Evaluating the OECD Gross Nitrogen Balance using Austrian Data

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***Abstract* - The OECD Gross Nitrogen Balance has been identified as a priority agri-environmental indicator. Recently available data on nitrate contamination in Austrian groundwater as well as on-site characteristics (land cover, precipitation, soil characteristics) as well as on agricultural production factors (land uses, livestock numbers, and crop cultivation practices) allow us to evaluate the OECD Gross Nitrogen Balance indicator. We link observed pollution levels to the theoretical concept of the Nitrogen Balance and evaluate the ability of the indicator to measure certain nitrate pollution effects. In addition, we explore the characteristics and the robustness of the indicator and suggest improvements.**

INTRODUCTION

Excess supply of nitrate in agricultural production can lead to environmental damage. The OECD takes note of this issue by providing the Gross Nitrogen Balance as agri-environmental indicator which measures the net nitrogen input into the soil. As mentioned in OECD (2008), "this calculation can be used as a proxy to reveal the status of environmental pressures (…)". The Nitrogen Balance is a theoretical concept and captures the potential nitrate pollution in a region. It is "not necessarily indicative of actual resource depletion or environmental damage" (cp. OECD, 2008). Thus, the pressing question arises to which degree the indicator is capable of reflecting actual nitrate pollution effects. That is, does the Nitrogen Balance provide an indication as to the level of actual nitrate pollution?

Previously, we have identified determinants of the nitrate level in Austrian groundwater aquifers (Wick et al., 2009). In this present work we first assess the power of the Nitrogen Balance to explain actual nitrate concentration in groundwater by regression analysis. Second, we take up an issue discussed in OECD (2008), and calculate the Nitrogen Balance on a disaggregated level, i.e. municipality level, rather than the national level (cp. Wick et al., 2009).

DATA AND METHOD

We use data from various sources. The concentration of nitrate in groundwater in mg/l (as a proxy for observed nitrate pollution) was provided by the Umweltbundesamt (2009). This data is available on a quarterly basis from 04/1991 to 04/2008 on the municipality level (1238 municipalities) in Austria. We aggregate the quarterly values to annual average values for each municipality (*Nitrate*).

Data on precipitation in mm (*Precip*) and the maximum temperature in °C (*Maxtemp*) was provided on a daily basis for the years 1975 to 2007 by ZAMG (Zentralanstalt für Meteorologie und Geodynamik) (Strauss et al. 2009).

The sum of the proportion of grassland and cropland, referred to as agricultural land (*Prop_AL*), and information on whether conventional or organic cultivation practices (*BioCon*) are chosen was provided by the IACS (Integrated Administrative and Control System) database on an annual basis.

Soil quality is controlled for by the field water capacity (*FWC*) at 33 kPa in topsoil (cm3/cm3) and the volume of stones in topsoil (*vs*) (Balkovic et al. 2007).

Detailed crop cultivation data by IACS as well as several coefficients provided by OECD (2007) allow us to compute the Nitrogen Balance on municipality level. The Nitrogen Balance includes biological nitrogen fixation, atmospheric deposition of nitrogen compounds, livestock manure and fertiliser as inputs and withdrawal of total harvested crop and forages as output (OECD, 2007).

Since many of our explanatory variables are (almost) time constant, we apply a clustered pooled Ordinary Least Squares (OLS) estimator on our data. This estimator also controls for group wise correlation among residual terms.

EMPIRICAL RESULTS

The Nitrogen Balance Indicator and Actual Pollution

We assess whether the Nitrogen Balance performs better as a proxy for actual environmental pollution once site characteristics are taken into account. We introduce interaction terms into the regression equation to evaluate the impact of site characteristics (*Feat*) such as precipitation, temperature, cultivation systems, stones, or field water capacity on the degree of explanatory power of the Nitrogen balance:

$$\begin{aligned} Nitrate_{it} &= \beta_0 + \beta_1 Precip_{it} + \beta_2 \mathrm{Maxtemp_{it}} + \beta_3 Prop\_AL_{it} \\ &+ \beta_4 BioConv_{it} + \beta_5 NBal_{it} + \beta_6 vs_i + \beta_7 FWC_i + \beta_8 Feat_{it} \cdot NBal_{it} \\ &+ \sum_k \beta_{9k} Year\_k_t + \varepsilon_{it} \qquad where \quad t \in \{2003,...,2007\} \end{aligned}$$

First results (cp. Table 1) suggest that if high annual precipitation is observed, the Nitrogen Balance does particularly well in predicting nitrate pollution. It seems that the degree to which the potential for environmental pollution translates into actual contamination depends significantly on the amount of

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precipitation. This can be explained by the leaching effect, which is stronger with higher precipitation (cp. Wick et al., 2009)

Table 1. Results of regression analysis.

Variables	Nitrate	Nitrate
Precipitation	-2.287***	-3.546***
Maxtemp	-1.310***	-1.294***
BioConv	6.149***	5.708***
vs	0.164	0.175
fwc	-203.3***	-202.7***
Nbal	0.0654***	-0.0275
Prop_AL	18.36***	18.28***
Nbal_Precip		0.0366**
Constant	95.52***	98.94***
Year Dummies	YES	YES
Observations	4432	4432
Adjusted R-squared	0.240	0.242

*** p<0.01, ** p<0.05, * p<0.1

Disaggregating the Gross Nitrogen Balance

OECD (2008) mentions that the Nitrogen Balance, typically provided on the national level, might be misleading, as there are often large differences between specific regions within a country. When calculating the Nitrogen Balance on municipality level, new methodological issues arise; especially the issue of correctly accounting for fertilisation deserves closer attention. Mineral fertilisers have been computed by the OECD using sales data, which are only available at the level of provinces. Hence, a fraction of total fertiliser per province needs to be allocated to each municipality, by distributing total fertilisation according to the total size of agricultural land of each municipality (Sinabell, 2009). This method assumes that all agricultural land is fertilised equally, which is not the case. Additionally, this approach takes no account of site-specific conditions, e.g. prevalent soil quality, and might estimate actual fertilisation per municipality wrongly.

Instead, we calculate the optimal quantity of fertiliser for each crop, based on recommendations of BMLFUW (2006), correcting for site-specific conditions such as soil quality (i.e. clay, stones, depth to rocks).

On an aggregate level our new measure and the OECD measure yield very similar results, but there are large differences when considering specific municipalities. For example, the OECD measure overestimates nitrogen fertilisation in about 10% of all municipalities by more than 38 kg/ha – which is rather significant given that average fertilisation takes on a value of around 90 kg/ha. Variation between our measure and the OECD measure is in particular high when the mentioned site characteristics are prevalent and the proportion of cropland is high. This is intuitive since our measure accounts for fertiliser-intensive crop cultivations whereas the OECD measure does not.

Conclusion

Our results suggest that the Gross Nitrogen Balance provided by the OECD should take into account environmental conditions, in particular the amount of precipitation. We also discuss the possibility to disaggregate the national Gross Nitrogen Balance to the municipality level, and suggest an alternative approach to arrive at realistic estimates for the fertilisation measure which accounts for different cultures and soil qualities at the municipality level.

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References

Balkovic, J., Schmid, E., Moltchanova, E., Skalsky, R., Poltarska, K., Müller, B. and Bujnovsky, R. (2007). Data processing for bio-physical process modelling in EU25. In: Stolbovoy V., L. Montanarella, and P. Panagos: *Carbon Sink Enhancement in Soils of Europe: Data Modelling, Verification*, pp. 74-139. JRC Scientific and Technical Reports. Luxembourg: European Communities .

BMLFUW (2006*). Richtlinien für die Sachgerechte Düngung. Anleitung zur Interpretation von Bodenuntersuchungsergebnissen in der Landwirtschaft*, Vienna.

Sinabell, F. (2009). An exploration of agricultural policy support and its impact on nitrate concentration in groundwater. In F. Sinabell. Roles of agriculture in the rural economy. An exploration exemplified by Austria, Vienna, Univ. für Bodenkultur, Diss.

Strauss, F., Schmid E. und Moltchanova, E. (2009). Simulation von Klimaszenarien und die ökonomische und ökologische Bewertung verschiedener Pflanzenproduktionsverfahren im Marchfeld. In: H. Peyerl (ed). Jahrbuch der Österreichischen Gesellschaft für Agrarökonomie, pp. 107-116, Band 18/3. Wien: Facultas.

OECD and EUROSTAT (2010). *Gross Nitrogen Balance Handbook* (2007), Paris, France, www.oecd.org/tad/env/indicators (March, 2010)

OECD (2008). *Environmental Performance of Agriculture in OECD Countries since 1990*, Paris, France, www.oecd.org/tad/env/indicators (March, 2010).

Umweltbundesamt GmbH Wien (2009). Erhebung der Wassergüte in Österreich gemäß Hydrographiegesetz i.d.F. des BGBl. Nr. 252/90 (gültig bis Dezember 2006) bzw. Gewässerzustandsüberwachung in Österreich gemäß Wasserrechtsgesetz, BGBl. I Nr. 123/06, i.d.g.F.; BMLFUW, Sektion VII/Abteilung 1 Nationale Wasserwirtschaft; Ämter der Landesregierungen

Wick, K., Heumesser, C. and Schmid, E. (2009). Agriculture and nitrate contamination in Austrian groundwater: An empirical analysis. In: Darnhofer, I. et al. (Eds.), *Rollen der Landwirtschaft in benachteiligten Regionen*, 19. Jahrestagung der Österreichischen Gesellschaft für Agrarökonomie, Tagungsband 2009.