Mean precip^2				0.31
				(0.49)
Δ Precip volatility		1.72***	2.93***	2.98***
		(0.58)	(0.71)	(0.71)
Observations	6617	6617	6617	6617

Measured Risk aversion: 1-5, 5 highest measured risk aversion. Regional inflation included in all regressions. Standard errors clustered at the cohort by province of birth level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table B.2. Excluding gamble averse individuals

Dep. Var: Δ Meas. Risk Av.	(1)	(2)	(3)	(4)
Indonesia				
Δ Mean temp	-0.70***		-0.52***	-36.06***
	(0.17)		(0.19)	(10.51)
Δ Mean temp^2				0.67***
				(0.20)
Δ SD temp		2.43***	1.69**	2.67***
		(0.68)	(0.72)	(0.72)
Observations	6673	6673	6673	6673

Measured Risk aversion: 1-4, 4 highest measured risk aversion (excluding gamble averse, measured as a 5). Regional inflation included in all regressions. Standard errors clustered at the cohort by province of birth level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

B.2 Alternate Specifications of Measured Risk Aversion

Table B.3. Binarized measure of risk aversion

Dep. Var: Δ Meas. Risk Av.	(1)	(2)	(3)	(4)
Indonesia				
Δ Mean temp	-0.34***		-0.29***	-15.64***
	(0.04)		(0.05)	(2.53)
Δ Mean temp^2				0.29***
				(0.05)
Δ SD temp		0.81***	0.40**	0.83***
		(0.19)	(0.18)	(0.18)
Observations	16267	16267	16267	16267
Mexico				
Δ Mean temp	-0.29***		-0.30***	-0.01
	(0.07)		(0.07)	(0.71)
Δ Mean temp^2				-0.01
				(0.02)
Δ SD temp		-0.02	-0.08	-0.09
		(0.15)	(0.15)	(0.16)
Observations	8126	8126	8126	8126
Mexico				
Δ Mean precip	-0.50*		-1.34***	-1.03
	(0.29)		(0.35)	(0.77)
Δ Mean precip^2				-0.06
				(0.14)
Δ SD precip		0.28*	0.76***	0.75***
		(0.17)	(0.21)	(0.21)
Observations	8126	8126	8126	8126

Measured Risk aversion: binarized measure of risk aversion (1-2 → 0, 3-5 → 1), where 1 is more risk averse than 0. Regional inflation included in all regressions. Standard errors clustered at the cohort by province of birth level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table B.4. Ordered Probit with two-way fixed effects

Dep. Var: Δ Meas. Risk Av.	(1)	(2)	(3)	(4)
Indonesia				
Δ Mean temp	-0.56***		-0.44***	-28.59***
	(0.07)		(0.08)	(4.44)
Δ Mean temp^2				0.53***
				(0.08)
Δ Temp volatility		1.65***	1.03***	1.83***
		(0.32)	(0.31)	(0.30)
Observations	16267	16267	16267	16267
Mexico				
Δ Mean temp	-0.54***		-0.56***	0.74
	(0.12)		(0.12)	(1.14)
Δ Mean temp^2				-0.03
				(0.03)
Δ Temp volatility		-0.20	-0.31	-0.35
		(0.24)	(0.25)	(0.26)
Observations	8126	8126	8126	8126
Mexico				
Δ Mean precip	-0.52		-1.99***	-1.34
	(0.46)		(0.57)	(1.27)
Δ Mean precip^2				-0.12
				(0.22)
Δ Precip volatility		0.62**	1.33***	1.32***
		(0.27)	(0.34)	(0.34)
Observations	8126	8126	8126	8126

Measured Risk aversion: 1-5, 5 highest measured risk aversion. Regional inflation included in all regressions. Standard errors clustered at the cohort by province of birth level in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

B.3 Results for province/state of residence climate conditions

Table B.5. Time series from province/state of residence at first survey

Dep. Var: Δ Meas. Risk Av.	(1)	(2)	(3)	(4)
Indonesia				
Δ Mean temp	-1.52***		-1.20***	-85.46***
	(0.16)		(0.19)	(9.39)
Δ Mean temp^2				1.59***
				(0.18)
Δ Temp volatility		4.65***	3.19***	5.88***
		(0.79)	(0.72)	(0.65)
Observations	14078	14078	14078	14078
Mexico				
Δ Mean temp	-1.32***		-1.34***	1.37
	(0.24)		(0.24)	(2.55)
Δ Mean temp^2				-0.07
				(0.06)
Δ Temp volatility		-0.13	-0.43	-0.53
		(0.53)	(0.55)	(0.57)
Observations	6929	6929	6929	6929
Mexico				
Δ Mean precip	-1.29		-4.40***	-4.24
	(1.06)		(1.24)	(2.89)
Δ Mean precip^2				-0.03
				(0.49)
Δ Precip volatility		1.55**	3.02***	3.02***
		(0.65)	(0.77)	(0.78)
Observations	6929	6929	6929	6929

Measured Risk aversion: 1-5, 5 highest measured risk aversion. Regional inflation included in all regressions. Standard errors clustered at the cohort by province of birth level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

B.4 Results for alternative specifications of climate variables

Table B.6. Alternative climatic variable specifications

Dep. Var: Δ Meas. Risk Av.	(1)	(2)	(3)	(4)
Indonesia (daily station mean)				
Δ Mean temp	-1.11***		-0.77**	-48.61***
	(0.27)		(0.37)	(11.23)
Δ Mean temp^2				0.98***
				(0.24)
Δ Temp volatility		3.30***	1.77***	3.43***
		(0.76)	(0.78)	(0.69)
Observations	16267	16267	16267	16267
Mexico (inverse distance weighting)				
Δ Mean temp	-1.32***		-1.32***	-0.39
	(0.21)		(0.21)	(1.95)
Δ Mean temp^2				-0.02
				(0.05)
Δ Temp volatility		0.01	-0.11	-0.12
		(0.51)	(0.52)	(0.53)
Observations	8126	8126	8126	8126
Mexico (inverse distance weighting)				
Δ Mean precip	-2.95***		-5.84***	-2.22
	(0.96)		(1.18)	(2.96)
Δ Mean precip^2				-0.64
				(0.49)
Δ Precip volatility		0.75	2.71***	2.50***
		(0.59)	(0.71)	(0.74)
Observations	8126	8126	8126	8126

Measured Risk aversion: 1-5, 5 highest measured risk aversion. Regional inflation included in all regressions. Standard errors clustered at the cohort by province of birth level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

B.5 Results with province/state level clustering

Table B.7. Province/state level clustering

Dep. Var: Δ Meas. Risk Av.	(1)	(2)	(3)	(4)
Indonesia				
Δ Mean temp	-1.13		-0.91	-58.09
	(0.38)		(0.42)	(0.17)
Δ Mean temp^2				1.08
				(0.11)
Δ Temp volatility		3.28**	1.99	3.61
		(0.04)	(0.37)	(0.18)
Observations	16267	16267	16267	16267
Mexico				
Δ Mean temp	-1.17*		-1.19	1.69
	(0.08)		(0.11)	(0.80)
Δ Mean temp^2				-0.07
				(0.56)
Δ Temp volatility		-0.10	-0.35	-0.44
		(0.95)	(0.90)	(0.94)
Observations	8126	8126	8126	8126
Mexico				
Δ Mean precip	-1.14		-3.99	-2.87
	(0.49)		(0.14)	(0.59)
Δ Mean precip^2				-0.21
				(0.55)
Δ Precip volatility		1.17	2.58	2.57
			(0.20)	
Observations	8126	8126	8126	8126

Measured Risk aversion: 1-5, 5 highest measured risk aversion. Regional inflation included in all regressions. Standard errors clustered at the province/state level using the wild bootstrap procedure in Roodman et al. (2019). P-values in parentheses.

B.6 Results from repeated cross section specification

Table B.8. Repeated cross section specification

Dep. Var: Δ Meas. Risk Av.	(1)	(2)	(3)	(4)
Indonesia				
Mean temp	0.05***		0.08***	-4.64***
	(0.02)		(0.02)	(1.47)
Mean temp^2				0.09***
				(0.03)
Temp volatility		0.00	0.10**	-0.01
		(0.03)	(0.04)	(0.04)
Observations	32776	32776	32776	32776
Mexico				
Mean temp	0.00		0.00	-0.01
	(0.00)		(0.00)	(0.04)
Mean temp^2				0.00
				(0.00)
Temp volatility		-0.06***	-0.06***	-0.06***
		(0.01)	(0.01)	(0.01)
Observations	17901	17901	17901	17901
Mexico				
Mean precip	0.08***		0.13**	0.14**
	(0.01)		(0.05)	(0.06)
Mean precip^2				-0.00
				(0.01)
Precip volatility		0.06***	-0.05	-0.05
		(0.01)	(0.04)	(0.05)
Observations	17901	17901	17901	17901

Measured Risk aversion: 1-5, 5 highest measured risk aversion. Regional inflation included in all regressions. Standard errors clustered at the cohort by province of birth level in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Bibliography

Acemoglu, By Daron, Asuman Ozdaglar, and Alireza Tahbaz-Salehi. 2017. “Microeconomic Origins of Macroeconomic Tail Risks.” *American Economic Review*, 107(1): 54–108.

Ampudia, Miguel, and Michael Ehrmann. 2017. “Macroeconomic experiences and risk taking of euro area households.” *European Economic Review*, 91(C): 146–156.

Arrow, Kenneth J. 1970. “Aspects of the Theory of Risk Bearing.” In *Essays in the Theory of Risk-Bearing*. Chapter 3.

Auffhammer, Maximilian, and Edward Rubin. 2018. “Natural gas price elasticities and optimal cost recovery under consumer heterogeneity: evidence from 300 million natural gas bills.”

Becker, Gary S., and George J. Stigler. 1977. “De Gustibus Non Est Disputandum.” *American Economic Review*, 67(2): 76–90.

Brown, Ryan, Verónica Montalva, Duncan Thomas, and Andrea Velásquez. 2019. “Impact of Violent Crime on Risk Aversion: Evidence from the Mexican Drug War.” *Review of Economics and Statistics*.

Bryan, Gharad, Shyamal Chowdhury, and Ahmed Mushfiq Mobarak. 2014. “Under-investment in a Profitable Technology : The Case of Seasonal Migration in Bangladesh.” *Econometrica*, 82(5): 1671–1748.

Caballé, Jordi, and Alexey Pomansky. 1996. “Mixed risk aversion.” *Journal of Economic Theory*, 71(2): 485–513.

Callen, Michael, Mohammad Isaqzadeh, James D Long, and Charles Sprenger. 2014. “Violence and Risk Preference : Experimental Evidence from Afghanistan.” *American Economic Review*, 104(1): 123–148.

Cameron, A. Colin, Jonah B. Gelbach, and Douglas L. Miller. 2008. “Bootstrap-Based Improvements for Inference with Clustered Errors.” *Review of Economics and Statistics*, 90(3): 414–427.

Cameron, Lisa, and Manisha Shah. 2015. “Risk-taking behaviour in the wake of natural disasters.” *Journal of Human Resources*, 50(2): 484–515.

Deck, Cary, and Harris Schlesinger. 2014. “Consistency of higher order risk preferences.” *Econometrica*, 82(5): 1913–1943.

Degroot, Morris H. 1970. *Optimal Statistical Decisions.* McGraw-Hill.

Dell, Melissa, Benjamin F Jones, and Benjamin A Olken. 2014. “What Do We Learn from the Weather? The New Climate-Economy Literature.” *Journal of Economic Literature*, 52(3): 740–798.

Dillenberger, David, and Kareen Rozen. 2015. “History-dependent risk attitude.” *Journal of Economic Theory*, 157: 445–477.

DOI. 2020. "Digital map of the state (political) boundaries of Mexico." *https://catalog.data.gov/dataset/digital-map-of-the-state-political-boundaries-of-mexico*.

Ebert, Sebastian, and Daniel Wiesen. 2014. "Joint measurement of risk aversion, prudence, and temperance." *Journal of Risk and Uncertainty*, 48: 231–252.

Eeckhoudt, Louis, Christian Gollier, and Harris Schlesinger. 1996. "Changes in Background Risk and Risk Taking Behavior." *Econometrica*, 64(3): 683–689.

Falk, Armin, Anke Becker, Thomas Dohmen, Benjamin Enke, and David Huffman. 2018. "Global Evidence on Economic Preferences." *Quarterly Journal of Economics*, 133(4): 1645–1692.

Gabaix, Xavier, Parameswaran Gopikrishnan, Vasiliki Plerou, and Eugene H. Stanley. 2003. "A theory of power-law distributions in financial market fluctuations." *Nature*, 423(May): 267–270.

Gabaix, Xavier, Parameswaran Gopikrishnan, Vasiliki Plerou, and Eugene H. Stanley. 2006. "Institutional Investors and stock market volatility." *Quartely Journal of Economics*, , (May): 461–504.

German-Soto, Vicente. 2005. "Generación del producto interno bruto Mexicano for entidad federativa, 1940-1992." *Trimestre Economico*, 72(3): 617–653.

Gollier, Christian, and John W. Pratt. 1996. "Risk Vulnerability and the Tempering Effect of Background Risk." *Econometrica*, 64(5): 1109–1123.

Hanaoka, Chie, Hitishi Shigeoka, and Yasutora Watanabe. 2018. "Do Risk Preferences Change? Evidence from the Great Eastern Japan Earthquake." *American Economic Journal: Applied Economics*, 10(2)(2): 298–330.

Jakiela, Pamela, and Owen Ozier. 2019. "The Impact of Violence on Individual Risk Preferences: Evidence from a natural experiment." *Review of Economics and Statistics*, 101(3).

Kelly, Bryan, and Hao Jiang. 2014. "Tail Risk and Asset Prices." *Review of Financial Studies*, 27(10): 2842–2871.

Kimball, Miles. 1990. "Precautionary Saving in the Small and in the Large." *Econometrica*, 58(1): 53–73.

Kimball, Miles S. 1993. "Standard Risk Aversion." *Econometrica*, 61(3): 589–611.

Livneh, Ben, Theodore J Bohn, David W Pierce, Francisco Munoz-arriola, Bart Nijssen, Russell Vose, Daniel R Cayan, and Levi Brekke. 2015. "A spatially comprehensive, hydrometeorological data set for Mexico, the U .S., and Southern Canada 1950 – 2013." *Scientific Data*, 150042: 1–12.

Malmendier, Ulrike, and Leslie Sheng Shen. 2019. "Scarred Consumption."

Malmendier, Ulrike, and Stefan Nagel. 2011. "Depression Babies: Do Macroeconomic Experiences Affect Risk Taking?" *The Quarterly Journal of Economics*, 126(1): 373–416.

Malmendier, Ulrike, and Stefan Nagel. 2016. "Learning from inflation experiences." *Quarterly Journal of Economics*, 131(1): 53–87.

Morris, Stephen, and Muhamet Yildiz. 2016. "Crises : Equilibrium Shifts and Large Shocks."

Murphy, K. P. 2007. "Conjugate Bayesian Analysis of the Gaussian Distribution."

NOAA-CDO. 2020. "National Climate Data Center." *https://www.ncdc.noaa.gov/cdo-web/datatools/selectlocation*.

Noussair, Charles N, and Stefan T Trautmann. 2014. "Higher Order Risk Attitudes, Demographics, and Financial Decisions." *Review of Economic Studies*, 81(September 2013): 325–355.

Pratt, John W. 1964. "Risk Aversion in the Small and in the Large." *Econometrica*, 32(1/2): 122–136.

Pratt, John W, and Richard J Zeckhauser. 1987. "Proper Risk Aversion." *Econometrica*, 55(1): 143–154.

Roodman, David, James G. MacKinnon, Morten Orregaard Nielsen, and Matthew D Webb. 2019. "Fast and Wild: Bootstrap Inference in Stata using boottest." *The Stata Journal*, 19(1).

Ross, Stephen A. 1981. "Some Stronger Measures of Risk Aversion in the Small and the Large with Applications." *Econometrica*, 49(3): 621–638.

Shigeoka, Hitoshi. 2019. "Long-Term Consequences of Growing up in a Recession."

Strauss, John, Firman Witoelar, and Sikoki Bondan. 2016. "The Fifth Wave of the Indonesia Family Life Survey: Overview and Field Report."

Strauss, John, Kathleen Beegle, Bondan Sikoki, Agus Dwiyanto, Yulia Herawati, and Firman Witoelar. 2009. "The Fourth Wave of the Indonesia Family Life Survey: Overview and Field Report." *RAND Working Paper*, WR-675/1-N(April 2009): i–82.

Weitzman, Martin L. 2007. "Subjective expectations and asset-return puzzles." *American Economic Review*, 97(4): 1102–1130.

Weitzman, Martin L. 2009. "On modeling and interpreting the economics of catastrophic climate change." *Review of Economics and Statistics*, 91(1): 1–19.

Yariv, Leeat, Ben Gillen, and Erik Snowberg. 2019. "Experimenting with Measurement Error: Techniques with Applications to the Caltech Cohort Study." *Journal of Political Economy*, 127(4): 1826–1863.