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OPIOID EPIDEMICS

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Opioid Epidemics*

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Abstract. In this paper, I propose an economic theory that addresses the epidemic character of opioid epidemics. I consider a community in which individuals are heterogenous with respect to the experience of chronic pain and susceptibility to addiction and live through two periods. In the first period they consider whether to treat pain with opioid pain relievers (OPRs). In the second period they consider whether to continue non-medical opioid use to feed an addiction. Non-medical opioid use is subject to social disapproval, which dependents negatively on the share of opioid addicts in the community. An opioid epidemic is conceptualized as the transition from an equilibrium at which opioid use is low and addiction is highly stigmatized to an equilibrium at which opioid use is prevalent and social disapproval is low. I show how such a transition is initiated by the wrong belief that OPRs are not very addictive. Under certain conditions there exists an opioid trap such that the community persists at the equilibrium of high opioid use after the wrong belief is corrected. Refinements of the basic model consider the recreational use of prescription OPRs and an interaction between income, pain, and addiction.

Keywords: addiction, pain, opioids, stigma, social interaction, information constraints.

JEL: D15, D91, I12, I14.

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1. Introduction

In this paper, I propose an economic theory that addresses the epidemic character of opioid epidemics. The prime application of the theory is the present opioid crisis in the U.S. whose core elements are briefly reviewed in the next paragraphs.

The crisis originated in the 1990s. Until then, the prescription of opioid pain relievers (OPRs) was mainly confined to treat acute pain and cancer pain (in palliative care). Morphine and its derivatives like heroin were known to be highly addictive and their non-medical use was mainly confined to marginalized groups of society. Then, a couple of research papers argued that OPRs could be prescribed on a long-term basis with insignificant risk to addiction (e.g. Portenoy and Foley, 1986; Zenz et al., 1992), the pharmaceutical industry developed new slow-release OPRs (oxycontin) and convinced many physicians that OPRs can be prescribed safely and more freely, and an increasing share of OPRs were paid by insurance (Zhou et al., 2016). In 1997, the American Pain Society and the American Academy of Pain Medicine issued a consensus statement endorsing opioid use for chronic pain (Haddox et al., 1997).

As a result of these developments, prescription OPR use increased from 134 morphine milligram equivalents (MME) per adult American in 1992 to a peak of 1,011 MMEs in 2011 (IQVIA, 2018). Many OPR patients developed an addiction and it is estimated that 25 million Americans initiated non-medical use of OPRs between 2002 and 2011 (SAMHSA, 2012). OPR-overdose and OPR-abuse treatments increased in sync with OPR sales (Kolodny et al., 2015). From 1999 to 2016, more than 630,000 people died from drug overdose, making it the leading cause of accidental death in the United States (CDC, 2017a). In 2007, the developer of oxycontin pled guilty to criminal charges for misrepresenting the risk of addiction (van Zee, 2009). Health care providers gradually prescribed OPRs more reluctantly and the CDC re-reformed their recommendation of pain treatment (CDC, 2016). Since 2011, OPR use decreased gradually to a level in 2017 that is about five times as high as in 1992 (IQVIA, 2018).

The decline of OPR use was accompanied by a sharp increase of heroin sales such that deaths from heroin overdose increased by about factor 5 from 2010 to 2016 (CDC, 2017a). These trends can be explained by the chemical similarity of OPRs and heroin. When a prescription runs out, addicted users have an incentive to avoid withdrawal pain by switching to illicit opioids. In terms of morphine equivalents, heroin is available at about one-tenth of the street price of OPRs (DEA, 2015; Gupta, 2016) and 94 percent of illicit opioid users state to use heroin because prescription opioids are far more expensive and harder to obtain. (Cicero et al., 2014). As a result of these developments, opioid addiction is no longer confined to a minority of impoverished men in marginalized inner city environments. It is now prevalent among white middle-class men and women living in suburban and rural areas (Cicero and Ellis, 2017). In other words, opioid use and addiction arrived in the mid of the American society.

An interesting but so far little discussed question is why the rapid increase in opioid use has been addressed as an "opioid epidemic". The Concise Medical Dictionary (2014) defines an epidemic as a " sudden outbreak of infectious disease that spreads rapidly through the population, affecting a large proportion of people." Since opioid use is clearly not infectious in an epidemiological sense, the use of the term "opioid epidemic" by the press, scientific scholars, and the Centers of Disease Control and Prevention (CDC, 2017a) could perhaps be based on a loose interpretation of the term, in the sense of "crisis". Here, we scrutinize the idea that the term "opioid epidemic" could actually be appropriate in a strict sense, namely through social contagion. Specifically, we consider the stigmatization of opioid addicts by social disapproval in their community. Fighting and overcoming an addiction is costly in terms of pain from withdrawal. The presence of social disapproval additionally motivates to fight an (accidental) addiction or to altogether avoid the use of addictive substances.

Social disapproval is likely to decline when an increasing share of a community deviates from the social norm. In particular, the exposure to colleges, friends, or family members who became addicted to opioids, perhaps in an accidental way through pain treatment, could motivate a decline in social disapproval. According to a survey of the Pew Research Center (2017), 46 percent of U.S. adults say they have a family member or close friend who is or has been addicted to drugs. The meta study by Cicero and Ellis (2017) argues that the transition of former prescription OPR users to heroin caused a dissipation of social stigma associated with heroin use. In this sense, an opioid epidemic is conceptualized as the transition from an equilibrium where non-medical opioid use is low and social disapproval of addicts is high to an equilibrium where non-medical opioid use is prevalent and social disapproval of addicts is low.

The modeling of the opioid epidemic as a social phenomenon allows to contribute to the literature with some points that have not yet been extensively addressed. It also offers an answer to the question why it is so hard to reverse the opioid epidemic. From a mechanistic viewpoint, the correction of wrong beliefs regarding the addictive power of OPRs and the discontinuation of OPR prescriptions should be sufficient to reestablish the initial pre-crisis situation. These supply side policies are likely to cause much hardship and further casualties because of the transition to illicit opioid use of individuals who are already addicted (Strulik, 2018). But one could naively expect that these policies prevent or drastically reduce the initiation of opioid use and thus gradually re-establish the pre-crisis state at which opioids were only used by a marginalized minority of society. Actually, however, we observe that an increasing share of new opioid users initiates an addiction with illicit opioids (Cicero et al., 2017). Chen et al. (2019) simulate the future development of opioid misuse and conclude that the epidemic will develop further and that prescription OPR policies are unlikely to fundamentally change these trends (see Pitt et al., 2018, for similar results).

The opioid-epidemics theory offers an explanation of these trends. Social dynamics self-enforce the equilibria of high and low opioid use. Once one policy (for example, the wrong information about addictive power of OPRs or the generous prescription of OPRs) has increased opioid use and decreased social disapproval of addiction in the community, it is insufficient to reverse the policy to re-establish the old equilibrium. The local stability of the old equilibrium required that addiction is strongly disapproved, a social norm that is no longer sustained. In other words, many individuals who are now observed (Cicero et al., 2017) or predicted (Chen et al., 2019) to initiate an opioid addiction would have prevented from doing so by social disapproval in the pre-crisis environment. The fact that there are now so many addicts in the community, however, keeps social disapproval low. The community is caught in an opioid trap.

A series of studies supports the notion that drug use is subject to social interaction, disapproval and stigma and that drug use of peers and community members reduces stigma and motivates drug use, in particular among adolescents and young adults (e.g. Bachmann et al., 1998; Poelen et al., 2008; Simon-Morteon and Chen, 2006; Palamar et al., 2011, 2012, Strickland and Smith, 2014). Social interaction may motivate drug use through other channels than declining disapproval such as learning from peers, greater availability of drugs, or social pressure to conform. The theory developed in this paper is consistent with all of these channels. Social disapproval, however, seems to be the most plausible channel. It can rationalize why the opioid epidemic has affected many social groups in communities such as villages and towns but still remains restricted to (large) minorities within the communities, a phenomenon that is harder to explain with learning or conformity.

In the economics literature, Becker (1992) has initiated the discussion of addiction and social interaction. Jones (1994), Cutler and Glaeser (2007), and Poutvaara and Siemers (2008) discuss the role of social interaction in smoking decisions. Christakis and Fowler (2007) show how obesity spreads from person to person in a large social network and Strulik (2014) proposes a theory of evolving obesity based on social disapproval. Manski (2000) highlights the difficulties in identifying social interaction empirically. Brock and Durlauf (2001) propose a general theory of social interaction and Reif (2018) integrates social interaction in the Becker-Murphy (1988) model of rational addiction. McDonald et al. (2012) document a large variation of prescription OPR use across U.S. counties of which less than a third is explained by the characteristics of the local population and the number and composition of health care providers. Finkelstein et al. (2018) show that opioid abuse of individuals increase when they move into counties in which OPR use is prevalent. These observations could reflect local differences in OPR prescription and monitoring policies. They can also be motivated by the proposed theory of social interaction and the local stability of disapproval of opioid addiction.

In mathematical biology, the epidemic character of addiction has been modeled by adapting the SIR model of infectious diseases of Kermack and McKendrick (1927), see, for example, Hoppensteadt and Murray (1987) and White and Comiskey (2007). Battista et al. (2019) apply this approach to study the prescription opioid epidemic. The main difference to the here proposed theory is that these models are rather mechanistic, in the sense that they do not model economic choices, attitudes and behavior.

By focussing on social dynamics the paper neglects several aspects of the opioid epidemic that have been addressed in related literature. Case and Deaton (2018) observed increasing deaths from suicide, alcohol-related liver diseases, and drug overdoses among middle-aged white Americans and hypothesized that these “deaths of despair” may be driven by declining opportunities for people without a college degree. Ruhm (2018) argues that increasing overdose deaths are largely driven by higher availability and lower costs of opioids rather than deteriorating macroeconomic indicators. Grossmann and Strulik (2018) propose a macroeconomic model to analyze the impact of deteriorating economic status and declining opioid prices and argue that both trends are necessary to motivate increasing opioid use of the middle class. Strulik (2018) integrates pain, pain treatment, and addiction into a general life cycle theory of human aging and analyzes the transition in demand for different analgesics and opioids and its impact on health. Schnell (2017) proposes a model of physician behavior when OPRs can be obtained legally as well as illegally. Evans et al. (2018) argue that abuse-deterrent oxycontin, which entered the market in 2010, is associated with less OPR-related death and more heroin deaths with no effect on total deaths from overdose.

The paper is structured as follows. I set up the basic model and develop the main results in Section 2. In Section 3, I extend the basic model by allowing to initiate addiction with recreational OPR use. In Section 4, I extend the model by integrating an association between income and pain and a feedback effect of opioid use and addiction on income. Section 5 concludes.

2. The Basic Model

2.1. **The Opioid Consumption Decision.**

Consider a community populated by a measure of size one of overlapping generations. Time t goes on forever and individuals live through two periods of unit length, indexed by 1 and 2. In the first period, they experience pain, agony, or despair and in the second period they are potentially addicted to opioids. Individuals are heterogenous with respect to the degree of pain p that they experience in the first period and with respect to their susceptibility to addiction a. For simplicity and in order to obtain closed-form solutions we assume that pain and susceptibility to addiction are independently and uniformly distributed in the unit interval, $p \in (0,1)$, $a \in (0,1)$. In order to relieve pain in period 1 or reduce cravings from addiction in period 2, individuals may use opioids. In order to reduce analytically complexity, we conceptualize the consumption of opioids, alternatively addressed as drugs d, as a bivariate yes (1) / no (0) decision, $d^1 \in \{0,1\}$, $d^2 \in \{0,1\}$.

Individuals experience linear utility from consumption in both periods. Expected lifetime utility without drug consumption for a member of the generation born at time t is thus given by:

$$V_t = c_t^1 - \pi p + \beta c_{t+1}^2, \tag{1}$$

in which c_k^j denotes consumption in period j and time k, β is the time discount factor, and π measures the general importance of pain for utility (relative to consumption).

Through drug consumption, individuals can mitigate the negative influence of pain or despair on utility in period 1. Drug consumption, however, causes addiction and generates negative utility through cravings in period 2. In period 2, the pain of period 1 is gone but individuals could continue drug consumption to dampen their cravings. While taking opioids as pain relief treatment is socially approved, abuse of OPRs or using other opioids (heroin) to feed an addiction is socially disapproved. The degree of social disapproval that an addict experiences at time t is given by σs_t, in which $s_t \in [0,1]$ is the potentially time-varying strength of social disapproval of addiction and σ is a weight that measures the impact of social disapproval for utility. We can (but need not) interpret s_t as the population share in the community that disapproves opioid addiction.

Taking the possibility of drug consumption into account, expected lifetime utility is given by

$$E(V_t) = c_t^1 - \frac{\pi p}{1 + \gamma d_t^1} + \beta \left[c_{t+1}^2 - \frac{\alpha E(a) d_t^1}{1 + \gamma d_{t+1}^2} - \sigma s_{t+1} d_{t+1}^2 \right], \quad (2)$$

in which γ is the power of the drug in pain reduction and in relief from cravings and α is the addictive power of the drug. In period 1, addiction has not yet been experienced and thus individuals do not know their susceptibility to addiction. They can form only expectations about their susceptibility. Given the simple distribution function, expected susceptibility to addiction is $E(a) = 1/2$. With reference to the rational theory of addiction (Becker and Murphy, 1988), the term $z_{t+1} \equiv \alpha E(a) d_t^1$ can be interpreted as the accumulated stock of addiction or addiction capital. Inspection shows that the utility function fulfils the three defining features of addiction (Cawley and Ruhm, 2012): tolerance, $\partial V / \partial z_{t+1} < 0$, reinforcement $\partial^2 V / (\partial z_{t+1} \partial d_{t+1}^2) > 0$, and withdrawal, $\partial V / \partial d_{t+1}^2 > 0$.

The price of consumption goods is normalized to 1 and the price of drugs is q_I in the initiation period of drug use and q_A in the addiction period. For the basic model q_I can be conceptualized as the out-of-pocket price of prescription OPRs. If addicted individuals maintain access to prescription OPRs, $q_A = q_I$. For $q_A > q_I$, q_A is conceptualized as the street price of OPRs or illicit opioids.

In the basic model, all individuals receive the same income y in both periods such that the budget constraints read $y = c_t^1 + q_I d_t^1$ for period 1 and $y = c_{t+1}^2 + q_A d_{t+1}^2$. Inserting the budget constraints into (2), lifetime utility becomes:

$$E(V_t) = y - q_I d_t^1 - \frac{\pi p}{1 + \gamma d_t^1} + \beta \left[y - q_A d_{t+1}^2 - \frac{\alpha / 2 d_t^1}{1 + \gamma d_{t+1}^2} - \sigma s_{t+1} d_{t+1}^2 \right]. \quad (3)$$

Notice that drug use in period 2 requires drug use in period 1 since otherwise there would be no need to dampen cravings from addiction. The basic model thus focusses on the most interesting case where therapeutic opioid use in pain treatment is the only gateway to non-medical opioid use and addiction. The initiation of addiction through recreational OPR use is discussed in Section 3.

Individuals maximize lifetime utility by choosing d_t^1 and d_{t+1}^2. Given that individuals born at time t had used drugs in period 1 ($d_t^1 = 1$), they use drugs in period 2 if utility is larger in this case than without drug use, i.e. if $y - q_A - \alpha a/(1+\gamma) - \sigma s_{t+1} > y - \alpha a$. This provides the condition for drug use in period 2. Individuals born at time $t-1$ who used drugs in period 1, use drugs in period 2 if:

$$a > a_t^* \equiv \frac{1+\gamma}{\alpha\gamma}(q_A + \sigma s_t). \tag{4}$$

Individuals with susceptibility to addiction a above the threshold a^* consume drugs in period 2, given that they had consumed drugs in period 1.

If individuals believe that they would not use drugs for addiction purposes, they use drugs for pain relief in period 1 if $y - q_I - \pi p/(1+\gamma) - \alpha\beta/2 > y - \pi p$, i.e. if

$$p > p^* \equiv \frac{1+\gamma}{\gamma\pi}\left(q_I + \frac{\alpha\beta}{2}\right). \tag{5}$$

Individuals who experience pain above the threshold p^* take opioids in period 1. In a similar way we obtain the pain threshold for individuals who use opioids in period 1 if they believe that this will turn them into a addict in period 2 as $p^{**} = [q_I + \beta q_A + \alpha\beta/2/(1+\gamma) + \beta\sigma s_{t+1}]\,(1+\gamma)/(\pi\gamma)$. Since $s \geq 0$, a sufficient condition for $p^{**} > p^*$ is $q_A \geq (\alpha/2)\gamma/(1+\gamma)$. In order to avoid uninteresting case differentiation, we henceforth assume that this condition is fulfilled such that all individuals who use opioids if they believe that they will get hooked also use opioids if they believe that they stay clean from addiction. This plausible assumption makes threshold p^{**} irrelevant and threshold p^* binding. In other words, individuals with pain greater than p^* take opioids irrespective of their belief on addiction in period 2. Inspection of (4)and (5) provides the following results.

Proposition 1. *The probability that an individual uses opioids for pain relief increases in the efficacy of opioids in pain reduction γ and the importance of pain for wellbeing π. It declines in the prescription price q_I, the discount factor β, and the addictive power of opioids α.*

Proposition 2. *The probability that an individual who used drugs for pain relief at time t continues to (ab-)use opioids for addiction purposes at time $t+1$ increases in the efficacy of opioids to reduce cravings γ and in the addictive power of opioids α. It declines in the street price of opioids q_A and the strength of social disapproval of addiction σs_{t+1}.*

From these individual-specific results we obtain immediately the population shares of opioid users for therapeutic (u_t^I) and addictive (u_t^A) purposes in period t as:

$$u_t^I = \max\{0, \;\; 1 - p^*\} \tag{6}$$

$$u_t^A = \max\left\{0, \;\; u_{t-1}^I(1 - a_t^*)\right\}. \tag{7}$$

2.2. **Drug Use Scenarios.** For most parameters, the comparative statics for the population shares of drug users is obtained straightforwardly as a corollary from Proposition 1 and 2. The interesting case here is the parameter α, the addictive power of opioids, because it affects the populations shares in opposite ways. A high addictive power reduces the incentive to take opioids for pain relief (Proposition 1) and it increases the incentive to use opioids to reduce cravings from addiction (Proposition 2). Depending on the size of α we thus obtain different drug use scenarios. To see this more clearly, insert (5) in (6) and observe that nobody uses opioids for pain relief if

$$\alpha \geq \alpha_I \equiv \frac{2}{\beta}\left(\frac{\pi\gamma}{1+\gamma} - q_I\right). \tag{8}$$

Next, insert (4) into (7) to find that given $u_{t-1}^P > 0$, nobody uses opioids for addictive purposes if

$$\alpha \leq \alpha_A \equiv \frac{1+\gamma}{\gamma}\left(q_A + \sigma s_t\right). \tag{9}$$

Combining (8) and (9) we obtain the following cases:

1) No Drug Use. If $\alpha_I < \alpha < \alpha_A$, nobody is using the drug. The power of addiction is too high to make drug use attractive for pain relief and too low to become addicted. Even if the generation currently in their second period had used drugs for pain relief, they terminate its used. Inspection of (8) and (9) show that, irrespective of α, this scenario requires $\alpha_I < \alpha_A$ and is more likely if both prices q_I and q_A are high, if the relief from drug use is low (γ is low) and if social disapproval of addiction σs is high.

2) Therapeutic Use Only. If $\alpha < \alpha_I$ and $\alpha < \alpha_A$, opioids are used only for pain relief in period 1. Such a scenario is more likely if q_I is low and q_A is high (relatively high street price of opioids) and if social disapproval of addiction σs is high.

3) Addiction Lock-In. If $\alpha_I < \alpha$ and $\alpha_A < \alpha$, then nobody of the current generation 1 uses the drug for pain relief but given that the previous generation 1 had used the drug for pain relief, it continues to use the drug to ameliorate addiction. This scenario is more likely if q_I is high and

q_A is low (the street price of opioids is relatively low), if the social disapproval of addiction σs is low, and if the drug is highly addictive (if α is high).

4) Opioid Epidemics Trap. Suppose social disapproval of opioid addicts s is high in the beginning and people believe that opioid pain relievers are not very addictive, for example, because the pharma industry, supported by medical research articles, announces $\alpha < \alpha_I$. Then some people, especially those suffering from severe pain, start using the drug. It turns out, however, that $\alpha > \alpha_I$. Had people known this beforehand, they would not have started using opioids. Initially, $\alpha < \alpha_A$ because of high disapproval s and people would not use the drug to feed an addiction. However, since many people started using drugs, social disapproval declines such that $\alpha > \alpha_A$ and some people who used the drug for pain treatment are motivated to continue using the drug to serve an addiction.

2.3. **Social Dynamics.** In order to elaborate on the dynamics of drug use and the opioid epidemic trap, suppose social disapproval of addiction evolves according to the following modified replicator dynamics:

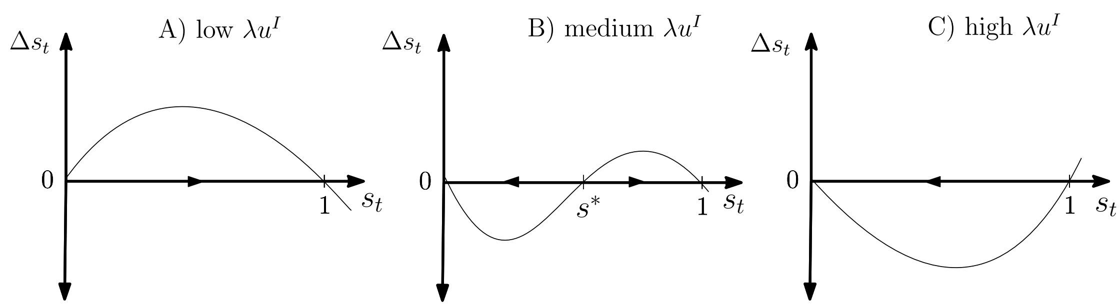
$$\Delta s_t \equiv s_{t+1} - s_t = s_t(1 - s_t)(1 - \lambda u_t^A). \tag{10}$$

The first two terms on the right hand side of (10) are reminiscent of the standard replicator dynamics (Bisin and Verdier, 2001). They support two social equilibria, $s = 1$ and $s = 0$. An intuitive (but not necessary) interpretation is to associate s with the share of the population that disapproves of non-medical opioid use. The corner equilibria are then associated with total disapproval or no disapproval. If $\partial \Delta s_t / \partial s_t = (1 - \lambda u_t^A)$ is positive, s increases and converges towards 1. If the derivative is negative, s converges towards 0. The third term captures the malleability of social norms. If the share of opioid addicts in the community increases, social disapproval declines and the strength of this feedback mechanism is measured by λ. Most importantly, the third term creates a tipping point. If u_t^A increases above $1/\lambda$, the direction of social dynamics changes from increasing disapproval to declining disapproval. Since the population share of addicts (u_t^A) depends itself on social disapproval, we obtain the "reduced-form" of social dynamics by inserting (4) and (7) into (10) which then becomes

$$\Delta s_t = s_t(1 - s_t)\left(1 - \lambda \max\left\{0,\ u_{t-1}^I\left[1 - \frac{1+\gamma}{\alpha\gamma}(q_A + \sigma s_t)\right]\right\}\right). \tag{11}$$

Depending on the size of the feedback effect, there exist either 2 or 3 social equilibria, as illustrated in Figure 1. Two equilibria are always obtained at the corners: absolute disapproval $s_t = 1$ and no disapproval $s_t = 0$. If λ is low, such that $1 - \lambda u_t^A$ is always positive, social dynamics converge always toward absolute disapproval, as shown on the left hand side of Figure 1. If λ is sufficiently high, social dynamics are unambiguously towards zero disapproval of addiction, as shown on the right hand side of Figure 1. For intermediate values of λ, a third, unstable equilibrium emerges, which operates as a separatrix, as shown in the center panel of Figure 1. If initial social disapproval exceeds s^*, social dynamics work in direction of disapproval of addiction. If initial disapproval falls short of s^*, social disapproval converges to zero.

Figure 1: Social Norm Dynamics



Solving (11) for the interior steady state, we obtain:

$$s^* = \frac{1}{\sigma} \left[\frac{\alpha\gamma}{1+\gamma} \left(1 - \frac{1}{\lambda u_{t-1}^I} \right) - q_A \right]. \tag{12}$$

The value s^* is a steady state because u_{t-1}^I changes only occasionally when the parameters of the system change and stays constant otherwise. For an interior steady state to exist, s^* needs to be $\in \{0, 1\}$. A necessary, not sufficient condition for this is $u_{t-1}^I > 1/\lambda$, i.e. that sufficiently many individuals initiated drug use with prescription opioids for pain relief. When s^* increases and moves to the right in Figure 1, the domain of attraction of the locally stable equilibrium without disapproval of addiction (at $s = 0$) gets larger. This notion, in conjunction with Proposition 1 and 2 verifies the following proposition.

Proposition 3. *The domain of attraction of the steady state without disapproval of addiction becomes larger if the feedback mechanism from current use becomes larger (if λ rises), if the street* *price of drugs q_A declines, if the utility weight of disapproval σ declines and if the share of people who initiate opioid use for pain treatment increases (i.e. for increasing efficacy of opioids in pain treatment γ, for increasing importance of pain π, and declining prescription price of OPRs q_I.*

If s^* increases beyond 1, the steady state at $s = 0$ becomes globally stable. Likewise, if $s^* < 0$, the equilibrium $s = 1$ becomes globally stable.

2.4. **Evolution of an Opioid Epidemic.** We now use the model to explain how a society unintentionally ends up in an opioid trap. For that purpose, we assume that initially u^I is low and few people use opioids for pain relief. Initially, $s > s^*$ such that society converges towards $s = 1$, the equilibrium where drug addiction is absolutely disapproved (the panel on the right hand side of Figure 1 applies). Then, the pharmaceutical industry launches a new opioid, which is effective in pain relief (γ is high), and announces that the addictive power of the drug is low (that α is low). As a result, more people start using OPRs for pain relief and u^I rises. It turns out, however, that the new OPR is highly addictive and some people, i.e. those with the greatest susceptibility to addiction, start using opioids to feed their addiction regardless of the initially high disapproval of addiction.

As a result of increasing opioid use, social disapproval of addiction declines and the threshold s^* increases. When s^* increases far enough, s falls below s^*, and the attitude of society towards addiction changes. A movement towards declining disapproval of OPR use sets in. With further declining disapproval, more individuals are motivated to use OPRs for addictive purposes. As σ converges to zero, the addiction threshold (4) converges towards $(1+\gamma)q_A/(\alpha\gamma)$ and the population share of OPR addicts converges towards

$$(u^A)^* = \left[1 - \frac{1+\gamma}{\gamma\pi}\left(q_I + \frac{\alpha\beta}{2}\right)\right]\left[1 - \frac{1+\gamma}{\alpha\gamma}q_A\right],$$

with straightforward comparative statics.

The formation of beliefs of a low α could be accompanied by a campaign that emphasizes pain as a serious impediment of wellbeing such that π rises (pain as the fifth vital sign) and an improvement of access to prescription OPRs, captured as a reduction of the initiation price q^I. These policies further increase the motivation to use OPRs and amplify the dynamics towards declining social disapproval and a high share of addicts in the community.

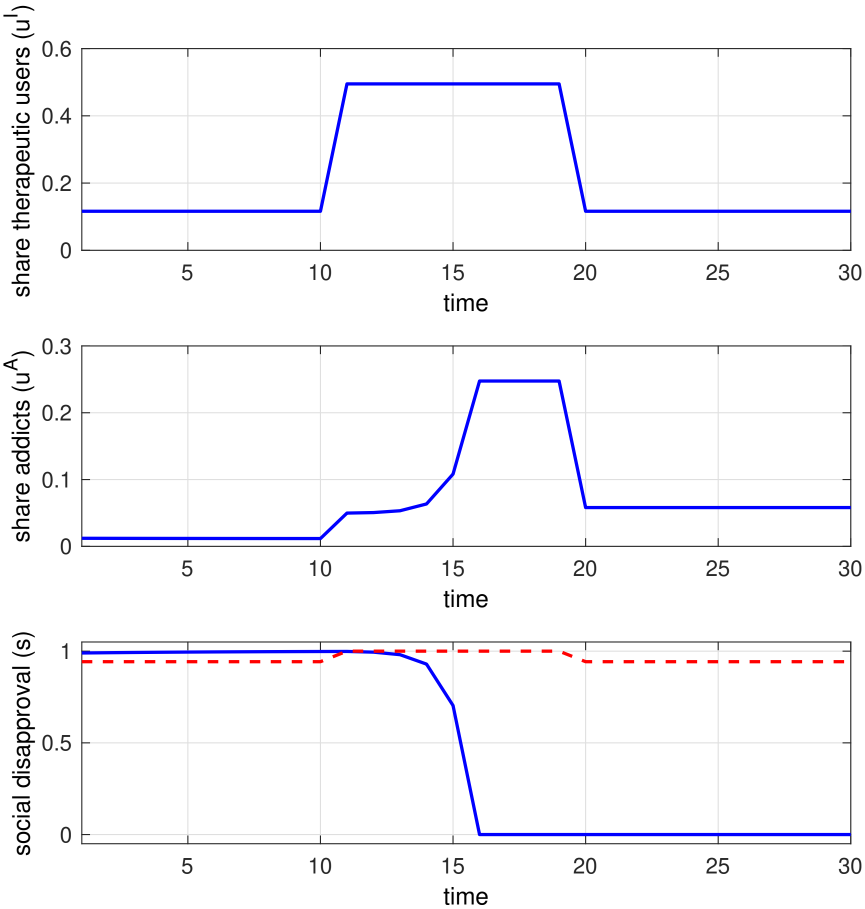
We next consider an illustration of an opioid epidemic with a numerical example. The parameter values are set in order to construct the most interesting case, in which a wrong belief of low addictive power of OPRs initiates a transition towards low social disapproval of opioid use, which persists after the belief has been corrected. Keeping in mind that this is an illustration not a calibration, some parameters can be set to target some stylized facts. I set $\gamma = 1.5$ such that taking OPRs reduces chronic pain by 40%. This is about the average reduction of chronic pain by oxycontin according to Kalso et al. (2004). I set $\alpha = 0.5$ and the wrongly believed low value of α to 0.2, such that wrong beliefs cause an about fourfold increase in OPR prescriptions (CDC, 2017b) and that at the steady state about 7% use prescription OPRs (Frenk et al. 2015). I set $\sigma = 0.1$ such that initially almost nobody is addicted to OPRs and $\lambda = 70$ such that the transition from high to low disapproval takes about 7 years. The prescription price q_I is set to 0.05 and the continuation price q_A is set to 0.15. The threefold price increase captures the notion that addiction is partly served by a continued prescription, partly by buying at street prices, which are estimated to be about 8 times higher than prescription prices, and partly by switching to heroin, which is available at about 10 percent of the OPR street price (DEA, 2015; Gupta, 2016).[1]

Figure 2 shows the implied adjustment dynamics (all parameter values are shown below the). Initially and up to time 10, individuals correctly believe that opioids are highly addictive ($\alpha = 0.5$). Social disapproval of addiction lies above s^* and is close (but not exactly equal) to its maximum at 1. In terms of Figure 1, we are in the middle regime with an interior s^* and s_t to the right of s^*. At time $t = 10$ a new opioid enters the market and it is announced and believed that addictive power is low, $\alpha = 0.2$. This belief, however is unjustified. Actually the new opioid (e.g. oxycontin) is as addictive as the previously existing ones (morphine). Individuals in period 1 make their decisions based on $\alpha = 0.2$ while in period 2 addiction unfolds with power $\alpha = 0.5$. As a result, therapeutic use increases drastically (top panel of Figure 2) and the share of opioid use for addictive purposes increases as well, albeit at first only gradually (center panel).

Because of increasing use, s^* increases and social disapproval of opioid addiction declines (bottom panel in Figure 2). The separatrix s^* is shown by red dotted lines. When s^* exceeds s, there is a tipping point in social dynamics. With increasing momentum more and more people abandon their disapproval of opioid addiction, which induces even more people to feed their addiction

[1] The simple model does not capture the consumers choice and substitution between non-medically used opioids. For this, see Strulik (2018).

Figure 2: Opioid Epidemics Dynamics



Parameters: $\alpha = 0.5$, $\beta = 0.5$, $\gamma = 1.5$, $\pi = 0.33$, $q_I = 0.05$, $q_A = 0.15$, $\lambda = 70$, $\sigma = 0.1$. From time 10 to 30 individuals believe that $\alpha = 0.2$. The red (dotted) line in the bottom panel shows the position of s^*.

because it is socially less disapproved. The society moves towards the steady state without social disapproval of opioid addiction. Intuitively, more and more people experience opioid addiction in their own neighborhood, family, or among friends. Opioid consumption turns from a disapproved activity of a (low class, inner-city) minority to a mass phenomenon. Notice that vanishing disapproval does not imply that people approve and encourage opioid consumption. It just means that people develop more understanding for opioid addicts and punish them less with disapproval.

At time 30, the wrong belief is corrected and it is now announced and correctly believed that therapeutic opioid treatment causes addiction with power $\alpha = 0.5$. Therapeutic use thus returns to its low initial level. Non-medical use by addicts declines as well but only to a level that is (much) higher than initially. This constitutes the opioid trap. Because addiction is no longer socially disapproved it is more prevalent than before the onset of the epidemic. Although s^*

returns to its initial value, s is now on its other side, $s < s^*$, and a social norm of zero disapproval of addiction is sustained. Although the fundamentals are the same as initially, the society is locked in an equilibrium of high prevalence of opioid addiction and non-medical opioid consumption.

3. Recreational Use of Opioid Pain Relievers

In the basic model, changing social norms explain a permanent change in the community with respect to second period opioid consumption (i.e. with respect to the prevalence of addiction disorder). First period consumpton (i.e. the initiation of opioid use) returns to its low initial level when the initial fundamentals (beliefs, prices etc) have been restored. In order to address this perhaps implausibly optimistic prediction, we now extend the analysis by considering a third motive of opioid consumption, aside from pain relief and addiction, namely the pleasure experienced in the initial period of opioid use. The fact that opioids, in contrast to other analgesics, provide not only pain relief but also a state of euphoria that motivates the take up of opioids by some individuals in period 1. We conceptualize individuals who initiate OPR independently from their pain level, as recreational users. Of course, the borderline between pain relief and opioid abuse for euphoria is not always clear-cut and recreational utility from opioids could mainly have the effect that people use prescription opioids at lower levels of pain than they would without this pleasant side-effect.

In order to integrate recreational opioid use into the model we assume that the utility experienced from opioids, denoted by r is individual-specific and independently and uniformly distributed in the unit interval, $r \in (0, 1)$. Like addiction, the abuse of prescription opioids for recreational purposes is potentially disapproved by the community. The net utility gain from recreational use at time t of an individual with preference r is given by $r - \rho - \tilde{\sigma} s_t$, in which $\tilde{\sigma}$ denotes the utility weight of social disapproval for opioid use in the first period and $0 \leq \rho < 1$ is a shifter that has no relevance in the theoretical analysis and prevents in numerical analysis that a majority of individuals uses drugs in period 1. It could be conceptualized as a general dislike of opioids. With these amendments, expected lifetime utility reads:

$$E(V_t) = y - q_I d_t^1 - \frac{\pi p}{1 + \gamma d_t^2} + (r - \rho - \tilde{\sigma} s_t) d_t^1 + \beta \left[y - q_A d_{t+1}^2 - \frac{\alpha d_t^1}{2(1 + \gamma d_{t+1}^2)} - \sigma s_{t+1} d_{t+1}^2 \right]. \quad (13)$$

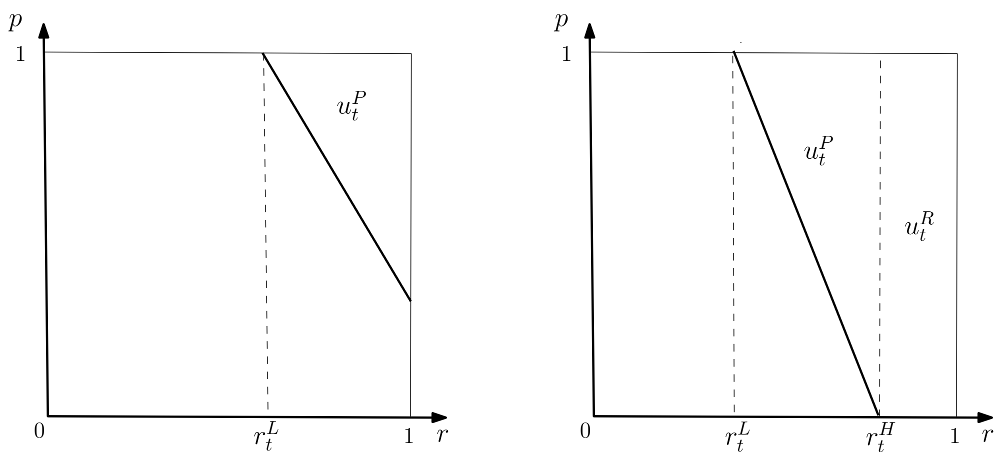
Notice that social disapproval (if it exists) applies to all period 1 users, independently from whether their opioid use is motivated exclusively by pain relief or by recreational purposes. This captures the notion that the "true" motive of opioid use is unobservable. Also, all period 1 users are assumed to have access to OPRs at price q_I. This means that individuals not suffering from pain *initiate* their recreational use by access to prescription opioids. Continuation of use in period 2, however, is subject to the higher street price.

Proceeding as for the basic model and comparing utility with and without opioid use in period 1, we obtain that individuals use opioids if

$$p > \bar{p}(r,t) \equiv p_t^0 - \frac{1+\gamma}{\gamma\pi} \cdot r, \qquad p_t^0 \equiv \frac{1+\gamma}{\gamma\pi}\left(q_I + \frac{\alpha\beta}{2} + \rho + \tilde{\sigma} s_t\right). \tag{14}$$

In contrast to the basic model, the decision space is now two-dimensional, consisting of pain p and preference for recreational drug use r. Diagrammatically, $\bar{p}(r,t)$ is a straight line in r–p–space above which individuals use opioids. It is represented by the bold downward sloping line in Figure 3, showing the feature that a higher preference for recreational drug use motivates opioid use at lower levels of pain. The position of the line is time-dependent because it is, among other things, determined by the prevailing disapproval of opioid use at time t. Inspection of (14) shows that declining disapproval shifts the line downwards.

Figure 3: Period 1 Opioid Users



Thanks to the simplifying assumptions on distributions, the prevalence of opioid use in period 1 generation can be immediately read off from Figure 3. The whole population is represented by the square of unit size and the population share of OPR users is given by the area above the bold line. There exist two qualitatively distinct cases. In the panel on the left hand side of Figure 3, there exists no purely recreational use of opioids in the sense that all opioid users experience at least some pain. In the panel on the right hand side a population share of $u_t^R = 1 - r_t^H$ uses opioids for purely recreational purposes. The total share of people who initiate opioid consumption is given by the share of pain patients u_t^P and the share of recreational users u_t^R, $u_t^I = u_t^P + u_t^R$.

Blanchflower and Oswald, (2018) observe that the prevalence of chronic pain is significantly higher in the U.S. than anywhere else in the developed world. This observation may appear puzzling if we consider pain as a purely physiological phenomenon. The model explains this observation by different social equilibria (or "cultures") of pain treatment. The distribution of physical pain is the same in both panels of Figure 3 but the share of diagnosed and OPR-treated pain patients is higher on the right hand side (reflecting the U.S.) than on the left hand side (reflecting other developed countries) because social disapproval of OPR use is lower and/or prescription prices are lower.

By setting $\bar{p}(r,t) = 0$ and $\bar{p}(r,t) = 1$, we obtain the intersections of the $\bar{p}(r,t)$–line with the population-square. They are given by:

$$r_t^L = \max\left\{0,\ \frac{\gamma\pi}{1+\gamma}\cdot(p_t^0 - 1)\right\} \tag{15}$$

$$r_t^H = \min\left\{1,\ \frac{\gamma\pi}{1+\gamma}\cdot p_t^0\right\} \tag{16}$$

Evaluating the conditions $r_t^H \geq 1$ and using (14) verifies the following result.

Proposition 4. *There is no purely recreational use of opioids in period 1 and time t if $\tilde{\sigma}s_t \geq 1 - q_I - \rho - \alpha\beta/2$, i.e. if social disapproval of recreational drug use $\tilde{\sigma}s_t$, the price q_I, or the addictive power α are sufficiently high. If there is recreational drug use at time t, the population share of recreational users is obtained as:*

$$u_t^R = 1 - r_t^H = 1 - q_I - \rho - \tilde{\sigma}s_t - \alpha\beta/2. \tag{17}$$

It is declining in social disapproval of recreational drug use $\tilde{\sigma}s_t$, the price q_I, and the addictive power α.

If there is no recreational use, the comparative statics of the model are as for the basic model from Section 2. The most interesting (and most plausible) case is were both r_t^L and r_t^H are interior, implying that there are some people who do not use opioids (those left to r_t^L), some therapeutic users, and some recreational users (those right to r_t^H). In this case the population share of therapeutic users u_t^P can be simply read off from Figure 3 as $u_t^P = \frac{1}{2}\left(r_t^H - r_t^L\right)$ (since the area of a triangle is half of the area of a rectangle with width $r^H - r^L$ and height one). By inserting (15)-(16) we conclude:

Proposition 5. *If in a population there are some therapeutic users, some recreational users, and some non-users of OPRs, then a change in addictive power α, or social disapproval σ_t, or OPR prices q_I leaves the share of therapeutic users unchanged. It is given by*

$$u_t^P = \frac{1}{2} \cdot \frac{\gamma\pi}{1+\gamma}. \tag{18}$$

Diagrammatically, a decline in α is represented by a shift of the $\bar{p}(r,t)$-line to the left in Figure 3. This shift illustrates how the *composition* of the u_t^P group changes although its size remains constant. To see this, imagine individuals as (r,p)-tuples in the diagram. Then, after a rightward shift of the $\bar{p}(r,t)$-line, some individuals who formerly would not take opioids without pain start using them for purely recreational purpose. They move from the u_t^P-group to the u_t^R-group. Other individuals who initially would not take opioids at all now start taking them for pain relief if pain is sufficiently high. They move from non-users to the u_t^P-group. Due to the simple linear structure of the model the in- and out-movements of the u_t^P-group balance each other such that group size stays constant. The following statement summarizes these results.

Corollary 1. *A decline in addictive power α or social disapproval of OPR use σ increases the population share of recreational OPR users and reduces the population share of non-users.*

The population share of addicts in period 2 is obtained analogous as in the basic case (7) with the refinement that OPR users of the previous period consist now of pain patients and recreational users, i.e. $u_t^A = \max\left\{0,\ (u_{t-1}^P + u_{t-1}^R)(1-a_t^*)\right\}$. By considering the evolution of disapproval of addiction (10), we obtain similar dynamics of an OPR epidemics. The distinguishing feature is that a potential OPR trap is now driven by recreational OPR users.

To elaborate on this in more detail, consider an initial situation where social disapproval of opioid use is high and there are only a few recreational users of opioids. Caused by a temporary wrong belief of low addictive power α, more people start using opioids for pain relief and for fun. As a result, the population share of addicted individuals increases and disapproval declines. This motivates more people (with lower values of p and/or lower values of r) to use opioids for pain relief and recreation. This reduces social disapproval further etc. When α rises again (the wrong belief is resolved) the share of recreational users declines but not towards its initially low level because recreational use is no longer socially disapproved. The following Proposition summarized this observation in more general terms.

Proposition 6. *If a policy change induces the transition from low opioid use and high disapproval of addiction ($s = 1$) to high opioid use and low disapproval ($s = 0$), the re-establishment of the original policy does not re-establish the initial situation of low initiation of opioid use. Instead the share of individuals who initiates opioid use for recreational purpose increases by σ.*

The proof inspects (17) for $s = 1$ and $s = 0$. As a corollary we observe that it needs a (drastic) increase of the initiation price by factor $\tilde{\sigma}/q_I$ in order to establish the low initial share of recreational users. Implementing a drastic price change, however, could be difficult when illicit drugs like heroin are cheap substitutes to prescription OPRs. Notice that the (drastic) price policy does not re-establish the original equilibrium. It keeps the initiation of opioid use low by high prices whereas in the original equilibrium initiation was kept low by social disapproval of addiction.

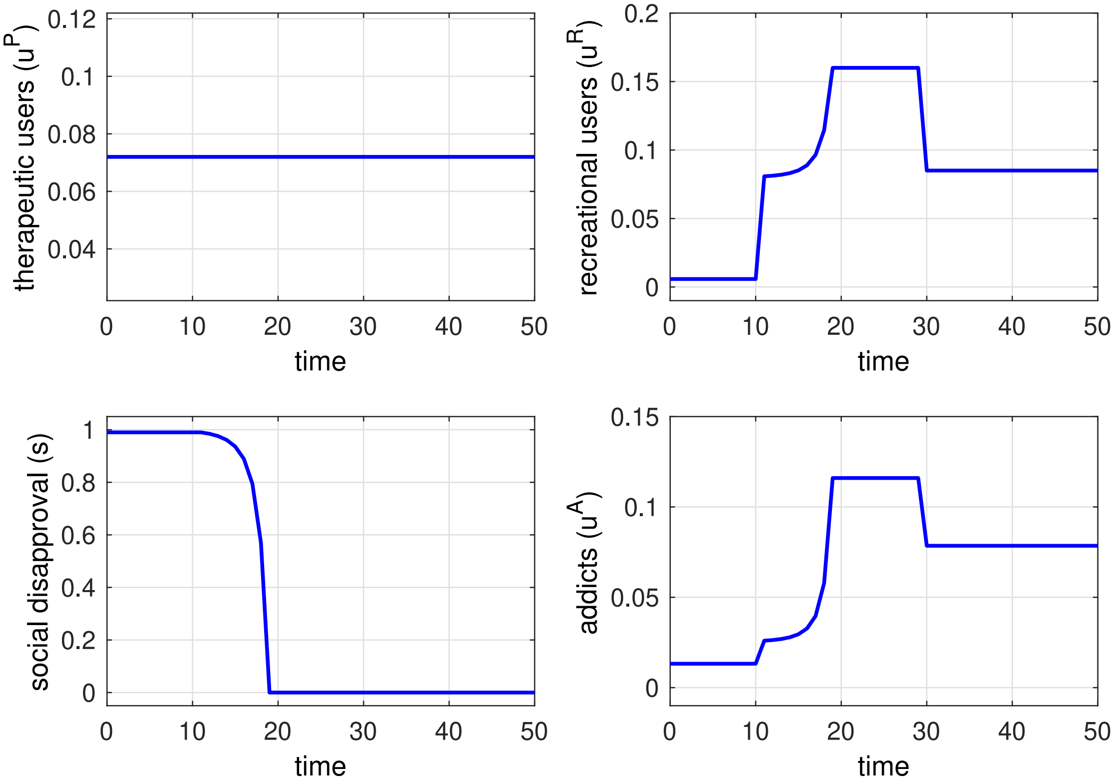
We next consider an illustration of the opioid epidemic by a numerical example. For that we take most of the parameter values of the basic model. Since there is an additional motive for OPR use, the weight of pain π is reduced from 0.33 to 0.24 match the target that there are about 7% medical OPR users in the community and ρ is set to 0.74 such that initially a positive but insignificantly small share of society uses OPRs for recreational purposes.

Adjustment dynamics are shown in Figure 4. Again, a new opioid is introduced at time 10 and people wrongly believe that its addictive power is 0.2 while in fact it is 0.5. This motivates a drastic increase of recreational OPR use (upper right panel). It also increases the population share of addicts. At first, however, addiction is highly stigmatized and most but not all individuals who tried OPRs for recreation successfully fight their addiction (lower right panel). Gradually, however the anti-addiction norm deteriorates, which motivates even more initiation of drug use for recreational purpose as well as more continuation of drug use as addiction. When the wrong belief is corrected at time 30, recreational use and addiction decline somewhat but not to their initially low level because the community does no longer sustain the anti-addiction norm.

4. Income and Addiction

In this section we abandon the assumption of homogenous income. Instead we assume that potential income is idiosyncratic and that it is independently and uniformly distributed in the unit

Figure 4: Recreational OPR Addiction Dynamics



$\alpha = 0.5$, $\beta = 0.5$, $\gamma = 1.5$, $\pi = 0.24$, $q_I = 0.05$, $q_A = 0.15$, $\lambda = 60$, $\sigma = 0.1$, $\tilde{\sigma} = 0.08$, $\rho = 0.74$. From time 10 to 30 individuals believe that $\alpha = 0.2$.

interval, $y \in (0, 1)$. Income plays two roles in conjunction with OPR use. In period 1, individuals of lower income experience greater pain and despair. This could capture a direct channel from low income to stress and pain (Marmot and Wilkinson, 2005) or Case and Deaton's (2017) notion of despair caused by low socio-economic status. In period 2, dealing with an addiction reduces labor supply (Krueger, 2017; Currie et al., 2018) and therewith income.

To simplify the analysis, we assume that an individual with income y experiences pain $(1-\theta y)$, in which θ measures the impact of income on pain. In period 2, an individual born at time t receives actual income $(1 - \delta d_{t+1})y$, in which δ measures the impact of addiction on labor supply and income. With these amendments, expected lifetime utility is given by

$$\begin{aligned} E(V_t) = {} & y - q_I d_t^1 - \frac{\pi(1-\theta y)}{1+\gamma d_t^1} + (r - \rho - \tilde{\sigma} s_t) d_t^1 \\ & + \beta \left[y(1 - \delta d_{t+1}^2) - q_A d_{t+1}^2 - \frac{\alpha d_t^1}{2(1+\gamma d_{t+1}^2)} - \sigma s_{t+1} d_{t+1}^2 \right]. \end{aligned} \tag{19}$$

Comparing utility with and without OPR use we find that opioids are taken in period 1 if

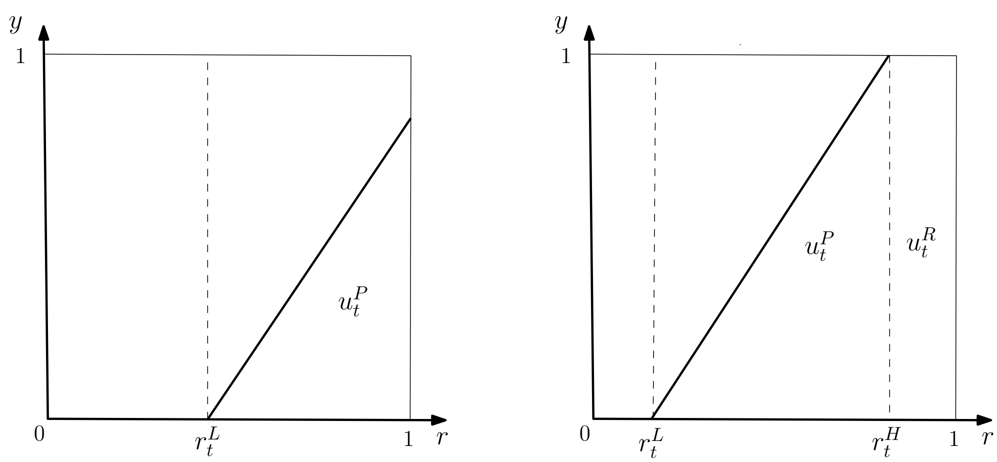
$$y < \bar{y}(r,t) \equiv \frac{1+\gamma}{\gamma\pi\theta} \cdot r - y_t^0, \qquad y_t^0 \equiv \frac{1}{\theta}\left[\frac{1+\gamma}{\gamma\pi}\left(q_I + \frac{\alpha\beta}{2} + \rho + \tilde{\sigma} s_t\right) - 1\right]. \tag{20}$$

As before, we assume that parameters are such that individuals who use OPRs when they believe that they will become addicted also use OPRs when they believe that they will stay clean. Analogously to Section 3, we discuss the implication on the prevalence of drug use in the r–y–space. Individuals situated below the threshold $\bar{y}(r,t)$ use OPRs. Setting $\bar{y}(r,t) = 0$ and $\bar{y}(r,t) = 1$, we obtain the intersections of the threshold with the borders of the population space as:

$$r_t^L = \max\left\{0,\ \frac{\gamma\pi\theta}{1+\gamma} \cdot y_t^0\right\} \tag{21}$$

$$r_t^H = \min\left\{1,\ \frac{\gamma\pi\theta}{1+\gamma} \cdot (1+y_t^0)\right\} \tag{22}$$

Figure 5: Income and Period 1 OPR Use



Results are shown in Figure 5. The threshold is now upward-sloping and people below the threshold use OPRs. Since $\theta > 0$, the pain intensity varies reverse-proportionally with income. Individuals to the left of r_t^L do not use OPRs, irrespective of their level of pain (income). The share of OPR users for any given level of income can be read off as the horizontal distance between the threshold and the vertical line at 1. We see that prevalence of drug use is negatively associated with income. Individuals with preference for recreational drug use below r_t^L do not use OPRs irrespective of their level of income (pain). In the panel on the left-hand side of Figure 5, there are no OPRs users for purely recreational purposes. These users emerge in the panel on the right hand side with population share $1 - r_t^H$ of the current period-1 generation. We focus again on the interior solution where there are some non-users, some OPR-pain patients, and some recreational users. The population shares can be read off from Figure 5.

PROPOSITION 7. *The population share of recreational users in period 1 is obtained as:*

$$u_t^R = 1 - r_t^H = 1 + \frac{\gamma\pi}{1+\gamma}(1-\theta) - q_I - \rho - \tilde{\sigma} s_t - \frac{\alpha\beta}{2}. \tag{23}$$

It is declining in social disapproval of recreational drug use $\tilde{\sigma} s_t$, the price q_I, and the addictive power α.

PROPOSITION 8. *If in a population there are some therapeutic users, some recreational users, and some non-users of OPRs, then a change in addictive power α, or social disapproval σ_t, or OPR prices q_I leaves the share of therapeutic users unchanged. It is given by*

$$u_t^P = \frac{1}{2} \cdot \frac{\gamma\pi\theta}{1+\gamma}. \tag{24}$$

The interesting comparative statics is here with respect to θ. A higher value of θ means that income has more influence on pain and that there is less pain at any given income level. It may thus appear puzzling that increasing θ leads to a higher population share of therapeutic OPR users u_t^P, see (24). The resolution becomes obvious when we consider the result in conjunction with recreational use and compute the total population share of first-period OPR users.

COROLLARY 2. *The total share of OPR users in period 1 is given by*

$$u_t^P + u_t^R = 1 + \frac{\gamma\pi}{1+\gamma}\left(1 - \frac{\theta}{2}\right) - q_I - \rho - \tilde{\sigma} s_t - \frac{\alpha\beta}{2}. \tag{25}$$

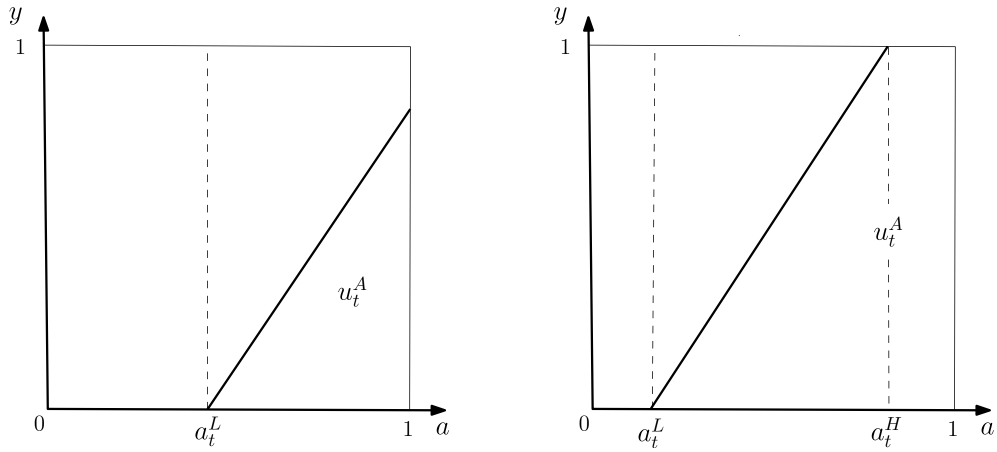
It is declining in the average level of pain (i.e. in θ), in the strength of addiction α, and in social disapproval of addiction.

When θ increases and pain declines at any income level, some former pain patients stop using OPRs (diagrammatically r_t^L moves to the right in Figure 5). Furthermore, some former recreational users (whose income was so low that marginal income improvement would not change OPR use) now use OPRs only if pain is high enough (diagrammatically r_t^H moves to the right in Figure 5). The proposition shows that the second effect dominates.

Inspection of the panel on the right hand side of Figure 6 verifies the following proposition.

PROPOSITION 9. *If there is purely recreational OPR use, then OPR use is prevalent at all income levels. The incidence of OPR use is higher at lower income levels.*

Figure 6: Income and Addiction



In period 2, individuals born at time t learn their actual susceptibility to addiction a and use drugs to feed the addiction if utility with drug consumption exceeds utility without, i.e. if $y(1-\delta) - q_A - \alpha a/(1+\gamma) - \sigma s_{t+1} > y - \alpha a$, i.e. if

$$y < \tilde{y}(a,t) \equiv \frac{\alpha\gamma}{(1+\gamma)\delta} \cdot a - \tilde{y}_t^0, \qquad \tilde{y}_t^0 \equiv (q_A + \sigma s_{t+1})/\delta > 0. \tag{26}$$

Compared to the basic model, addictive drug consumption has an opportunity cost in terms of foregone income (and thus consumption of normal goods) due to reduced labor supply. This opportunity cost is higher for richer individuals who are thus less likely addicted opioid consumers. There are, however, also rich addicted individuals, namely those who are equipped with strong susceptibility to addiction (and who were previously treated for pain relief). Figure 6 shows the prevalence of addiction (among those who took OPRs in period 1). The bold upward-sloping line shows the threshold $\bar{y}(a,t)$. Its borders are obtained from (28) as

$$a_t^L = \frac{(1+\gamma)\delta}{\alpha\gamma} \cdot \tilde{y}_t^0 > 0 \tag{27}$$

$$a_t^H = \min\left\{1, \ \frac{(1+\gamma)\delta}{\alpha\gamma} \cdot \left(1 + \tilde{y}_t^0\right)\right\}. \tag{28}$$

Again focussing on an interior solution (i.e. $a_t^H < 1$), we obtain the following result

Proposition 10. *The population share of opioid addicts in period 2 (conditional on initiation of OPR use in period 1) is obtained as*

$$u_{t+1}^A = 1 - a_t^H - \frac{1}{2}\left(a_t^H - a_t^L\right) = 1 - \frac{(1+\gamma)}{\alpha\gamma}\left(\frac{\delta}{2} + q_A + \sigma s_{t+1}\right). \tag{29}$$

The comparative statics are as for the basic model (3). Additionally, a greater effect of drug use on income (higher δ) reduces the prevalence of addiction.

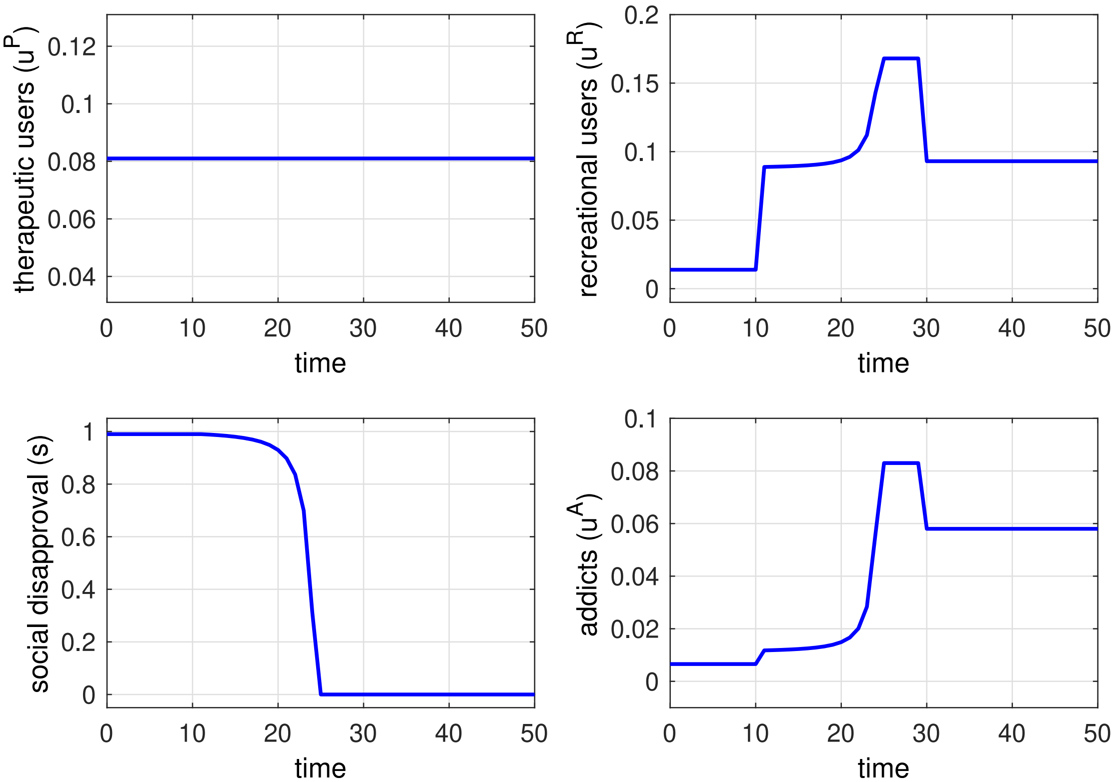
The total population share of drug users in generation 2 born in period t is given by $(u_t^P + u_t^R) \cdot u_{t+1}^A$. In conjunction with Proposition 8 we obviously arrive at the following conclusion.

Corollary 3. *Opioid addiction is prevalent at all income levels. Its incidence is higher at low income levels.*

We next consider an illustration of the opioid epidemic by a numerical example. For that we take most of the parameter values of the model from the last Section. We set $\theta = 0.9$, implying that pain steeply increases with declining income thus capturing in a stylized way the despair hypothesis. In terms of income effects of OPR use the literature has not yet converged to consensus. Krueger (2017) provides evidence in favor of a large negative impact of the opioid crisis on labor force participation. Currie et al. (2018), however, cannot confirm this result and provide evidence in favor of a mild positive effect of opioid consumption on female employment and no effect for male employment. Here we consider a mild negative impact and set $\delta = 0.1$

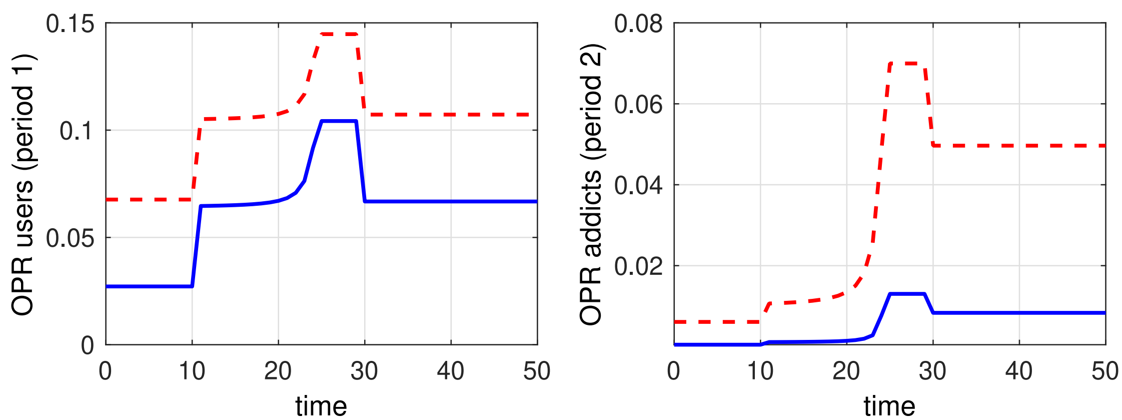
The implied evolution of the opioid epidemic is shown in Figure 7. At time 10, individuals start wrongly believing that a new OPR has low addictive power. At time 30 the belief is corrected. Adjustment dynamics are very similar to those shown in Figure 4 and discussed in Section 3. This is unsurprisingly so because the consideration of income effects concerns the distribution rather than the aggregates of the opioid epidemic. To illustrate the distributional effects in a stylized way we define two social classes. The rich earn above median income and the poor earn below median income. Figure 8 shows the implied adjustment dynamics for the two classes. The poor are more susceptible to initiate OPR use than the rich because of greater pain. They are also more likely to continue an addiction because of lower opportunity costs (less income lost due to addiction). In terms magnitude, social differences in opioid use are greater due to addiction disorders than due to pain therapy or recreational use. This outcome suggests that opportunity can be more important than despair to motivate opioid consumption of the poor.

Figure 7: Opioid Use Dynamics with Endogenous Income



$\alpha = 0.5$, $\beta = 0.5$, $\gamma = 1.5$, $q_I = 0.05$, $q_A = 0.15$, $\lambda = 100$, $\sigma = 0.08$, $\tilde{\sigma} = 0.08$, $\rho = 0.75$, $\theta = 0.9$, $\delta = 0.08$. From time 10 to 30 individuals believe that $\alpha = 0.2$.

Figure 8: Opioid Use Dynamics of the Rich and Poor



Population share of rich (blue solid lines) and poor (red dashed lines) opioid users. Rich: $y > 1/2$; Poor: $y < 1/2$.

5. Conclusion

This paper has proposed a new view on opioid epidemics that takes the 'epidemic' feature seriously. In a series of simple models a theory has been introduced that explains how a community ends up in an opioid trap by a deteriorating anti-addiction norm. In the paper, we focussed on an initiation of these developments by wrong beliefs about the addictive power of new opioids. The transition could equally well be initiated by declining (out-of-pocket) prices of prescription OPRs or an increasing emphasis on pain in utility (pain as the fifth vital sign). Further refinements of the theory are conceivable. For example, anti-addiction norms may be specific to addictive goods. In such a scenario, the opioid epidemic would first weaken and eventually eliminate disapproval of non-medical OPR use and in a second phase, when increasing shares of addicts in the community moved to cheaper heroin, reduce the disapproval of injecting illicit opioids.

The local stability of the OPR trap calls for strong policy action. Small prices changes of OPRs are not able to move the community out of the OPR trap. Drastic price increases could move the community out of the bad equilibrium but they are difficult to implement for illicit drug use. If increasing prices of prescription OPRs mainly motivate the consumption of cheaper but more dangerous opioids, price policies are likely to reduce rather than to improve welfare. In contrast, the model supports anti-addiction policies. An ideal methadone would be captured by the model as a reduction of susceptibility to addiction (a) that maintains the pain reducing power (γ). If it is administered at low cost and for a sufficiently long duration such a policy would not only improve individual welfare but, by reducing the number of opioid addicts, it could also move society out of the opioid trap and help to re-construct a prevailing anti-addiction norm.

The epidemics model explains how communities that face the same fundamentals (preferences, prices, structure of society) can end up in different equilibria of high and low prevalence of opioid use and addiction. This feature is helpful to motivate the great variation of the U.S. opioid crisis across similar communities. It offers an explanation for the part of the variance that is left unexplained by macroeconomic conditions, individual hardship or loss of status, physician behavior, or the characteristics of the local population and the number and composition of health care providers.

References

Battista, N.A., Pearcy, L.B., and Strickland, W.C. (2019). Modeling the prescription opioid epidemic. *Bulletin of Mathematical Biology*, forthcoming.

Bachmann, J. R., Johnston, L. D., and O'Malley, P. (1990). Explaining the recent decline in cocaine use among young adults. *Journal of Health and Social Behavior* 31, 173-184.

Becker, G.S., and Murphy, K.M. (1988). A theory of rational addiction. *Journal of Political Economy* 96(4), 675-700.

Becker, G.S. (1992). Habits, addictions, and traditions. *Kyklos* 45(3), 327-345.

Blanchflower, D.G., and Oswald, A. (2019). Unhappiness and Pain in Modern America: A Review Essay, and Further Evidence, on Carol Grahams Happiness for All? *Journal of Economic Literature*, forthcoming.

Brock, W. A., and Durlauf, S. N. (2001). Discrete choice with social interactions. *Review of Economic Studies* 68(2), 235-260.

Carpenter, C. S., McClellan, C. B., and Rees, D. I. (2017). Economic conditions, illicit drug use, and substance use disorders in the United States. Journal of Health Economics, 52, 63-73.

Case, A., and Deaton, A. (2017). Mortality and morbidity in the 21st century. Brookings papers on economic activity, 2017, 396-467.

Cawley, J., and Ruhm, C. (2012). The economics of risky health behaviors, in: in Mark V. Pauly, Thomas G. McGuire, and Pedro P. Barros (eds.) *Handbook of Health Economics* Volume 2. New York: Elsevier, 2012, 95-199.

CDC (2017a). Understanding the Epidemic. Centers for Disease Control and Prevention. `https://www.cdc.gov/drugoverdose/epidemic/index.html`

CDC (2017b) Vital Signs: Changes in Opioid Prescribing in the United States, 20062015. Centers for Disease Control and Prevention. `https://www.cdc.gov/mmwr/volumes/66/wr/mm6626a4.htm`.

Chen, Q., Larochelle, M. R., Weaver, D. T., Lietz, A. P., Mueller, P. P., Mercaldo, S., ... and Pandharipande, P. V. (2019). Prevention of Prescription Opioid Misuse and Projected Overdose Deaths in the United States. *JAMA Network Open* 2(2), e187621-e187621.

Christakis, N.A., and Fowler, J.H. (2007). The spread of obesity in a large social network over 32 years, *New England Journal of Medicine* 357, 370-379.

Cicero, T. J., Ellis, M. S., Surratt, H. L., and Kurtz, S. P. (2014). The changing face of heroin use in the United States: a retrospective analysis of the past 50 years. JAMA Psychiatry, 71(7), 821-826.

Cicero, T. J., Ellis, M. S., and Kasper, Z. A. (2017). Increased use of heroin as an initiating opioid of abuse. *Addictive Behaviors* 74, 63-66.

Cicero, T. J., and Ellis, M. S. (2017). The prescription opioid epidemic: a review of qualitative studies on the progression from initial use to abuse. *Dialogues in Clinical Neuroscience* 19(3), 259-269.

Concise Medical Dictionary (2014). 8th edition. Oxford University Press. https://www.oxfordreference.com/view/10.1093/acref/9780199557141.001.0001/acref-9780199557141

Currie, J., Jin, J.Y., Schnell, M. (2018). U.S. employment and opioids: is there a connection? NBER Working Paper 24440.

Cutler, D.M.,and Glaeser, E.L. (2007). Social Interactions and Smoking. National Bureau of Economic Research Working Paper w13477.

DEA (2015). National Heroin Threat Assessment Summary. DEA Intelligence Report, April 2015. https://www.dea.gov/documents/2015/04/01/2015-national-heroin-threat-assessment-summary.

Deiana, C., and Giua, L. (2018). The US Opidemic: Prescription Opioids, Labour Market Conditions and Crime.

Evans, W.N., Lieber, E., and Power, P. (2018). How the reformulation of OxyContin ignited the heroin epidemic (No. w24475). National Bureau of Economic Research.

Finkelstein, A., Gentzkow, M., and Williams, H. (2018). What drives prescription opioid abuse? Evidence from migration. SIEPR Working Paper 18-028.

Frenk, S.M., K.S. Porter, and L.J. Paulozzi. 2015. Prescription opioid analgesic use among adults: United States, 19992012. NCHS Data Brief No. 189.

Grossmann, V. and Strulik, H. (2018). Illicit Drugs and the Decline of the Middle Class, cege Discussion Paper 353, 2018.

Gupta, S. (2016) Unintended consequences: Why painkiller addicts turn to heroin, CNN International, June 2, 2016. https://edition.cnn.com/2014/08/29/health/gupta-unintended-consequences/index.html

Haddox, J. D., Joranson, D., Angarola, R. T., Brady, A., Carr, D. B., Blonsky, E. R., ... and Simon, D. (1997). The use of opioids for the treatment of chronic pain. *Clinical Journal of Pain* 13(1), 6-8

Hoppensteadt, F. C., and Murray, J. D. (1981). Threshold analysis of a drug use epidemic model. *Mathematical Biosciences* 53(1-2), 79-87.

IQVIA (2017). Medicine Use and Spending in the U.S. A Review of 2017 and Outlook to 2022. Institute for Human Data Science.

Jones, A. M. (1994). Health, addiction, social interaction and the decision to quit smoking. *Journal of Health Economics* 13(1), 93-110.

Kalso, E., Edwards, J. E., Moore, R. A., and McQuay, H. J. (2004). Opioids in chronic non-cancer pain: systematic review of efficacy and safety. *Pain* 112(3), 372-380.

Kermack, W.O., and McKendrick, A.G. (1927). A contribution to the mathematical theory of epidemics. *Proceedings of the Royal society of London. Series A* 115(772), 700-721.

Kolodny, A., Courtwright, D. T., Hwang, C. S., Kreiner, P., Eadie, J. L., Clark, T. W., and Alexander, G. C. (2015). The prescription opioid and heroin crisis: a public health approach to an epidemic of addiction. Annual review of public health, 36, 559-574.

Krueger, A.B. (2017). Where have all the workers gone? *Brookings Papers on Economic Activity*, Fall 2017, 1-87.

Luty, J., and Arokiadass, S. M. R. (2008). Satisfaction with life and opioid dependence. Substance abuse treatment, prevention, and policy, 3(1), 2.

Manski, C.F. (2000). Economic analysis of social interactions. *Journal of Economic Perspectives* 14(3), 115-136.

Marmot, M., and Wilkinson, R. (eds.). (2005). *Social Determinants of Health.* Oxford University Press, Oxford.

McCabe, S. E., West, B. T., Teter, C. J., and Boyd, C. J. (2012). Medical and nonmedical use of prescription opioids among high school seniors in the United States. Archives of pediatrics and adolescent medicine, 166(9), 797-802.

McDonald, D. C., Carlson, K., and Izrael, D. (2012). Geographic variation in opioid prescribing in the US. *The Journal of Pain* 13(10), 988-996.

National Academies of Sciences, Engineering, and Medicine. (2017). Pain management and the opioid epidemic: balancing societal and individual benefits and risks of prescription opioid use. National Academies Press.

Palamar, J. J., Kiang, M. V., and Halkitis, P. N. (2012). Predictors of stigmatization towards use of various illicit drugs among emerging adults. Journal of Psychoactive Drugs, 44(3), 243-251.

Palamar, J. J., Halkitis, P. N., and Kiang, M. V. (2013). Perceived public stigma and stigmatization in explaining lifetime illicit drug use among emerging adults. Addiction Research and Theory, 21(6), 516-525.

Pitt, A. L., Humphreys, K., and Brandeau, M. L. (2018). Modeling health benefits and harms of public policy responses to the US opioid epidemic. *American Journal of Public Health* 108(10), 1394-1400.

Poelen, E. A., Scholte, R. H., Willemsen, G., Boomsma, D. I., and Engels, R. C. (2007). Drinking by parents, siblings, and friends as predictors of regular alcohol use in adolescents and young adults: a longitudinal twin-family study. Alcohol & Alcoholism, 42(4), 362-369.

Portenoy, R.K., and Foley, K.M. (1986). Chronic use of opioid analgesics in non-malignant pain: report of 38 cases. *Pain* 25(2), 171-186.

Poutvaara, P., and Siemers, L. H. (2008). Smoking and social interaction. *Journal of Health Economics* 27(6), 1503-1515.

Reif, J. (2019). A model of addiction and social interactions. *Economic Inquiry* 57(2), 759-773.

Ruhm, C. J. (2018). Deaths of despair or drug problems? (No. w24188). National Bureau of Economic Research.

SAMHSA (2012) Substance Abuse and Mental Health Services Administration, Center for Behavioral Health Statistics and Quality. Results from the 2011 National Survey on Drug Use and Health: summary of national findings. NSDUH series H-44, HHS publication No. (SMA) 12-4713. Rockville, MD.

Schnell, M. (2017). Physician behavior in the presence of a secondary market: The case of prescription opioids. Mimeo, University of Princeton.

Simons-Morton, B., and Chen, R. S. (2006). Over time relationships between early adolescent and peer substance use. *Addictive Behaviors* 31(7), 1211-1223.

Strickland, J.C., and Smith, M. A. (2014). The effects of social contact on drug use: Behavioral mechanisms controlling drug intake. *Experimental and Clinical Psychopharmacology* 22(1), 23-34.

Strulik, H. (2018). Smoking kills: An economic theory of addiction, health deficit accumulation, and longevity. *Journal of Health Economics* 62, 1-12.

Strulik, H. (2019). From Pain Patient to Junkie: An Economic Theory of Painkiller Consumption and its Impact on Wellbeing and Longevity, cege Discussion Paper 359.

The White House. (2018). President Donald J. Trumps initiative to stop opioid abuse and reduce drug supply and demand. `https://www.whitehouse.gov/briefings-statements/president-donald-j-trumps-initiative-stop-opioid-abuse-reduce-drug-supply-demand/`.

White, E., and Comiskey, C. (2007). Heroin epidemics, treatment and ODE modelling. *Mathematical Biosciences* 208(1), 312-324.

Van Zee, A. (2009). The promotion and marketing of oxycontin: commercial triumph, public health tragedy. *American Journal of Public Health* 99(2), 221-227.

Volkow, N.D. (2014) America's Addiction to Opioids: Heroin and Prescription Drug Abuse. National Institute on Drug Abuse.

White, E., and Comiskey, C. (2007). Heroin epidemics, treatment and ODE modelling.*Mathematical Biosciences* 208(1), 312-324.

Zenz, M., Strumpf, M., and Tryba, M. (1992). Long-term oral opioid therapy in patients with chronic nonmalignant pain. *Journal of Pain and Symptom Management* 7(2), 69-77.

Zhou, C., Florence, C.S., and Dowell, D. (2016). Payments For Opioids Shifted Substantially To Public And Private Insurers While Consumer Spending Declined, 19992012. *Health Affairs* 35(5), 824-831.