

Essays on Risk and Uncertainty: Insights from Behavioral Economics

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SENSITIZATION AND EXTRAORDINARY PERSISTENCE

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Abstract:

There is emerging evidence that risk-aversion rises after negative shocks and that this heightened risk-aversion may persist for decades. This extraordinary persistence presents a challenge for conventional risk preferences. In this paper, we develop a set of preferences based on Kahneman's (2011) work to account for this extraordinary persistence. We believe that our preferences reflect the phenomenon that Nobel Laureate Kandel (2001) refers to as sensitization. We demonstrate how our model of sensitization leads to distinct financial distortions with three novel policy findings. First, minimum liquidity requirements enhance welfare. Second, the Modigliani-Miller (1958) theorem is overturned in favor of equity-financing. Finally, the optimal monetary policy closely resembles Operation Twist.

“Sensitization, a form of learned fear in which a person or an experimental animal learns to respond strongly to an otherwise neutral stimulus.” —Eric Kandel, 2000 Nobel Laureate in Physiology or Medicine

1. Introduction

There is emerging and compelling evidence that shocks not only affect risk preferences¹ but that the effects of major economic shocks can linger for decades². We refer to this latter finding

¹Recent papers suggest that shocks such as war, natural disasters, and even scary movies can cause individuals to behave more risk-averse. See Kim and Lee (2013), Cameron and Shah (2012), and Guiso, Sapienza, and Zingales (2013).

²Other recent papers document the long-lasting impacts that major shocks, such as recessions and depressions, can have on risk preference. See Malmendier, Tate, and Yan (2011), Knüpfer, Rantapuska, and Sarvimäki (2014), Schoar and Zuo (2011), and Gordon and St.-Amour (1999).

as *extraordinary persistence*, and we argue that such high levels of persistence are not compatible with conventional models of time-varying risk preferences³. Instead, we argue that a particular bias in emotional probabilities that is discussed by Kahneman (2011) may account for such persistence, and we show that the emergence of this bias—which we refer to as sensitization—has significant economic consequences.

According to Kahneman, one of the biases of the emotional system⁴ is due to the availability heuristic. As a result of this heuristic, the emotional system assigns greater likelihood to outcomes that either agree with autobiographical experiences or that are vivid, emotionally charge, and easily recalled. Since first-time experiences from early adulthood have been consistently shown to be vivid, emotionally charged, and easily recalled forty years later⁵, we believe that the availability heuristic may generate shifts in risk preferences consistent with the findings of extraordinary persistence.

We refer to the phenomenon combining the availability heuristic and the persistence of memories capturing first-time experiences during early adulthood as sensitization. We show that one of the consequences of sensitization is that it results in adaptive risk preferences⁶. After a negative economic shock, people act more risk-averse, and after a positive economic shock, people act more risk-seeking. In an overlapping generations setting, sensitization implies that agents who experienced negative shocks when young will assign greater probability to future losses, causing them to act more risk-averse. In contrast, agents who experienced positive economic shocks when young will now assign higher probability to future gains, causing them to act more risk-seeking.

³ Two prominent papers of time-varying risk preferences include Campbell and Cochrane (1999) and Barberis, Huang, and Santos (2001). In the literature review, we argue that both papers are not consistent with multi-decade persistence.

⁴ He refers to it as *System 1*.

⁵ See Rathbone, Moulin, and Conway (2008) for a recent summary of this literature and Rubín, Rahhal, and Poon (1998) for an earlier but more comprehensive review.

⁶ In his Nobel Lecture, Kandel (2001) referred to sensitization as a “form of learned fear.” We believe this description is consistent with our finding of adaptive risk preferences.

To capture sensitization's macroeconomic consequences, we start with an endogenous growth framework. In our model, financial entrepreneurs are assumed to manage investment projects while subject to potential cost overruns. If entrepreneurs have sufficient liquidity to meet the realized cost overrun, their projects are successful and generate abundant capital per consumption unit invested. If they have insufficient liquidity, their projects are unsuccessful and generate little capital. In this paper, the representative entrepreneur's liquidity choice characterizes how agents manage risk.

Our main theoretical finding is that sensitization implies that the representative entrepreneur's liquidity choice creates an intergenerational externality. If one generation holds less liquidity, negative realizations are more likely. Future generations then become more pessimistic and biased towards loss, which reduces welfare. Consequently, two distortions emerge in the economy that reduce the potential growth rate. At the extensive margin, this increased pessimism implies that agents take on too little risk, and we show that investment in the sensitized economy falls short of the emotionless benchmark. At the intensive margin, adaptive risk preferences imply that investment is too risky, and we show that the cost of capital is no longer minimized.

Although these distortions both limit the economy's growth rate, they differ in cyclicity. In our model, investment distortions are countercyclical with investment falling after a negative shock. Conversely, liquidity distortions, as measured per consumption unit of investment, are procyclical⁷ with demand for liquidity rising after a negative shock.

⁷ As documented by Kato (2004).

We show that the distortions caused by sensitization can be counteracted by policymakers. We identify three policies that should be particularly effective: minimum liquidity ratios, changes in the Federal Reserve's balance sheet, and greater corporate reliance on equity financing.

First, policymakers should impose minimum liquidity ratios and support higher short-term interest rates. These policies would discourage excess risk-intensity by encouraging more sensible liquidity management. In contrast, conventional monetary policy exacerbates excess risk-intensity by favoring lower short-term rates.

Second, policymakers should encourage lower long-term borrowing costs following a negative shock. These lower long-term borrowing costs offset investment distortions caused by sensitization. Due to their countercyclical nature, these distortions are greatest following a negative shock. Our model predicts that the most effective monetary policy is Operation Twist, which lowers long-term borrowing costs while simultaneously raising short-term rates. Higher short-term interest rates result in increased liquidity, which reduces the second distortion.

Third, we argue that policymakers should favor greater equity financing. Since equity financing allows for more diversification, which reduces risk exposure, then the time-varying risk preferences (i.e., sensitization) should have less of an impact. Thus, greater equity financing reduces risk distortions.

The rest of this paper proceeds as follows. Section 2 presents a review of the literature, while Section 3 develops our benchmark model in the absence of emotions. Section 4 formally introduces sensitization and discusses our major policy findings. Section 5 establishes the cyclicity of the distortions under systemic shocks, and our final section concludes with our general findings.

2. Relationship to the Economic Literature

Our model is motivated by the finding that major economic shocks can affect risk preferences for decades. There are four papers that document the persistent effects of such shocks. First, Malmendier, Tate, and Yan (2011) study CEOs from 1980 to 1994 and find that CEOs born before the Great Depression finance their corporate investments more conservatively than their post-depression contemporaries. Second, Knüpfer, Rantapuska, and Sarvimäki (2014) document how individuals more exposed to the Finnish financial crisis in the 1990s were less likely to participate in the stock market twelve years later. Third, Schoar and Zuo (2011) find that CEOs who experienced a recession at age 24 (roughly when they entered the job market) made more conservative career choices throughout their careers. Finally, using a Markov-Switching model to estimate shifts in risk regimes, Gordon and St.-Amour (1999) find that risk preferences vary over time at the aggregate level and that shifts in risk regimes last for roughly ten years.

There are many existing models of time-varying risk preferences⁸, but most of these models cannot explain the findings we refer to as extraordinary persistence. We believe one advantage of our model over other models is its ability to explain the finding of extraordinary persistence. Two prominent examples in the time-varying risk preferences literature include Campbell and Cochrane (1999) and Barberis, Huang, and Santos (2001), but neither can explain multi-decade persistence in shocks to risk preferences. Using habits to explain excess volatility, Campbell and Cochrane find that three-quarters of the adjustment in habits occurs in the first ten years following a shock. As a result, it is unclear how this paper can generate extraordinary persistence⁹, which has been

⁸ Most of the literature focusing on time-varying risk preferences developed in response to the findings of excess volatility by Shiller (1981) and LeRoy and Porter (1981). See Farmer, Nourry, and Venditti (2012) for a comprehensive review of the time-varying risk preferences and excess volatility literatures.

⁹ Another weakness of a habits approach is that there is very little support for habits at the microeconomic level. See Dynan (2000), Brunnermeier and Nagel (2008), and Melino and Yang (2003).

shown to linger for up to forty years. Barberis, Huang, and Santos (2001) generate some persistence using time-varying reference points, but this persistence is limited to a single year in their model. In our paper, we argue that this persistence may result from the multi-decade persistence in memories of first-time experiences from early adulthood. When combined with the availability heuristic, we argue that these two phenomena should result in multi-decade persistence in shifts in risk preferences, which we refer to as sensitization.

Additionally, our paper is related to the economic literature of the availability heuristic. This literature is exceedingly small; however, there are two notable exceptions. Akerlof and Yellen (1987) discuss potential implications of the availability heuristic and other behavioral phenomenon but do not construct a formal model for analysis. Fuster, Hebert, and Laibson (2011) provide a formal model but assume that only “sophisticated” people have rational expectations. The non-sophisticated people in their model are assumed to be irrational because they are assumed exclusively rely on biased reasoning such as the availability heuristic. Yet, Fuster, Hebert, and Laibson do not identify why some agents use biased reasoning in equilibrium that results in significant economic inefficiencies.

In our paper, we rely on a psychological model of human decision-making endorsed by Kahneman (2011), which he refers to as the Two Systems model. Throughout his work, Kahneman argues that people’s decisions are informed by both logic-driven beliefs (e.g., rational expectations) and emotions. In his view, emotions are influenced by the availability heuristic. To capture the complex interaction between logic-driven beliefs and emotions, we allow all agents to have both rational expectations and availability-heuristic-determined emotional probabilities. We then characterize how biased emotional probabilities distort behavior from the conventional emotionless benchmark.

We are not the first to consider the economic implications of what Kahneman (2011) refers to as the Two Systems model. Other authors use a Two Systems framework to study primarily microeconomic phenomena. For example, Brocas and Carillo (2008) use a Two Systems model to study impatience while Fudenberg and Levine (2006) study self-control. In our analysis, we study implications of the Two Systems model on risk preferences, which to the best of our knowledge has not been formally done in the literature.

We are also not the first to study the interactions of emotions and macroeconomics. Di Tella, MacCulloch, and Oswald (2003) document how the state of the macroeconomy affects people's emotions. Unlike our paper, their work does not formally consider how these changes in emotions might feed back into the macroeconomy.

3. The Emotionless Benchmark Model

Our paper studies how sensitization, through generational shifts in risk preferences, affects risk choices and the economy's growth rate. Thus, our analysis will require three elements: endogenous growth, risk choices¹⁰, and overlapping generations. Since we could not find a suitable model in the existing literature to serve as a benchmark, we combined the models of Bernanke and Gertler (1989), Tirole (2006), and Romer (1986) in order to construct our benchmark model. We refer to this benchmark as our emotionless benchmark, since agents in this model do not experience sensations of gain or loss.

This benchmark model contains three sectors: a production sector, a household sector, and a financial sector. Production firms employ factors of production and pay according to the private marginal products. Households provide labor when young and consume when old, while financial

¹⁰ As an example of risk management, we study ex ante liquidity arrangements by the financial sector.

entrepreneurs' main role is to funnel household savings into capital generating projects. The risk-neutral entrepreneurs in the financial sector choose liquidity to manage potential cost overruns.

A timeline of events in our model given below. The events identified in the timeline will be discussed more in-depth later in this section.

1. Generation t arrives.
2. The investment projects from the last generation are realized and aggregate capital K_t is formed.
3. Capital and labor are allocated to firms, production occurs, and factors are paid according to their private marginal products.
4. Households choose consumption and offer savings to financial entrepreneurs at interest rate R_t .
5. Entrepreneurs choose liquidity l_t .
6. An idiosyncratic cost overrun ρ_t is realized on the representative entrepreneur's project. The cost overrun is paid if $l_t \geq \rho_t$ and the project is said to be successful. Following success, the entrepreneur will have capital $k_{t+1} = \kappa_H(1 - l_t)i_t$ next period, where i represents the amount of funding available to the entrepreneur for the investment project. When $l_t < \rho_t$, the cost overrun cannot be paid and the project is said to fail. Following failure, the entrepreneur will have capital $k_{t+1} = \kappa_L(1 - l_t)i_t$ next period.

3.1 Production Sector

The production sector consists of firms with Romer's (1986) increasing returns to scale, in which factor prices are determined by private marginal products. In this sector, there is a unit mass of atomistic firms indexed by $j \in [0,1]$, with production function at time t given by $y_{j,t} =$

$Ak_{j,t}^\alpha (\bar{K}_t l_{j,t})^{1-\alpha}$, where \bar{K}_t represents the capital stock of the average firm. The firm employs labor and rents capital in perfectly mobile and competitive factor markets. As a result, the marginal products of each factor will be equalized across firms, so that $k_{j,t} = \bar{K}_t$ and $l_{j,t} = L_t$ for all firms in equilibrium.

The economy as a whole can be represented by the aggregate capital stock $K_t = \int_{j=0}^1 k_{j,t} dj$ and the aggregate production function:

$$Y_t = AK_t^\alpha (\bar{K}_t L_t)^{1-\alpha}.$$

Normalizing $L_t = 1$ and noting that $K_t = \bar{K}_t$ in equilibrium, we can solve for our usual factor prices:

$$r_t = \alpha A,$$

$$w_t = (1 - \alpha)AK_t.$$

3.2 Household Sector

Our household sector follows Bernanke and Gertler's (1989) model, which employs the overlapping generations model of Samuelson (1958) and Diamond (1965). In each generation of size $N_t = 1$, some proportion $1 - \phi$ are households, with the remaining ϕ financial entrepreneurs discussed in the next subsection.

Households supply one unit of labor inelastically when young and have utility function $U(c_{0,t}, c_{1,t+1}) = \frac{c_{0,t}^{1-\theta} - 1}{1-\theta} + \beta \frac{c_{1,t+1}^{1-\theta} - 1}{1-\theta}$. Each household also provides savings s_t to entrepreneurs at interest rate R_t . Since households do not work when old, they fully consume both principal and interest and have per period budget constraints:

$$c_{0,t} + s_t = w_t,$$

$$c_{1,t+1} = R_t s_t.$$

Intertemporal maximization yields the usual first-order condition:

$$\beta \left(\frac{c_{0,t}}{c_{1,t+1}} \right)^\theta = \frac{1}{R_t}.$$

To determine the equilibrium savings function, we substitute in the relevant constraints and factor prices:

$$s_t = \frac{(1 - \alpha)AK_t}{1 + \beta^{-\left(\frac{1}{\theta}\right)}(R_t)^{\frac{\theta-1}{\theta}}} \quad (1)$$

Equation (1) shows that an increase in capital stock increases the economy's total savings, while an increase in the financial interest rate has mixed effects. Increases in the interest rate create a positive income effect but a negative substitution effect. If $\theta = 1$, the two effects cancel out, while if $\theta < 1$, the income effect dominates. To generate a savings curve with a non-negative slope¹¹, we assume $\theta \leq 1$ for the rest of this paper.

3.3 Financial Sector

As mentioned earlier, the role of the financial entrepreneurs is to convert household savings into physical capital. Like Bernanke and Gertler (1989), we assume that a proportion ϕ of each generation are financial entrepreneurs with investment projects. These entrepreneurs inelastically provide one unit of labor when young, and for this benchmark model, we assume they have preferences $U^e = c_{1,t+1}^e$.

Entrepreneurs borrow amount b_t from households and pay rate of interest R_t . This borrowing may take the form of bonds if R_t is fixed or equity if R_t^x depends on the investment

¹¹ We employ this assumption since savings curves are generally thought to be upward sloping. However, this assumption also strengthens our results. Note that if this assumption were not satisfied, then policies that lower R_t , would increase savings and could lead to faster growth.

project's realization x . For the moment, we consider the case of bond financing, but we later extend our analysis to consider the case of equity financing.

The role of entrepreneurs is to let their investment projects generate capital for the economy. To do so, they use their savings (here, w_t) and money borrowed from households to generate k_{t+1} units of capital. They face consumption constraint:

$$c_{t+1}^e = q_{t+1}k_{t+1} - R_t b_t,$$

where q_{t+1} represents the price of capital when the entrepreneur will sell it. For tractability, we momentarily¹² assume full capital depreciation, so that $q_{t+1} = \alpha A$.

In order to later study how adaptive risk preferences affect endogenous risk-taking, we borrow the investment characteristics from Tirole (2006, p. 209—210). Central to his model is a tradeoff between liquidity and scale. To simplify the analysis, he assumes that investment projects are identical across the representative entrepreneur and that they exhibit constant returns to scale. In both Tirole's model and ours, risk stems from to the presence of liquidity shocks. These shocks take the form of a potential cost overrun¹³, so that entrepreneurs' initial investment outlay may require a further cash injection ρ_t to successfully bring the project to completion.

In order to manage the risk of a cost overrun, entrepreneurs will need to arrange for access to liquid assets. Let $l_t \in [0,1]$ denote the fraction of total funding for the investment project, $i_t = w_t + b_t$, allocated toward liquid assets. The remaining fraction, $(1 - l_t)$ will be allocated towards the initial investment outlay, $(1 - l_t) * (w_t + b_t)$.

When a cost overrun occurs, there are two possibilities. The representative entrepreneur (she) may pay the cost overrun, so then the project is said to be successful and $k_{t+1} = \kappa_H *$

¹² In the appendix, we relax this assumption and show that the effects of sensitization are even more powerful when capital does not depreciate.

¹³ These cost overruns may stem from a variety of sources: these overruns may be due to design flaws, strategic behavior by a contracted party seeking to renegotiate the contracted terms, or from the inability to secure a key input.

$(1 - l_t) * i_t$ units of capital are generated. If she does not pay the cost overrun, then the project is said to be unsuccessful and only $k_{t+1} = \kappa_L * (1 - l_t) * i_t$ units of capital are generated, with both $\Delta\kappa = \kappa_H - \kappa_L > 0$ and $\kappa_L > 0$. Like Tirole (2006), we assume that the supply of liquid assets is perfectly elastic, and we normalize the return to liquid assets to zero, so that equilibrium demand for liquidity would also be zero in the absence of potential cost overruns. In addition, these simplifying assumptions will imply that entrepreneurs will pay the cost overrun when able. These assumptions allow us to focus on the entrepreneur's ex ante liquidity choice, which is the main concern of this paper.

The properties of cost overruns are as follows. First, the size of the cost overrun is proportional to the amount of funding acquired by the entrepreneur, i_t . Second, the magnitude of the shock $\rho_t \in [0,1]$ has density function $f(\rho_t)$ and distribution function $F(\rho_t)$. Third, liquidity arrangements must be made before the shock is realized. Finally, entrepreneurs must pay all cost overruns from their liquid assets¹⁴.

Together, the amount of liquidity on hand and the size of the cost overrun (or liquidity shock) determine the project's outcome. If the liquidity ratio is at least as large as the realized shock, $l_t \geq \rho_t$, the project is successful. This outcome occurs with probability $F(l_t)$. Otherwise when $l_t < \rho_t$, the project fails. Failure occurs with probability $(1 - F(l_t))$.

Risk-neutral entrepreneurs maximize their expected net returns. These returns depend on the price of capital, the expected quantity of capital produced, and their total borrowing costs:

$$\underbrace{\alpha A}_{\text{rental price of capital}} \underbrace{\frac{E[\kappa(l_t)]}{(1 - l_t)[\kappa_H F(l_t) + \kappa_L (1 - F(l_t))]} * \frac{i_t}{(w_t + b_t)}}_{E[k_t]=\text{expected units of capital generated}} - \underbrace{R_t b_t}_{\text{borrowing costs}} \quad (2a)$$

¹⁴ In the interest of tractability, we assume away the possibility of credit sharing. Liquidity can be thought of as a reduced form variable that captures all contingency planning resources spent by the firm.

This first-order conditions for liquidity and borrowing, respectively, are given by:

$$f(l_t^*)(1 - l_t^*)\Delta\kappa - E[\kappa^*] = 0, \quad (2b)$$

$$\alpha A(1 - l_t^*)E[\kappa^*] = R_t, \quad (2c)$$

where $E[\kappa(l_t)]$ represents the expected number of capital units for per unit of investment and $E[\kappa^*]$ its expected level when l_t is chosen optimally.

Equation (2b) characterizes the demand for liquidity in the economy and states the tradeoffs faced by entrepreneurs when choosing liquidity. Any increase in liquidity results in a good outcome being more likely. As captured by the first term, but at the cost of a smaller scale, as captured by the second term.

Equation (2c) characterizes investment demand for this economy. Entrepreneurs are assumed to be price-takers with regard to both the rental rate of capital and the interest rate for borrowing. Since their projects exhibit constant returns to scale, they make zero economic profit and investment demand is perfectly elastic. If households were to demand interest rate $R_t > \alpha A(1 - l_t^*)E[\kappa^*]$, entrepreneurs would not borrow. If households were to accept interest rate $R_t < \alpha A(1 - l_t^*)E[\kappa^*]$, entrepreneurs would be willing to undertake investment projects of infinite scale.

For liquidity, we also have the second-order condition:

$$f_l \Delta\kappa(1 - l_t) - 2 * f(l_t)\Delta\kappa < 0. \quad (2d)$$

Note that if $f_l < 0$, then condition (2d) is always satisfied. This assumption is analogous to saying that larger shocks are less likely. In the next section, we will employ this assumption to ensure that our system is stable.

Finally, we assume that following bad outcomes, entrepreneurs have enough income to pay back loans:

$$\frac{\kappa_L}{E[\kappa^*]} \geq \frac{b_t}{w_t + b_t} \quad (2e)$$

This last assumption guarantees that entrepreneurs are able to pay back debts in all states of the world, which allows us to study sensitization without also introducing additional concerns, such as credit constraints or pledgeable income. Satisfying equation (2e) will require some minimum restriction on ϕ ¹⁵.

3.4 Macroeconomic Equilibrium

Consider now the dynamics for capital. Assuming idiosyncratic shocks, the economy's success rate matches its expectation and capital evolves according to:

$$K_{t+1} = \phi k_{t+1} = (1 - l_t^*)E[\kappa^*] * \phi(w_t + b_t), \quad (3a)$$

where k_{t+1} represents the expected capital generated per project or per entrepreneur. Equation (3a) shows that the capital available for production depends on two key variables: aggregate funding available to financial sector $\phi(w_t + b_t)$ and the productivity of the financial sector in generating physical capital. In our model, the productivity of the financial sector is the expected units of capital generated per consumption unit of investment, $(1 - l_t^*)E[\kappa^*]$, while the cost of capital is given by $\frac{1}{(1 - l_t^*)E[\kappa^*]}$.

Equation (3a) will also help solve for the growth rate in the economy, $g_{t+1} = Y_{t+1}/Y_t$. In our model, the growth rate in the economy is nothing more than the growth rate in the capital stock, $g_{t+1} = K_{t+1}/K_t$. To solve for the growth rate in capital, we first note that total saving by households, $S_t = (1 - \phi)s_t$, must equal total borrowing by entrepreneurs, $B_t = \phi b_t$. Using equations (2b), (2c), and (3a), we can solve for the equilibrium growth rate:

¹⁵We find that $\frac{\phi}{1-\phi} \geq \frac{F(l_t^*)\Delta\kappa}{\kappa_L \left(1 + \beta^{-\frac{1}{\theta}} (\alpha A (1 - l_t^*) E[\kappa^*])^{\frac{\theta-1}{\theta}}\right)}$ is sufficient.

$$g_{t+1} = (1 - \alpha)A(1 - l_t^*)E[\kappa^*] \left\{ \phi + \frac{(1 - \phi)}{1 + \beta^{-\frac{1}{\theta}}(\alpha A(1 - l_t^*)E[\kappa^*])^{\frac{\theta-1}{\theta}}} \right\} \quad (3b)$$

Equation (3b) lists all of the factors that determine the equilibrium growth rate. The two terms outside the brackets represent the financial sector productivity as well as the fraction of income allocated to wages. The two terms inside the brackets capture the fractions of income saved by entrepreneurs and households, respectively. Entrepreneurially savings are clearly inelastic, while household savings are not. Equation (3b) suggests that policies encouraging greater saving or greater financial sector productivity would boost growth.

Note that in the benchmark model, economic growth is maximized because l_t^* is chosen to maximize $(1 - l_t)E[\kappa(l_t)]$, which in turn maximizes R_t . Alternatively, l_t^* can be thought of the level of liquidity that minimizes the cost of capital, $\frac{1}{(1-l_t^*)E[\kappa^*]}$. Under the assumption $\theta \leq 1$, s_t will also be maximized and l_t^* therefore maximizes growth.

The finding that liquidity is chosen to maximize growth results from entrepreneurs being risk-neutral. If entrepreneurs no longer acted in a risk-neutral manner because of sensitization, then growth would fall.

4. Emotional Sensitization and Idiosyncratic Shocks

4.1 Introducing Sensitization

Our model of sensitization implies that agents feel more optimistic after experiencing a gain and more pessimistic after a loss. Our starting point is the gain-loss utility model¹⁶ of Koszegi and Rabin (2006, 2007). In their model, Koszegi and Rabin argue that the recent rational expectation, here represented by $E[\kappa(l_t)]$, serves as the entrepreneur's reference point. When the

¹⁶ We use their choice-acclimating personal equilibrium (CPE) framework. In Koszegi and Rabin (2007), they argue this is appropriate when individuals have a long time to consider their available choices.

entrepreneur is successful and gets $\kappa_H > E[\kappa(l_t)]$, this triggers an emotional gain proportional to $\kappa_H - E[\kappa(l_t)]$. Likewise, when unsuccessful, the entrepreneur receives less than she expected and this triggers a loss proportional to $\kappa_L - E[\kappa(l_t)]$.

Assuming the entrepreneur rationally calculates the probabilities of gain and loss, we can write the entrepreneur's expected gross utility¹⁷ (ignoring borrowing costs) as proportional to the expected real return and the expected feelings of gain and loss:

$$\underbrace{E[\kappa(l_t)]}_{\text{expected return}} + \eta \underbrace{F(l_t)}_{\text{prob. of gain}} \underbrace{(\kappa_H - E[\kappa(l_t)])}_{\text{gain}} + \eta\lambda \underbrace{(1 - F(l_t))}_{\text{prob. of loss}} \underbrace{(\kappa_L - E[\kappa(l_t)])}_{\text{loss}} \quad (4a)$$

In expression (4a), $\lambda \geq 1$ captures the finding that losses might be more powerful than gains, while $\eta > 0$ measures the strength of the emotions of gain and loss. The use of the *ex ante* probabilities of gain and loss, $F(l_t)$ and $(1 - F(l_t))$, implies that anticipations of gain and loss are forward-looking.

In order to isolate role of sensitization from loss-aversion, we will proceed under assumption of loss-neutrality¹⁸, $\lambda = 1$, for most of the paper. Yet, we will also show that our main results—that risk creates intergenerational spillovers and that these intergenerational spillovers lead to excessive risk-intensity—are robust to the introduction of loss-aversion.

We make one further departure from the preferences in Koszegi and Rabin (2006, 2007). Instead of assuming anticipations of gain and loss stem from rational probabilities, we follow

¹⁷ Expected net utility would be written as: $E[U] = \alpha A(1 - l_t)\{E[\kappa(l_t)] + \eta F(l_{t-1})(\kappa_H - E[\kappa(l_t)]) + \eta\lambda(1 - F(l_{t-1}))(\kappa_L - E[\kappa(l_t)])\} * (b_t + w_t) - R_t b_t$

¹⁸ The main issue with incorporating loss-aversion is tractability. Loss-aversion may create multiple equilibria or corner solutions. Infinitely loss-averse entrepreneurs could minimize the sense of loss by moving to $l_t \in \{0,1\}$. Another advantage of using loss-neutrality is that the loss-neutral model without sensitization collapses to our emotionless benchmark model.

Kahneman¹⁹ (2011) and consider the possibility that anticipations of emotions are generated by subconscious beliefs according to the availability heuristic²⁰. As argued in the introduction, we believe that these emotional anticipations depend on autobiographical experiences and are adaptive. We refer to the presence of adaptive risk preferences as sensitization.

To capture the role of sensitization, we assume entrepreneurs maximize what we call anticipated utility, in which emotional probabilities depend on the realization of economic conditions when the entrepreneur was young. Anticipated utility therefore depends on the prior generation's realized success rate, $F(\widehat{l_{t-1}})$, which is the *ex post* success rate. Anticipated gross utility²¹ is then proportional to:

$$\begin{aligned} & \underbrace{E[\kappa(l_t)]}_{\text{expected return}} + \eta \underbrace{F(\widehat{l_{t-1}})}_{\text{anticipated prob. of gain}} \underbrace{(\kappa_H - E[\kappa(l_t)])}_{\text{gain}} \\ & + \eta\lambda \underbrace{(1 - F(\widehat{l_{t-1}}))}_{\text{anticipated prob. of loss}} \underbrace{(\kappa_L - E[\kappa(l_t)])}_{\text{loss}} \end{aligned}$$

Anticipated net utility will then be:

$$\begin{aligned} & \alpha A(1 - l_t) \{ F(l_t)\kappa_H + (1 - F(l_t))\kappa_L + \eta F(\widehat{l_{t-1}}) (\kappa_H - E[\kappa(l_t)]) \\ & + \eta\lambda (1 - F(\widehat{l_{t-1}})) (\kappa_L - E[\kappa(l_t)]) \} * (b_t + w_t) - R_t b_t \end{aligned}$$

All other terms are exactly the same as before, though η has a slightly different interpretation. η now measures the strength of sensitization. If $\eta = 0$, entrepreneurs are never sensitized, emotions do not matter, and our model collapses to the emotionless benchmark.

¹⁹ Kahneman (p. 105) argues that loss-aversion comes from the part of the mind he refers to as System 1. He argues (p. 130) that System 1 generates probabilities according to the availability heuristic instead of formal reasoning, such as Bayes' rule.

²⁰ Even though these emotions are irrational (non-Bayesian), ignoring them is also irrational. Kahneman (2011, p.144-145) argues that emotions are part of one's overall risk-preferences. Ignoring emotions completely would be irrational because risk-adjusted utility would no longer be maximized.

²¹Note that even if anticipations of gain and loss are not fully adaptive, our analysis may still be valid. If the adaptive and rational components are adaptively separable, then the rational expectations will cancel out as in Equation (4a) and only the adaptive component will survive under our maintained assumption of loss-neutrality.

What is the impact of sensitization? Suppose for some reason that one generation of agents experienced an economic collapse with all investment projects failing, $F(\widehat{l_{t-1}}) = 0$. In this case, we would expect that entrepreneurs would be predisposed to extreme pessimism. Pessimism will cause the agent to feel like she will always fail, triggering a state of fear. Even though she may know this feeling is irrational, accommodating her fear by investing more conservatively will give her greater peace of mind. Her pessimism will therefore induce her to act more conservatively than the emotionless benchmark.

In the present section, we consider the case of idiosyncratic shock. With atomistic entrepreneurs, the average realization agents experience early in life, $F(\widehat{l_t})$, coincides with the prior expectation, $F(l_t)$, at every generation born at time t , and anticipated net returns are now:

$$A[U] = \alpha A(1 - l_t) \{ F(l_t) \kappa_H + (1 - F(l_t)) \kappa_L + F(l_{t-1}) \eta \Delta \kappa (1 - F(l_t)) - (1 - F(l_{t-1})) \eta \lambda \Delta \kappa F(l_t) \} * (b_t + w_t) - R_t b_t \quad (4b)$$

In the above expression, $A[\cdot]$ is the anticipation operator and allows the entrepreneurs to be forward-looking in terms of actual returns but adaptive in terms of emotions. Our anticipation operator is introduced to distinguish between the expected utility operator implicit in the emotionless benchmark equation (2a).

Assuming loss-neutrality, $\lambda = 1$, the first-order condition for liquidity is:

$$f(l_t) \Delta \kappa [1 - \eta] (1 - l_t^*) - [F(l_t) \kappa_H + (1 - F(l_t)) \kappa_L + \eta (F(l_{t-1}) - F(l_t)) \Delta \kappa] = 0 \quad (4c)$$

Equation (4c) differs from the emotionless benchmark presented in Equation (2b) because the private benefits²² of extra liquidity, as represented by the first term, are reduced. With sensitization, increases in liquidity increase the expectation of success but not the emotional

²² Higher liquidity creates a positive externality enjoyed by future generations. This externality results from the adaptive nature of emotional anticipations.

anticipation component, which is adaptive²³. With the benefits of liquidity reduced, we would expect agents to hold fewer liquid assets than in the emotionless equilibrium, which will prove harmful to growth.

That agents' liquidity arrangements prove insufficient is our first major finding for policymakers. Private liquidity falls short because one generation's protection against risk provides a positive externality for future generations. When one generation chooses more liquidity, future generations are expected to be more optimistic and happier. Unless future generations are able and willing to compensate for this benefit, investment projects will excessively risky from a central planner's perspective²⁴. Although our model formulates the externalities of risk management in terms of liquidity, we believe the same intuition would apply to other variables correlated with risk, such as leverage. To encourage greater liquidity arrangements (or in other models to encourage less leverage), policymakers should favor higher short-term rates than would be required under the emotionless second-best. In addition, minimum liquidity ratios or maximal leverage ratios would further reduce these distortions.

Our finding of insufficient demand for liquid assets (or more generally, the excessive intensity of risk) complements the existing literature. Fahri and Tirole (2012) find that firms may collectively demand too little liquidity in order to increase the probability of a future bailout. In both their paper and ours, liquidity distortions could be fixed with minimum liquidity ratios.

Our first-order condition for borrowing yields:

$$\alpha A(1 - l_t)E[\kappa(l_t)] - R_t = 0 \quad (4c)$$

²³ If the emotional component were completely forward-looking, equation (4c) would collapse to the emotionless benchmark under loss-neutrality.

²⁴ As long as the discount factors for different generations in the central planner's social welfare function are positive, then the central planner would choose more liquidity than in our decentralized model.

This equation is almost identical to equation (2c) from before. The main difference is that under sensitization, l_t is no longer chosen to maximize expected returns, $(1 - l_t)E[\kappa(l_t)]$. As a result, investment under sensitization will be below the emotionless benchmark²⁵.

That investment demand is too low is our second major finding for policymakers. The shortfall in investment stems both from sensitization and the positive externalities of capital in our model. Both would argue for lower long-term rates, which could be achieved by investment tax credits, quantitative easing, or Operation Twist. Of these policies, Operation Twist is likely to be particularly effective. By selling short-term assets to purchase long-term assets, short-term interest rates should rise and long-term interest rates should fall, thereby addressing both liquidity and investment distortions.

To ensure stability in the dynamics of liquidity in our model, we need to verify that the following stability condition holds:

$$\left| \frac{\partial l_t}{\partial l_{t-1}} \right| = \left| \frac{\eta}{1 - \eta} * \frac{f(l_{t-1})}{f_l(l_t)(1 - l_t) - 2f(l_t)} \right| < 1 \quad (4d)$$

Near steady-state and assuming the degree of sensitization is not too large, $\eta < \frac{2}{3}$, the stability condition (4d) will be satisfied if $f_l(\cdot) \leq 0$. To guarantee that our system is stable, we will maintain the assumption that $f_l(\cdot) \leq 0$ for the rest of the paper.

If condition (4d) is met, liquidity holdings will converge²⁶ to some equilibrium value.

Once there, the economy grows along its balanced growth path:

²⁵ Note that the emotionless benchmark already had insufficient investment due to the positive externalities of capital in the production function.

²⁶ The second order condition for liquidity from Equation (2d) will ensure that $\frac{\partial l_t}{\partial l_{t-1}} < 0$. Thus, the dynamics of liquidity along the convergence path will be characterized by cycles. Increases in liquidity during one period will increase the next period's optimism and will lead to lower liquidity in the future. These cycles will generate excess volatility in asset prices in the economy that we consider in the next section and the appendix.

$$f(l_t)\Delta\kappa(1-l_t) = \frac{E[\kappa(l_t)]}{1-\eta} \quad (4e)$$

The equilibrium level of liquidity in Equation (4e) is lower than our benchmark model due to the aforementioned dynamic externality for risk. This distortion will lower the economic growth rate, since $(1-l_t)E[\kappa(l_t)]$ will be too low:

$$g_{t+1} = (1-\alpha A)(1-l_t)E[\kappa(l_t)] \left\{ \phi + \frac{(1-\phi)}{1 + \beta^{-\left(\frac{1}{\theta}\right)}((1-l_t)E[\kappa(l_t)]\alpha A)^{\frac{\theta-1}{\theta}}} \right\} \quad (4f)$$

Under sensitization, entrepreneurs no longer choose liquidity to maximize expected capital formation, $(1-l_t)E[\kappa(l_t)]$, or minimize the cost of capital, $\frac{1}{(1-l_t)E[\kappa(l_t)]}$. Instead, liquidity is chosen to maximize emotionally-adjusted anticipations of capital formation. The backward-looking nature of emotional likelihood leads to insufficient liquidity because the social benefits of liquidity are not fully internalized. This deviation of l_t from its optimum will cause growth to slow. In addition, since sensitized entrepreneurs act more risk-averse with respect to the extensive margin of investment, R_t will fall and growth will slow further. These distortions will be greater under debt financing and under higher degrees of sensitization, as shown in the next two parts.

Our finding that sensitization lowers growth is not what one would first expect from the literature. At a broad level, sensitization can be thought of as the opposite of habituation²⁷. However, the dynamics of our model are very different²⁸ than standard models of habituation. We find that sensitization unambiguously lowers growth while conventional analyses of habits²⁹ find

²⁷ Patients who become habituated to a drug exhibit smaller and smaller reactions. Patients who become sensitized to a drug exhibit larger and larger reactions.

²⁸ Models of habituation assume people develop habits which primarily affect agent's elasticity of intertemporal substitution, but in our model, sensitization primarily affects time-varying risk-aversion. In models in which these two concepts are linked, habits-based models and models of sensitization should produce similar results. In our model, these two concepts are not linked because entrepreneurs choose their consumption within a single period.

²⁹ Such as Carroll, Overland, and Weil (2000).

that the effect of habituation is ambiguous and critically depends on the relative magnitudes of the capital stock to the habit level.

4.2 Comparative Statics

In our comparative statics, we wish to show that the liquidity distortions (and hence growth distortions) are greater for higher levels of sensitization (η) and loss-aversion (λ). Starting with the degree of sensitization and differentiating equation (4c), we find that:

$$\frac{\partial l_t}{\partial \eta} = \frac{f(l_t)\Delta\kappa(1-l_t)}{f_l\Delta\kappa[1-\eta](1-l_t) - 2f(l_t)\Delta\kappa[1-\eta]} = \frac{[+]}{[-]} < 0 \quad (4g)$$

As expected, higher degrees of sensitization exacerbate the problem of insufficient liquid holdings by financial entrepreneurs.

Next, we want determine the impact of introducing loss-aversion. To do this, we evaluate the effect of an increase in λ in the neighborhood of $\lambda = 1$:

$$\left. \frac{\partial l_t}{\partial \lambda} \right|_{\lambda=1} = \frac{\Delta\kappa\eta(1-F(l_{t-1}))[f(l_t)(1-l_t) - F(l_t)]}{f_l(l_t)\Delta\kappa[1-\eta](1-l_t) - 2f(l_t)\Delta\kappa[1-\eta]} \quad (4h)$$

From the first-order condition (4c) and our second-order condition, we find that this expression is negative. Loss-aversion in this model exacerbates the impact of loss. Since both anticipations of gain and loss are responsible for sensitization and insufficient liquidity arrangements, higher sensations of loss render sensitization even more powerful. An increase in λ causes liquidity demand to fall even further below the growth-maximizing level.

4.3 Liquidity Distortions Under Equity Financing

In this last part, we present our third major policy finding, which is that equity financing may promote faster economic growth. Under equity financing, sensitization may be moderated because diversification of idiosyncratic risk may be achieved at lower cost. Diversification is beneficial because it reduces agents' risk exposures so that the impacts of sensitization is reduced.

To capture equity financing, we now allow payouts to be state-contingent. Under state-contingent payouts, if households lend to a single entrepreneur, then they will be exposed to risk. To protect themselves from idiosyncratic shocks, households should diversify their investments across all projects. Suppose households have access to a mutual fund with zero administrative costs and that this fund can funnel savings into shares of each of the investment projects. Under idiosyncratic shocks and with atomistic entrepreneurs, the actual return enjoyed by the mutual fund will equal its expected returns.

In the absence of agency problems, there is no reason to expose entrepreneurs to risk in our model. Hence, optimal contracts will prevent potentially loss-averse entrepreneurs from experiencing loss. As a result, l_t is chosen to maximize:

$$\alpha A(1 - l_t)[F(l_t)\kappa_H + (1 - F(l_{t-1}))\kappa_L]i_t - F(l_t)R_t^H i_t - (1 - F(l_t))R_t^L i_t,$$

where R_t^x represents the entrepreneur's payment to the mutual fund following realization $x \in \{L, H\}$. Entrepreneurs will get zero economic profit because they compete for funding. Consequently, $R_t^x = \kappa_x \alpha A(1 - l_t)$ are the entrepreneur's optimal equity payouts to households. Under these payouts, entrepreneurs will choose to maximize the expected return and to minimize the cost of capital and sensitization will no longer create distortions. When expected returns are maximized, liquidity reaches its first-best level and growth is maximized, which stands in contrast to our findings under debt financing.

We find that equity financing enhances growth, which is in contrast to the findings of earlier authors. Earlier authors generally argue that the type of financing should not affect growth or that if financing matters, then debt financing is optimal; however, these authors do not formally consider the financial diversification benefits of equity financing, which are magnified in the presence of sensitization. For example, Modigliani and Miller (1958) argue that the source of

financing largely does not affect the equilibrium cost of capital and thus growth. Brock and Turnovsky (1981) further argue that given the tax preferences for debt in the United States, debt financing reduces the firm's cost of capital, which should lead to more rapid growth.

Of course, there is an older literature going back to Fisher (1933) arguing that equity financing may be optimal. Fisher's argument rests on the vulnerability of debt financing to deflationary shocks, which make debt-based economies more volatile. Fisher's findings are different from in two ways. First, Fisher analyzes volatility while we primarily focus on growth. The second difference regards timing. In Fisher's model equity financing is optimal because debt contracts are costly to renegotiate *following* a negative shock. In our model, equity contracts are optimal because they encourage better risk-management *prior* to the realization of a shock. We view our finding as complementary to Fisher's.

5. Cycles with Systemic Shocks

In this section, we consider the impact of shocks that affect all entrepreneurs simultaneously, such as a financial crisis. Analyzing systemic shocks allows us to determine how the risk distortions identified in the paper evolve with the business cycle. Our approach follows Holmström and Tirole (2001), and we consider the extreme case of a single cost overrun affecting all investment projects.

Under a common and systemic shock with representative agents, there are two cases for investment projects. Either every representative entrepreneur has sufficient liquidity and all projects are successful, or all liquidity arrangements prove insufficient, resulting in the simultaneous failure of all projects.

These extreme realizations create two types of entrepreneurs. At time t , entrepreneurs may have grown up in a good state of common success, creating an optimistic emotional anticipation

of success $F(\widehat{l_{t-1}}) = 1$. Or they may have grown up during widespread economic stress with the pessimistic emotional anticipation of success $F(\widehat{l_{t-1}}) = 0$.

In a pessimistic regime, entrepreneurs maximize:

$$A[U_L] = \alpha A * (1 - l_t) [F(l_t)\kappa_H + (1 - F(l_t))\kappa_L - \eta F(l_t)\Delta\kappa] (w_t + b_t) - R_t b_t,$$

with first-order condition for liquidity:

$$E[\kappa(l_t)] + \frac{\eta}{1 - \eta} \kappa_L = f(l_t)\Delta\kappa(1 - l_t) \quad (5a)$$

Equation (5a) reveals two findings. First, since $E[\kappa(l_t)] + \frac{\eta}{1 - \eta} \kappa_L < \frac{E[\kappa(l_t)]}{1 - \eta}$, entrepreneurs make better use of liquidity compared to the decentralized steady-state under idiosyncratic shocks from equation (4c). Entrepreneurs are incentivized to increase liquidity in order to minimize their anticipated loss. Even though they increase liquidity in response to their anticipated loss, since $E[\kappa(l_t)] + \frac{\eta}{1 - \eta} \kappa_L > E[\kappa(l_t)]$, entrepreneurs still employ less liquidity than the emotionless benchmark from equation (2b).

When looking at the first-order condition for borrowing,

$$\alpha A * (1 - l_t) [F(l_t)\kappa_H + (1 - F(l_t))\kappa_L - \eta F(l_t)\Delta\kappa] = R_t, \quad (5b)$$

the Envelope Theorem suggests that the social return to scale and the private return to scale are further apart after a negative shock. Fearful and pessimistic individuals have heightened perceptions of risk, reducing both anticipated returns and the investment demand.

There are two reasons why the investment demand from equation (5b) is too small from the central planner's perspective. First, there are positive externalities for capital. Consequently, the private return of new investment often falls short of the return enjoyed by society. Even the emotionless benchmark is characterized by insufficient investment demand in equation (2a).

Second, following bad shocks, agents are caught up with negative emotions, causing them to be fearful. This increased risk premium causes investment to fall even further.

Under a good regime, when $F(\widehat{l_{t-1}}) = 1$, our findings will be reversed. After a good shock, R_t , which also captures our investment demand curve, will increase as agents are more optimistic. This increased optimism, however, will lead them to reduce their liquid holdings even further below the idiosyncratic second-best of equation (4e).

After a good shock, entrepreneurs now maximize:

$$A[U_H] = \alpha A * (1 - l_t) [F(l_t)\kappa_H + (1 - F(l_t))\kappa_L + \eta(1 - F(l_t))\Delta\kappa] (w_t + b_t) - R_t b_t.$$

This gives us the first-order condition for liquidity:

$$E[\kappa(l_t)] + \frac{\eta}{1 - \eta} \kappa_H = f(l_t)\Delta\kappa(1 - l_t) \quad (5c)$$

Following good shocks, Equation (5c) shows that the opportunity cost of liquidity now increases. Since $E[\kappa(l_t)] + \frac{\eta}{1 - \eta} \kappa_H > \frac{E[\kappa(l_t)]}{1 - \eta}$, entrepreneurs make even worse use of liquidity compared to the pessimistic agents from equation (4c). With the probability of gain fixed at one, entrepreneurs maximize their overall anticipations by curtailing liquidity in favor of a higher scale. This optimistic bias exacerbates the liquidity shortage found in equation (4c).

An increase in optimism, which results in lower liquidity, will also boost investment according to the Envelope Theorem:

$$\alpha A * (1 - l_t) [F(l_t)\kappa_H + (1 - F(l_t))\kappa_L + \eta(1 - F(l_t))\Delta\kappa] = R_t \quad (5d)$$

When agents are optimistic, they anticipate larger returns to investment projects than is rational. This optimism, so long as it is not too excessive, should be beneficial for the economy because it

should reduce the difference between the private and social returns to investment. When $\theta \leq 1$, investment will rise.

Overall, it is difficult to determine whether the overall growth rate is faster in optimistic or pessimistic regimes. In terms of risk-management, we have shown that entrepreneurs in bad states have smaller liquidity distortions than entrepreneurs in good states; however, this is offset by a reduced willingness to undertake investment projects. Any comparison of growth rates across both regimes would require a calibration of the magnitudes of both effects.

The implications of our model for optimal monetary policy are somewhat troubling. If short-term asset purchases decrease short-term interest rates, then this should increase risk-intensity even further. Under adaptive risk preferences, steady-state investment and growth would be further depressed. To offset the decentralized economy's liquidity and investment distortions, our model suggests that policymakers should instead favor lower long-term interest rates and higher short-term rates. We believe that Operation Twist, as analyzed by Hamilton and Wu (2012)³⁰, is likely to be a particularly effective policy tool.

6. Conclusion and Policy Implications

In this paper, we develop a model with adaptive, persistent, and time-varying emotions, which we assume influence agents' risk-preferences. We believe such preferences capture the psychological phenomenon of sensitization. Our model predicts that people feel more pessimistic after a negative shock and that this pessimism may last for decades. Our model captures the empirical finding of extraordinary persistence found by Malmendier, Tate, and Yan (2011). As a result, we believe our model is an original contribution to the literature.

³⁰ Unlike Hamilton and Wu (2012) our analysis indicates that Operation Twist would likely be even more effective in the Long Run than similarly sized programs of Quantitative Easing.

The main economic insight of our model is that one generation's risk-seeking behavior will impose negative externalities on future cohorts. We find that in the decentralized economy, the extent of risky activities, such as investment, will be distorted below the emotionless second-best, while the intensity of risk—captured in our model by the lack of liquidity arrangements—will be socially excessive.

Our analysis identifies instruments available to policymakers that may address the distortions we find in the decentralized economy. First, to limit risk-intensity, policymakers may enforce minimum liquidity ratios and favor higher short-term rates, as suggested by Farhi and Tirole (2012). Second, to encourage investment and growth, policymakers should promote lower long-term rates³¹ by purchasing long-term assets. The optimal monetary policy is likely Operation Twist, which simultaneously raises short-term rates and lowers long-term rates, addressing both distortions identified in our model. In contrast, we show that short-term asset purchases emerge as counterproductive by decreasing liquidity holdings even further. Third, favoring equity financing more and eliminating the tax preference for debt³² should promote greater economic resiliency by increasing risk diversification and blunting the effects of sensitization.

We propose a few possible extensions to our model. One obvious extension would be to introduce nominal rigidities to better characterize optimal monetary policy. A second possible extension would be to construct a more detailed model of sensitization to allow for a bias in memory for recent events. A third extension would be to introduce agency costs and study their interaction with our sensitization cycles. A final extension would be to consider sensitization in

³¹ Because of production externalities, much of the endogenous growth literature (e.g., Romer (1986, 1990) and Hellwig and Irmen) finds that there too little investment occurs in a decentralized equilibrium. Our model of sensitization merely provides another reason why investment distortions might occur, and we argue that monetary policy such as Operation Twist can be used to simultaneously address both investment and liquidity distortions.

³² De Mooij (2011) reviews recent findings and argues that the cost of tax preferences for debt may be larger than previously thought. In addition, his work discusses proposals to reduce this preference.

other areas of the economy, such as the household or international sector, to determine how optimal policies might change.

References

- Akerlof, George, and Janet Yellen, “Rational Models of Irrational Behavior,” *American Economic Review*, May 1987, 77(2), 137—142.
- Barberis, Nicholas, and Richard Thaler, “A Survey of Behavioral Finance,” *Handbook of the Economics of Finance*, 2003, 1, 1053—1128.
- Barberis, Nicholas, Ming Huang, and Tano Santos, “Prospect Theory and Asset Prices,” *Quarterly Journal of Economics*, February 2001, 116(1), 1—53.
- Bernanke, Ben, and Mark Gertler, “Agency Costs, Net Worth, and Business Fluctuations,” *American Economic Review*, March 1989, 79(1), 14—31.
- Brocas, Isabelle, and Juan Carrillo, “The Brain as a Hierarchical Organization,” *American Economic Review*, September 2008, 98(4), 1312—1346.
- Brock, William, and Stephen Turnovsky, “The Analysis of Macroeconomic Policies in Perfect Foresight Equilibrium,” *International Economic Review*, February 1981, 22(1), 179—209.
- Brunnermeier, Markus, and Stefan Nagel, “Do Wealth Fluctuations Generate Time-Varying Risk Aversion? Micro-Evidence on Individuals’ Asset Allocation,” *American Economic Review*, June 2008, 98(3), 713—736.
- Cameron, Lisa and Manisha Shah, “Risk-Taking Behavior in the Wake of Natural Disasters,” 2013, NBER Working Paper No. 19534.
- Campbell, John, and John Cochrane, “By Force of Habit: A Consumption-based Explanation of Aggregate Stock Market Behavior,” *Journal of Political Economy*, April 1999, 107(2),

205—251.

- Carroll, Christopher, Jody Overland, and David Weil, “Saving and Growth with Habit Formation,” *American Economic Review*, June 2000, 90(3), 341—355.
- De Mooij, Ruud, “Tax Biases to Debt Finance: Assessing the Problem, Finding Solutions,” May 2011, IMF Working Paper.
- Di Tella, Rafael, Robert MacCulloch, and Andrew Oswald, “The Macroeconomics of Happiness,” *Review of Economics and Statistics*, November 2003, 85(4), 809—827.
- Diamond, Peter A., “National Debt in a Neoclassical Growth Model,” *American Economic Review*, December 1965, 55(5), 1126—1150.
- Dynan, Karen, “Habit Formation in Consumer Preferences: Evidence from Panel Data,” *The American Economic Review*, June 2000, 90(3), 391—406.
- Farhi, Emmanuel, and Jean Tirole, “Collective Moral Hazard, Maturity Mismatch, and Systematic Bailouts,” *American Economic Review*, February 2012, 102(1), 60—93.
- Farmer, Roger, Carine Nourry, and Alain Venditti, “The Inefficient Market Hypothesis: Why Financial Markets Do Not Work Well in the Real World,” 2012, NBER Working Paper No., 18647.
- Fisher, Irving, “The Debt-Deflation Theory of Great Depressions,” *Econometrica*, October 1933, 1(4), 337—357.
- Fudenberg, Drew, and David Levine, “A Dual-Self Model of Impulse Control,” *American Economic Review*, December 2006, 96(5), 1449-1476.
- Fuster, Andreas, Benjamin Hebert, and David Laibson, “Natural Expectations, Macroeconomic Dynamics, and Asset Pricing, 2011, NBER Working Paper No., 17301.
- Gordon, Stephen, and Pascal St-Amour, “A Preference Regime Model of Bull and Bear

- Markets,” *The American Economic Review*, September 2000, 90(4), 1019—1033.
- Guiso, Luigi, Paola Sapienza, and Luigi Zingales, “Time varying Risk Aversion,” 2013, Working Paper.
- Hamilton, James, and Jing Wu, “The Effectiveness of Alternative Monetary Policy Tools in a Zero Lower Bound Environment,” *Journal of Money, Credit, and Banking*, 2012, 44(s1), 3—46.
- Heilman, Renata, Liviu Crisan, Daniel Houser, Mircea Miclea, Andrei Miu, “Emotion Regulation and Decision Making Under Risk and Uncertainty,” *Emotion*, April 2010, 10(2), 257—265.
- Hellwig, Martin and Andreas Irmen, “Endogenous Technical Change in a Competitive Economy,” *Journal of Economic Theory*, November 2001, 101(1), 1—39.
- Holmström, Bengt and Jean Tirole, “LAPM: A Liquidity-Based Capital Asset Pricing Model,” *Journal of Finance*, October 2001, 56(5), 1837—1867.
- Kahneman, Daniel, *Thinking, Fast and Slow*, New York: Farrar, Straus and Giroux, 2011.
- Kandel, Eric, “The Molecular Biology of Memory Storage: A Dialogue Between Genes and Synapses,” *Science*, November 2001, 294(5544), 1030—1038.
- Kato, Ryo, “Liquidity, Infinite Horizons and Macroeconomic Fluctuations,” *European Economic Review*, July 2006, 50(5), 1105—1130.
- Kim, Young-Il and Jungmin Lee, “The Long-Run Impact of Traumatic Experience on Risk Aversion,” March 2013, Working Paper.
- Knüpfer, Samuli, Elias Rantapuska, and Matti Sarvimäki, “Labor Market Experiences and Portfolio Choice: Evidence from the Finnish Great Depression,” January 2014, Working Paper.

- Koszegi, Botond, and Matthew Rabin, “A Model of Reference-Dependent Preferences,” *The Quarterly Journal of Economics*, November 2006, 121(4), 1133—1165.
- Koszegi, Botond and Matthew Rabin, “Reference-Dependent Risk Attitudes,” *The American Economic Review*, September 2007, 97(4), 1047—1073.
- LeRoy, Stephen, and Richard Porter, “The Present-Value Relation: Tests Based on Implied Variance Bounds,” *Econometrica*, May 1981, 49(3), 555—574.
- Malmendier, Ulrike, Geoffrey Tate, and Jon Yan, “Overconfidence and Early-life Experiences: The Effect of Managerial Traits on Corporate Financial Policies,” *Journal of Finance*, October 2011, 66(5), 1687—1733.
- Melino, Angelo, and Alan Yang, “State-Dependent Preferences Can Explain the Equity Premium Puzzle,” *Review of Economic Dynamics*, October 2003, 6(4), 806—830.
- Modigliani, Franco, and Merton Miller, “The Cost of Capital, Corporation Finance, and the Theory of Investment,” *American Economic Review*, June 1958, 48(3), 261—297.
- Rathbone, Clare J., Chris J.A. Moulin, and Martin A. Conway, “Self-centered Memories: The Reminiscence Bump and the Self,” *Memory and Cognition*, December 2008, 36(8), 1403—1414.
- Romer, Paul, “Endogenous Technical Change,” *Journal of Political Economy*, October 1990, 98(5), S71—S102.
- Romer, Paul, “Increasing Returns and Long-Run Growth,” *Journal of Political Economy*, October 1986, 94(5), 1002—1037.
- Rubin, David C., Tamara A. Rahhal, and Leonard W. Poon, “Things Learned in Early Adulthood are Remembered Best,” *Memory and Cognition*, January 1998, 26(1), 3—19.
- Samuelson, Paul A., “An Exact Consumption-Loan Model of Interest with or without the Social

Contrivance of Money,” *The Journal of Political Economy*, December 1958, 66(6), 467—482.

Shiller, Robert, “Do Stock Prices Move Too Much to be Justified by Subsequent Changes in Dividends?,” *American Economic Review*, June 1981, 71(3), 421—436.

Schoar, Antoinette, and Luo Zuo, “Shaped by Booms and Busts: How the Economy Impacts CEO Careers and Management Style,” 2011, NBER Working Paper No., 17590.

Tirole, Jean, *The Theory of Corporate Finance*, Princeton: Princeton University Press, 2006.

Appendix A: Introducing Durable Capital

In this section, we extend the analysis of systemic shocks but consider the case of zero capital depreciation. We assume that the older entrepreneurs can sell their capital to the younger generation according to the following timing:

1. Generation t arrives.
2. The investment projects from the last generation are realized and aggregate capital K_t is formed.
3. Capital and labor are allocated to firms, production occurs, and factors are paid according to their private marginal products.
4. Households choose consumption and offer savings to financial entrepreneurs at interest rate R_t . Entrepreneurs of generation t purchase existing capital of entrepreneurs from generation $t - 1$.
5. Entrepreneurs choose liquidity l_t .
6. A systemic (perfectly correlated across projects) cost overrun ρ_t is realized on the representative entrepreneur’s project. The cost overrun is paid if $l_t \geq \rho_t$ and the project will be successful. Following success, the entrepreneur will have capital

$k_{t+1} = \kappa_H(1 - l_t)i_t$ next period, where i represents the original investment.

When $l_t < \rho_t$, the cost overrun cannot be paid and the project fails. Following failure, the entrepreneur will have capital $k_{t+1} = \kappa_L(1 - l_t)i_t$ next period.

How does the analysis change without depreciation? We show that when capital does not depreciate, the resulting liquidity shortages become even more severe. The main insight is that capital, with a time-invariant return $r_t = \alpha A$, acts as a safe asset. As a result, when their collective actions result in a systemic shock, entrepreneurs are partially compensated by an increase in the price of their safe assets. This partial insurance means that investment will become even more risk-intensive.

To see why capital acts as a safe asset, note that the value of capital at any point in time is derived from its replacement cost, inclusive of risk-premia. During good states of the world, entrepreneurs feel optimistic about their investment projects. They are then willing to pay a premium for the privilege of financings these projects, which should cause the value of existing capital to fall. After an adverse shock, entrepreneurs instead feel more pessimistic about investments and will need to be compensated for risk. A positive risk-premium will emerge and existing capital will become more valuable.

No-arbitrage conditions will emerge from the indifference of entrepreneurs between holding existing capital and creating new capital for each state of the world:

$$\begin{aligned} & \frac{\alpha A + q_L - F(l_L)(q_L - q_H)(1 - \eta)}{q_L} \\ & = (1 - l_L)[(q_L + \alpha A)\kappa_L + F(l_L)(1 - \eta)(\alpha A\Delta\kappa + q_H\kappa_H - q_L\kappa_L)] \end{aligned} \quad (A1)$$

$$\begin{aligned} & \frac{\alpha A + q_H + (1 - F(l_H))(q_L - q_H)(1 - \eta)}{q_H} \\ & = (1 - l_H)[(\alpha A + q_H)\kappa_H - (1 - F(l_H))(1 - \eta)(\alpha A\Delta\kappa + q_H\kappa_H - q_L\kappa_L)] \end{aligned} \quad (A2)$$

In the above equations, l_L denotes the liquidity chosen following a bad regime and q_L the resulting price of capital. l_H denotes the level of liquidity chosen following a good regime and q_H is likewise the resulting price of capital. The left hand sides of equations (A1) and (A2) denote the anticipated return to buying existing capital. Anticipated returns consist of the dividends and anticipated capital gains or losses. The anticipated capital gains or losses are reduced by the factor $(1 - \eta)$ below the rational expectation because entrepreneurs subconsciously anticipate the current state of the world persisting with probability one.

In addition to our no-arbitrage conditions, the durability of capital also changes the first-order conditions for liquidity, as the opportunity cost of liquidity now includes the value of foregone capital:

$$(1 - l_L)f(l_L) - F(l_L) = \frac{[(q_L + \alpha A)\kappa_L]}{[\alpha A\Delta\kappa + q_H\kappa_H - q_L\kappa_L](1 - \eta)} \quad (A3)$$

$$(1 - l_H)f(l_H) - F(l_H) = \frac{[(q_L + \alpha A)\kappa_L]}{[\alpha A\Delta\kappa + q_H\kappa_H - q_L\kappa_L](1 - \eta)} + \frac{\eta}{1 - \eta} \quad (A4)$$

Equations (A1)—(A4) define our macroeconomic system. Once the values of liquidity and price of capital in each state of the world are known, it will be easy to solve for all other variables. As a result, the main question for the rest of this section is how state-contingent capital prices affect liquidity.

If we consider equations (A3) and (A4), two observations emerge. First, equations (A3) and (A4) can be solved to determine the values of l_L and l_H . These values must satisfy $l_H < l_L$ due to the $\frac{\eta}{1-\eta}$ term in equation (A3), which is just as before. Second, if $\frac{\partial q_L}{\partial \eta} > 0$ and $\frac{\partial q_H}{\partial \eta} < 0$, then liquidity shortages become even worse³³ with more durable capital, as originally conjectured.

³³ Note that if $q_L = q_H$ then equations (A3) and (A4) collapse to equations (5a) and (5c), respectively.

We now show that the introduction of low levels of sensitization causes the capital prices to move in the directions we have described. If we differentiate our no-arbitrage conditions at $\eta = 0$, we get:

$$\frac{q(1 - F(l)) \left(\frac{\partial q_L}{\partial \eta} - \frac{\partial q_H}{\partial \eta} \right) \Big|_{\eta=0} - (\alpha A) \frac{\partial q_H}{\partial \eta} \Big|_{\eta=0}}{q^2(1 - l)} = (1 - F(l))(\alpha A + q)\Delta\kappa + \left[\kappa_L(1 - F(l)) \frac{\partial q_L}{\partial \eta} \Big|_{\eta=0} + F(l)\kappa_H \frac{\partial q_H}{\partial \eta} \Big|_{\eta=0} \right] \quad (A5)$$

$$\frac{-qF(l) \left(\frac{\partial q_L}{\partial \eta} - \frac{\partial q_H}{\partial \eta} \right) \Big|_{\eta=0} - \alpha A \frac{\partial q_L}{\partial \eta} \Big|_{\eta=0}}{q^2(1 - l)} = -F(l)(\alpha A + q)\Delta\kappa + \left[\kappa_L(1 - F(l)) \frac{\partial q_L}{\partial \eta} \Big|_{\eta=0} + F(l)\kappa_H \frac{\partial q_H}{\partial \eta} \Big|_{\eta=0} \right] \quad (A6)$$

From equations (A5) and (A6), we can now solve for our variables of interest:

$$\frac{\partial q_L}{\partial \eta} \Big|_{\eta=0} = \Delta\kappa F(l) * \frac{[\alpha A + \kappa_H(1 - l) * q^2]}{\left(\kappa_L + \Delta\kappa F(l) + \frac{\alpha A}{(1 - l)q^2} \right)} > 0$$

$$\frac{\partial q_H}{\partial \eta} \Big|_{\eta=0} = -\Delta\kappa(1 - F(l)) \frac{(\alpha A + \kappa_L(1 - l)q^2)}{\left(\kappa_L + \Delta\kappa F(l) + \frac{\alpha A}{(1 - l)q^2} \right)} < 0$$

Overall, we conclude that durable capital generates countercyclical safe asset prices, which exacerbate the previously documented liquidity shortages. Since financial entrepreneurs are partially insured against bad states occurring but future generations are not, the interests between the financial sector and the rest of society are even further misaligned. Management of risk-taking behavior in the financial system then becomes even more critical.

Reference Points, Leaders, and Organizational Culture

Benjamin Keefer: August 20, 2013

Abstract:

Different organizations have different cultures. In our paper, we show that in the presence of moral hazard, the optimal culture depends on how agents measure their performance against their reference points. If production metrics are used, we show that reference points should be fully exogenous to the agent's choices. We call the resulting type of culture competitive. If cost metrics are used, then the reference points should be fully endogenous to the agent's choices. We call the resulting type of culture individualistic. If the principal chooses both culture and metric, the optimal arrangement involves competitive culture and production metrics.

Introduction

When individuals provide their services to an organization, they may develop a feeling of belonging. Once they identify with the organization, individuals may choose actions they would otherwise avoid. Akerlof and Kranton (2005) provide a few examples. For instance, they discuss how West Point makes cadets more willing to take risks in battle, how soldiers' growing loyalty to one another makes them more willing to break the rules, and how workers at Lincoln Electric so strongly identified with the culture that they were willing to let subjective evaluations determine half of their compensation.

Of course, the values and culture of an organization are not randomly generated. Instead, Hermalin (2013) argues that leaders play a critical role¹, begetting the immediate question: What type of culture should a leader pursue?

In this paper, we use an agency setting to analyze the types of culture that best foster incentives. To do so, we break culture down into three components. First, the culture will identify a particular performance metric used by an agent to assess his performance. For example, agents might not care about the profit they generate but instead care about their production² or cost. Second, the culture will have a benchmark, denoting a level of performance expected of the agent. This cultural benchmark or target will serve as the agent's reference point³, as modeled by Koszegi and Rabin (2006, 2007). Finally, a particular culture will specify the degree to which an agent's actions will influence the benchmark. In the reference point literature, Koszegi and Rabin (2007) refer to this last property as acclimation.

In our model, we consider different forms of culture that may result in different degrees of acclimation. In the first type of culture we consider, the agent's reference point is determined the moment the agent chooses his effort. In this case, the reference point is said to acclimate to the agent's choice of effort, and since the agent is responsible for generating his own reference

¹ To justify the assumption that the leader can influence an organization's culture, we give three arguments. First, both Berger and Luckmann's (1967) as well as Akerlof and Kranton's (2005) works suggest that culture spreads through socialization. By manipulating variables accommodating socialization—promoting after work events, consolidating the workers in one central location, and designing collaborative projects—the principal could influence the strength of the culture. Second, Akerlof and Kranton (2005) document examples of companies spending resources in order to secure buy-in for the firm's overall culture, such as uniforms and specialized terminology for the firm. McDonald's is even known to offer training and networking opportunities through their Hamburger University. Finally, Koszegi and Rabin (2007) argue that the degree of acclimation, which forms a key element of culture in our model, increases with time elapsed. Consequently, the principal could simply make the cultural expectations more rigid and less acclimating by giving the agent little time to think things over.

² Our notion of production is not necessarily the same as output. Legal firms measure production by the billable hour. As a result, it's possible a production culture could be based on certain inputs.

³ The type of metric will have a key impact on the polarity of the reference point. Production metrics will generate positive reference points while cost metrics will generate negative ones.

point, we refer to this type of culture as individualistic. In the other two types of culture we consider, the agent compares his own performance to his expectations regarding the performance of others. If the comparison involves his contemporaneous peers, we refer to this type of culture as competitive. If the comparison involves previous cohorts, we refer to this type of culture as traditions-based. In both instances, reference points are determined outside of the agent's own choices and are said to be unacclimating.

We start our analysis with a standard model of moral hazard from Laffont and Martimort (2002) and add in reference-dependent preferences⁴. The agent (he) knows his own effort, while the principal (she) only observes the outcome. The principal selects the appropriate monetary transfers and the type of culture in order to best solicit effort, while the agent chooses effort to maximize his expected utility. With reference-dependent preferences, some component of the agent's utility now includes expectations of gain and loss resulting from any deviations from the reference point.

We consider production and cost metrics as they have differing effects on both the agent's experiences of gain or loss and the organization's incentives. Consider the moral hazard situation outlined above. When agents have only production metrics, an increase in effort makes the agent more likely to beat his production target and feel a gain, which is good for incentives. We call this effect the likelihood effect. Yet, depending on the degree of acclimation, the production target may also rise and now be harder to beat, making the agent feel worse off. We call this effect the reference point effect, which is harmful to incentives in this case. However, if the agent's targets are in terms of costs only, these two findings are reversed. With cost targets,

⁴ Throughout most of our paper, we consider loss-neutral agents in order to demonstrate that our findings are derived from the properties of reference points and not loss-aversion. Introducing low levels of loss-aversion will only strengthen several of our findings.

an increase in effort raises the agent's costs and makes the agent more likely to exceed the target⁵ and feel a loss⁶. Of course, this is partially offset by the fact that in the presence of acclimation, the cost target will also rise, making the target easier to beat and the agent feeling slightly better off. In the case of cost targets, the reference effect thus strengthens incentives.

If agents use both production and cost metrics (we refer to this type of metric as a profit metric, capturing the agent's overall quality of life), the likelihood effect and reference point effect have little impact on incentives because the production motive and cost motive will offset each other. Thus, these cultures will not differ much from the standard second-best incentives.

The above discussion suggests two findings that we formally prove in our paper. First, the likelihood effect always weakly dominates the reference point effect. As a result, we show that cultures that emphasize production have incentives that are at least as strong as those emphasizing cost. Second, more acclimating reference points have stronger reference point effects. Consequently, if a leader is stuck with a predominantly production culture, acclimation is bad, but if a leader inherits a predominantly cost culture, acclimation is good.

These mixed findings for acclimation stem from differences in how effort affects the reference point⁷ between each type of metric. Compared to the case of unacclimation, acclimating reference points influence the agent to distort his effort to get a lower reference point regardless of the chosen metric. Under cost metrics, the reference point is negative because it is

⁵ The agent could always meet or beat the cost target by putting in zero effort and generating zero cost. Zero effort is good for reference-based utility but will result in the agent getting low transfers. In our model, since agents care about both transfers and reference-based utility, zero effort will generally not be optimal.

⁶ With cost metrics, the agent feels a loss whenever his costs are above the target and a gain whenever costs are below the target.

⁷ The importance of effort's impact on the reference point (either positive or negative) in this paper stands in contrast to Koszegi and Rabin (2007). In their paper, they focused on the degree of acclimation, essentially the absolute value of the variable we consider.

a cost. Higher effort makes the reference point even more negative. In this case, the incentives of the agent and principal regarding the reference point are well-aligned and acclimating reference points should be used. However, when the culture specifies a production metric, the reference point becomes positive and effort now has a positive impact on the reference point. With acclimating reference points, the agent will cut back on production to secure a lower reference point, which is clearly bad for incentives. Therefore, the principal should favor unacclimating reference points.

To develop testable implications, we use the insights of Kahneman (2011) and Koszegi and Szeidl (2013) to argue that certain environments are more likely to favor production metrics while others are more likely to favor cost metrics. In the environments⁸ favoring production metrics, our model suggests that competitive or traditions-based cultures with low retention are more likely to emerge. In the environments⁹ favoring cost metrics, individualistic cultures with longer retention are more likely.

Our findings represent a contribution to the literature on reference points. Namely, of Koszegi and Rabin's (2006, 2007) two equilibrium concepts,—acclimating reference points¹⁰ and unacclimating reference points¹¹--we ask which one is preferred by the principal. Our findings show that the preferred form of reference points depend critically on whether reference points are based on expectations of production or costs. To the best of our knowledge, the optimal degree of acclimation has not been explored in the literature.

⁸ Such as car dealerships and technology startups.

⁹ Such as U.S. Federal Government agencies.

¹⁰ Which they call a *choice-acclimating personal equilibrium* (CPE).

¹¹ Referred to as an *unacclimating personal equilibrium* (UPE).

The literature largely focuses on either acclimating or unacclimating reference points. This choice is made at the outset and is appropriate if the timing is assumed to be exogenous. For instance, Koszegi and Rabin (2007) argue that reference points become more acclimating if agents have enough time to consider their actions. Acclimating reference points are used by Eisenhuth (2012) and Herweg, Mueller, and Weinschenk (2010). In other situations, agents are faced with unanticipated contingencies requiring immediate actions. In these situations, Koszegi and Rabin (2007) argue that unacclimating reference points are more relevant. Unacclimating reference points are considered by Carbajal and Ely (2012), Daido and Itoh (2005), Heidhues and Koszegi (2012), Herweg and Mierendorff (2011), and Macera (2009).

However, in a standard principal-agent problem, such as the one we consider¹², the principal may have significant control over the timing of production. When the timing is endogenous, the principal may want to speed up production to secure more unacclimating reference points. In contrast, if the cost of rapid production were too high, she might rather choose to delay production at the potential cost of more acclimating reference points.

In our final extension, we choose to model culture based on some combination of the present and past, which is consistent with the cultural literature in sociology¹³, macroeconomics¹⁴, and microeconomics¹⁵. Our contribution to these works is to model endogenous reference points, instead of assuming some exogenous ideal. Endogenous reference points allow us to characterize the optimal degree of acclimation as well as the optimal metric.

¹² Not all models in the literature focus on a principal agent problem. For example, Heidhues and Koszegi (2012) is based on industrial organization while Carbajal and Ely model screening contracts offered by monopolists.

¹³ Our approach owes heavily to the works of Wilkins and Ouchi (1983) as well as Berger and Luckmann (1967).

¹⁴ Guiso, Sapienza, and Zingales (2008) study culture through social capital, which by construct, is inherently backward-looking.

¹⁵ See, for example, Rob and Zemsky (2002) as well as Akerlof and Kranton (2005).

Our model of culture contributes to the literature on leadership by expanding the role for the principal (leader) by giving her influence over the organization's benchmark and the benchmark's degree of acclimation. Previous models have instead focused on the leader's role in managing and disseminating information (see the seminal paper of Hermalin 1998) and the optimal characteristics of the leader concerning empathy (Rotemberg and Saloner 1993, 2000), resolve (Bolton, Brunnermeier, and Veldkamp 2013), and the preference for conformity (Huck and Rey-Biel 2006). For a recent and exhaustive review of this literature, see Bolton, Brunnermeier, and Veldkamp (2013).

Finally, our model of culture is also related to models of social norms. The key advantage of using reference points over social norms is that deviations from reference points are easily interpreted in terms of gain and loss. As such, the impacts on utility is easy to understand. Theories of social norms, such as Huck, Kubler and Weibull (2012) as well as Fischer and Huddart (2008), have to make additional assumptions in order to interpret deviations from the norm as either increasing or decreasing utility. These additional assumptions limit the predictive power of social norms based models.

Benchmark Model

Our benchmark model is based on a standard moral hazard model (Laffont and Martimort 2002). In our model, the organization is represented by a principal (she), who has a project that only the agent (he) can perform. The value of the project depends on whether it is successful or not. A successful project generates surplus \bar{S} for the principal while an unsuccessful project only generates surplus $\underline{S} < \bar{S}$.

The outcome of the project is stochastically determined by the actions of the agent. The agent chooses an effort $e \in [0,1]$, which represents the probability of success. By choosing higher levels of effort, the agent increases the likelihood that a successful \bar{S} is realized, with the return to effort captured by $\Delta S = \bar{S} - \underline{S} < 1$. However, effort is costly for the agent, and the cost of effort is given by $\psi(e) = \frac{e^2}{2}$.

The principal's profit is captured by her expected surplus net of transfers. We assume that effort is the private information of the agent, so that the agent's wage can only depend on the project's success. Let \bar{w} capture the agent's wage when successful and \underline{w} the wage when unsuccessful. Δw will capture the strength of incentives. The principal's objective is to maximize:

$$E[\Pi] = \underline{S} + e\Delta S - (e\bar{w} + (1 - e)\underline{w})$$

The timing of the arrangement is given below:

1. The principal offers a contract (\bar{w}, \underline{w}) .
2. The agent accepts or rejects the contract.
3. The agent exerts effort e at cost $e^2/2$.
4. An increase in surplus is realized with probability e .
5. Transfers are paid contingent on the project's outcome.

Assuming risk-neutrality and normalizing the agent's outside option to zero, the principal faces the following constraints:

$$(IR) \quad e\bar{w} + (1 - e)\underline{w} - \frac{e^2}{2} \geq 0,$$

$$(IC) e = \arg \max_{e \in [0,1]} \tilde{e}\bar{w} + (1 - \tilde{e})\underline{w} - \frac{\tilde{e}^2}{2}.$$

With no other constraints, it is easy to verify that the principal is able to achieve the first-best effort level $e^* = \Delta S$.

From now on, we will assume that the principal faces a limited liability constraint, $\underline{w}, \bar{w} \geq 0$. With limited liability, the second-best contract requires that effort is distorted downward, $e^{LLC} = \frac{\Delta S}{2}$. The principal motivates the agent by giving him rent. Since such rent is costly for the principal, the costs of soliciting effort are now higher and the principal chooses to reduce effort below its first-best level.

Main Model

We now introduce two types of reference points into the benchmark model: acclimating and unacclimating reference points. One particular source of unacclimation that we consider is the possibility that these reference points may be external to the agent's own actions. Instead, agents may compare their performance to that of their contemporaneous¹⁶ peer group. We assume that the principal can influence the reference points and we characterize the optimal organizational arrangements.

We start with the Koszegi and Rabin (2006, 2007) framework in which reference points matter because deviations from reference points will trigger feelings of gain and loss. The

¹⁶ We allow the agent to compare his performance to prior generations in an extension.

organization's representative agent chooses effort to maximize expected utility, now including some referential utility component.

The principal has two new instruments. The first instrument is the performance dimension M used by agents to compare their performance. Agents may focus on production and the associate output-contingent payouts (recall that $\bar{w} = w(\bar{S})$ and $\underline{w} = w(\underline{S})$), which we capture by letting $M = w$. High production triggers the best performance realization $\bar{M} = \bar{w}$ while low production triggers the worst performance realization $\underline{M} = \underline{w}$. Alternatively, agents may focus on the cost of their effort, $M = -e^2/2$. In our model, when performance is specified in terms of costs, the agent is never exposed to risk and $\underline{M} = \bar{M} = -e^2/2$. If the agent uses both production and cost metrics, then the combined metric is given by $M = w - e^2/2$ with performance realizations $\bar{M} = \bar{w} - e^2/2$ and $\underline{M} = \underline{w} - e^2/2$. We refer to this combined metric as a profit metric.

As a second instrument, we assume the principal can influence the degree of acclimation of the agent's reference point through the chosen culture. If the reference point is fully acclimating, the agent i is free to generate his own reference point and $R_i = e_i \bar{M} + (1 - e_i) \underline{M}$. Yet, sometimes the reference point may be fully unacclimating. In this section, we consider the possibility that external reference points may generate unacclimation. Under the external reference points we consider, the representative agent compares his performance to the average expected performance $\hat{M} = \frac{\sum_i^N E[M_i]}{N}$ of all $N > 1$ agents within the organization. Under fully external reference points, $\frac{1}{N}$ becomes captures the degree of acclimation.

In a general culture, the reference point will be a combination of the two extremes and

$$R_i = \alpha(e_i\bar{M} + (1 - e_i)\underline{M}) + (1 - \alpha)\hat{M},$$

where $\alpha \in [0,1]$ captures the degree of acclimation of the reference point. We call this variable culture. When $\alpha = 1$, we refer to the culture as individualistic. When $\alpha = 0$, we refer to the culture as competitive.

With reference-dependent preferences, when the agent's performance exceeds the reference point, he feels a sense of gain of size $\eta(\bar{M} - R)$, where η is the coefficient for both gains and losses and can be thought of the strength of the reference point in our model. This gain is realized with probability e . With probability $(1 - e)$, the agent receives the bad performance realization and feel a loss of size $\eta(\underline{M} - R)$.

To get the agent to sign the contract, the principal needs to ensure the agent's expected utility, which now includes expectations of gains and losses, is non-negative:

$$(IR) U(\bar{w}, \underline{w}, e) = e\bar{w} + (1 - e)\underline{w} - \frac{e^2}{2} + \eta e(\bar{M} - R) + \eta(1 - e)(\underline{M} - R) \geq 0,$$

The agent's only goal is to maximize expected utility. His utility-maximizing level of effort is given by:

$$(IC) e = \Delta w + \eta \left(\frac{\partial [e\bar{M} + (1 - e)\underline{M}]}{\partial e} - \frac{\partial R}{\partial e} \right).$$

α and M determine how effort influences the reference point, here captured by $\partial R / \partial e$. How should the principal choose both α and M ?

We hypothetically ask: which reference point would the agent like? If we look at the (IR), it is clear that the agent prefers a low reference point. If he has a production metric, he

would desire his (positive) reference wage to be as low as possible. If instead he has a cost metric, he would desire his negative reference point (because the agent thinks of costs as bad) to be as negative as possible.

Of course, the agent does not have full control over the reference point. Either it is acclimating and depends on his chosen effort or it is unacclimating and exogenous to him. When the reference point is fully unacclimating, the agent has no control over the reference point and has no incentive to strategically distort his effort. Yet, when the reference point is at least partially acclimating, agents will have incentives to choose an effort that lowers their reference point. Under production metrics and partially acclimating reference points $\alpha > 0$, agents wishing a low reference wage should distort their effort below the second-best case. As a result, the reference point should be made as unacclimating as possible and $\alpha^* = 0$ is optimal. In contrast, under cost metrics and partially acclimating reference points, agents desiring a high reference cost of effort (generating a low and negative reference point) should distort their effort above the second-best case. To promote incentives, the principal should make $\alpha^* = 1$. This finding leads to an immediate proposition.

Proposition 1. Under cost metrics, $\alpha^* = 1$ provides the strongest incentives. Under production-based metrics, we have the opposite result because acclimation now dilutes incentives. As a consequence, $\alpha^* = 0$ is optimal.

Proof. Consider the case of a cost metric, $M = -e^2/2$ with a fully acclimating reference point, $R = -e^2/2$. Since effort has a negative impact on the reference point, then from the (IC), it is clear that increases in α strengthen incentives. Hence, $\alpha^* = 1$ is optimal.

Under production metrics, the equilibrium reference point R is based on expected wages, $e\bar{w} + (1 - e)\underline{w}$. Effort therefore has a positive impact on the reference point and increases in α result in weaker incentives from the (IC). The principal should then favor competitive cultures with $\alpha^* = 0$.

When the metric captures both production and costs, as in the case of $M = w - e^2/2$, the two effects above will offset each other. In our specification, the impact becomes zero and the degree of acclimation does not affect incentives. Consequently, the profit metric has the second-best incentives. ■

Our first proposition studies the optimal acclimation for a given metric but what metric should the principal choose? It is straightforward to show that under fully acclimating reference points and our maintained assumption of loss-neutrality, the choice of metric (production, cost, or profit) does not matter. Since only the difference between $E[M]$ and R enters the agent's utility, and effort affects both equally under fully acclimating reference point, the agent faces the standard second-best incentives.

Under fully unacclimating reference points, performance metrics do matter. At the moment the agent considers various levels of effort, R has already been determined. Variations in effort now trigger variations in $E[M]$ but not R . If effort positively impacts $E[M]$, increases in effort will make the agent will feel better and equilibrium effort will increase. If effort has a negative impact on $E[M]$, the agent's effort will decrease.

Proposition 2. Cost metrics yield weaker incentives than both the standard second-best incentives and the incentives under production metrics for $\alpha < 1$. When $\alpha = 1$, the incentives under all performance metrics are equal to the standard second-best.

Proof. Let us start with the last claim first. When $\alpha = 1$, it is easy to show that

$\frac{\partial[e\bar{M}+(1-e)M]}{\partial e} - \frac{\partial R}{\partial e} = 0$. From the (IC), the principal is then faced with her standard second-best incentives.

Now suppose that $\alpha < 1$. In this case, $\left| \frac{\partial[e\bar{M}+(1-e)M]}{\partial e} \right| > \left| \frac{\partial R}{\partial e} \right|$. As a result, when the agent considers various levels of effort, effort's impact on $E[M]$ will be stronger than effort's impact on the reference point. Expected performance considerations will thus dominate reference point considerations and he will adjust his effort to increase $E[M]$. Under production metrics, e influences $E[M]$ positively and the desire to beat the reference point strengthens incentives above the second-best level. Under cost metrics, effort has a negative influence on $E[M]$ and the agent will distort his effort down in order to increase $E[M]$. Cost metrics with acclimating reference points make the principal worse off by reducing incentives. Under profit metrics, effort has no effect on $E[M]$ and the degree of acclimation does not matter. ■

We can translate Proposition 2 to argue that when $\alpha = 1$, the choice of metric does not matter. However, when $\alpha < 1$, production metrics are optimal because it is better for agents to compete with higher production than to incentivize them to compete on lower effort.

Extensions

The driving force of our main model has been the degree of acclimation. We showed that lower degrees of acclimation are optimal under production metrics but not under cost metrics.

We wish to now demonstrate that our main findings are robust to considerations of low levels of loss-aversion as well as diminishing sensitivity. In our final extension, we consider

dynamic reference points and study the potential benefits and costs of retaining agents for multiple periods.

Extension 1: Loss-Aversion

We start off this extension by showing that the introduction of low levels of loss-aversion strengthens Proposition 1. Suppose that losses are stronger than gains. To capture this effect, we introduce the coefficient of loss-aversion $\lambda > 1$ from Koszegi and Rabin (2006). Rewriting the (IR) and (IC) from our main section, we get two equations:

$$(E1) \quad \bar{w}e - \frac{e^2}{2} + \eta e(\bar{M} - R) + \eta\lambda(1 - e)(\underline{M} - R) \geq 0,$$

$$(E2) \quad e = \bar{w} + \eta \left(\frac{\partial [e\bar{M} + \lambda(1 - e)\underline{M}]}{\partial e} - (\lambda(1 - e) + e) \frac{\partial R}{\partial e} + R(\lambda - 1) \right)$$

If λ is small enough so that equation (E1) does not bind¹⁷, the only impact comes from the incentive constraint (E2). We then obtain the following proposition:

Proposition 3. Increases in loss-aversion strengthen the impact of α on incentives. Acclimation now further strengthens incentives under cost metrics while further weakening incentives under production metrics.

Proof. When $\lambda = 1$, the coefficient on $\partial R/\partial e$ in equation (E2) is -1 . With loss-aversion, this coefficient becomes more negative and acclimation has a greater impact. Under

¹⁷ $\lambda \leq 1 + \frac{e^{SB} w - \frac{(e^{SB})^2}{2}}{\eta e^{SB}(1 - e^{SB})}$, where $e^{SB}(\alpha, M)$ is the second-best effort level assuming the limited-liability and (IC) constraints both bind, is sufficient.

cost-based metrics, the gains to acclimation are now larger. Under production metrics, the costs of acclimation are now more severe. ■

Proposition 3 strengthens Proposition 1 for low levels of loss-aversion¹⁸. In essence, introducing acclimation ratchets up the impact of reference points on incentives as loss-aversion compounds the feeling of loss when agents fall below their reference point.

While loss-aversion strengthens the impact of acclimation in Proposition 1, the impact of loss-aversion has mixed effects on Proposition 2. Since production is uncertain in our model while the costs are certain, our model is inherently biased toward cost metrics when agents are loss-averse and do not like uncertainty. When $\alpha = 1$, cost metrics can now be strictly better than production metrics, negating the strong form of Proposition 2. We are, however, able to save a weaker form¹⁹ of Proposition 2 if we consider only the best cultural arrangement under production metrics to the best cultural arrangement under cost metrics:

Proposition 4. As long as loss-aversion is not too severe²⁰, the optimal culture under production metrics has stronger incentives than the optimal culture under cost metrics.

Furthermore, the difference between the two arrangements' incentives is increasing in loss-aversion.

¹⁸ Under cost metrics, since there is no uncertainty, the (IR) is satisfied even for larger λ . For production metrics, however, arbitrarily large λ may harm participation because of the uncertainty in our model. If production were non-random, the value of λ would also not matter for production metrics.

¹⁹ The proposition also shows that the weaker form becomes even stronger with greater loss-aversion, provided that loss-aversion is not too strong.

²⁰ When λ becomes more severe, the (IR) is likely to bind for production cultures but not cost cultures. However, note that under the optimal cost culture, the principal chooses to implement effort $e = \Delta S/2$. One can show that as long as $\lambda \leq 1 + (1 + \eta)/2\eta$, then even if the (IR) binds under the optimal production culture, $e = \Delta S/2$ is cheaper to implement under production metrics with $\alpha = 0$ than under cost metrics with $\alpha = 1$.

Proof. From (E2), incentives are maximized whenever $\partial R/\partial e$ is minimized. When performance metrics capture production (costs), this occurs when $\alpha = 0$ ($\alpha = 1$). Starting first with production metrics and $\alpha = 0$, we can rewrite the incentive compatibility constraint as:

$$(E5) \quad e = \bar{w} + \eta(\bar{w} + e\bar{w}(\lambda - 1))$$

In (E5), agents are motivated to exceed their reference point, which is assumed to be independent of their action. When they work harder, they increase the likelihood of a gain and reduce likelihood of loss, without also giving themselves a tougher reference point. When $\lambda > 1$, avoiding losses brings greater utility, and less acclimating reference points strengthen incentives even further.

When cost metrics and $\alpha = 1$, the lack of uncertainty in costs causes R and M to cancel out. As a result, the incentive compatibility constraint simplifies to the textbook second-best incentives:

$$(E6) \quad e = \bar{w}.$$

To conclude our proof, we note that the difference between the right-hand sides of (E5) and (E6) is increasing in λ . ■

Extension 2: Diminishing Sensitivity

In this extension we consider the case of diminishing sensitivity. Diminishing sensitivity implies that an increase in gain or loss near the reference point has greater impact than increases that are further away. In other words, the first dollar of loss harms the agent's utility more than the hundredth dollar lost. Mathematically, when the agent experiences a gain or loss of magnitude, $(M - R)$, this gain or loss will enter his utility function with magnitude $\mu(M - R)$,

where $\mu(\cdot)$ captures our new referential-utility function. To capture diminishing sensitivity, Koszegi and Rabin (2006) assume $\mu(\cdot)$ is concave for positive arguments and convex for negative ones.

For this section, we show that when reference points exhibit diminishing sensitivity, moving between *choice-acclimating* and *unacclimating* reference points can have strong effects on incentives, especially when performance measures are deterministic as found under our model's cost metric case ($\underline{M} = \bar{M} = -\frac{e^2}{2}$).

With diminishing sensitivity and assuming cost metric $M = -e^2/2$, we can rewrite the principal's (IR) and (IC) constraints as follows:

$$(E7) \quad e\bar{w} + (1 - e)\underline{w} - \frac{e^2}{2} - \mu\left(\frac{e^2}{2} - R\right)$$

$$(E8) \quad e = \Delta w - \mu'(0)(e - \partial R/\partial e)$$

Under diminishing sensitivity, $\mu'(0)$ is the maximal value of $\mu'(\cdot)$, which means that decreasing α below 1 can have large effects²¹ on incentives as captured by equation (E8) and the following proposition:

Proposition 5. Diminishing sensitivity implies that the difference in incentives between *choice-acclimating* and *unacclimating* reference points may be arbitrarily large under deterministic metrics and representative agents.

²¹Consider the functional form $(\cdot) = (\cdot)^{\frac{1}{3}}$. This form satisfies the necessary properties of diminishing sensitivity and may create infinitely strong incentives as $\lim_{x \rightarrow 0} \mu'(x) \rightarrow \infty$.

Diminishing sensitivity imply that the first unit of gain and loss may be very powerful. An increase in costs from \$1 below average to \$1 above average may have a much bigger impact on utility than an increase in costs from \$100 above average to \$102 above average. With representative agents in our model, agents may have very strong incentives to avoid being seen as any bit below average. For stochastic performance measures, we are unable to characterize the impact of diminishing sensitivity on incentives without knowing the specific functional form assumed for $\mu(\cdot)$.

Extension 3: Dynamic Reference Points

We now build off of the arguments from the previously cited articles in sociology, organizational theory, macroeconomics, and microeconomic theory to model reference points as being influenced by past realizations.

If reference points also depend on the past, the principal may use the choice of retention policy as an instrument in a dynamic setting. If she chooses to retain the agent for more than one period of production, she can influence the total degree of dynamic acclimation in the reference points. In addition, when reference points depend fully on the past, a new cultural form emerges, which we call a traditions-based culture. We show that traditions-based cultures have even less acclimation than competitive cultures whenever the principal retains each agent for a single period.

We start our analysis with an overlapping generations model with an infinitely-lived principal. Each generation, we assume she has N identical projects and faces N identical agents, each of whom lives for two periods. All actors are assumed to have discount factor of one. In order to keep the model of this section directly comparable to our prior analysis, we assume she

can only offer period-by-period contracts each period, which are only contingent on the agent's own performance each period.

Her main choice involves whether to retain the agents or not. Given our assumption, the only impact of introducing dynamics will be on the reference point for agent i at time t , denoted $R_{i,t}$. To be consistent with the above literature, we assume that the relevant reference point depends on the agent's expectation of his own performance metric, $e_i\bar{M} + (1 - e_i)\underline{M}$, his expectation regarding the performance of her peers, \hat{M}_t , as well as prior realizations by some previous generation, which we now denote as \tilde{M}_{t-1} with asymptotic distribution

$N\left(\hat{M}_{t-1}, \frac{\bar{M}-\underline{M}}{N}e_{t-1}(1 - e_{t-1})\right)$. The reference point is now given by:

$$R_{i,t} = \alpha_0(e_i\bar{M} + (1 - e_i)\underline{M}) + \alpha_1\hat{M}_t + \alpha_2\tilde{M}_{t-1}$$

Assuming $\alpha_0 + \alpha_1 + \alpha_2 = 1$, our only change to the agent's reference point has been to include the past realization, \tilde{M}_{t-1} . α_2 captures how past practices influence present reference points. If $\alpha_2 = 1$, we refer to this type of culture as traditions-based. Aside from α_2 , the agent's utility each period, is just as before:

$$U_t(\bar{w}, \underline{w}, e) = e_t\bar{w}_t + (1 - e_t)\underline{w}_t - \frac{e_t^2}{2} + \eta e_t(\bar{M}_t - R_t) + \eta(1 - e_t)(\underline{M}_t - R_t)$$

Starting with the first generation, the principal has two broad choices. She can choose to contract only with young agents forever. After one period of contracts, she would then move on to the new generation. On the other hand, she could choose to contract with the young agents for two periods.

If she chooses to contract only for a single period, the problem is almost identical to the problem she faces in our earlier analysis, with two new differences. First, it is possible that following a high realization at time $t - 1$, $\tilde{M}_{t-1} = \bar{M}$, and the current reference point R_t may be large enough that the agent would not sign the contract²². Second, and more importantly, the degree of acclimation is now reduced whenever $\alpha_2 > 0$. Since the agent has no ability to influence his past reference point, the reference point's total acclimation is now $\left| \frac{\partial R_t}{\partial e_t} \right| = \left| \left(\alpha_0 + \frac{\alpha_1}{N} \right) \frac{\partial (e_t \bar{M}_t + (1 - e_t) \underline{M}_t)}{\partial e_t} \right|$.

The constraints facing the principal are otherwise identical to our main model:

$$(YIR) U_t \geq 0$$

$$(YIC) e_t = \arg \max_{e_t} U_t$$

Alternatively, the principal can choose to contract with every odd generation and retain them for two periods. Agents in the even period would never be contracted with. By choosing to retain the odd period agents, the principal faces four constraints for each agent:

$$(RIR_t) U_t \geq 0$$

$$(RIR_{t+1}) U_{t+1} \geq 0$$

$$(RIC_t) e_t = \Delta w_t + \eta \left(\frac{\partial [e_t \bar{M}_t + (1 - e_t) \underline{M}_t]}{\partial e_t} - \frac{\partial R_t}{\partial e_t} \right) - \eta \frac{\partial E_t [R_{t+1}]}{\partial e_t}$$

²² If we assume η is sufficiently small or N is sufficiently large so that \tilde{M}_t converges to its expected value, we can ignore this consideration. When these conditions are not satisfied, the value of α_2 for the principal is reduced, but this will be true for both single-period retention and multi-period retention. As a result, we do not believe that the optimal retention policy would be affected.

$$(RIC_{t+1}) e_{t+1} = \Delta w_{t+1} + \eta \left(\frac{\partial [e_{t+1} \bar{M}_{t+1} + (1 - e_{t+1}) \underline{M}_{t+1}]}{\partial e_{t+1}} - \frac{\partial R_{t+1}}{\partial e_{t+1}} \right)$$

From the above constraints, the main impact of retention is to introduce a new dynamic complication into the first period's incentive constraint. Since reference points are non-separable with respect to time, an increase in effort in the first period will now affect the agent's future expected reference point:

$$\frac{\partial E_t[R_{t+1}]}{\partial e_t} = \frac{\alpha_2}{N} * \frac{\partial (e_t \bar{M}_t + (1 - e_t) \underline{M}_t)}{\partial e_t}.$$

Aside from introducing this dynamic acclimation, the constraints are identical to contracting only with the young generation.

As before, it is easy to demonstrate that the introduction of dynamic acclimation is good whenever effort has a negative impact on the reference point. Whenever the impact is positive, incentives will be harmed by dynamic acclimation. This yields Proposition 6:

Proposition 6. Multi-period retention increases incentives under cost metrics and weakens incentives under production metrics.

The proof is exactly as for Proposition 1. Retention is simply a mechanism to introduce acclimating reference points. Acclimating reference points are good for the principal whenever the interests of the principal and agent are aligned—i.e., a higher effort triggers a lower reference point but not otherwise.

Proposition 1 implies that whenever M captures costs, $\alpha_0^* = 1$ and $\alpha_1^* = \alpha_2^* = 0$, while under production metrics, $\alpha_0^* = 0$. We have not yet shown what the optimal value of α_1 and α_2 under production metrics.

From Proposition 1, we know that under production metrics, less acclimation is better. Thus, the principal should generally only retain the agent for a single period in order to eliminate across-period acclimation. If she then relies maximally on tradition, $\alpha_2 = 1$, within-period acclimation is now zero and the total lifetime acclimation is likewise zero. If she chooses to introduce a competitive culture, $\alpha_1 = 1$, within period acclimation becomes positive, $\left| \frac{\partial R_t}{\partial e_t} \right| = \left| \left(\frac{1}{N} \right) \frac{\partial(e_t \bar{M}_t + (1-e_t) \underline{M}_t)}{\partial e_t} \right| > 0$. In order to eliminate acclimation, the principal should favor traditions-based cultures over competitive cultures:

Proposition 7. $\alpha_2^* = 1$ provides the strongest possible incentives in combination with production metrics and single-period retention.

Proof. From Proposition 2, we know that production metrics yield stronger incentives than cost metrics. Likewise, from Proposition 1, we know that the optimal culture under production metrics will minimize lifetime acclimation, which from the work above, is achieved whenever $\alpha_2^* = 1$ and when agents are retained for a single period. ■

Proposition 7 states that if η is sufficiently small or N is sufficiently large, the optimal production culture relies on both tradition and single-period retention as acclimation is minimized. However, by the same reasoning, traditions-based cultures and single-period retention are the worst cultural arrangement when agents compare performance based on costs.

Overall, this extension demonstrates that retention policies and tradition provide the principal further mechanisms to affect acclimation, and hence, incentives.

Testable Implications

We identify two testable implications of our model. First, as we have shown in an extension, the strongest organizational forms involve competitive and traditions-based cultures, single-period retention, and production metrics. As these types of cultures may require significant investments by the principal²³, we would expect them to emerge only when there is a large conflict of interest between the two parties that monetary compensation cannot resolve, such as when the individual's life is at risk when performing the contracted service. Our model would predict that branches of the military as well as police and fire departments would be more likely to undertake these cultural investments.

A second prediction implied by our model is that competitive cultures are more likely to emerge in organizations in which the environment favors production metrics over cost metrics. According to Kahneman (2011) and Koszegi and Szeidl (2013), such environments are more likely when the production is either more visible than the costs or the payouts have greater variation—either within the organization or across firms. As a result, organizations in environments favoring production²⁴ should be more likely to have stronger competitive or traditions-based culture and less retention. In contrast, when cost differences are more visible than production across organizations in the same industry, such as the case of government agencies, we would expect them to have the most individualistic cultures and the longest retention.

Conclusion

²³ We view the default reference point as being generated by the individual as in Koszegi and Rabin (2006, 2007). However, we follow the arguments of Berger and Luckmann (1967) as well as Wilkins and Ouchi (1983) that reference points may depend on the past and the practices of others in organizations with a high degree of socialization. The obvious cost to allowing socialization is that it may slow down production. This cost would likely only make sense in the presence of significant agency problems.

²⁴ Technology startups in Silicon Valley generally have these characteristics.

In the literature on reference points, modelers generally choose to analyze a phenomenon using either choice-acclimating personal equilibrium (CPE) or unacclimating personal equilibrium (UPE). Authors can justify their assumption by assuming a particular exogenous timing. If there is a significant delay between intention and action, Koszegi and Rabin (2007) argue that the reference point will likely be more acclimating, and CPE would be more appropriate. If the agent faced a choice that was unanticipated, the reference point will not have time to adjust, which is consistent with unacclimating reference points in an unacclimating personal equilibrium (UPE).

In situations with strategic interaction, an assumption of exogenous timing may be problematic if one party has significant influence over the timing of production. In a principal-agent framework, the principal may ask the agent to produce immediately if unacclimating reference points are more favorable or to delay production if acclimating reference points are more favorable. Moreover, in a dynamic setting, her choice to retain an agent for multiple periods may affect the total degree of dynamic acclimation. According to sociologists Berger and Luckmann (1967), just allowing agents to socialize will create reference points with greater dependence on tradition and past practices. Similar assumptions are found in the economics literature on culture and social norms.

Taken together, these arguments imply that the principal should use her control over the timing of production to secure favorable equilibrium concepts. If agents make comparisons based on costs, CPE are favored, while if agents make comparisons based on production, UPE are favored.

Our approach has two primary limitations. First, if the timing is outside of the principal's control and no other instruments exist to influence the reference point, either CPE or UPE may be possible. Second, the majority of our paper focused on loss-neutral agents. This had the advantage of demonstrating that our main results were independent of loss-aversion. However, when loss-aversion is introduced, multiple UPE may be possible. Choosing among the UPE becomes difficult. Koszegi and Rabin (2006) propose the refinement of *preferred personal equilibrium* (PPE), in which the agent chooses the reference point that maximizes utility, but this refinement assumes that agents have a large degree of control over their own reference points.

An alternative refinement from the literature on social norms and culture is that the actions of others from the past and present create expectations that agents adhere to. Under this alternative, reference points are formed through interaction and through shared histories. Past observations are a second possible refinement to UPE and provide a tractable way to generate testable implications regarding culture and social norms. This alternative refinement represents our final contribution.

References

- Akerlof, George A., and Rachel E. Kranton, "Identity and the Economics of Organizations," *Journal of Economic Perspectives*, Winter 2005, 19 (1), 9—32.
- Berger, Peter and Thomas Luckmann, *The Social Construction of Reality*, New York: Penguin Books, 1967.
- Bolton, Patrick, Markus K. Brunnermeier, and Laura Veldkamp, "Leadership, Coordination, and Corporate Culture," *Review of Economic Studies*, April 2013, 80 (2), 512--537.
- Carbajal, Juan Carlos and Jeffrey C. Ely, "Optimal Contracts for Loss-Averse Consumers,"

- 2012, <http://www.juancarloscarbajal.net/uploads/1/2/1/3/12130149/contractslac.pdf>
- Daido, Kohei, and Hideshi Itoh, “The Pygmalion Effect: An Agency Model with Reference Dependent Preferences,” 2005,
http://papers.ssrn.com/soL3/papers.cfm?abstract_id=676281.
- Eisenhuth, Roland, “Reference Dependent Mechanism Design,” 2012,
<http://gradstudents.wcas.northwestern.edu/~rei724/paper.pdf>.
- Fischer, Paul and Steven Huddart, “Optimal Contracting with Endogenous Social Norms,”
American Economic Review, September 2008, 98 (4), 1459—1475.
- Guiso, Luigi, Paolo Sapienza, and Luigi Zingales, “Alfred Marshall Lecture Social Capital as Good Culture,” *Journal of the European Economic Association*, Spring 2008, 6 (2-3), 295—320.
- Heidhues, Paul and Botond Koszegi, “Regular Prices and Sales,” *Theoretical Economics*, forthcoming.
- Hermalin, Benjamin, “Leadership and Corporate Culture,” *Handbook of Organizational Economics*, 432—478, 2013.
- Hermalin, Benjamin, “Toward an Economic Theory of Leadership: Leading by Example,” *The American Economic Review*, December 1998, 88 (5), 1188—1206.
- Herweg, Fabian, Daniel Mueller, and Phillipp Weinschenk, “Binary Payment Schemes: Moral Hazard and Loss Aversion,” *American Economic Review*, December 2010, 100 (5), 2451—2477.
- Herweg, Fabian and Konrad Mierendorff, “Uncertain Demand, Consumer Loss Aversion, and Flat-Rate Tariffs,” *Journal of the European Economic Association*, forthcoming.
- Huck, Steffen, Dorothea Kuebler, and Jorgen Weibull, “Social Norms and Economic Incentives

- in Firms,” *Journal of Economic Behavior and Organization*, July 2012, 83 (2), 173—185.
- Huck, Steffen and Pedro Rey-Biel, “Endogenous Leadership in Teams,” *Journal of Institutional and Theoretical Economics*, June 2006, 162 (2), 253—261.
- Kahneman, Daniel, *Thinking, Fast and Slow*, New York: Farrar, Straus and Giroux, 2011.
- Koszegi, Botond and Adam Szeidl, “A Model of Focusing in Economic Choice,” *The Quarterly Journal of Economics*, February 2013, 128 (1), 53—104.
- Koszegi, Botond and Matthew Rabin, “A Model of Reference-Dependent Preferences,” *The Quarterly Journal of Economics*, November 2006, 121 (4), 1133—1165.
- Koszegi, Botond and Matthew Rabin, “Reference-Dependent Risk Attitudes,” *The American Economic Review*, September 2007, 97 (4), 1047—1073.
- Laffont, Jean-Jacques and David Martimort, *The Theory of Incentives*, Princeton: Princeton University Press, 2002.
- Masera, Rosario, “Intertemporal Incentives Under Loss Aversion,” 2012, Working Paper.
- Rob, Rafael, and Peter Zemsky, “Social Capital, Corporate Culture, and Incentive Intensity,” *RAND Journal of Economics*, Summer 2002, 33 (2), 243—257.
- Rotemberg, Julio J. and Garth Saloner, “Leadership Style and Incentives,” *Management Science*, November 1993, 39 (11), 1299—1318.
- Rotemberg, Julio J. and Garth Saloner, “Visionaries, Managers, and Strategic Direction,” *RAND Journal of Economics*, Winter 2000, 31 (4), 693—716.
- Wilkins, Alan L. and William G. Ouchi, “Efficient Cultures: Exploring the Relationship Between Culture and Organizational Performance,” *Administrative Science Quarterly*, September 1983, 28 (3), 468—481.

USING THE PRECAUTIONARY PRINCIPLE TO EXTRACT RENT

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1. INTRODUCTION

In this paper, we study how policymakers should manage the risks of new innovations. One approach, which is becoming increasingly prevalent, is to rely on the Precautionary Principle¹. Although the Precautionary Principle has many formulations, in this paper we interpret the Precautionary Principle to urge policymakers to assume a product entails some harm in the presence of uncertainty.

Despite its emerging prominence, the Precautionary Principle remains controversial. On a theoretical level, some authors² argue that the Precautionary Principle is only employed because of behavioral biases. They further argue that since these behavioral biases are not rational, neither is adhering to the Precautionary Principle. However, this view is not universally held. For example, Dana (2003) argues that the Precautionary Principle may not aggravate but instead correct for behavioral biases. On an empirical level, there is also controversy regarding which risks justify a precautionary approach. Vogel (2003) notes that American regulation is more precautionary toward possible carcinogens and individual health risks, such as diesel emissions, second

¹Löfstedt (2004) reviews the history of the Precautionary Principle in Europe.

²See Cross (1996) and Sunstein (2003).

hand smoke, food additives, and British beef, while European regulation is more precautionary toward environmental and agricultural risks, such as biotechnology (e.g., GMO), growth hormones for animals, and new chemicals.

In this paper, we use an agency setting to study how the Precautionary Principle may be used to encourage potential entrepreneurs to mitigate the potential harm inherent in new innovations. Our main finding is that even in the absence of behavioral biases, a precautionary approach may be beneficial. We show that one significant benefit of a precautionary approach is its ability to extract rent. Our findings suggest that policymakers could enhance efficiency by applying greater precaution in highly concentrated industries, such as GMO and banking.

We start our analysis with a standard model of moral hazard from Laffont and Martimort (2002). The risk-neutral agent (he) knows his own level of harm mitigation (i.e., effort), while the principal's (she) observation depends on the state of nature. With some exogenous probability, nature is fully revealing, and the outcome (whether or not the innovation entails some harm) is observed by all. However, with positive probability, the outcome is not observed until after the contract is executed, and neither the principal nor the agent knows whether the innovation is harmful. In the static setting we consider, we assume that the principal must either approve (pay the high transfer) or reject (pay the low transfer) the innovation, regardless of the state of nature.

In our model, we show that one significant advantage of the Precautionary Principle is its ability to extract rent. In order to focus on rent extraction, we assume all potential harm is limited. In our first proposition, we show that in this setting, any approach can achieve the first-best level of harm mitigation when the transfers are appropriately designed. As a result, a precautionary approach is not necessary.

However, in the presence of rent (we consider the case of limited liability), this proposition no longer holds. When the limited liability constraint is binding, the principal's objective is to provide the strongest incentives at minimal cost. She can maximize incentives by only compensating the agent after observing the signal most informative of effort. Since the non-revealing state of nature is by assumption not informative, its state-contingent compensation should be minimized. Our second proposition captures this finding, and states that a precautionary approach can achieve any desired level of harm mitigation at lowest cost. For our third proposition, we find that as the cost of mitigating harm declines, the principal will incentivize a level of harm mitigation closer to the first-best level. For our fourth proposition, we show that the total value of a precautionary approach is convex in precaution. Since greater precaution lowers the cost of incentives, incentives should become used more strongly, which further increases the value of precaution. This convexity suggests that corner solutions are likely if there is a fixed cost to adopting precaution.

2. BENCHMARK MODEL

Our benchmark model is based on a standard moral hazard model from Laffont and Martimort (2002). In our model, an agent (he) has a new innovation that has value to society, represented by a principal (she). The value of the innovation depends on the agent's ability to mitigate its potential harm. If the agent successfully mitigates the potential harm, the innovation generates surplus S for the principal. If the agent is unsuccessful at mitigating the potential harm $h \in (0, 1)$, the innovation generates surplus $S - h > 0$.

The outcome of the innovation is stochastically determined by the actions of the agent. In order to mitigate harm, the agent applies a level of effort $e \in [0, 1]$, which also represents the probability that the agent successfully mitigates the potential harm. By choosing higher levels of effort, the agent increases the likelihood that the innovation generates surplus S , with the return to effort captured by h . However, effort is costly for the agent, and the cost of effort is given by $\psi(e) = \frac{e^2}{2}$.

The principal's profit is captured by expected surplus net of transfers. We assume that effort is private information of the agent, so that the agent's transfer can only depend on the outcomes observed by the principal. If the principal finds that the innovation is safe, we say that she approves the innovation and pay transfer \bar{t} . If the principal finds that the innovation provides harm, we say that she rejects the innovation and pays transfer \underline{t} . $\Delta t = \bar{t} - \underline{t}$ will capture the strength of

incentives. The principal's objective is to maximize:

$$E[\Pi] = S - h(1 - e) - (e\bar{t} + (1 - e)\underline{t})$$

The timing of the arrangement is given below:

- (1) The principal offers a contract (\bar{t}, \underline{t}) .
- (2) The agent accepts or rejects the contract.
- (3) The agent exerts some effort toward mitigating harm, e , at cost $\frac{e^2}{2}$.
- (4) Harm is mitigated with probability e .
- (5) Transfers are paid contingent on the project's outcome.

Assuming risk-neutrality and normalizing the agent's outside option to zero, the principal faces the following constraints:

$$(IR) \quad e\bar{t} + (1 - e)\underline{t} - \frac{e^2}{2} \geq 0,$$

$$(IC) \quad e = \arg \max_{\tilde{e} \in [0,1]} \tilde{e}\bar{t} + (1 - \tilde{e})\underline{t} - \frac{\tilde{e}^2}{2}.$$

With no other constraints, it is easy to verify that the principal is able to achieve the first-best level of effort, $e^* = h$.

This benchmark model will be used to evaluate our first proposition. However, for the later propositions, we will assume that the principal faces a limited liability constraint, $\bar{t}, \underline{t} \geq 0$. With limited liability, the second-best contract requires that effort is distorted downward, $e^{LLC} = \frac{h}{2}$. The principal must motivate the agent to mitigate harm by providing rent. Since rent is costly for the principal, the cost of

mitigating harm is now higher and the principal chooses to accept a greater likelihood of harm.

3. MAIN MODEL

We now wish to study the role of the Precautionary Principle at mitigating harm. Specifically, we wish to analyze the impact on incentives when the principal assumes the innovation is harmful in the presence of uncertainty. In order to introduce uncertainty, we will assume that there are two states of nature. With probability $\sigma \in [0, 1]$ we assume that nature is revealing and the quality of the innovation—as either safe or harmful—is observed by all. However, with probability $[1 - \sigma]$ we assume that nothing is observed by either party. Let t_\emptyset denote the transfer when nothing is observed.

In order to study the Precautionary Principle, we assume that the principal is limited to either approving or rejecting the innovation³. No other choice is available, even when nothing is observed. When nothing is observed, the principal will have three choices. First, she may assume that the innovation is harmful for sure, reject it, and pay transfer $t_\emptyset = \underline{t}$. This assumption is analogous to adhering to the Precautionary Principle. The principal may also assume that the product is safe for sure, approve it, and pay transfer $t_\emptyset = \bar{t}$. This assumption is analogous to a Presumption of Innocence. We also allow the principal to

³This assumption may not always be valid. For example, in the case of pharmaceutical innovations, policymakers have the ability to postpone approval until more evidence is obtained following the adoption in other countries. Yet, for many innovations, the downsides may not manifest for years. For example, the downside risks for many biotechnological or financial innovations may only manifest following rare and extreme environmental shocks. In these situations, multi-decade lags may be needed to guarantee that the innovation is safe.

reject the innovation with probability $\alpha \in [0, 1]$. α represent the level of precaution chosen by the principal. If $\alpha = \frac{1}{2}$, we believe this choice is analogous to simply requiring a Preponderance of Evidence.

Rewriting the objective function and constraints in terms of α , we find that the principal's problem is to maximize:

$$E[\Pi] = S - h(1 - e) - \sigma(e\bar{t} + (1 - e)\underline{t}) - (1 - \sigma)(\alpha\underline{t} + (1 - \alpha)\bar{t}),$$

subject to the constraints:

$$(IR) \sigma[e\bar{t} + (1 - e)\underline{t}] + (1 - \sigma)(\alpha\underline{t} + (1 - \alpha)\bar{t}) - \frac{e^2}{2} \geq 0,$$

$$(IC) e = \arg \max_{\tilde{e} \in [0, 1]} \sigma[\tilde{e}\bar{t} + (1 - \tilde{e})\underline{t}] + (1 - \sigma)(\alpha\underline{t} + (1 - \alpha)\bar{t}) - \frac{\tilde{e}^2}{2}.$$

With no other constraints, it is easy to verify that the principal is able to select transfers $\{\underline{t}, \bar{t}\}$ that achieve the first-best level of effort $e^* = h$ for any choice of α . This leads us to our first proposition.

Proposition 1. *In the absence of rent, any level of precaution α is compatible with the first-best outcome.*

Proof. Note that $\bar{t} = h^2/2 + h(1 - h) + \alpha h(1/\sigma - 1)$ and $\underline{t} = -h^2/2 - h(1 - \alpha)(1/\sigma - 1)$ exactly satisfy both constraints at the first-best level of effort, $e^* = h$. □

Proposition 1 states that in the absence of rent, the Precautionary Principle will neither harm nor benefit the principal. This is not surprising, since in the introduction of this paper, we stated that the main benefit in the precautionary is its ability to extract rent. In the absence of rent, precautionary approaches provide little value.

In order to characterize exactly how the Precautionary Principle will benefit the principal, we will assume that the agent is protected by limited liability for the rest of the paper. As a result, the principal has the additional constraint:

$$(LLC) \bar{t}, \underline{t} \geq 0.$$

When the agent is protected by limited liability, how should the principal choose α ? We show that the principal will optimally set $\alpha^* = 1$. To show this, suppose that the principal wishes to implement a level of effort denoted by \hat{e} . Note that when the limited liability constraint binds, the (IR) constraint will become slack. If we then rewrite the (IC) , we obtain: $(IC) \hat{e} = \sigma(\bar{t} - \underline{t})$. Since neither the limited liability constraint nor the (IC) constraint contains α , α will not affect \hat{e} . From the objective function, we note higher levels of α lower the expected transfer to the agent. This leads us to our second proposition.

Proposition 2. *In the presence of rent, the principal should maximally adhere to the Precautionary Principle ($\alpha^* = 1$) in order to minimize the cost of implementing any given level of effort \hat{e} .*

Proof. Suppose transfers are chosen to implement \hat{e} and to satisfy all constraints. In order to minimize rent, the principal will choose $\underline{t} = 0$.

Consequently, \bar{t} will be chosen to satisfy the (IC) , $\bar{t} = \hat{e}/\sigma$. The expected transfer to the agent is then given by: $\sigma\hat{e}\bar{t} + (1 - \sigma)(1 - \alpha)\bar{t}$. In order to minimize the expected transfer, the principal should choose $\alpha^* = 1$. \square

Proposition 2 highlights the main benefit of adopting precaution: adopting a precautionary approach reduces rent. The intuition for this result comes from Holmström's (1979) Sufficient Statistic Theorem. Since the case of an uncertain outcome is not informative⁴, uncertain outcomes should not be compensated. When agents are risk-neutral, these transfers should be minimized in order to reduce the cost of implementing effort \hat{e} .

As more precautionary approaches reduce the cost of incentivizing any given level of harm mitigation, we would expect that more precautionary approaches encourage greater levels of harm mitigation. This logic leads to our third proposition:

Proposition 3. *In the presence of rent, more precautionary approaches induces levels of harm mitigation closer to the first-best level.*

Proof. If we substitute in the binding constraints into the objective function, we find that the optimal effort depends on the level of precaution chosen:

$$e(\alpha) = \frac{h}{2} - \frac{(1 - \sigma)(1 - \alpha)}{2\sigma} < e^*$$

⁴Given the constraints studied in this paper, this result would still hold even if the uncertain state were slightly informative, as long as the state of uncertainty was less informative than a certain success.

From the expression above, the second-best effort implemented by the principal is increasing in α . As α rises, the distortion in effort caused by the limited liability constraint will shrink. \square

Propositions 2 and 3 suggest that higher levels of precaution benefit the principal. From Proposition 2, one benefit of greater precaution is that it lowers the virtual cost of incentivizing a given level of effort. From Proposition 3, a second benefit is that as the cost falls, the principal will incentivize higher levels of harm mitigation in order to reduce distortions in effort.

For our fourth proposition, we wish to show that the benefits of precaution are increasing α . If there is a fixed cost to precaution, this convexity implies that corner solutions will occur:

Proposition 4. *The marginal value of precaution is increasing in α .*

Proof. We can write the indirect expected profit function as $E[\hat{\Pi}] = S - h + e(\alpha) * h - \frac{(1-\alpha)(1-\sigma)e(\alpha)}{\sigma} - e(\alpha)^2$, where $e(\alpha)$ is the solution to our constrained optimization problem. Using the Envelope Theorem, the marginal value of precaution is given by:

$$\frac{dE[\hat{\Pi}]}{d\alpha} = \frac{1-\sigma}{\sigma}e.$$

Since e is decreasing in α , then so too is $\frac{dE[\hat{\Pi}]}{d\alpha}$. \square

The reason for this convexity is due to the premium $\Delta t > 0$ that the principal must offer to solicit rent. With probability $(1-\sigma)(1-\alpha)$, the premium is given to the agent, even though the signal is non-informative. As α increases, the premium is paid out less frequently,

which reduces the cost of providing incentives. As α increases, the principal will respond by making incentives stronger, which further increases the value of precaution, α .

4. DISCUSSION OF FINDINGS

Many legal authors debate whether the Precautionary Principle is useful for informing regulation concerning new innovations. In this paper, we argue that one primary advantage of a precautionary approach is its ability to extract rent. Using a principal-agent model, we show that when agents are protected by limited liability, more precautionary approaches are better at extracting rent. We also show that greater rent extraction is compatible with greater level of harm mitigation, which is beneficial to society.

One implication of our analysis concerns the optimal design of new product regulation. Our results suggest that regulation is improved when it considers the industrial organization within a given sector. Highly concentrated sectors with large rents should be handled with greater precaution, especially for incumbent firms. With regard to new innovation from potential entrants, we predict a precautionary approach would have less value.

One of the shortcomings of our analysis is that it does not explicitly model how entrepreneurs' choose their research and development efforts. In order to focus on the Precautionary Principle's ability to extract rent, we have assumed that all potential entrepreneurs develop their innovation at zero cost. The representative entrepreneur's only choice concerns how much effort to devote to mitigating downside risks.

However, in many settings this assumption is not realistic, as firms may spend considerable resources developing new ideas. In real-world settings, policymakers should consider the potential negative effects that precautionary approaches may have on research and development. These negative effects may temper our findings regarding the net benefits of precaution. Nonetheless, we believe that the Precautionary Principle may have strong appeal whenever firms have large rent, and especially in the case of a Natural Monopoly. We further believe that this finding deserves greater consideration from policymakers.

5. REFERENCES

- Cross, Frank, “Paradoxical Perils of the Precautionary Principle,” *Washington and Lee Law Review*, June 1996, 53(3), 851–925.
- Dana, David, “A Behavioral Economic Defense of the Precautionary Principle,” *Northwestern University Law Review*, Spring 2003, 97(3), 1315–1346.
- Hölmstrom, Bengt, “Moral Hazard and Observability,” *Bell Journal of Economics*, Spring 1979, 10(1), 74–91.
- Laffont, Jean-Jacques and David Martimort, *The Theory of Incentives*, Princeton: Princeton University Press, 2002.
- Löfstedt, Ragnar, “The Swing of the Regulatory Pendulum in Europe: From Precautionary Principle to (Regulatory) Impact Analysis,” *Journal of Risk and Uncertainty*, May 2004, 28(3), 237–260.
- Sunstein, Cass, “Beyond the Precautionary Principle,” *University of Pennsylvania Law Review*, January 2003, 151(3), 1003–1058.

Vogel, David, "The Hare and the Tortoise Revisited: The New Politics of Consumer and Environmental Regulation in Europe," *British Journal of Political Science*, October 2003, 33(4), 557–580.