Modelling “Breaking Bad”: An economic model of drugs and population dynamics to predict how the series itself feeds back into the drug market

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Abstract: This stock&flow-model predicts population dynamics of crystal meth addicts related to the price development of drugs, inspired by the TV series “Breaking Bad”. The potential impact of the broadcasting of the TV series on the system it tested by using sudden (pulsed) changes of selected flows and rates to reveal the sensitivity of selected variables: **Addicts**, **price relationship**, **dealers’ saturation** and **Stock of Crystal Meth**. While **consumption**, **purchase** and **production** show strong responses to those changes, other variables like **getting_addicted** and **weaning_off** show weaker responses. These flows’ reactions to pulsed changes of model parameters are analysed and their significance is discussed.

Keywords: **economic systems, modelling, intensity changes, population dynamics, drugs, breaking bad**

1. INTRODUCTION

The TV show “Breaking Bad” (2008-2012) shows a school chemistry teacher who starts producing and selling crystal meth. “I’ll continue to wonder about the long term effects of mainstreaming such a dangerous drug into popular culture”, Blake Ewing said (Ewing 2013). The model (Fig. 1) shows addicts’ and drug dynamics in correlation to price development. It is used to test the system’s sensitivity to outside influences such as the influence of the TV series “Breaking Bad” on the modelled drug market. These influences can cause with an increase in meth users, for example, in reaction to the TV series.

2. METHODS

The stock&flow-model is built in Vensim 5.11A. It is based on the given conditions in “Breaking Bad” and parameterised with data from the world drug report (United Nations Office on Drugs and Crime 2014). The model runs for 120 months, integration type is Euler and time step is defined with **Δt**=1 month. Units for crystal meth are [g], **Addicts** ($\mathbf{N^a}$) and **Non_Addicted** ($\mathbf{N^{na}}$) are [persons]. The models’ main structure is shown in Fig. 1. The total **Stock of Crystal Meth** ($\mathbf{C^{stock}}$) is specified by

$$\frac{\Delta C^{stock}}{\Delta t} = +\alpha \cdot C^{stock} + g - \beta \cdot C^{stock} \cdot \left(1 - \frac{C^{circ}}{k}\right) \qquad (1)$$

where $\boldsymbol{\alpha}$ is the intrinsic production rate, $\boldsymbol{g}$ represents the smuggled goods, $\boldsymbol{\beta}$ is the actual purchasing rate and $\mathbf{C^{circ}}$ is the amount of **Crystal Meth in Circulation**, which is further defined by (2). That follows from the constant actual purchasing rate $\boldsymbol{\beta}$, consumption rate $\boldsymbol{\gamma}$ and distribution rate $\boldsymbol{d}$. The dynamics of $\mathbf{N^{na}}$ are modelled by (3), where the actual growth rate is $\boldsymbol{\delta}$, normal death rate is $\boldsymbol{\varepsilon}$, weaning off rate is $\boldsymbol{\mu}$, addiction rate is $\boldsymbol{\varphi}$ and the **dealers’ saturation of crystal meth** is $\boldsymbol{s}$. Equation 4 determines the dynamics of $\mathbf{N^a}$ that grow in number with $\boldsymbol{\varphi}$ and $\boldsymbol{s}$ and drop with $\boldsymbol{\mu}$ and drug related death rate $\boldsymbol{\omega}$. The **purchasing price relationship** $\boldsymbol{p}$ is a regulator for the drug flow; it is defined by supply - $\mathbf{C^{stock}}$ - and demand – $\mathbf{N^a}$, $\boldsymbol{s}$, $\boldsymbol{\gamma}$ and $\boldsymbol{r}$ the daily requirement. The price elasticity $\boldsymbol{a}$ is the measurement of how responsive the price relationship is to a change in the proportion of demand to supply. These relationships are described in (5).

$$\frac{\Delta C^{circ}}{\Delta t} = +\beta \cdot C^{stock} \cdot \left(1 - \frac{C^{circ}}{k}\right) - MIN\left\{\begin{matrix} C^{circ} \cdot d \\ \gamma \cdot N^a \cdot s \end{matrix}\right\} \qquad (2)$$

$$\frac{\Delta N^{na}}{\Delta t} = +\delta \cdot N^{na} - \varepsilon \cdot N^{na} + \mu \cdot N^a \cdot (1-s) - \varphi \cdot N^{na} \cdot s \qquad (3)$$

$$\frac{\Delta N^{a}}{\Delta t} = +\varphi \cdot N^{na} \cdot s - \mu \cdot N^a \cdot (1-s) - \omega \cdot N^a \qquad (4)$$

$$p = \frac{a \cdot \dfrac{N^a \cdot (1-s) \cdot \gamma \cdot r}{C^{stock}+1}}{\sqrt{1 + \left(a \cdot \dfrac{N^a \cdot (1-s) \cdot \gamma \cdot r}{C^{stock}+1}\right)^2}} \qquad (5)$$

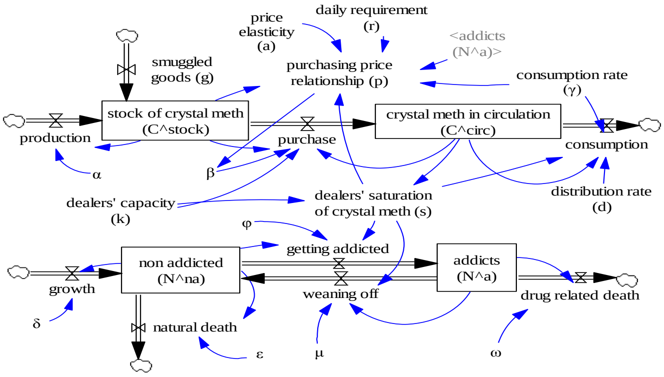

Fig. 1: Excerpt of the stock&flow-model of “Breaking Bad”, showing the main structure of its system components.

The **dealers’ saturation** $\boldsymbol{s}$ has influence on consumption and on $\boldsymbol{p}$, as apparent from (6). The **dealers’ saturation** also regulates the **getting_addicted** and the **weaning_off** flow. A 100% **dealers' saturation** implies a maximum addiction rate. Thus forming is the link between drugs and addicts. Equation 6 is given by

$$s = \frac{C^{circ}}{k} \qquad (6)$$

where $\mathbf{C^{circ}}$ is given in (2) and $\boldsymbol{k}$ is the dealers' maximum capacity. A PULSE function was used to test the drug system's sensitivity to the series' influence. This PULSE changes a chosen flow in a defined time interval from 1 to X by multiplication. The series ran for 5 years, thus we applied the PULSE for 5 years to perturb the system with different strengths (0% to +50%). To quantify the influence of the PULSE, the data at t=73 are observed.

3. RESULTS

Fig. 2 shows the reactions of **Addicts**, **purchasing price relationship**, **dealers' saturation** and **Stock of Crystal Meth** after the PULSE influenced the affected flows. The abscissa shows the increase and the decrease of the PULSE effect relative to the starting conditions. The ordinate shows the relative change of the observed variables. In general, responses are almost linear.

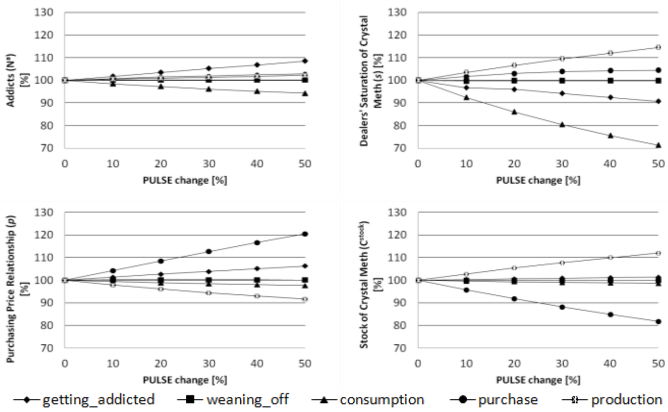

Fig. 2: Results of sensitivity tests by PULSE change

$\mathbf{N^a}$ is most reactive to positive changes of the flow **getting_addicted** and negative changes of **consumption**. **Purchase** and **production** show less reaction and similar linear scaling of reaction. The **price relationship** increases with a positive change in **purchase** and **decreases** with a rise in **production**. **Getting_addicted** shows as slight increase, **production** is reacting least to a change. **Dealers' saturation** grows strongest with a rise in **production** and decreases with an increase in **consumption**; with changes in **getting_addicted** and **purchase** it shows little decrease. $\mathbf{C^{stock}}$ is most influenced by increased **production** volumes and by decreased **purchase**. The other observed flows show similar linear responses, but on a low level. **Weaning_off** universally remains constant throughout all perturbation experiments.

4. DISCUSSION

On the one hand, we showed that the modelled drug market is intrinsically stable in response to extrinsic perturbations. On the other hand, significant medium-term effects of perturbations are predicted, as they can be caused by the TV series itself. These responses, which are shifts of equilibria during the perturbed period, have been analysed systematically in a quantitative way generating testable hypotheses. Results show different sensitivities of analysed observed variables to the changes in parameters governing important flows in the system: The more **consumption** increases, the more **dealers' saturation** decreases. Consequently the **price relationship** and $\mathbf{N^a}$ decrease. This seems implausible at first sight but it is accurate according to the model's hypothesis of market regulation. Since demand is determined by the consumption rate and not by the **consumption** flow, the **price relationship** does not react as expected. The saturation reacts with a time delay, which is a result of the multi-stock structure of the modelled system. With regard to **production**, the model's behaviour is governed by the feedback loop "$\mathbf{C^{stock}}$ to **purchase**", which prevents oversaturation. The growing **purchase** flow reacts with an enhancement of $\mathbf{N^a}$, **price relationship** and **dealers' saturation** while $\mathbf{C^{stock}}$ decreases. This is consistent to the underlying hypothesis of market regulation. A positive change in **getting_addicted** leads to an increase in $\mathbf{N^a}$. As **price relationship** is not very responsive to small changes, it grows subtly, due to a remote growth in supply ($\mathbf{C^{stock}}$). **Dealers' saturation** decreases with higher **consumption** caused by more $\mathbf{N^a}$. **Weaning_off** conspicuously is insensitive in consequence of a low **weaning_off** rate. Since there are no over-proportional changes the system is considered to be stable. This stability is caused by the negative feedback loop established by the interaction of demand and **price relationship**. The higher the price elasticity is, the more stable the system becomes due to higher flexibility in the **price relationship**, which induces an enhancement of the negative feedback loop. One disturbance of the drug market that was simulated by the PULSE experiment (on all flows) was found to be the effect of the broadcast of the series itself (Ewing 2013). In agreement to our model predictions, the UNODC reports an increase in production, consumption and purchase of methamphetamines between 2008-2012 (United Nations Office on Drugs and Crime 2014, Fig. 49.). Based on various stories it can be assumed that "Breaking Bad" still has an impact on the raise in meth-use. State-Time plots (not shown here) indicate long-term effects, concerning the ratio of $\mathbf{N^{na}}$ to $\mathbf{N^a}$ without a decrease of total population. $\mathbf{N^a}$ get more while $\mathbf{N^{na}}$ decline in amount. It is remarkable that the **price relationship** always reaches its equilibrium after the PULSE ceases to act on an altered flow. This is a consequence of (5) which varies the terminal point by alternating $\boldsymbol{p}$ in a self-stabilizing way.

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