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### **Mapping GDP and PPs at sub-national level through earth observation in Eastern Europe and CIS countries**

The adoption of the Sustainable Development Goals in September 2015 by the United Nations General Assembly is calling National Statistics Offices (NSOs) worldwide to underpin a data revolution, as they are asked to extend both the scope and disaggregation of the data traditionally produced, and measure new economic, social and environmental phenomena, leaving none behind.

There is a growing consensus in the digital era that Big Data, particularly satellite images captured from the above, might strengthen the capacity of traditional data sources and official statistics to help in monitoring sustainable well-being, thus facing the increasing request for more spatially disaggregated data.

Following the line of research originated from the paper by Henderson et al. (2012), this paper focuses on how 'observations from the above', in the form of night-lights satellite data, might contribute in mapping at very fine geographical level (ideally, one square km), two core macroeconomic indicators used extensively in the SDG monitoring and reporting framework: Gross Domestic Product, GDP, and Purchasing Power Parities, PPPs.

The analyses are carried out for 17 Eastern Europe and CIS countries for the period 1992-2013. Therefore, the paper focuses on at least two main topics of the IARIW 2019 conference, namely: sub-national macroeconomic indicators and national accounts; and PPP based comparisons across and within countries.

Nowadays, the use of night-light as proxy of GDP has become a standard in empirical economics (see, e.g., Donaldson and Storeygard (2016)). The obvious advantage in using night-lights is that they generally show a good correlation with GDP, they are available for free and for a long time span, and they are objectively measured.

This research uses extensively the set of information coming from satellite images, as processed by the US Department of Defense, and its Defense Meteorological Satellite Program's Operational Linescan System (DMSP-OLS). Scientists at the National Geophysical Data Center (NGDC) process these raw data and distribute the final set to the public, thus making freely available 34 annual products from six satellites spanning 22 years, from 1992 to 2013. The

stable night lights are those used in this research to proxy GDP in real and PPP terms for 17 CIS and Eastern Europe countries: Azerbaijan, Armenia, Belarus, Bulgaria, Czechia, Hungary, Kazakhstan, Kyrgyzstan, Poland, Republic of Moldova, Romania, Russian Federation, Slovakia, Tajikistan, Turkmenistan, Ukraine and Uzbekistan.

Henderson et al. (2012) were the first to use night-lights in a complete statistics and econometric framework to estimate, in a panel of world time series, real economic growth. Following their examples, the relation between lights and GDP at sub-national administrative levels have been deeply investigated for North Korea, Kenya, Rwanda, Sweden, Nigeria, India and China.

More recently, while some papers have confirmed the ideas underlying the lights-to-GDP hypothesis at the country level (see, e.g., Elvidge et al. (2014)), the approach used by Henderson et al. (2012) have been criticized due to the implicit assumption of stable elasticity made in obtaining sub and/or supra-national estimates (Bickenbach et al. (2016), Addison and Stewart (2015)). Particularly, it has been stressed that the elasticity of GDP-to-lights should be statistically significant and positive, as well as temporally and spatially stable.

For CIS and Eastern Europe countries, the literature on lights and GDP is practically non-existent, the only indirect reference being a global exercise carried out by Elvidge et al. (2014) on the correlation (in levels) between GDP, night-lights and population at national level during 1992-2012.

Our paper innovates with respect to the preceding literature in at least four respects. First, it analyses in a systematic way the relationship between DMSP-OLS night-lights and GDP in CIS and Eastern Europe countries at the finer extent possible, looking at conditions under which lights can be used to obtain estimates of GDP and PPPs at detailed geographical level. Second, the research uses both a time and spatial approach in the analysis, particularly through the use of unbalanced panel regressions models, and tests the conditions of spatially and time stability of GDP-to-light elasticity. Third, use is made of the available national and sub-national data produced by NSOs of the region. Finally, after testing for the existence of temporally and spatially stable elasticity of GDP both in real and PPP terms with respect to lights, the estimated coefficients are used to map economic activity and parities at very fine geographical level, thus offering two sets of information that are mostly needed for SDGs monitoring and reporting.

We are fully aware that the estimations provided in this paper cannot replace primary statistics produce by NSOs of the region. However, we hope these estimates will be of some use for policy makers and researchers for their policy intervention, analyses and discussion, and

contribute in partially answering the increasing demand for more spatially disaggregated macroeconomic data to further advance the sustainable development agenda.