Stress and Coping - An Economic Approach

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We present a psychological model of stress. Appraisal translates stressors into subjective stress. Stress reduces instantaneous utility of an individual directly and via cognitive load. Coping can be under the control of the individual or more automatic. We predict the occurrence of uncontrolled coping – emotional outbursts – as a function of an individual's theory-consistent personality and environment. We explain when stressors reduce income. We also explain under which conditions rising income does not go hand in hand with rising stress. First steps towards a theory of therapy show how stressed individuals can improve their well-being beyond standard coping measures.

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1 Introduction

[Motivation] Stress is a feeling everybody knows. There are those days when there are too many demands that fall upon one and it is just impossible to respond to them all. Ever since the (originally physical) concept emerged in medical science following the seminal work by Selye (Selye, 1936, Szabo et al., 2012), it has received a lot of attention. Whether one reads handbooks on stress written more than 30 years ago, or looks at current discussions in science and the media, it is an amazingly and perhaps disturbingly popular topic.[2]

The importance of stress stems from (i) its prevalence and from the many channels through which it affects (ii) an individual's subjective well-being and (iii) the individual's social environment. Individual effects include reduced productivity on the job, negative feelings and detrimental health implications. Stressed individuals are less pleasant to interact with, both in private life and professionally. They provide fewer social services, might damage the reputation

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[2]Selye (1982, p. 7) wrote: "Nowadays, everyone seems to be talking about stress". The psychologists Lazarus and Folkman (1984, p. 1) wrote: "It is virtually impossible today to read extensively in any of the biological or social sciences without running into the term stress." A German governmental agency issued a stress report (Lohmann-Haislah, 2012) and a major health insurance company reports that sickness leave due to psychological illness increased by almost 80% over the last 10 years (AOK, 2017). Helliwell, Layard and Sachs (2013) edited a world happiness report whose ch. 4 is full of references regarding the concept of stress. The American Psychological Association (2015) issued a report on 'Stress in America' and the NPR (National Public Radio) jointly with Harvard's Health Institute undertook a large-scale telephone survey on 'The Burden of Stress in America' (NPR, 2014).

of firms if in contact with customers or simply provide less input into value-added of a firm (see section 2 for more details).

[The open issue] Despite the huge relevance of stress, a formal analysis of stress does not seem to exist. This is problematic for stress analysis *per se*. This is also problematic for economics as many economic events are or generate stressors. Biased technological change, distributional effects caused by globalization, unemployment or the great recession are undeniably related to stress experienced by individuals. What is missing in economics is a concept of stress that can be integrated into standard economic analyses.[3] If stress exists as a determinant of (experienced) utility, in addition to standard economic arguments such as consumption or leisure, the policy implications of these many economic events would go into different directions. Even if stress did not have a direct utility effect, there would still be a lot of convincing evidence that stress affects other variables of immediate economic interest. Stress reduces income, well-being and causes verbal or even physical violence.

[The objectives] This paper provides a formal psychologically-grounded framework within which to think about stress and its implications for economics and beyond. This approach follows "a desire to expose how <existing views> are wrong" (all quotes in this paragraph are from Rabin, 2013) or, to put it a bit more positively, to work out what existing views actually mean. Theories developed in most social sciences are what could be called "imprecise theories". Models of stress and coping developed in other disciplines lack mathematical rigor and precision. This makes it "just harder to identify flaws". Translating standard psychological views into an otherwise mainstream economic model allows us to "see their limits that can guide us in further improvements".

[The setup] Stress is represented as a subjective feeling captured by a stochastic state variable. Stress increases in the presence of stressful events (stressors), and decreases via coping measures and in the presence of pleasant events. The process starting with the stressor and ending with stress is called an appraisal process in psychology.

Starting with stressors and following the psychology tradition, we distinguish between stressors that occur relatively often and others that occur more rarely. Historically, rare stressors were seen as the classic sources of stress. The Social Readjustment Rating Scale (Holmes and Rahe, 1967) includes events (in descending order of stressfulness) such as 'death of spouse', 'divorce', 'jail term', 'fired at work' and so on, concluding with 'vacation, 'Christmas' and 'minor violations of law'. It was later discovered that stress can also result from "daily hassles" (Kanner et al., 1981) such as 'losing things', 'don't like fellow workers' and 'too many obligations'. Our model includes both types of stressors. Stressors are exogenous in our setup.

When modelling the effect of a stressor on the stress level of an individual, we allow for intermediate cognitive processes of the individual (Lazarus, 1993). This appraisal process stands for the evaluation of stressors "with respect to their implications for well-being" for the person facing the stressors (e.g. Lazarus, 1999, p. 75). These appraisal processes are captured by personality parameters in our setup.[4]

The channel through which stress is detrimental to an individual's utility is motivated by the literature on cognitive load.[5] This literature builds on the view that cognitive processes can best

[3] There are some empirical analyses using measures of stress to understand the impact on birth weight (Camacho, 2008), to understand the link between parental stress and child outcomes (Baker et al. 2008), the effect of housing vouchers on mental health (Kling et al. 2007) and the gender differences in abilities to cope with stress (Kling et al. 2005). The theoretical analysis by Caplin and Leahy (2001) use stressful events as an example of how anxiety can be built up (e.g. a medical procedure, see Caplin and Leahy, 2004). Yaniv (1995) presents a static model of worker health where the firm takes the effects of a stressful environment into account. None of these analyses studies the evolution of stress over time or the role of appraisal and coping.

[4] The personality measures to be used here are "deeper" measures of personality than measures such as the "Big 5". For the background in psychology, see John et al. (2008). Applications in economics are discussed, for example, by Borghans et al. (2009).

[5] This literature consists of various relatively independent substrands. An introduction from the perspective

be understood by using the concept of a working memory.[6] The working memory has a certain capacity for processing information. Stress, anxiety or other strong feelings imply cognitive load which reduces the amount of resources available for other information processing. We model the negative effects of stress on individual well-being by allowing for a performance-reducing effect. Stress thereby reduces effective labour supply at work.

Turning to coping strategies, standard classifications distinguish between "emotion focused" copying strategy as opposed to "problem focused" behaviour, which addresses the stressor itself (Lazarus and Folkman, 1984, ch. 6).[7] Other classic categories include "functional" vs. "dysfunctional" approaches. Frequent strategies ranked in this way start with 'problem solving' and 'support seeking', continue via 'emotional expression' and 'aggression' to end up with 'wishful thinking' and 'worry' (Skinner et al., 2003). Finally, modern views of coping often include a distinction between "automatic" and "controlled" processes (e.g. Connor-Smith et al. 2000, Skinner and Zimmer-Gembeck, 2007).[8] The feature of coping we emphasize in our model is its stress-reducing nature. We, therefore, model an "emotion focused" coping strategy chosen optimally by an individual.[9] This strategy reduces stress in a gradual and deterministic fashion. This is a "controlled" process. At the same time, we allow the individual to be overwhelmed by stress experiences. Being overwhelmed triggers behaviour that can be understood as uncontrolled and that leads to a discrete and fast reduction of stress. This reflects the "automatic" process of the categorization above. As examples for the smooth coping style, think of 'sorting things out', 'talking to a friend' or 'doing sports'. The more violent and less controlled behaviour is called 'emotional outburst' here, taking the form of yelling, making gestures while driving the car, getting drunk, becoming aggressive and the like (see Straus et al., 1996, for more background).

[Findings] There are three main findings. First, we derive conditions under which an individual's stress level leads to emotional outbursts. These conditions reflect exogenous factors such as stressors on the job, individual personality traits concerning the evaluation of and expectations about stressors and optimally chosen coping measures. Personality traits are defined (and could be estimated) in a theory-consistent way. We also derive conditions when an individual has to quit their job due to "stress-overflow".

Second, despite popular claims that stress is bad for health and is very costly to an economy in terms of lost output, we show that one should distinguish between "pure stressors" and "productive stressors". Pure stressors are unambiguously bad for income and detrimental to health. This is in line with the empirical estimates by Goh et al. (2016). Productive stressors, by contrast, do have income-increasing features, at least up to some point.

Finally, we derive conditions under which "money buys happiness". More precisely, we provide an explanation of the Kahneman and Deaton (2010) finding that stress-free time increases up to an annual income of (on average) US$ 75,000 but falls thereafter. We offer explanations why this amount is an average over individuals and derive personal determinants of this income

of learning is provided by Paas et al. (2003). A recent contribution to the understanding of the effect of cognitive load on performance is by Hoffmann et al. (2013). The role of cognitive load in the context of anxiety and performance is surveyed in Derakshan and Eysenck (2009).

[6] The view goes back to Baddeley and Hitch (1974). See, for example, Smith and Kosslyn (2007, ch. 6) for an introduction.

[7] Economics is full of problem-focused coping styles. An unemployed worker putting effort into searching for a job would be one such example.

[8] This follows the tradition of dual-process models used in psychology more widely. See Chaiken and Trope (1999) for an overview and Strack and Deutsch (2004) or Sherman et al. (2008) for more recent contributions.

[9] We do not claim that optimal control theory captures all aspects that matter for the general development of theories of emotions. Learning, signalling and strategic behaviour also play a major role (see e.g. Winter et al., 2017 and the references therein). Given the emphasis in psychology on (conscious) emotion regulation, automatic reactions, processes and uncertainty, we do believe that optimal control theory provides insights into the understanding of the dynamics of emotions.

level.

[Related literature] In spirit, we see our paper in the tradition of the strand of behavioural economics that uses ideas from psychological research to better understand human behaviour. One can trace back the formal tradition at least to Strotz (1956) on time-inconsistencies, with the more recent new interest inspired by Laibson (1997). As a recent example, Kaur et al. (2015) show that time-inconsistent workers can prefer dominated contracts by a principal and that this has high empirical relevance.[10] Our interest in stress places our analysis into the modern literature analysing emotions from an economic perspective. Economic analyses of emotions include ex-post emotions such as regret, disappointment or surprise (Loomes and Sugden, 1982, 1986, Gul, 1991, Ely et al., 2015), ex-ante emotions such as joy and fear (Caplin and Leahy, 2001, 2004, Kőszegi, 2006, Becker and Rubinstein, 2011) and immediate emotions or visceral factors. Examples are desire and compulsion (Laibson, 2001, Bernheim and Rangel, 2004, Brocas and Carrillo, 2008) or hunger and thirst (Loewenstein, 2000). A final group consists of belief-based emotions either in psychological games (Geanakoplos et al., 1989), for which an application studies guilt in marriage (Dufwenberg, 2002), or in non-strategic settings as in Compte and Postlewaite (2004), who analyse self-confidence. Aggrievement, resulting from a departure of economic policy from what an individual perceives as a fair policy, as the basis of political unrest is studied by Passarelli and Tabellini (2017). See Wälde (2016) and Wälde and Moors (2017) for more extensive reviews of emotion research in economics.

[Table of contents] Section 2 of the paper provides background to stress research and argues why stress is important for economic thinking. Section 3 presents a mathematical version of a psychological model of stress. This model is extended by an optimal control structure that allows to understanding coping, i.e. optimal stress-management by individuals. Given optimal coping measures, section 4 derives findings on the dynamics of stress and coping, including the occurrence of spontaneous 'emotional outbursts'. These findings build on the definition of theory-consistent personality traits also introduced in this section. Section 5 contains our central economic results on pure vs. productive stressors and the link between income and stress. Section 6 presents further applications and section 7 concludes.

2 The importance of stress for economics

As stress has not been an everyday topic for economic analysis, this section provides some general background on stress. The section also argues – beyond the specific applications in this paper – why stress should be central to economic analysis.

- What do we know about stress?

After decades of stress research in psychology, medical science, biology and beyond, this question cannot be answered comprehensively in one section.[11] We provide instead novel descriptive cross-section evidence based on the "Burden of Stress in the US" dataset.[12] Concerning

[10] The link between psychology and economics is, of course, much older, starting at least with Bentham's (1789, 1970, p. 11) "two souvereign masters, pain and pleasure". For a revival of the link between subjective well-being (happiness) and choice, see inter alia Benjamin et al. (2012), Rayo and Becker (2007) and Kahneman, Wakker and Sarin (1997). A short history of bounded-rationality models is provided by Harstad and Selten (2013).

[11] See the overviews by Aldwin (2009) or Thoits (1995) as starting points from a psychological perspective. For the allostatic load approach in biology, see e.g. McEwen (2007). Surveys on the effect of stress from a medical perspective (including animal and human studies) include Lupien et al. (2009) and Sandi and Haller (2015). A recent medical gender-fMRI study with many further references is by Chung et al. (2016). A very broad overview spanning biology, psychology and medical science is by Baum and Contrade (2010).

[12] We are grateful to Robert Blendon from the Harvard T.H. Chan School of Public Health for having generously shared the data with us. Stata files producing these findings are available upon request.

prevalence, stress is a widely experienced feeling. In a 2014 telephone survey of the US population, 13.7% responded they had "no stress at all" in the previous month, 24.7% responded "not very much" but 36.1% had some stress and 25.3% had "a great deal" of stress. Women reported being stressed slightly more often than men (28.8% vs. 20.9% for "a great deal" of stress but only 10.8% vs. 17.3% for "no stress at all") but different ethnic or age groups were similarly hit by perceived stress.

When people were asked about the sources of stress, 61.5% of the answers attribute stress to the private life, 23.7% to the professional life and 14.8% state that there are "too many responsibilities overall". The second most frequent answer (after "too many responsibilities") is "problems with finances" (13.6%), followed by "problems at work, such as too much work" (11.8%), own health problems (11.3%) and the health problems of family members (11.0%) and problems with family members (10.0%).

This cross-sectional information complements the psychological rating analyses in the spirit of Holmes and Rahe (1967) and Kanner et al. (1981) discussed in the introduction. According to Hamermesh and Lee (2007), (time) stress rises in income and hours worked in the market. Furthermore, an increase in full earnings of the husband (in three out of four countries) increases time stress of his wife.[13] These income findings are related to Kahneman and Deaton (2010) and will be discussed in more detail below. If we add evidence on reduction in happiness (as a proxy for increase in stress), unemployment would turn out to be the only persistent stressor as compared e.g. to divorce or widowhood (Clark et al., 2008). Colantone et al. (2016) show how an increase in import competition stresses individuals (measured by the generalized health questionnaire) *beyond* the material effect due to job loss or reduced income. Haushofer and Fehr (2014), to which we will return to below, survey various studies that show how job-loss, bad weather conditions for farmers or cash transfer affect stress.

- The effect on the individual

Once stress is experienced, it affects an individual's subjective well-being and their social environment in many ways. Starting with subjective well-being and focusing first on the productivity channel, the effects can be understood when adopting a psychological perspective where responses to stress are often summarized under the heading of 'coping' (Carver and Connor-Smith, 2010). Whether coping behaviour is emotion- or problem-focused, voluntarily chosen or more automatic, coping measures are time-consuming, require attention and, more generally speaking, use up resources individuals could use for other potentially more productive activities. While some of these reactions can be described as the outcome of optimal behaviour, some others violate principles of individual optimality.[14] Goh et al. (2016) estimated the economy-wide effect of stressors on productivity on the work place. They estimated that they relate to "more than 120,000 deaths per year and approximately 5%-8% of annual health care costs" (p. 608).

Concerning the feeling of stress per se, individuals are affected as they consciously try to manage stress: Returning to the "Burden of Stress in the US" data, 61.7% of all answers suggest that individuals try to manage stress by relying on themselves, whereas 27% get help from other individuals – or their pet (in addition to 11.2% doing something else). The answer given most often was to regularly spend time with family or friends (11.3%), followed by spending time

[13] Buddelmeyer et al. (2018) study the effects of children on time-stress and financial stress of parents in Australia and Germany.

[14] We see a parallel between resource-consuming coping measures and other sources of distraction. In a classic experiment by Shiv and Fedorikhin (1999), individuals lose self control when being distracted (by having to remember e.g. a long number). Resources are being occupied by the distraction and the individual eats the chocolate cake.

outdoors (10.1%) and eating healthfully (10%).[15] Only 2.8% of the answers state that the individual got professional help.

Turning to health implications, the immediate short-term bodily reaction to an acute stressful event via the release of stress hormones is usually *beneficial*. Energy is made available (e.g. via higher blood sugar and increased blood pressure) that is needed to react quickly. When stress becomes chronic, however, the strain on the body has negative health consequences. Chronically increased blood pressure puts excessive strain on the heart and arteries and permanently increased levels of stress hormones suppress the immunity (see e.g. Schneiderman et al., 2005 or Lupien et al., 2009, fig. 1). Helliwell et al. (2013, ch. 3 and especially 4) collect a wealth of medical evidence on the negative effects of stress on health.

Zhong et al. (2017) show in lab experiments that more competitive tournament tasks induce higher cortisol responses (i.e. higher stress levels) than less competitive tasks. They also show that these responses depend on personality of individuals.[16] In the experiment by Goette et al. (2015), stress exposure has an impact on an individual's competitive self-confidence. The latter is also a function of an individual's personality (trait anxiety).

- The effect on an individual's social environment

Turning to family economics or industrial organization, stress of one person can also cross over to other individuals, i.e. colleagues, partners, family and friends (Bakker and Demerouti, 2013). Stress makes individuals more aggressive, leads to counterproductive work behaviour (Penney and Spector, 2005), to bullying, more aggressive communication styles in couples (Bodenmann et al., 2010) and to less social support (Bodenmann et al., 2015, Lavner and Bradbury, 2017). Given the absence of a price system for many of these interactions, stress causes externalities which lead to suboptimal factor allocation.[17]

Returning to the "Burden of Stress in the US" and using an ordered logit model indicates that individuals also care about stress as it affects their private and professional environment. When an individual's subjective perception of stress moves from "no stress at all" to "some stress" (findings are of similar magnitudes when moving from "not very much" to "a great deal" of stress), the share of individuals that report that stress does not at all affect their health decreases by 37.4 percentage points, by 46.4 pp. for family life and by 43.2 pp. for work life.

Randomized telephone interviews by Stets (1990) showed that 75% of couples reported verbal aggression and 10% reported physical aggression. She argues that this behaviour, examples for 'emotional outbursts', can be related to stress. Own analysis for Germany based on the GSOEP showed that 44% of women and 52% of men report "having arguments or conflict" where conflict is with a partner (45%), parents (14%), children (13%) and siblings (7%) and hardly at all with colleagues or outside family.

- The importance of stress for economic thinking

Following the concepts of experienced vs. decision utility (see e.g. Loomes and Sugden, 1982, 1986 or Kahneman et al., 1997), this paper follows the Bentham-tradition and allows non-observables (stress in our case) to enter the utility function describing hedonic experience of an

[15] Other answers with sufficiently high precentages included (regularly) "gotten a full night's sleep" (9.9%), "exercised" (8.7%), spent time on "a hobby" (8.6%), "with a pet" (7.3%) and "meditated or prayed" (8.3%).

[16] See Cahlíková et al. (2016) for evidence on the response to stress by gender.

[17] Laboratory findings show that acute stress can increase pro-social behaviour (von Dawans et al., 2012). The relationship between these laboratory findings and field findings still needs to be explored. One could hypothesize that laboratory findings are on acute stress while field findings mostly are on chronic stress.

individual.[18] As stress is ubiquitous in life and as utility functions are ubiquitous in economics, stress is as central to economics as other emotions that affect human decision making.

Given the quantitative impressions from the "Burden of Stress in the US" and the suggested link between stress and *experienced* utility, it seems clear that stress plays a huge role for economic issues: (i) Stress affects professional life. Going beyond individual productivity and income (which are studied in detail in sect. 5.1), models of teams (e.g. the principal-agent model) should take stress into account. A principal who wants to maximize profits should take the stress effect on the agent of the chosen incentive scheme into account. This would be perfectly in line e.g. with Goh et al. (2016) who write that life and health-care costs "are associated with and may be attributable to how U.S. companies manage their work forces" (p. 608). The empathy of the principal would be an important parameter of such a model. (ii) Stress affects private life. When thinking of family models (Becker, 1991), stress (co-) determines utility of the family and, ultimately, allocation of resources within the family. This could be stress "crossing over" from professional activities to private life and then "spilling over" from one partner to the other (Bakker and Demerouti, 2013). (iii) Stress affects social interactions more generally. Thinking about situations where an agreement needs to be found, modeled by Nash- or Rubinstein-type bargaining setups, stress (and emotions such as surprise or disappointment e.g. about offers) should be considered in these bargaining models as well.

3 The model

This section first introduces stressors and appraisal as the starting point for understanding stress. We then discuss the effects of stress on the individual. As the individual dislikes stress, coping measures are introduced subsequently. Using this background, we are then able to describe feasible paths of stress and, finally, to solve for the optimal coping choice.

3.1 The origin of stress: stressors and appraisal

Stress results from stressors and appraisal. These two concepts are covered now.

- Stressors

The starting point of emotional tension (which we use interchangeably with stress) is a stressor. Stressors can occur in a variety of circumstances. As discussed in the introduction, we distinguish between two types of events: those that occur only rarely and those that occur more frequently, say daily. The stressfulness of rare events can be measured by the Social Readjustment Rating Scale (Holmes and Rahe, 1967, Hobson et al., 1998), more frequent events can be called 'daily hassles' in the tradition of Kanner et al. (1981).[19]

Our model describes the randomness of the rare events by a Poisson process with a random jump level $h(t)$ at a point in time t and an exogenous arrival rate λ^g. The jump $h(t)$ can be positive or negative and has a mathematical mean μ^h. Our individual forms subjective expectations about the jump level. The expected level is given by μ. The surprise $g(t)$ implied by a rare event that occurs at t is then given by

$$g(t) \equiv h(t) - \mu. \tag{1}$$

[18] For a broad and thorough discussion of this distinction and many other aspects concerning current economic methodology, see Caplin and Schotter (2008).

[19] To be fair, Kanner et al. (1981) also inquire about stress-reducing "uplifts" in their questionaire.

In the spirit of Bell (1985) and Loomes and Sugden (1986), among others, we call a positive surprise, defined by $g(t) > 0$, elation and a negative surprise disappointment.[20] Both elation and disappointment are measured relative to the mean μ. We consider the realization to be an exogenous and objective quantity, while the expected value μ is a personality measure of the person under consideration.[21]

As an example, let an increment of the Poisson process denote the point in time when a paper is accepted for publication. Let $h(t)$ represent the quality of the accepting journal or the number of citations a paper gets, say, within the first two years after publication. When the quality or the number is very high and the subjective expectation is modest (i.e. μ is not too high), the individual is positively surprised.

In addition to this rare source for emotional tension, there is a daily flow of events that has an impact on a person. These events imply certain (exogenous) demands p, the stressors, which have to be met given the abilities $b > 0$ of the individual. When 'hassles' dominate relative to 'uplifts', p is positive. Just as with surprises, let us assume that pressure and abilities are objective quantities. We call p/b the intensity of the stressor p.

An example for p would be the number of emails an individual receives per day. If the ability b to reply to emails is high, the intensity of the stressor 'email' is low. If an individual is not that good at communicating by email, the intensity of the stressor email is high.

It might appear restrictive as we do not allow p/b to be a function of time. One might wish to understand how cyclical pressure (relative to ability), due to more or less demanding days, induces stress. Examples include a deadline that is approaching vs. the teaching term that comes to an end or the pressure in recession when a firm is about to shut down relative to an expanding firm in a boom. We leave these highly interesting questions for future work. We will undertake below a comparative static analysis, however, to understand how changes of p/b affect an individual's behaviour.

- Appraisal

We model the effect of stressors on stress $W(t)$ by taking a clear causal view. Stressors cause (a change of) stress. The mechanism through which stressors increase emotional tension follows 'appraisal theory' where "emotions are elicited by evaluations (*appraisals*) of events and situations" (Roseman and Smith, 2001, p. 3).[22] The appraisal process is strongly influenced by personal characteristics of the person under consideration.[23] We capture this appraisal process by individual-specific parameters, to be introduced in (6) below, that specify how the intensity of daily hassles or rare events influence the evolution of stress.

[20] See the alternative definition of surprise as a change in one's belief from one period to the next in Ely et al. (2015). They study the optimal revelation of information over time for an audience consisting of Bayesian learners in the presence of surprise and suspense.

[21] One can think about μ as a reference point (Kahneman and Tversky, 1979) indicating what the individual finds "appropriate" concerning the outcome of $h(t)$. Such a reference point could be made endogenous as in Gul (1991) or Köszegi and Rabin (2006). See the section on therapy for further elaboration of the personality view.

[22] Appraisal is a highly complex process which we do not model in all details. Ellsworth and Scherer (2003) provide a list of dimensions along which individuals evaluate a certain event. For a full-scale summary of appraisal theory, see Scherer et al. (2001). A recent analysis of the role of appraisal in emotion is in Moors and Scherer (2012). A comparison to alternative views is e.g. in Roseman and Smith (2001) or Lewis (2005, p. 170).

[23] See e.g. Kuppens et al. (2008), Scherer and Brosch (2009) and Tong (2010) or the cognition-emotion literature focusing on personality or clinical aspects, (see Lewis, 2005, p. 171 for a short overview).

3.2 The effect of stress on individual well-being and sickness-leave

Once stressors and appraisal have created stress, how does this stress level affect the individual?

- The effect of stress on individual well-being

Whether looking at semi-popular sources (e.g. www.stress.org/stress-effects) or at various scientific literatures, there are long lists of how stress reduces one's general well-being. Stressed individuals enjoy food less, play less with kids, no longer enjoy and therefore skip playing soccer and so on. There are also various bodily symptoms (among which headache, dizziness, sweating and sleeplessness). We capture these direct negative effects by letting stress negatively affect the utility level of an individual.

There is a lot of evidence, however, that stress also affects the individual in more sophisticated, yet not less important, ways. One of these indirect channels is the effect of stress on performance via cognitive load. The argument is simple: We start from the general view of human mental processes (see Smith and Kosslyn, 2007, ch. 6) that an individual is endowed with a certain amount of working memory M. This working memory can be used for various purposes of which some are chosen consciously while others are more automatically determined. In our setup, the appraisal process evoked by stressors is one such example of an automatic, exogenous, allocation of working memory resources. As stressors are exogenous to the individual, the amount of working memory used for the appraisal process is exogenous as well.

Generally speaking, one can distinguish between low-level and high-level appraisal. Low-level appraisal tends to be more automatic and preattentive while high-level appraisal requires attentional and working memory resources (Kalisch et al., 2006). Most of the examples for 'daily hassles' or 'rare events' clearly require high-level appraisal. Losing the car key on the way towards an important meeting requiring a one-hour drive requires weighing various options from 'not showing up' to 'going by taxi'. Similar working-memory intensive considerations are required after rare events like 'divorce', and even 'Christmas' requires lots of thinking. We therefore capture this pre-emption of the working memory by stressors by assuming that the working memory capacity required for appraisal is given by $M(W(t))$ and that a higher stress level causes more costly appraisal processes, $M'(W(t)) > 0$.

To understand the effect on performance, we specify a working memory constraint,

$$M(W(t)) + M(a(t)) = M. \tag{2}$$

What is left of the working memory M can be used for everyday activities like, taking the example of a performance measure, paying attention $a(t)$ to work, $M(a(t))$. Returning to consumption and income of our individual, this constraint implies a consumption level falling in stress. To see this, start from a budget constraint that equates consumption with income, $c(t) = wl(a(t))e$. Income is determined by the wage rate w per efficiency unit of labour (taking the educational level $\tilde{h}$ into account), by effective labour supply $l(a(t))$ and by effort e (to be employed in detail in sect. 5.1). When $l(a(t))$ rises in attention $a(t)$, consumption rises in attention as well. As by (2) attention falls in stress, consumption is a falling function of stress, $c(t) = c(W(t))$.

If we are willing to make a simplifying assumption concerning the link between memory and attention in (2), i.e. if we set $M(a(t)) = a(t)^{1/\varepsilon}$ with $\varepsilon > 0$, the amount of attention that can be provided amounts to $a(t) = (M - M(W(t)))^{\varepsilon}$. Consumption is then given by $c = wl([M - M(W(t))]^{\varepsilon})e$. A simpler version sets $\varepsilon = 1$, specifies effective labour supply $l(.)$ to be the identity function and $M(W(t))$ to be linear in $W(t)$. This implies that consumption falls linearly in $W(t)$

$$c(t) = w[M - \kappa W(t)]e, \tag{3}$$

where $\kappa > 0$ is the marginal effect of stress on pre-emptying the memory system and thereby on reducing consumption. Summarizing this cognitive load idea, performance at work goes down when an individual is kept busy thinking about many other non-job related issues, i.e. when the individual just finds it hard to focus.[24]

Both the direct level and the indirect level of stress suggest that the instantaneous utility function is a function of the consumption level and of the level of stress. We denote it by $u(c(t), W(t))$ and let it rise in consumption and fall in stress.

Note that there is a huge literature on cognitive load in psychology, in experimental economics and elsewhere which strongly supports our modelling approach. In psychology, Sweller (1988) is the classic reference for cognitive load theory and learning (see Paas et al., 2003 for a more recent review). According to these findings, cognitive load reduces learning. Eysenck and Calvo (1992) in their 'processing efficiency theory' and later in their 'attentional control theory' (Eysenck et al., 2007) argue that the primary effect of anxiety in stressful situations is "to pre-empt some of the processing and storage resources of the working memory system" (Eysenck and Calvo, 1992, p. 415). Hoffmann et al. (2013) provide a short literature overview in their introduction showing that accuracy of judgements generally falls under cognitive load.[25]

In economics, cognitive load is modeled by Fudenberg and Levine (2006) as a parameter for the cost of self control in their dual-self model. One of their motivations is the self-control experiment by Shiv and Fedorikhin (1999) that show that individuals have a higher tendency to choose a chocolate cake rather than a fruit salad when they have to perform cognitively demanding tasks like remembering seven-digit (rather than two-digit) numbers. In terms of our mental resource constraint (2), remembering seven-digit numbers takes up more memory resources ($M(W)$ is higher) as when remembering two-digit numbers. As a consequence, resources $M(a(t))$ left for paying attention to self-control (i.e. choosing the healthy desert) are reduced.

Our approach also shares the idea of an additional resource constraint in human decision making with other analyses, even though the modelling is different. Banerjee and Mullainathan (2008) allow individuals to allocate one unit of attention to activities at home and at work in a development context. This choice of allocating attention is made optimally and therefore differs from the idea here that a certain amount of resources is taken up automatically by whatever the stress level happens to be.[26] Fudenberg and Levine (2012) use the concept of costly cognitive resources to obtain convex costs of cognitive control. Cognitive resources are a stock ("willpower") in their setup, however, which can also become negative. This differs from our resource constraint where a stock M of mental resources is available at each instant.

Mani et al. (2013) provide evidence that cognitive performance is lower for poor farmers. This can be explained partially by poor farmers being more stressed (measured by heart rate and blood pressure). This is perfectly in line with a cognitive load argument as employed here.[27]

[24] To make a positive example, think about adolescents or young adults falling in love. They should focus on their education, study hard for exams or apply for jobs. Being in love just takes up all of their working memory and no resources are left for thinking about anything else.

[25] To be fair, the point of Eysenck and Calvo (1992) and Hoffmann et al. (2013) is that performance can under specific circumstances actually increase under cognitive load as either motivation rises in stressful situations (which increases M) or individuals switch to less resource-consuming strategies. We believe that these circumstances are more the exception than the rule.

[26] Limited resources are also taken into account by Mullainathan (2002) who emphasizes the limited capacity of a human's memory.

[27] Clearly, stress does not fully explain variations in cognitive performance in Mani et al. (2013). Poverty per se causally captures attention and thereby also reduces cognitive resources. See Mullainathan and Shafir (2013) for the broader perspective.

- Sickness leave

Introducing the working memory constraint (2) naturally leads to an endogenous job-quitting. As only positive values of consumption make sense, consumption is zero when stress exceeds the sickness-level

$$W^s \equiv M/\kappa. \tag{4}$$

When an individual reaches or exceeds this stress level, he or she stops working and is on sickness-leave. The individual might require financial support or even full-time care in a clinic or elsewhere.

When off work, stressors p reduce dramatically. Not only does it reduce the direct stressors from work (23.7% according to the above stylized facts) but also the induced stressors in private life (according to the spill-over cross-over view) and the 14.8% "too many responsibilities overall". We will assume in what follows a stressors level p^s close to or equal to zero for $W \geq W^s$.

3.3 Coping with stress

Stressors via appraisal implies stress and stress affects the individual in a negative way. We now study how the individual can react to stress.

Employing the classification of coping from the introduction, we model coping strategies which are controlled and emotion-focused and which feature some automatic and dysfunctional properties. Example for controlled emotion-focused coping activities come from stylized facts above: Individuals can e.g. talk to friends, spend time outdoors or get a lot of sleep. Coping strategies will be captured by a control variable $m(t)$ in the maximization problem described below.

A less controlled emotion-focused coping activity is what we call an 'emotional outburst'. Outbursts occur when individuals feel overwhelmed by a situation, when the stress level is too high and individuals can't help but "explode". This can take the form of honking while driving the car, swearing when sitting in the office, banging one's fist on the table, shouting at others, stomping out of the room, or drinking. See the 'conflict tactics scale' by Straus et al. (1996, table 3) for more background. We view an outburst as a relatively short event (say, less than 5 seconds). This approach is dysfunctional in the sense that it is generally bad for the individual's environment and might even be bad for the stress level of the perpetrator.

Formally, outbursts occur at a rate $\bar{\lambda}^{\Delta}$ once the stress level exceeds a tolerance level $\bar{W}$. Denoting the instant before an emotional outburst by t_-, the effect of an outburst is to change stress by an exogenous random amount $\Delta(t)$,

$$W(t) = W(t_-) - \Delta(t). \tag{5}$$

The realization of $\Delta(t)$ is drawn at the moment of the outburst from some well-defined distribution with positive and negative realizations. The distribution has a mean of μ^{Δ}.

Is there evidence that supports sudden discrete changes in stress? One could understand a positive realization of $\Delta(t)$ as an example of the ancient idea of "catharsis", a quick purification from overwhelming feelings. There are many metaphors that suggest so. In everyday life, people in angry situations often suggest to "let it out", the recommendation "do not bottle your anger up inside" is well-known and the idea of a "air-cleaning" angry outbursts is common. Bushman et al. (2001), from where these examples were taken, follow this intuition and device experiments that show that people reacted more aggressively when they believe that outbursts reduce their anger. If one wanted to give a choice interpretation to a random variable, individuals "choose a larger $\Delta(t)$".

Evidence for a positive catharsis effect (which would mean $\mu^{\Delta} > 0$ in our model) comes from self-reports of individuals perpetrating psychological aggression. Shorey at al. (2012) report

very heterogeneous results showing that 42.6% of respondents "felt less angry" while 41.7% felt more angry. Some of the perpetrators (25.7%) felt less stressed, 40.2% felt more stressed. When computing the average effect of these outcomes (adding up the level of changes times the share of individuals reporting this change), individuals clearly reduced stress or anger.

3.4 Feasible paths for stress

We are now finally in a position to combine stressors, appraisal, stress and coping in one equation. Formally, stress $W(t)$ follows a stochastic differential equation that reads

$$dW(t) = \left\{ \phi \frac{p}{b} W(t) - \delta_0 W(t) - \delta_1 m(t) \right\} dt - \chi g(t)\, dq_g(t) - \Delta(t)\, dq_\Delta(t). \tag{6}$$

The first term $\phi \frac{p}{b} W(t)$ combines situational and personal components to describe the source of stress.[28] The term p/b captures the effect of demand relative to ability. A classic definition (Lazarus and Folkman, 1984), that was adopted by numerous authors thereafter, defines stress as the mismatch between demands of a task and the abilities of a person to cope with those demands. Our approach follows this definition in spirit but goes beyond it by adopting a dynamic perspective. The stressor intensity p/b is a source of a *change* of tension, not of tension itself. Tension is a subjective feeling that can increase and decrease over time. Only in exceptional cases does it change in a discrete way. The views of Lazarus and other researchers sound more static which would imply that stress is gone once the stressor is gone. Here, tension persists beyond the point where the cause of tension, the stressor, was present. Tension can be reduced subsequently.

Individual ability b is not the only individual characteristic which matters for how a stressor p affects an individual's stress level. The stressor increases stress more strongly when the current stress level $W(t)$ of the individual is high. This captures the idea that someone already relatively tense will react more "nervously", i.e. will build up tension even more when confronted with additional demands as compared to a person with lower $W(t)$. In addition to this multiplicative effect, we also allow for personality effects via the appraisal parameter $\phi > 0$. Two individuals in identical circumstances, i.e. facing an identical stressor intensity p/b at the same tension level $W(t)$, experience different paths for how stress builds up. An individual with a low ϕ will not become as tense as an individual with a high ϕ. Note that there is strong evidence for this view. Meier et al. (2006) study the reaction of individuals to aggression-related cues. Individuals with low measures of agreeableness (one of the Big 5 personality measures) reacted considerably less aggressive than the average individual.

The second and third terms in the deterministic part of (12), $-\delta_0 W(t) - \delta_1 m(t)$, are depreciation functions that capture the effect of automatic and intentional reduction in tension. Automatic reduction takes place as there is some natural tendency in humans to "cool down" over time. Absent new stressors and given a historically given stress level, one should expect that emotional tension $W(t)$ stabilizes over time to end up at some constant level. We call this mechanism the "autonomous stress reduction potential" of a person, captured by the parameter $\delta_0 > 0$. One can draw an analogy between δ_0 and a depreciation parameter e.g. for physical capital. As time goes by (e.g. while the individual sleeps at night), emotional tension ceteris paribus reduces. Intentional reduction of emotional tension results from coping activities $m(t)$. This is a control variable of the individual. The higher the productivity parameter $\delta_1 > 0$, the more stress is reduced for a given level of coping.

While the first three terms affect stress in a deterministic and foreseeable way and thereby capture common everyday events, surprises come at random points in time. The arrival of

[28] Given that there is no formal analysis of stress in psychology or economics, the functional forms suggested here and in what follows are explorative in nature. Their structure needs to tested or parameters of generalized versions need to be estimated in subsequent work.

(potential) surprises is governed by a Poisson process $q_g(t)$ with an exogenous arrival rate λ^g. As explained after (1), the surprise $g(t)$ can be positive or negative. Given the current tension level $W(t)$, a positive surprise translates into less tension. By how much tension reduces given a positive (or negative) surprise depends on personal characteristics, i.e. on the appraisal parameter $\chi > 0$. Some individuals have somatic responses (like heart attacks in extreme cases) while others just seem to able to "ignore" negative surprises (where χ would be zero).[29] The factor χ could be identical to the personality factor ϕ that translates daily hassles into building up of stress. Our results do not depend on whether they differ or not. Psychologically speaking, one would have to argue that the appraisal process is the same for daily hassles as for rare events. As this seems questionable in such generality, we allow these two personality factors to differ.[30]

There is systematic empirical evidence from field experiments on the stress-reduction effect of positive surprises. Haushofer and Shapiro (2013) study the effect of random unconditional cash transfers of around $400 or $1500 on households in Kenya. They find that for the large transfer, there was a significant reduction of the households' stress level.[31] Haushofer and Fehr (2014) summarize several further studies concluding that "cash transfers reduce distress" (p. 864). If we are willing to consider random positive cash transfers as positive surprises ($h(t) > \mu$), this is strong systematic support for our setup. Evidence for stress-increasing effects of negative surprises ($h(t) < \mu$) is just as strong (see again Haushofer and Fehr, 2014, and the studies reported therein): Whether one looks at bad weather conditions for farmers in Kenya or job-loss for Swedish workers, these events all lead to an increase in the stress levels of individuals.

The final term describes the effects of outbursts. They never occur when the individual is sufficiently relaxed, they occur at a fixed rate $\bar{\lambda}^{\Delta}$ when the individual's stress level is too high,

$$\lambda^{\Delta}(W) = \left\{ \begin{array}{c} 0 \\ \bar{\lambda}^{\Delta} \end{array} \right\} \Leftrightarrow W \left\{ \begin{array}{c} \leq \\ > \end{array} \right\} \bar{W}. \tag{7}$$

We define emotional tension $W(t)$ to be non-negative. An individual can either be tense at various levels ($W > 0$) or completely relaxed (at $W = 0$). As the differential equation for $W(t)$ in (12) implies that stress becomes zero in finite time, stress will remain there unless a surprise pushes the individual back to positive values. Being completely relaxed is the desirable state in this model. One could associate absence of tension also as complete apathy or depression as opposed to being deeply relaxed.[32] Such a distinction could be modeled if a second dimension measuring how positive or negative a feeling is was introduced. This would then follow the valence-arousal tradition in emotion research (Russell and Barrett, 1999).[33] Here, stress is seen as something inherently negative, i.e. we model distress.[34]

[29] To put it simple: Whatever the objective state of the world ($g(t)$ in the case of suprises), it is the individual's appraisal parameter χ that determines how much an individual is affected emotionally.

[30] The fact that surprises $g(t)$ are not proportional to current stress means that a surprise can push an individual away from $W = 0$, the state of being perfectly relaxed. Daily hassles cannot do so as they affect changes in stress proportional to $W(t)$. Empirical analysis needs to identify the most appropriate functional specification.

[31] While households receiving the $400 transfer had a lower stress level as well, it was not significantly lower relative to the treatment group receiving no transfer. This could be due to expectations μ rising immediately when a representative of a foreign NGO contacts an inhabitant of a rural village in a poor country.

[32] In fact, Selye (1976, p. 137) argues "complete freedom from stress is death". He also developed the distinction between positive stress (eustress) and negative stress (distress).

[33] See Fontaine et al. (2007) for an argument that an additional two dimensions (potency-control and unpredictability) need to be taken into account. Lerner and Keltner (2000) argue that two emotions with the same valence can imply very different perceptions e.g. of risk.

[34] For an analysis of potential positive effects of stress via subsequent "growth processes" of an individual, see e.g. Karlsen et al. (2006) and the references therein.

The literature on the highly pleasurable state of being "in flow" (e.g. Nakamura and Csikszentmihalyi, 2001) states that demand p can be too high but also too low. When p/b is just at the right level, the individual is "in flow". When demands go up, the individual "first becomes vigilant and then anxious", i.e. a mismatch in the Lazarus sense arises and stress builds up. If demand falls below the level that is just right, an individual "first relaxes and then becomes bored". One could therefore look at our lower limit of $W = 0$ as the state of "in flow" and analyse boredom as a negative value for W in future work.

3.5 Optimal coping

As the last ingredient of our stress model, we allow the individual to optimally react to stress.

So far, only positive effects of coping activities $m(t)$ were discussed: Coping reduces stress and thereby increases expected utility. Coping measures take time, however. This is true for talking to friends or to professional therapists or for practicing sports. We therefore include utility costs from coping

$$v(m(t)) = v_0 m(t)^{1+\zeta} \tag{8}$$

as an argument of the intertemporal utility function (11) below. We assume $v_0 > 0$ and $\zeta > 0$ where the latter implies a convex cost function. This is similar to the many quadratic adjustment cost structures in other papers in economics.

The instantaneous utility function $u(c)$ in (11) is specified in a risk-neutral way,

$$u(c, W) = \eta c - \alpha W. \tag{9}$$

The marginal effect of stress on utility is captured by the parameter $\alpha > 0$, marginal utility from consumption is denoted by $\eta > 0$. When we merge the expression for consumption (3) with the utility function (9), taking the sickness-level from (4) into account, the utility function reads

$$u(c, W) \equiv u(W) = \left\{ \begin{array}{c} \eta c - \alpha W = \eta w M e - (\eta w \kappa e + \alpha) W \\ -\alpha W \end{array} \right\} \text{ for } W \left\{ \begin{array}{c} < \\ \geq \end{array} \right\} W^s. \tag{10}$$

Marginal utility from stress therefore becomes less negative (by the amount of $\eta w \kappa e$) when the individual stops working and turns sick. Utility is a continuous function of stress at W^s, the slope has a kink.

Given instantaneous utility in (10) and costs from coping in (8), we define intertemporal utility $U(t)$ by forming expectations E_t about the state and control variables, $W(\tau)$ and $m(\tau)$, respectively, and by employing a time preference rate $\rho > 0$ and a time variable $\tau > t$,

$$U(t) \equiv E_t \int_t^\infty e^{-\rho[\tau - t]} \left[u(W(\tau)) - v(m(\tau)) \right] d\tau. \tag{11}$$

The individual maximizes (11) subject to the following stress constraint(s)

$$dW(t) = \left\{ \begin{array}{l} \left\{ \phi \frac{p}{b} W(t) - \delta_0 W(t) - \delta_1 m(t) \right\} dt - \chi g(t) \, dq_g(t) \\ \left\{ \phi \frac{p}{b} W(t) - \delta_0 W(t) - \delta_1 m(t) \right\} dt - \chi g(t) \, dq_g(t) - \Delta(t) \, dq_\Delta(t) \\ \left\{ \phi \frac{p^s}{b} W(t) - \delta_0 W(t) - \delta_1 m(t) \right\} dt - \chi g(t) \, dq_g(t) - \Delta(t) \, dq_\Delta(t) \end{array} \right\} \tag{12}$$

$$\text{for } \left\{ \begin{array}{c} 0 \leq W(t) \leq \bar{W} \\ \bar{W} < W(t) < W^s \\ W^s \leq W(t) \end{array} \right\},$$

and the effect of an outburst in (5) by choosing a path $\{m(\tau)\}_t^\infty$ of calm coping. The constraint (12) is a more explicit version of (6) as we need to distinguish between three ranges of stress.

The outburst-free range $\left[0, \bar{W}\right]$ where by (7) the arrival rate of q_Δ is zero, the outburst but still-working region $\left]\bar{W}, W^s\right[$ and the out-of-work region $[W^s, \infty[$. As implied by (12), outbursts can occur before an individual is on sick leave, $\bar{W} < W^s$.

The tolerance level $\bar{W}$ could also be modeled in an endogenous way. This choice is clearly a matter of which feature of outbursts one would like to emphasize. If outbursts are viewed as a rational choice, costs of outbursts could be included. If the discrete technology (5) yields higher returns than the smooth technology, there will be an outburst.[35] One appealing factor of an endogenous $\bar{W}$ is the fact that it would reduce the degrees of freedom of the model. The outburst stress level $\bar{W}$ would be tight to personality factors of the individual which would find some support from personality psychology.

From a psychological perspective, some authors define coping mechanisms as voluntary responses (Compas et al. 2001). Skinner and Zimmer-Gembeck (2007) include automatic reactions, which would argue in favour of an exogenous $\bar{W}$, into their concept of coping. If we allow for learning, however, the two concepts can become intertwined. Carver and Connor Smith (2010) write that "distinguishing between voluntary and involuntary responses to stress is not simple; indeed, responses that begin as intentional and effortful may become automatic with repetition". Given our intention to model behaviour that is partly beyond the control of an individual, we stick to $\bar{W}$ as being exogenous in our model.[36]

The optimisation problem can be solved in closed-form.[37] We find

Proposition 1 *Define Φ and Φ^s as the growth rates of stress,*

$$\Phi \equiv \phi\frac{p}{b} - \delta_0, \qquad \Phi^s \equiv \phi\frac{p^s}{b} - \delta_0 \tag{13}$$

and assume $\rho > \Phi \geq \Phi^s$. Then, optimal coping chosen by a working individual is independent of the tolerance level $\bar{W}$ and given by

$$m = \left(\Lambda_1 \frac{\delta_1}{(1+\zeta)\, v_0}\right)^{1/\zeta} \quad \textit{for } 0 \leq W < W^s, \tag{14a}$$

where $\Lambda_1 \equiv \frac{\eta w \kappa e + \alpha}{\rho - \Phi}$ is minus the shadow price of stress.[38] When the individual does not work, the coping level drops to

$$m^s = \left(\Lambda_1^s \frac{\delta_1}{(1+\zeta)\, v_0}\right)^{1/\zeta} \quad \textit{for } W \geq W^s, \tag{14b}$$

where $\Lambda_1^s \equiv \frac{\alpha}{\rho - \Phi^s}$ is minus the shadow price of stress when sick.

Proof. see app. A.1.2 ■

Expressions (14) share a lot of interesting and intuitive properties concerning emotion regulation. They are summarized in

Corollary 1 *Smooth coping m rises in (minus) the shadow price Λ_1, in δ_1 and falls in v_0. The shadow price Λ_1 increases in the composite term $\eta w \kappa e$, in α and the growth rate Φ of stress and falls in the time preference rate ρ. Apart from the composite term, the same results hold for coping m^s when off work.*

[35] The classic example, whose truth is not fully confirmed (Taubman, 2003), is the shoe banging of Nikita Khrushchev at a 1960 UN meeting in New York when in rage about a speech of a Philippine delegate.

[36] This view is shared with the approach of Benhabib and Bisin (2005) who also take automatic behaviour into account. They let individuals choose, however, whether they want to act in an automatic or in a controlled way.

[37] Closed-form solutions are used in economics at least since Merton (1975) and include optimal stopping problems (Stokey, 2008). See Wälde (2005) for an application in the analysis of endogenous growth cycles and Wälde (2011) for a survey.

[38] As shown in prop. 4 below, the value function is given by $V(W) = \Lambda_0 - \Lambda_1 W$.

The rise of coping activity in δ_1 is clearly a productivity issue. When the tension reduction effect of coping rises, calm coping becomes more attractive and more coping takes place. On the other hand, higher costs of coping via higher v_0 decrease its intensity. Coping intensity m also rises when the effect of stress on the value function increases, i.e. when Λ_1 rises. Examples for a rise in Λ_1 are increasing marginal disutility α from stress or marginal utility η from consumption. The higher α or η, the more stress is detrimental for the value function and the higher are incentives to reduce stress via coping measures. Another example is the growth rate Φ of stress. The faster stress increases (see the phase diagram in fig. 1 for more discussion of Φ), the more coping measures take place.

Interestingly, stress-reducing measures are not affected by the risk of outbursts, i.e. m is the same whether stress is larger or smaller than $\bar{W}$. This follows from the linearity of the value function $V(W)$ in our closed form solution (see prop. 4): The reduction in the present value $V(W)$ of life-time utility from more stress is independent of the level of tension. When tension reduces by one unit, the value function $V(W)$ always increases by the same constant amount Λ_1.[39]

Stress-reduction measures do change, however, when the individual quits working, i.e. when $W(t) \geq W^s$. This is due to the three additional parameters $\eta w \kappa e$ visible in (14a), all "motivating" the individual to increase smooth stress-reduction measures. When marginal utility v from consumption increases, when the wage w or effort e increase or when stress occupies the working memory more quickly (i.e. when κ rises), m increases. As a worker on sick leave due to too high stress levels lacks any of these incentives, stress reduction measures drop when a worker needs to quit their job.

4 Personality, environment and spontaneous behaviour

To summarize the structure of our stress model, appraisal of stressors cause a change in stress where stress reduces utility. Coping measures are chosen to reduce stress and occasional outbursts occur when the stress level is beyond the tolerance level $\bar{W}$. Stress beyond $W^s > \bar{W}$ makes the individual sick such that they are unable to earn any income.

Given this background, this section predicts stress and coping patterns. We define personality in a theory-consistent way and use this to derive conditions under which spontaneous uncontrolled behaviour, emotional outbursts, occur. This leads to a first central prediction: uncontrolled socially non-desirable behaviour occurs when an individual is simultaneously in an environment with high intensity of stressors (high p/b) and the individual has neurotic personality traits (in the sense of the 'big 5', here high ϕ and low δ_0). We argue that this can provide a novel and testable view of violent behaviour.

4.1 The dynamics of stress in the absence of surprises

The results and predictions in this section can be obtained from a model without surprises. We return to surprises in the next section. In a world without surprises, stress follows

$$\frac{dW(t)}{dt} \equiv \dot{W}(t) = \Phi W(t) - \delta_1 m \quad \text{for} \quad 0 \leq W(t) \leq \bar{W}, \tag{15a}$$

$$dW(t) = \{\Phi\ W(t) - \delta_1 m\ \}\, dt - \Delta(t)\, dq_\Delta(t) \quad \text{for} \quad \bar{W} < W(t) < W^s, \tag{15b}$$

$$dW(t) = \{\Phi^s W(t) - \delta_1 m^s\}\, dt - \Delta(t)\, dq_\Delta(t) \quad \text{for} \quad W^s \leq W(t), \tag{15c}$$

[39] For a risk-averse individual (and appropriate functional forms), a closed-form solution exists which implies coping levels that linearly rise in stress. The value function is then conave in stress.

where coping intensities m and m^s in (15) are the optimally chosen levels from (14). As long as stress is below the tolerance level, $W(t) < \bar{W}$, stress evolves in a deterministic fashion as in (15a). Whenever stress exceeds the tolerance level $\bar{W}$, outbursts occur at rate $\bar{\lambda}^{\Delta}$ from (7).

To understand the dynamics of stress, we start by setting $\dot{W}(t) = 0$ in (15a) and find a steady state for $\Phi \neq 0$ at

$$W^* = \frac{\delta_1 m}{\Phi}. \tag{16}$$

This value can be positive or negative and, more importantly, the steady state can be stable or unstable. When Φ from (13) is positive, W^* is positive as well. When we plot the time derivative $\dot{W}(t)$ in fig. 1 with intercept $-\delta_1 m < 0$ for this case, we see that W^* is unstable. In this figure, the horizontal axis plots the tension level $W(t)$ while the vertical axis shows its change over time. Obviously, the threshold level W^* might be larger than $\bar{W}$.

For a stress level of zero, stress would fall from (15a) by $\dot{W}(t) = -\delta_1 m$. As stress cannot become negative by construction, the point $(0, -\delta_1 m)$ is a stable steady state. Any small disturbance to emotional tension would always bring the individual back to this steady state. The figures also displays the case of a negative growth rate Φ of stress. The sign of the corresponding steady state would be negative. The intercept differs from one Φ to another as both the intercept, via (14a), and the slope, via (13), are a function of p.

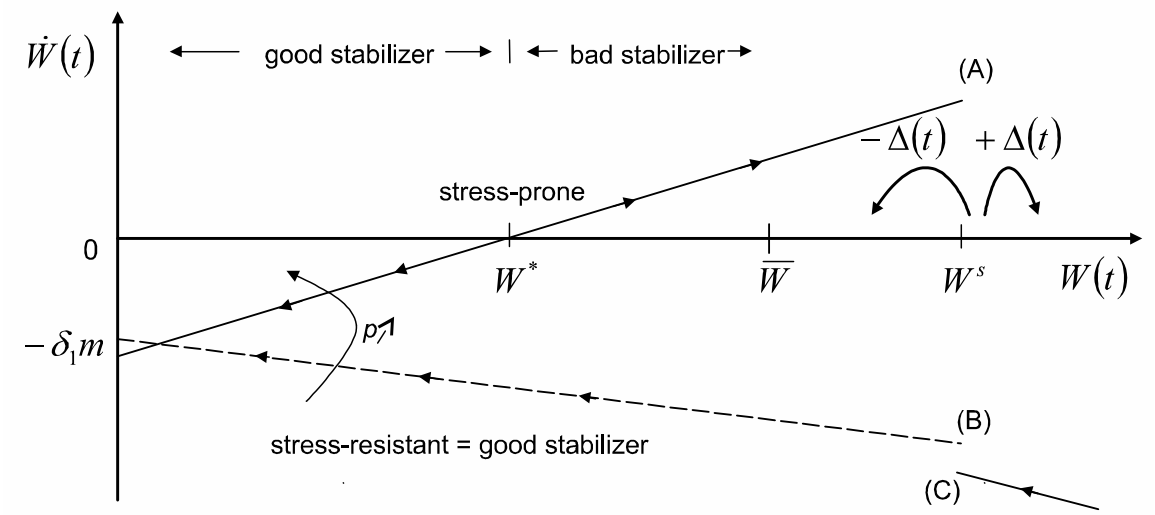

Figure 1 *The phase diagram for stress $W(t)$ in the absence of surprises*

4.2 Theory-consistent personality types

Before continuing, we introduce two concepts: stress-prone and stress-resistant individuals on the one hand and good and bad stabilizers on the other. The idea behind these four definitions is to distinguish between individuals per se (stress-prone or resistant) and between individuals conditional on a given stress level.

Definition 1 *An individual that* $\left\{ \begin{array}{c} \textit{potentially} \\ \textit{never} \end{array} \right\}$ *displays outbursts is called* $\left\{ \begin{array}{c} \textit{stress-prone} \\ \textit{stress-resistant} \end{array} \right\}$. *An individual whose stress level* $\left\{ \begin{array}{c} \textit{is} \\ \textit{is not} \end{array} \right\}$ *converging to a level implying outbursts is called a* $\left\{ \begin{array}{c} \textit{bad} \\ \textit{good} \end{array} \right\}$ *stabilizer.*

The intuition behind this definition becomes clear when we return to fig. 1. An example for a stress-prone individual is provided by the line going through the threshold level W^* from

(16). If the current tension level is slightly below W^*, the stress level falls over time. Above the threshold level W^*, the stress level rises. Hence, a stress-prone individual is characterized by personal abilities b, personality characteristics ϕ and stress processing abilities δ_0 such that for the given level of demands p, the future evolution of tension crucially depends on the current tension level. If the individual is relatively calm (the current W is below the threshold W^*), the individual smoothly reduces tension by consciously chosen smooth coping m and by the autonomous process captured by δ_0. If this individual happens to have a high current stress level above the threshold W^*, stress will continue to rise over time. The individual is doomed to exceed the tolerance level $\bar{W}$ where an emotional outburst will eventually occur.

For such an individual one can predict the occurrence of an outburst for any given tension level. As an example, imagine a person working in a team and a colleague notorious for occasional outbursts. If the person has the feeling that the colleague's tension level lies above the threshold W^*, the person should make sure not to see the colleague too often during the day. Otherwise the person might be hit by an outburst. The speed with which an individual's stress level changes is an exponential function of time $\tau > t$ and described by the solution to (15a),

$$W(\tau) = (W(t) - W^*)\, e^{\Phi[\tau - t]} + W^*. \tag{17}$$

The growth rate of stress Φ displayed in this equation and defined in (13) has an interesting interpretation: Current requirements p and ability b translate into stress accumulation as a function of personality characteristic ϕ, measuring how strongly p/b affects the individual psychologically. At the same time, however, the individual is characterized by an autonomous stress reduction process whose speed is driven by δ_0. If the individual "takes things to heart", i.e. has a high ϕ and at the same time is not good at digesting stress autonomously, i.e. δ_0 is low, stress levels change very quickly.

Figure 1 also displays a stress-resistant individual. By definition, they always experience falling stress levels. Stress-resistant individuals are therefore good stabilizers. The figure further shows the dynamics of stress once the (either stress-prone or stress-resistant) individual quit working, i.e. when $W(t) > W^s$. As the work environment provides a lot of stressors for most individuals, we set p to a low value p^s, as discussed after (4), such that Φ^s is negative. The growth rate of stress for either stress-prone or stress-resistant individual therefore drops from (A) and (B), respectively, to (C) at W^s (as visible from the deterministic parts of (15a) and (15b) joint with (14)).

4.3 The outburst theorem

Let us now turn to the question under which conditions emotional outbursts will take place. The question about outbursts is at the same time the question about the optimal choice of stress-reduction technologies. In psychology, Gross (2008) in a survey article on how individuals "try to influence which emotions we have, when we have them, and how we experience and express these emotions" (p. 497) writes that "one intriguing puzzle is why people use one emotion regulation strategy rather than another" (p. 505). Seeing stress as an emotion, our findings on the occurrence of outbursts and the determinants of smooth coping provide some answers.

By construction, emotional outbursts can take place when the stress level exceeds the tolerance level $\bar{W}$. Apart from bad surprises, this can happen only for bad stabilizers. The question is therefore under which conditions an individual turns, first, into a stress-prone individual and, then, into a bad stabilizer. We characterize an individual by preference and cost parameters $(v, \alpha, \rho, v_0, \zeta)$, fixed personality traits $(\phi, b, \delta_0, \delta_1, \kappa, \bar{W}, \mu^{\Delta})$, by the situation (p, w) and by the current tension level $W(t)$. We find

Proposition 2 *(Outburst theorem) An individual is*

(i) stress-prone if and only if her growth rate Φ *of stress is larger than* Φ^**, where* Φ^* *is defined by*

$$\Phi^* \equiv \frac{\delta_1 m}{\bar{W}}. \tag{18}$$

(ii) The individual turns into a bad stabilizer when $\Phi > \Phi^*$ *and the current stress level* $W(t)$ *is larger than* W^**. This is the case for*

$$\Phi > \frac{\delta_1 m}{W(t)}. \tag{19}$$

Proof. See app. A.2 ■

The proof can be understood intuitively most easily by looking at fig. 1. (i) The time derivative $\dot{W}(t)$ for $\Phi = \Phi^*$ is a straight line that starts at $(0, -\delta_1 m)$ and ends at $\left(\bar{W}, 0\right)$. Such an individual would never display outbursts. For the individual to eventually display outbursts, Φ must exceed Φ^*. (ii) When we look at an individual with a given stress level $W(t)$, the growth rate Φ of stress must be sufficiently large such that W^* is smaller than $W(t)$. In this case, the individual is a bad stabilizer.

The insights of the proposition are illustrated in fig. 2. The horizontal axis plots the individual's autonomous stress reduction ability δ_0. The vertical axis plots $\phi \frac{p}{b}$ as these parameters occur jointly only. Part (i) of the proposition in the form of $\Phi = \Phi^*$ is depicted as the thick solid line. This line separates stress-prone individuals above this line from stress-resistant individuals on or below the line. When $\Phi > \Phi^*$, the individual lies above the thick solid line.

Whether a stress-prone individual displays outbursts depends on the current stress level. When we fix the stress level $W(t)$ and ask which type of individual would display outbursts in finite time (with probability one), then we require (19) to hold. All individuals with $\phi p/b$ sufficiently high such that (19) holds will display outbursts.

When we ask under which conditions outbursts do not occur, i.e. when an individual lies below the thick solid line, then we find two reasons. First, an individual is stress resistant per se, i.e. even when coping measures are absent ($m = 0$). This is the case for a non-positive growth rate of stress, $\Phi \leq 0$. Or an individual is stress-resistant due to a sufficiently high level of smooth coping measures. These individuals are characterized by a positive growth rate of stress, $\Phi > 0$. But this rate is so low, given the negative intercept $-\delta_1 m$, that the threshold level W^* lies to the right of (or just at) $\bar{W}$. Outbursts therefore never occur (in the absence of negative surprises).

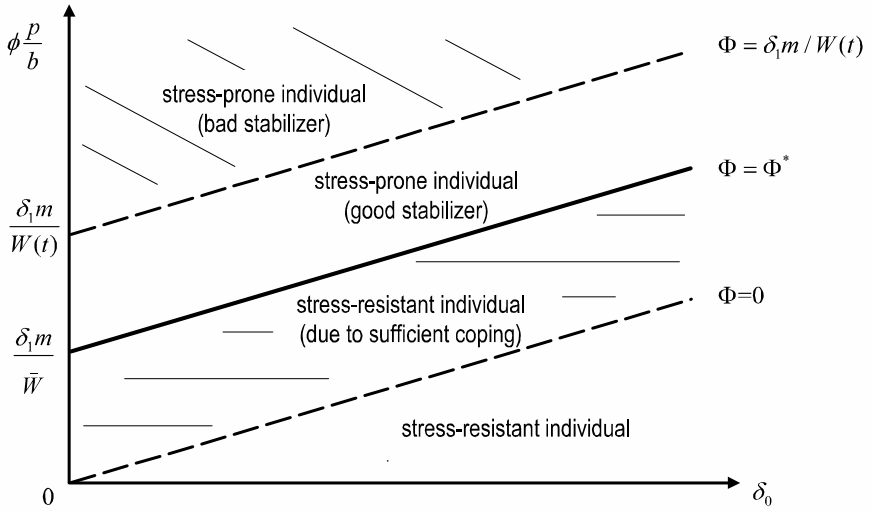

Figure 2 *Stress-resistant and stress-prone individuals and regions of bad stabilizers implying emotional outbursts*

This figures nicely allows us to summarize conditions for being stress-resistant and stress-prone in the following

Corollary 2 *(Determinants of emotional outbursts)*
For a given autonomous stress-reduction potential δ_0,
(a) an individual will be (unconditionally) stress-resistant if $\phi p/b$ *is sufficiently low.*
(b) an individual will be stress-resistant if coping activities are sufficiently high or the tolerance level $\bar{W}$ *is sufficiently* low*.*
(c) a given coping level m *and a given tolerance level* $\bar{W}$*, an individual will be stress-prone if* $\phi p/b$ *is too high.*
(d) an individual is a bad stabilizer if $\phi p/b$ *rises further.*

We see from the above findings that, taking a situation p and an individual's ability b as fixed, personality is crucial. The appraisal parameter ϕ and stress reduction abilities δ_0 determine whether an individual is stress-resistant or stress-prone. How one looks at the world, i.e. how an individual perceives and evaluates stressors is crucial for determining whether the individual will display emotional outbursts or not. If ϕ is sufficiently small (however large the intensity of stressors), the individual will remain calm and not display outbursts. Similarly for the autonomous stress reduction ability δ_0, when we fix $\phi p/b$ and move horizontally through the figure. If δ_0 is only sufficiently high, an individual will not display outbursts.

What is the role of controlled coping m? For a given set of parameters (other than those fixing m), any parameter that increases m reduces the risk of an outburst. Trying to reduce one's tension level e.g. by talking through stressors and their implications for one's well-being should help. One can even say more: For a given set of parameters and a given tension level $W(t)$, there is a coping intensity m that makes sure that outbursts can be avoided.

Individuals regularly employ stress-managing techniques as reported in section 2 from "The Burden of Stress in the US". Examples range from spending time with friends or outdoors to getting professional help. Stress-resistant individuals (the white area in fig. 2) should not report any coping measures. At least, coping measures are not needed (even though they might be optimal) for them to end up with a stress level of zero. Good stabilizers should report stress-managing activities as well as bad stabilizers. The 'conflict tactics scale' by Straus et al. (1996) includes measures that allow to identify outbursts such as insulting, swearing or shouting. Stets (1990) reports that verbal aggression plays a role for 75% of couples (and physical aggression for 10%). This behaviour should be reported by bad stabilizers (the top area in fig. 2).

4.4 An alternative approach to understanding violence

One fundamental assumption of our model states that uncontrolled and spontaneous acts, emotional outbursts here, occur when the stress level of an individual exceeds a certain threshold level (the tolerance level $\bar{W}$). This view opens an avenue for understanding the occurrence of violence in a manner different from existing models in economics.

Card and Dahl (2011) in their study of family violence and football argue that violent behaviour can be the outcome of utility maximizing behaviour or e.g. of arguments that escalate *out of control*. There are economic models where violence is enjoyed by the perpetrator (see e.g. the unitary family model in Tur-Prats, 2015) or comes at a cost but serves as an instrument (to signal marriage dissatisfaction) as in Bloch and Rao (2002). Violence is also costly in the intergroup conflict analysis of Mitra and Ray (2014) but the potential payoff rises in the victim's income. In these papers (and in other violence papers cited therein), violence is a rational choice.

While a full model of violent behaviour based on high levels of stress still needs to be worked out, the empirical claims to be studied are: (i) Violent crimes occur when perpetrators are at

high levels of emotional arousal. (ii) High arousal is the result of a lot of stressors p and neurotic personality traits (low δ_0 and high ϕ).

5 Stress, productivity and income

Having understood stress and coping dynamics and the determinants of emotional outbursts, we now turn to economic findings. We first suggest a distinction between *pure* stressors (they increase stress and thereby reduce income) and *productive* stressors (they also increase stress but income might nevertheless increase). This provides novel insights into the income effects of stressors and suggests further empirical strategies extending the findings of Hamermesh and Lee (2007) or Goh et al. (2016). We then explain why stress strongly increases once income of an individual rises above a certain threshold level. We thereby explain the empirical finding of Kahneman and Deaton (2010). We also show, however, that income thresholds leading to rising stress levels crucially depend on individual characteristics – suggesting a wide variation of income thresholds. These findings are based on the complete model in (12) with coping levels coming from (14).

5.1 Pure stressors, productive stressors and income

- Linking stressors to income

The specification of labour supply in the discussion before the budget constraint (3) introduced a new determinant of income: effective labour supply $l(a(t))$ being a function of attention $a(t)$, which in turn falls in the stress level of an individual. Further empirically relevant determinants for income in (3) are effort e on the job and educational levels $\tilde{h}$. Effective labour supply is empirically proxied by measures of stress (e.g. self-reported, cortisol level in saliva or physiological measures), effort corresponds to hours worked (taking ideally lunch breaks, chats with colleagues, surfing on the internet etc. into account) and $\tilde{h}$ are years of schooling or quality of highest educational degree.

To provide a better foundation and to study the income effect of stress further, consider a production function $y = y(K, L)$ requiring capital K and L efficiency units of labour. Labour is provided by N workers and amounts to $L \equiv \Sigma_{i=1}^{N} l(a_i(t)) e_i \tilde{h}_i$. This provides an extension to standard production functions to also allow for the attention-reducing effect of stress via $l(a_i(t))$. A firm chooses the capital stock and efficiency units of labour yielding standard first order conditions. Under perfect competition, the wage per efficiency unit would be given by marginal productivity, $\tilde{w} \equiv \partial Y(.)/\partial L$. Defining $w \equiv \tilde{w}\tilde{h}$, income of a worker is given by

$$\text{inc}(t) \equiv \tilde{w} l(a(t)) e\tilde{h} = w[M - \kappa W(t)] e. \tag{20}$$

Income is given by the wage $\tilde{w}$ times individual productivity $l(a(t)) e\tilde{h}$.[40] Income here is identical to income in (3), only that now we have a competitive foundation and can study the effects of human capital and firm characteristics. This equation implies

Corollary 3 *Ceteris paribus, stress $W(t)$ reduces income.*

We now endogenize effort e on the job by suggesting a link to stressors p. Stressors p can be split into stressors on the job and private stressors. Stressors on the job, which we see as

[40] Obvious generalizations of the multiplicative structure $\tilde{w} l(a) e\tilde{h}$ to e.g. a Cobb-Douglas form joint with logs would yield a standard wage regression where firm effects are in $\tilde{w}$. The new explanatory variable in the regression would be stress.

demand driven, induce effort e by workers as their labour supply response. If workers minimize effort, effort is identical to job stressors. As effort e increases individual productivity, we call stressors on the job productive stressors. Private stressors do not have any productive nature. We call them pure stressors p^{pure} and obtain[41]

$$p = e + p^{\text{pure}}. \tag{21}$$

Unfortunately, the effect of pure and productive stressors on stress $W(t)$ cannot be computed as $W(t)$ is stochastic. When we replace actual stress $W(t)$ by the expected value of stress, $\tilde{\Psi}(t) \equiv E_0 W(t)$ and we also compute expected income from (20) as

$$E_0 \text{inc}(t) = w\left[M - \kappa\tilde{\Psi}(t)\right] e, \tag{22}$$

we can study the effect of different stressor types on expected stress and expected income.[42] We obtain

Result 1 *(i) Pure stressors p^{pure} cause stress and reduce expected income. (ii) Productive stressors e have an ambiguous effect on income.*

Note that part (i) provides more information than cor. 3 which presents a ceteris paribus property about stress. Part (i) of this result describes a causal link from pure stressors to expected income.[43] Part (ii) is also intuitively clear from (22): When effort e increases, this has a direct positive effect on average income. It has an indirect negative impact on average income if effort increases average stress $\tilde{\Psi}(t)$. Both channels are illustrated in fig. 3.

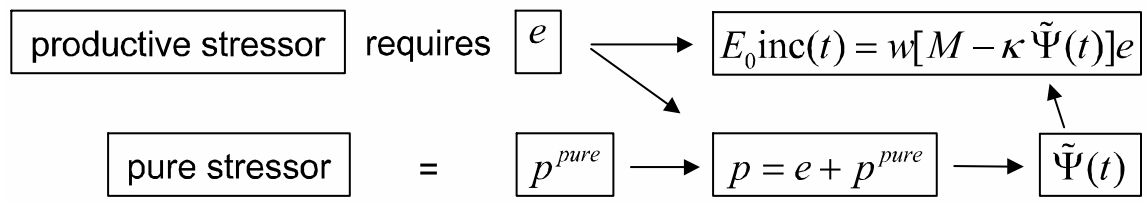

Figure 3 *Productive and pure stressors, average stress and average income*

- Empirical relevance

When we return to empirical estimates of the health costs of stress (e.g. Goh et al., 2016), our framework provides a rationale for "weaker" and "stronger forms" of negative health effects of stress. Weaker would stand for health implications of stress that do allow the individual to continue to work, i.e. $W(t) < W^s$. Our model offers the interpretation that stressors p imply stress $W(t)$ which reduces attention on the job. Individual productivity goes down and output is reduced. The stronger forms are those where stress exceeds the sickness level, $W(t) > W^s$. This stands for more severe health effects. If we want to understand health findings of Goh et al. (2016) in the strict sense of our model, we would have to posit that all stressors in their study are pure stressors. These stressors cause stress and have detrimental effects on income and health.

Maybe more importantly, however, our model offers a second channel through which workplace stressors can actually *increase* output and income. If stress $W(t)$ results from effort e on

[41] Of course pure stressors can also originate in the workplace. They would then have to be added to p^{pure}.

[42] The empircal counterparts to these expectations would be averages. We therefore use expected and average interchangeably in what follows.

[43] Section 5.3 provides a formal background to the results in this section.

the job, there is a trade-off between more output due to more effort and more stress due to this very effort. Candidates for productive stressors from Goh et al. (2016) are 'long working hours' or 'high job demand'. Future empirical analysis could therefore try to distinguish between "pure" and "productive" stressors.

- The effect of stressors on stress and income

To provide a full picture of the effect of productive stressors, we simulate the dynamics of stress following (12) with (14). We compute $\tilde{\Psi}(t)$ as defined for (22) and expected income from (22). Figure 4 plots stressors p on the horizontal axis and average stress and average income on the vertical axes. An increase in p is understood as originating from productive stressors on the job, i.e. causing a rise in effort e.[44]

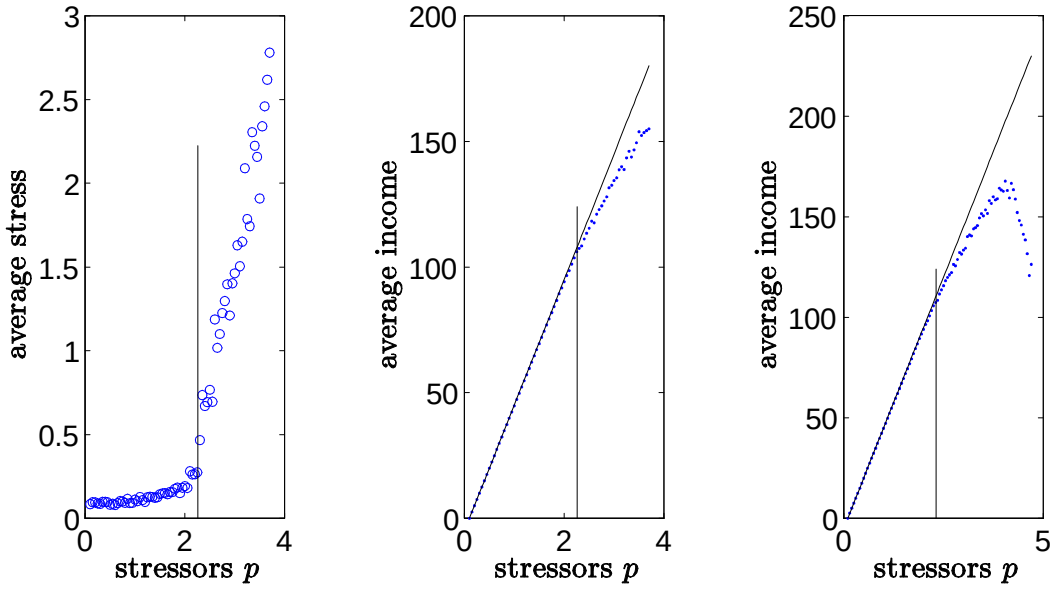

Figure 4 *The effect of productive stressors on expected stress* $\tilde{\Psi}(t)$ *(left panel), on expected income* $E_0 inc(t)$ *for low* κ *(middle panel) and on income for high* κ *(right panel)*

When stressors p increase, $\tilde{\Psi}(t)$ is initially unaffected as visible on the left. As soon as stressors p are close to some threshold level p^{**} (the vertical line in the figure), the average stress level $\tilde{\Psi}(t)$ rises quickly. Below the threshold level, income in the middle figure rises linearly in effort e as visible in (22). This linear growth of income in p at unchanged stress level $\tilde{\Psi}(t)$ is shown by the line starting in the origin in the middle (and right) figure. Beyond the threshold level p^{**}, income growth is reduced such that income lies below this line, as summarized in

Result 2 *Stress is hardly affected by stressors for* $p < p^{**}$ *but rises quickly thereafter. Income increases linearly in productive stressors* p *for* $p < p^{**}$*. For larger stress levels, expected income grows under-proportionally in* p*.*

The income effect of stressors beyond p^{**} is summarized in

Result 3 *When the effect of more stress* $W(t)$ *on cognitive load is relatively low, i.e. when* κ *from (3) is small, more productive stressors do lead to more income also for* $p > p^{**}$*. When the cognitive load effect of more stress is high (*κ *closer to 1) more stressors eventually lead to a fall in income.*

[44] Private stressors p^{priv} are therefore held constant. The matlab code is available upon request.

The latter case is visible in the right panel of fig. 4. The stress effect of stressors is so large that the positive productivity effect on income is eventually overcompensated by the negative stress effect.

5.2 Income and stress

It has long been claimed that money cannot buy happiness. As has been emphasized by Kahneman and Deaton (2010), such a claim can be discussed in any meaningful way only when a distinction is drawn between two types of subjective well-being: emotional well-being (also called hedonic well-being or experienced happiness) and life evaluation. Kahneman et al. (2006) suggest reasons that higher annual income does not necessarily increase subjective well-being. First, relative income might matter instead of absolute income, second, individuals might get used to material goods. Most importantly for our study of stress, they argue that individuals overestimate the effect of income (a 'focusing illusion') as they believe that higher income allows for more pleasurable activities but in reality higher income individuals spend more time at work and in commuting. Kahneman and Deaton (2010, fig. 1) find that an increase of annual family income beyond approx. 75,000 US$ does *not* lead to an increase of positive affect, does *not* lead to an increase of feeling 'not blue' and, most important for our comparison, actually does lead to a *decline* of the number of 'stress free' hours.[45]

To understand why individuals report highest levels of the feeling 'stress free' at 75,000 US$, we now relate income to average stress levels. We can obviously not undertake comparative statics with respect to income or stress as both variables are endogenous. As both are a function of effort e, the causal third factor we propose for this correlation is the number of stressors, i.e. demands on the job. The slope of stress with respect to income is therefore given by the ratio of the derivatives of average stress $\tilde{\Psi}(t;e)$ and income $E_0\text{inc}(t;e)$ with respect to stressors e,

$$\frac{d\tilde{\Psi}(t;e)}{dE_0\text{inc}(t;e)} = \frac{\partial\tilde{\Psi}(t;e)/\partial e}{\partial E_0\text{inc}(t;e)/\partial e}.$$

As long as stress does not change ($\partial\tilde{\Psi}(t;e)/\partial e = 0$), a rise in income does not imply an increase in stress. When more stressors do lead to more average stress, however (and as long as income rises in stressors), more income is associated with more average stress. This is indeed what fig. 5 shows.

The left panel of fig. 5 is a scatter plot of the middle panel and the left panel of fig. 4. More income has hardly any effect on the average stress level below the threshold level. Once beyond, income still rises in stressors, but stress increases strongly. More income comes at a high individual price.[46] The theoretically counterpart for the 'Stress free' measure in the Deaton Kahneman (2010) figure is $\bar{W} - \tilde{\Psi}$, plotted in the right panel of fig. 5. Times without stress remain basically unchanged when income rises up to the threshold level. Once income rises beyond this level, the share of hours without stress falls dramatically.

[45] This seems to be the big difference of their findings to Hamermesh and Lee (2007). The latter report a monotonic relationship of the form that "additional market work does generate more time stress, additional earnings, holding hours of market and home work fixed, also increase time stress" (p.382). Kahneman and Deaton (2010) emphasize the non-monotonicity: positive affect or stress-free time first rises and then falls in income.

[46] This reminds of the Peter-principle where individuals are promoted up to the point where demands are beyond their competence.

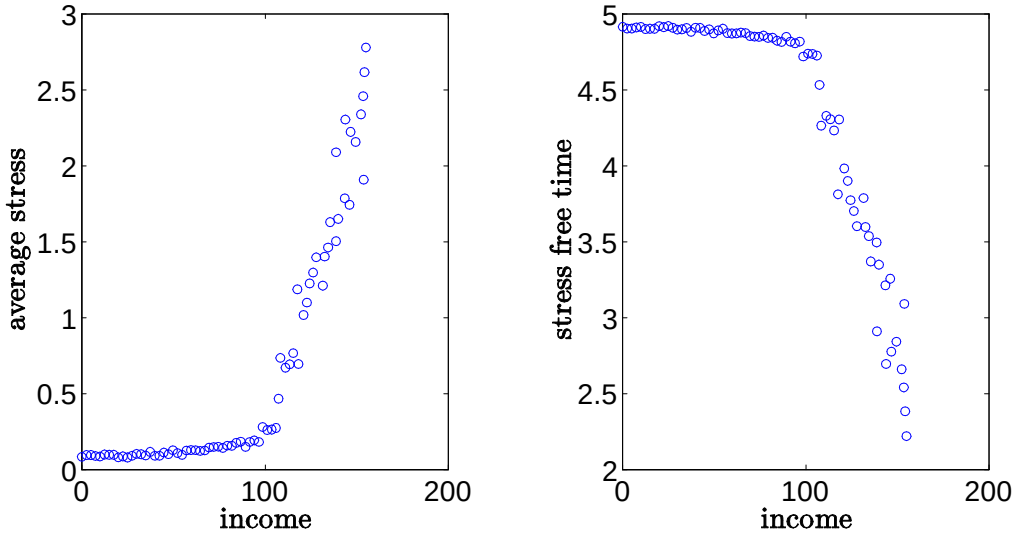

Figure 5 *Income* $E_0 inc(t)$ *and mean stress* $\tilde{\Psi}(t)$ *(left panel) and stress-free time* $\bar{W} - \tilde{\Psi}(t)$ *(right panel)*

5.3 Understanding income and stress effects

We now provide a more formal explanation for the results and findings in figures 4 and 5.

- The expected change of stress

In our model with surprises, stress levels no longer evolve in some deterministically predictable way, even when stress is below the tolerance level $\bar{W}$. To understand the effect of uncertainty resulting from surprises and outbursts, we can, however, easily describe the expected instantaneous change of stress. Its dynamics is again deterministic (see app. A.3),

$$\frac{E_t dW(t)}{dt} = \left\{ \begin{array}{c} \Phi\ W(t) - \Omega \\ \Phi\ W(t) - \Omega - \bar{\lambda}^{\Delta}\mu^{\Delta} \\ \Phi^s W(t) - \Omega^s - \bar{\lambda}^{\Delta}\mu^{\Delta} \end{array} \right\} \text{ for } \left\{ \begin{array}{c} 0 < W(t) \leq \bar{W} \\ \bar{W} < W(t) < W^s \\ W^s \leq W(t) \end{array} \right. , \tag{23}$$

where $\Omega \equiv \delta_1 m + \lambda^g \chi \left[\mu^h - \mu\right]$ and $\Omega^s \equiv \delta_1 m^s + \lambda^g \chi \left[\mu^h - \mu\right]$. Intuitively speaking, it can be derived by simply applying the expectations operator to both sides of (12). The expectation applies both to the occurrence, captured by the arrival rates, and to the size of an outburst or a surprise. This differential equation describes the expected change of stress in t when the current stress level is $W(t)$. Surprises increase the expected change of stress if $\mu^h - \mu$ is negative as negative surprises increase the stress level. If individuals are very sceptical about rare events, i.e. if the subjective expectation μ is low and therefore $\mu^h - \mu$ is positive, surprises decrease the expected change. For stress-prone individuals, there is a steady state at $W^{**} = \Omega/\Phi$, in analogy to (16). This equation strongly reminds of equation (15a), determining the evolution of stress in the absence of surprises – only that the intercept Ω now also takes expected surprises into account.

A parallel can also be drawn between the evolution of expected stress $\Psi(t)$ and the evolution of stress $W(t)$ in fig. 1 when using a (slightly modified) concept of stress-prone and stress-resistant individuals for this world with surprises: An individuals is called stress-resistant when the expected change in stress is negative. This is the case for $\Phi < \Phi^{**}$, where

$$\Phi^{**} \equiv \frac{\Omega}{\bar{W}} \tag{24}$$

is – in analogy to (18) in the outburst theorem – the growth rate of (expected) stress such that expected stress falls for all levels of stress.[47] Examples for stress-prone (denoted by $\Phi > 0$ in fig. 6) and stress-resistant individuals ($\Phi < 0$) are drawn in the following figure.

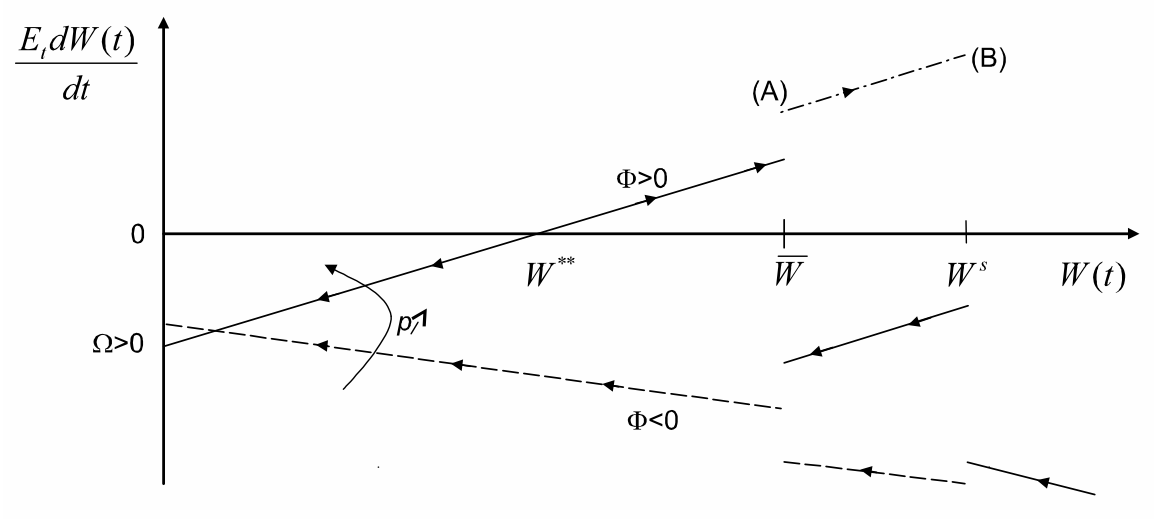

Figure 6 *The expected change of stress for a stress-resistant individual (dashed line) and a stress-prone individual (solid line)*

Outbursts can also have a decreasing or increasing effect on the dynamics of stress. If outbursts on average decrease stress ($\mu^{\Delta} > 0$), the time derivative of expected stress drops at $\bar{W}$. This is the case depicted in fig. 6 both for the solid line of a stress-prone individual and the dashed line of a stress-resistant individual. If outbursts increase stress ($\mu^{\Delta} < 0$), expected stress would increase faster in the range above $\bar{W}$ than below. This is also shown in this figure for the stress-prone individual as the dotted line from (A) to (B). Should the stress level exceed W^s, expected stress falls for the same reasons as discussed after (4).

We summarize the essential dynamics of the expected change of stress in the following

Corollary 4 *(i) When outbursts reduce stress on average, $\mu^{\Delta} > 0$ and the growth rate of stress is sufficiently low, i.e. $\Phi < \Phi^{**}$, the expected change of stress is negative over the entire range $W(t) > 0$.*
(ii) When the individual's growth rate of stress is given by $\Phi > \Phi^{**}$ and outbursts reduce stress on average by sufficiently much, $\bar{\lambda}^{\Delta}\mu^{\Delta} > \Phi W^s - \Omega$, the stress is expected to fall for all values $0 < W(t) < W^{**}$. For values above W^{**}, the stress is expected to rise.
(iii) When $\Phi > \Phi^{**}$ and outbursts even increase stress ($\mu^{\Delta} > 0$), the expected change of stress would be positive below W^s and negative above W^s.

Case (i) is illustrated by the dashed line of the stress-resistant individual. Case (ii) describes a stress-prone individual that stabilizes stress due to outbursts at $\bar{W}$. In case (iii), outbursts increase stress (and the individual is stress-prone) and stress stabilizes at W^s.

- The mechanism behind positive or negative income effects of more stressors

We can now understand the results illustrated in figures 4 and 5. The threshold level p^{**} in these figures is the level of stressors p such that $\Phi = \Phi^{**}$ from (24). When stressors and the growth rate of stress are small, $\Phi < \Phi^{**}$, any increase in stressors does not affect average stress:

[47] In addition to $\Phi \gtrless \Phi^{**}$, we should also study $\Omega \gtrless 0$. We restrict our attention to $\Omega > 0$ as this is the most plausible assumption, even in the presence of overconfidence (see app. A.3 for more discussion).

As long as the individual is stress-resistant, additional stressors do increase the growth rate of stress. Yet, coping strategies and the automatic stress-reduction ability keeps the stress level "under control", i.e. stress levels tend to fall, as visible in fig. 6. This is why an increase in (productive) stressors does increase income. Individuals perform more tasks on the job, accept more responsibilities without - on average - experiencing a rise in their stress level. Their attention on the job hardly falls and the increase in effort leads to higher productivity and thereby income.

When the growth rate of stress rises beyond p^{**} due to more and more stressors, surprises occasionally push stress above W^{**}. As $\Phi > \Phi^{**}$, expected stress now rises beyond W^{**} and converges towards $\bar{W}$. It is this level p^{**} of stressors where individuals turn from stress-resistant to stress-prone individuals and where more income implies a strong increase in stress. Average stress levels move quickly from around zero to $\bar{W}$. More productive stressors still increase productivity of the worker, but the average stress level that increases at the same time reduces attention and thereby productivity at work.

5.4 High income without stress

It would be a simplistic view of income if it only resulted from increasing effort by performing more tasks at work. Human capital determined by educational background and experience clearly also plays a role. A worker with higher $\tilde{h}$ has a higher marginal productivity at the same level of effort e. Put differently, the threshold level above which more income reduces stress-free time depends on an individual's human capital. The higher $\tilde{h}$, the higher the threshold level. The ability b of an individual to cope with stressors also rises the threshold level as does the autonomous stress-reduction potential δ_0.

The same is true for a higher capital stock or higher total factor productivity. In these cases, w would go up and thereby income. Stress would mildly reduce as higher income provides more incentives to undertake coping measures as visible in (14a). On the downside, when pure stressors p^{pure} increase, income falls due to more stress. We summarize these findings in the following

Corollary 5 *Income rises and stress mildly falls when (i) an individual has a higher human capital level $\tilde{h}$ or (ii) the capital stock or total factor productivity in the economy rise. (iii) Income rises and stress-free time rises in productive stressors when low income is a pure stressor. (iv) A reduction in pure stressors reduces stress and raises income.*

A divergence from the Kahneman-Deaton finding lies in the independence of stress on income below the threshold level. Deaton and Kahneman find that stress reduces and stress-free time rises when individual rises. This would be true in our setup as well if we followed the findings of Mani et al. (2013) or Mullainathan and Shafir (2013) and made pure stressors p^{pure} a decreasing function of income. More income always relaxes budget constraints and makes trade-offs less difficult. This would add a positive effect of becoming richer to our framework. Yet, the basic conclusion that income creates stress as soon as additional stressors make the individual stress-prone would remain valid.

6 Further applications

The above model can be used to gain a lot of further insights related to stress and stress reduction. We can understand the positive effects of holidays or weekends, provide a first step towards a "theory of therapy", use this framework to structurally estimate personality parameters and we can think about new experimental setups to clarify the stress and anger effects of catharsis.

6.1 The persistence of temporary events

It has been documented repeatedly that individual's perception of stress reduces over weekends (Harter and Arora, 2008, Kahneman and Deaton, 2010). We now show under which conditions temporary stressors have permanent effects and then relate these findings to the weekend effect, to the effect of an inpatient clinic treatment or to taking holidays.

6.1.1 Temporary stressors and permanent stress?

The impact of a surprise as a temporary stressor can be best understood when we again distinguish between stress-resistant and stress-prone individuals, here as defined by (24). Fig. 7 shows the evolution of stress for a given realization of surprises for both types of individuals.

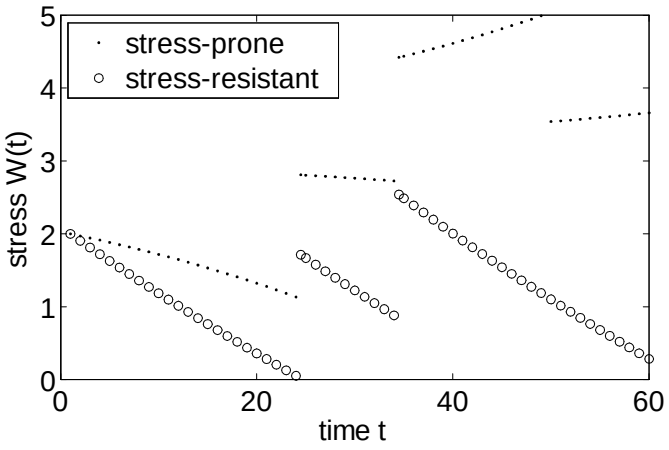

Figure 7 *Time series for a stress-resistant a stress-prone individual under identical surprises*

We assume that both individuals are good stabilizers to start with. As a consequence, their tension levels fall. Now we allow for a negative surprise after a day, i.e. at $t = 24$, meaning that $h(t) - \mu < 0$. As a consequence, stress of both goes up by the same amount given by $dW(t) = \chi[h(t) - \mu]$ from (12) with $dq_g(t) = 1$ and $dt = 0$ (meaning the jump is instantaneous). We assume that the increase in stress is not enough to push the stress-prone individual above the threshold level W^*. Both individuals therefore continue reducing their stress level thereafter. When the next surprise comes early (the stress level is still high) or the negative surprise is stronger, stress levels of both individuals will be pushed up to an even higher level than before. This takes place at $t = 36$ in our figure.

The subsequent evolution of stress for the stress-prone and the stress-resistant individual are now different. The stress-prone individual experiences a rise in stress while the stress level of the stress-resistant individual goes down. An identical history of surprises leads to an almost identical history of stress up to the point where stress crosses the threshold level W^* for the stress-prone individual. As of this level, the stress-prone individual is a bad stabilizers and is heading towards an emotional outburst. The outburst takes place in this example at $t \approx 48$. The stress-resistant individual's stress level keeps falling over time.

While fig. 7 just illustrates one possible realization for surprises and the evolution of stress for stress-resistant and stress-prone individuals, this example points to a more general finding.

Proposition 3 *A temporary surprise only temporarily changes the stress level of an individual if the individual is stress resistant. A temporary surprise will have a permanent effect on an individuals stress level if (i) the individual is stress prone and (ii) if the temporary surprise pushes the individual's stress level above or below the threshold level W^*.*

Clearly, a temporary surprise for a stress prone individual can make changes towards the good or the bad. A positive surprise can push the individual from outburst cycles to an evolution of stress that eventually leads to being fully relaxed. In the bad case, a negative surprise would lift the individual above W^* and frequently recurring outbursts would result.

6.1.2 Poverty alleviation and the weekend-effect

This finding helps to inform further empirical work e.g. on the effect of poverty alleviation on psychological well-being. Haushofer and Fehr (2014, p. 866) conclude that "little is known about whether poverty alleviation leads to a permanent or only temporary increase in psychological well-being". Our theoretical analysis suggests that it depends on (i) how strong a positive surprise (through poverty alleviation) is and on (ii) the personality of a person.

A further regularity on stress can naturally be understood with our model. The weekend effect says that feelings of stress fall over the weekend (see Harter and Arora, 2008 or Kahneman and Deaton, 2010). It naturally occurs in our framework when daily hassles are set to zero for a certain amount of time and reset to normal thereafter. Looking at fig. 1 immediately makes clear that zero stressors ($p = 0$) turn any individual into a stress-resistant individual. Stress goes down over the weekend. When individuals are stress-prone during the week and negative surprises occur, stress would rise during the week.

The importance to distinguish between stress-resistant and stress-prone individuals suggests, however, that future empirical analysis should try to identify these types of individuals. Individuals that react more strongly to stressors (e.g. via a higher ϕ) or for whom stress is harder to "digest" (a higher δ_0) should – at identical changes of stressors between the week and weekends – display stronger stress cycles than individuals who are stress-resistant.[48]

6.2 The gains from psychotherapy

What can individuals do against undesirable stress reactions apart from choosing emotion-regulation strategies? If coping does not help, one would need more professional help e.g. from a therapist. What this means in terms of our setup will now be discussed in first steps towards a "theory of therapy". These steps departs from one of the most fundamental building blocks in economics and also from (parts of) personality psychology. By contrast, this application is very much in line with clinical psychology and therapy studies more generally speaking.

We ask what would happen if individuals could change their tastes and attitudes. There are powerful arguments in economics that tastes should be regarded as stable and maybe even identical across individuals (Stigler and Becker, 1977). By contrast, more modern views argue that preferences are influenced by social circumstances (Fehr and Hoff, 2011) and are therefore endogenous. Personality psychologists also seem to be moving from the more traditional view of stable personalities to personalities that change over time (e.g. Specht et al., 2011), a fact also emphasized by Borghans et al. (2008). Clinical psychology has always hinted at the importance of reappraisal of certain outcomes (stressors in our application) to improve emotional stability (e.g. Allen et al., 2008, p. 230). We model this clinical psychology approach by inquiring into the effects of changes in personality parameters. If individuals were able (say, by therapy) to change their personality, how would they want to do this?

We describe the effects of psychotherapy by allowing an individual to influence some appraisal processes or undertake some reappraisals, i.e. adjust the way they evaluate certain

[48] Various academics claim to relax in the office and enjoy working and to get stressed from non-professional duties. If autonomy in the office is larger than in private life (e.g. due to various family commitments), this is highly plausible as the absence of autonomy has repeatedly turned out to be an important stressor (e.g. Thompson and Prottas, 2005). Reverse patterns from stress cycles, going down during office hours and rising outside of the office, should result.

stressors. In modelling terms, the individual would be able to adjust personality parameters like ϕ, δ_0 and δ_1, χ and μ. Even though endogenizing the costs of going through therapy has to be postponed to future research, we can still provide measures of the benefits of such therapy.[49]

If we want to understand how a therapy would allow to reduce the occurrence of outbursts, we can simply go back to the outburst theorem in prop. 2. We would find that outbursts can be avoided if the following changes are sufficiently large: (i) coping measures m increase, (ii) the intensity of stress is appraised in a less threatening way, i.e. ϕ goes down, (iii) the autonomous stress reduction ability δ_0 rises or (iv) the productivity δ_1 with which coping measures reduce tension increases.

At some deeper level, however, one would like to understand how therapy affects well-being of an individual and not just a certain behaviour. While equating a utility or value function to happiness appears difficult,[50] the value function is the closest measure we can use here to measure effects of therapy as reported in questionnaires. In the absence of a better alternative, we use the value function here to proxy the effects of personality changes on well-being.[51] As we are interested in reducing the stress level before an individual needs to quit working, the following proposition focuses on $W < W^s$ (see app. A.1.3 for the range $W \geq W^s$).

Proposition 4 *Given our closed-form solution from prop. 1, the value function $V(W)$ of the individual is given by*

$$V(W) = \Lambda_0 - \Lambda_1 W \text{ for } W \in [0, W^s[\tag{25}$$

where

$$\begin{aligned} \rho\Lambda_0 &= \eta w M e - v_0 m^{1+\zeta} + \Lambda_1 \left[\delta_1 m + \lambda^g \chi \left[\mu^h - \mu\right] + \lambda^\Delta(W)\, \mu^\Delta\right], \\ \Lambda_1 &= \frac{\eta w \kappa e + \alpha}{\rho - \Phi} \end{aligned} \tag{26}$$

and the arrival rate $\lambda^\Delta(W)$ for outbursts is given by (7).

Proof. See app. A.1.3 ■

The value function has intuitive properties. First, it falls in the stress-level W. Second, (minus) the shadow price Λ_1 of stress is given by the present value of marginal utility from stress from (10), where discounting takes place at the time preference rate corrected for the growth rate of stress. Third, the value for a fully relaxed individual ($W = 0$) is given by Λ_0 in (26) which summarizes many channels resulting from the structure of the Bellman equation. They include (parts of the expressions for) the benefits from consumption, the costs of coping, the benefits of coping and the influence of surprises and outbursts.

How strongly well-being changes as a result of therapy is summarized in the following

Corollary 6 *A therapy increases the value function $V(W)$ if the individual*
(i) enjoys higher productivity δ_1 in coping
(ii) becomes emotionally more stable *(χ falls) conditional on the individual being on average* negatively *surprised*
(iii) reduces expectations with respect to surprises (μ falls)
(iv) experiences outbursts that reduce stress more on average (μ^Δ rises)
(v) displays outbursts earlier or more frequently ($\lambda^\Delta(W)$ rises) conditional on μ^Δ being positive
(vi) has a higher shadow price of stress conditional on being sufficiently relaxed/ stressed.

[49] I am grateful to Ernst Fehr for having suggested that such an analysis can be undertaken in this context.

[50] Benjamin et al. (2012, 2014) provide convincing evidence that other factors than happiness matter for decision making. Integrating their findings in a theoretical framework is a highly interesting research to be done in the future. A lot of very helpful insights are already gathered in Kimball and Willis (2006).

[51] Aghion et al. (2016, p. 3874) in their analysis of creative destruction follow the same approach. They write "Life satisfaction is captured by the average present value of an individual employee", i.e. by the value function.

The first finding is straightforward. The second finding is ambiguous as by (26) becoming less emotional (χ falls) can have positive or negative effects. If an individual is on average positively surprised, i.e. if $\mu^h > \mu$, subjective well-being of the individual actually falls if the person becomes less emotional. Therapy attempting to make an individual emotionally more stable is therefore only advisable if the individual tends to be negatively surprised, i.e. if $\mu^h < \mu$. If therapy could influence both the degree μ of optimism and appraisal χ of surprises, one should aim at reducing μ (the third finding) and increasing χ. The individual should expect little and be emotional.

The forth finding is also intuitive: Making a technology (outbursts) more productive in reducing a state variable with a negative shadow price increases the value function. If this technology is sufficiently advanced (if μ^Δ is positive), finding (v) tells us that it should be used more frequently (from the perspective of the individual, not necessarily from the perspective of its social environment).

The final finding (vi) shows that objectives of therapy might not be straightforward. Any parameter that increases Λ_1 has a direct positive effect on $V(W)$ via (25) but an indirect negative effect via Λ_0 in (26). Computing the derivative $dV(W)/d\kappa$ as one example, one finds that well-being increases only if stress is sufficiently low, i.e. if $W < \left(\delta_1 m + \lambda^g \chi \left[\mu^h - \mu\right] + \lambda^\Delta(W)\,\mu^\Delta\right)/\rho$. A lot of understanding of the current individual situation of a person is required (among other the current stress level and the subjective expectations parameter μ) before any attempt at changing some personal characteristics should be undertaken.

6.3 Structurally estimating personality

Our setup emphasizes that there is a large heterogeneity in how stressors translate into stress. Individuals exhibit heterogeneous behaviour in identical situations given their heterogeneous appraisal of stressors. This stressor-stress link is captured by personality traits and coping dispositions in our setup. Looking at (12) with (14), the central parameters in this respect are ϕ for translating daily hassle into changes of stress, δ_0 and δ_1 for how quickly an individual can reduce stress and χ how strongly an individual reacts to surprises. The general optimism parameter μ also captures a personality dimension. With this framework, we defined theory-consistent personality types in sect. 4.2.

It is a natural question to ask how these parameters and personality types can be reconciled with the more standard measures of personality like e.g. the Big 5.[52] These five measures are usually called 'neuroticism' ("the ease and frequency with which a person becomes upset and distressed"), 'agreeableness' (agreeable individuals "get less angry over others' transgressions than do less agreeable people") and 'conscientiousness' (in the sense of taking "future contingencies into account", all quotes from Carver and Connor-Smith, 2010). The remaining two personality factors, 'extraversion' and 'openness to experience', play a less important role in our framework.

To systematically establish a link between the personality parameters in the model (ϕ, δ_0 and δ_1, χ and μ) and the *questions* underlying the Big 5 personality measures, one could proceed as follows. The dependent variable could be behaviour, say the frequency of outbursts, or self-reports on stress $W(t)$. Explanatory variables are stressors (p and $h(t)$) in addition to various control variables (like education, occupation, age etc.) that capture inter alia ability b. In an exploratory setup, one would estimate the effects of BIG 5 measures on the dependent variable in a linear regression. For a *structural* interpretation of personality characteristics, however, it would be more interesting to jointly estimate standard model parameters (like

[52] See e.g. John et al. (2008) for a psychological perspective and Borghans et al. (2008) for first steps towards integrating economics and personality psychology. Borghans et al. provide, inter alia, a criticism of the atheoretical nature of the Big 5 personality measures and compare it to other taxonomies of personality.

preference parameters) with the model's personality parameters. The current state of the art (see e.g. Heckman et al., 2006 or Conti et al., 2014) uses linear simultaneous equation models with latent factors as explanatory variables (see Piatek, 2010 for an introduction). The ideal approach building on models like the one developed here would use the density provided by the theoretical model (e.g. on outbursts or stress) for the formulation of a likelihood function combined with the densities of the latent variables. The difference to existing analyses would consist in the closer link of the personality estimates to the theoretical model resulting from the use of the model density for estimation. This would not only be interesting for the present stress-coping model but also more generally for improving our theoretical understanding of the factors explaining the answers in standard questionnaires for personality.

More in detail, estimation would employ two equations. The first one results from the theoretical model and provides us with a closed-form expression of the density of stress $g\left(W|\Theta_i, X_i, \sigma\right)$. This density is conditional on the latent personality factors $\Theta_i = \{\phi, \delta_0, \delta_1, \chi, \mu\}$, covariates X_i and model parameters σ (other than latent personality factors, i.e. $\sigma = \{\rho, v_0, \zeta, \kappa, v, \alpha\}$)

$$\begin{aligned} W_i \tilde{} g\left(W|\Theta_i, X_i, \sigma\right), \\ Y_i^* = X_i\beta + \alpha\Theta_i + \varepsilon_i. \end{aligned}$$

The second equation explains latent outcomes Y_i^* of personality by covariates X (like p, b and w), latent personality factors Θ_i, factor loadings α and the error term ε_i. Employing the density from the theoretical model in the likelihood function then makes sure that the estimated personality factors $\hat{\Theta}_i$ obtain a very precise meaning.[53]

6.4 Catharsis vs. increase in anger

According to the above framework, spontaneous outbursts occur when the stress level, or physiological arousal more generally speaking, becomes too high (induced e.g. by a demanding learning task). Can this fundamental building block be confirmed in experiments or in the field? The challenge in both cases consists in obtaining a continuous measure of arousal. Options include portable electrocardiograms or more modern devices for high-frequency measurement of skin temperature and conductance and pulsewave (Yoon et al., 2016). This could be combined with emotion recognition devices (Poria et al., 2017, esp. ch. 6) to identify outbursts in the lab or on private PCs where individuals play computer games. If spontaneous outbursts occur only above certain threshold levels, the view that control gets lost with higher levels of arousal would be supported. This would support the above discussed model of stress-driven violent behaviour.

These setups would further help in clarifying the question whether outbursts reduce stress or not (i.e. whether μ^{Δ} introduced after (5) is positive or negative). Common wisdom in social psychology seems to be that "catharsis does not work" where catharsis is understood as a reduction in anger. Following these findings, μ^{Δ} would have to be negative. The modern experimental evidence supporting this claim often combines two simultaneous interventions. One is a "pure" venting intervention like hitting a punching bag and the other is a rumination intervention (Bushman, 2002). In another setup (Bushman et al., 1999, study 2, p. 371, right column), participants were reminded of the person who had made them angry before hitting the punching bag. As Bushman (2002) writes, cognitive neoassociation theory would suggest that aggressive thoughts activate further aggressive thoughts which are linked to each other in an associative network. Rumination and thinking of the other person therefore makes individuals more aggressive. Even if the pure venting intervention of boxing had a anger-reducing effect, the negative association effect would more than overcompensate the boxing effect. As a conclusion

[53] I am grateful to Rémi Piatek for discussions of aspects related to latent factor models.

(and leaving aside considerations on causality in setups with self-selection), venting of anger makes individuals more angry.[54]

The big difference between these experimental approaches and our model consists in the idea of spontaneous acts as opposed to deliberate activity. In terms of the general aggression model of Anderson and Bushman (2002, fig. 2), we see outbursts as an impulsive action and smooth coping as a thoughtful action. In all catharsis experiments, participants are willingly performing some act (e.g. hitting). They never display some automatic reaction. Future research allowing for spontaneous displays of anger, possibly guided by modern economic theory on anger (see Battigalli et al., 2016 and the references therein), would help to cast new light on the catharsis hypothesis.[55]

A further difference to be elaborated upon in future work is the difference between anger and stress and, more generally, the multiplicity of emotions. When anger goes up via cathartic behaviour and participants displayed this behaviour, the vast majority (72%) enjoyed this behaviour (Bushman et al., 1999, p. 372). This can be understood as stress reduction as it gave individuals the feeling to have resources to meet the demands after all. One would need a model with two to three feelings to study this in detail.

7 Conclusion

The feeling of being stressed is known by everybody. At times, demands on the job, by family or from friends exceed personal abilities. Demands beyond abilities imply stress. But why is it that some individuals remain calm even in times of highest work load while others start becoming nervous and might even display strong emotional reactions? This paper has presented a model that builds on concepts borrowed from psychology and translates them into standard economic model building. This yields the advantage that we can now, to return to Rabin (2013) again, understand psychological concepts in more detail, understand where the flaws are and see their limits that guide us in further advancing our knowledge.

We have seen that stress is an inherently dynamic concept. Stress builds up gradually as a function of appraisals of stressors. Stressors can come as a surprise or they are present at each instant. Surprises can be positive or negative, daily stressors can be uplifts, which would reduce stress – again only gradually and slowly – over time. We have also seen how some of the most popular concepts in psychology, cognitive load and mental resource constraints, can easily be introduced into economic models. Employing such a resource constraint explains how stress reduces performance of an individual on the job. When it comes to optimal reactions to stress, this paper formalizes many of the psychological views about functional vs. dysfunctional, problem-focused vs. emotion-focused and reflective (rational) vs. automatic (impulsive) strategies.

Our setup allows us to explain stress and coping patterns given the optimal stress regulation of an individual. We saw that emotional outbursts, the socially less desirable coping strategy, occur at predictable (in means) points in time. All individuals employ smooth and constructive stress-coping strategies for some time. These strategies help to reduce the current stress level (or at least reduce the speed with which stress builds up). However, in certain cases, it might be optimal to allow emotional outbursts to take place. After all, socially desirable or not, emotional outbursts are just one out of two technologies to reduce emotional tension. If various technologies are available to achieve a certain goal (here: stress reduction), it is not surprising to see that optimizing individuals employ both technologies. Emotional outbursts due to elevated stress levels are suggested as an alternative trigger of violence.

[54] This arousal effect is also known and confirmed by findings from the field in Dahl and DellaVigna (2009).

[55] I am grateful to Brad Bushman for discussions of this issue.

The entire analysis builds on the distinction between two types of individuals: stress-prone and stress-resistant. The advantage of this definition of a personality trait is its theoretical foundation. Psychological measures of personality (think about the Big 5) are based on questionnaire answers and factor analysis. The paper works out which steps would have to be undertaken to estimate theory-consistent personality measures structurally.

Our setup also explains how stress reduces productivity. In doing so, we suggest a distinction between pure and productive stressors. While pure stressors only increase stress without increasing productivity, productive stressors can increase productivity: As long as the individual is stress-resistant, income rises. When a rise in stressors turns an individual stress-prone, productive stressors also increase stress. When the increase in stress has a weak effect on attention at work, more productive stressors still increase income but only in an underproportional way. An increase in income now goes hand in hand with a fast increase in stress. When the increase in stress has a stronger effect on attention at work, income actually decreases. This transition from being stress-resistant to stress-prone provides a rationale for the Kahneman and Deaton (2010) finding of a threshold level of income beyond which the life of an individual becomes stressful.

Future research should empirically identify the link between stressors and stress and how this affects well-being (captured by happiness measures or measures based on e.g. the generalized health questionnaire). This research could also show whether coping measures are independent of the current stress level (as in our model) or rise in stress. Experimental studies on catharsis in the presence of spontaneous reactions to stress would yield very informative results both for economic and psychological thinking. Stressors on the job can be empirically decomposed into their pure nature and into their productive nature. The effect of stressors as the causal factor behind the income-stress correlation can be estimated. From a theoretical perspective, imperfect knowledge about the effect of stressors on stress or self-deception about the negative effects on stress in the presence of overconfidence would also be highly promising future research avenues.

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