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ANALYSIS

Inorganic fertilizer use and biodiversity risk: An empirical investigation☆

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ABSTRACT

There are persistent concerns and accumulating evidence of rapid losses in biodiversity. A critical issue is that biodiversity loss may lead to changes in ecosystem functioning, with concordant threats to the stability and resilience of agricultural systems. Against this backdrop, this research investigates the empirical relationship between the intensity of inorganic fertilizer use and biodiversity risk. Using cross-country biodiversity risk indices, our statistical estimates indicate that the amount of inorganic fertilizer use per hectare of arable land is significantly related to increasing biodiversity risk. Robust findings across various specifications hold after controlling for heterogeneity across countries, including the scale of agricultural production.

1. Introduction

There are persistent concerns and accumulating evidence of rapid losses in biodiversity (Pimm et al., 1995; MEA, 2005). Biodiversity is critical to the provision of ecosystem services, and human well-being crucially depends on ecosystem services (MEA, 2005). Ecosystem services include production of food, fiber, medicine, water, air; formation and retention of soil fertility; hosting of the genetic library; pest and disease control; crop pollination; climate regulation; flood control; water filtration and cleansing; maintaining and balancing biogeochemical cycles; and recreational, cultural and aesthetic benefits (Heal and Small, 2002; Armsworth et al., 2004; Heal, 2004).

Ecosystems are composed of biotic (living) and abiotic (non-living) elements. Ecosystem processes are controlled by the diversity of living communities in the ecosystem. Modifications to these processes can alter ecological functions that are vital to human well-being (Naeem et al., 1999). Baumgartner (in press) notes that the mean level of ecosystem services increases with biodiversity and the variance of ecosystem services decrease with biodiversity. Thus, benefits from biodiversity include both productivity and stability in the provision of ecosystem services. Given the interdependence of organisms in complex ecosystems, the implication is that even small changes to ecological processes may lead to far-reaching consequences.

The role of biodiversity in providing diverse ecosystem services cannot be fully captured in market prices (Dasgupta and Maler, 2004). Ecological economists argue that even from a utilitarian point of view, continuing to drive vast numbers of species to extinction is an unwise course of action (Costanza

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Table 1 – Descriptive statistics for the dependent and independent variables

Variable	Definition	Usable obs.	Mean	Standard deviation	Minimum	Maximum
LNADJNABRAI	Log of Adjusted NABRAI	103	−4.938	1.382	−7.642	−1.417
LNUPGNABRAI	Log of Upgraded NABRAI	61	0.009	0.618	−1.347	1.398
LNFERT	Log of inorganic use (100 g/ha of arable land)	101	6.057	1.842	0.441	8.987
LNPCGDP	Log of per-capita GDP (PPP, in thousand current international $)	101	1.379	1.181	−0.750	3.338
AGVAD	Value added from Agriculture as % of GDP	98	19.155	15.175	1.368	57.653
LNTOUR	Log of number of tourists arrived	102	13.482	2.128	6.908	17.910
URBAN	Urban population (% of total)	103	51.292	24.264	5.7	97
FDI	Gross foreign direct investment as % of GDP	227	2.013	3.518	−5.423	29.478
LNAID	Log of per-capita aid (foreign Aid received in current U.S. $ divided by population)	227	2.466	1.709	−0.089	5.423
LNBOD	Log of Organic Water Pollutant (BOD) emissions (kg/day/worker)	105	4.573	6.306	−2.040	14.760
CROPLAND	Permanent Cropland (% of total Land Area)	141	2.407	4.300	0.005	26.471

Notes: In World Bank (2002) for the year 1995, a number of developed countries (Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, and United States) do not have information on foreign aid received. For these countries we use LNAID = 0 in the regression analyses, as these countries did not receive any foreign aid. For a number of developing countries (Algeria, Belgium, Bhutan, Central African Republic, Chad, Congo, Ethiopia, Malawi, Nepal, Oman, Sudan, United Arab Emirates, Zambia, and Zimbabwe) we do not have information on foreign direct investment. For these countries we use FDI = 0 in the regression analyses. BOD refers to Biochemical Oxygen Demand, an important measure of water quality in lakes and rivers.

et al., 1997). A primary concern is that biodiversity losses are irreversible after crossing critical thresholds, thus restricting the ability to mitigate or substitute.[1] Further, there is a real "option value" for conserving biodiversity from the viewpoint of bioprospecting (Heal, 2004).

Agriculture remains a predominant activity through which humans interact with the natural world (Tilman et al., 2002). Total cultivated systems cover 25% of earth's terrestrial surface in 2000 (MEA, 2005). Agriculture is an activity that extracts renewable resources from a biological base (Heal and Small, 2002). Thus, sustainable agriculture must be embedded in sustainable ecosystems and the protection of our stock of biodiversity.[2] Inorganic fertilizer use in agriculture changes the energy and nutrient cycling and storage that lead to disruption of normal ecosystem functioning (Pagiola et al., 1998). Unfortunately, quantitative studies that estimate the impact of agriculture on environmental quality are surprisingly scant (Lichtenberg, 2002). Investigating the impact of inorganic fertilizer use is important due to recent massive increases in nutrient pollution that have occurred over the last several decades.[3]

Against this backdrop, this research investigates a simple question — what is the empirical relationship between the intensity of inorganic fertilizer use and biodiversity risk? Using available cross-country biodiversity risk indices, our statistical analyses indicate that the amount of inorganic fertilizer use per hectare of arable land significantly increases biodiversity risk across countries. Results are robust across various specifications, and also controlling for the scale of agricultural production. This finding has implications for crafting conservation policy.

2. Analyzing the impact of inorganic fertilizer use and biodiversity risk: data and methods

As argued by a number of conservation biologists and ecologists, a comprehensive definition of biodiversity must be comprised of species, genetic and ecosystem diversity; further, biodiversity risk is determined by the interplay of three important aspects: stock, pressure and response (Reyers et al., 1998). Following from these arguments, Reyers et al. (1998) and Reyers and James (1999) compute three variants of a National Biodiversity Risk Assessment Index (NABRAI) for different countries that are each composed of stock, pressure and response factors. These indices consider species, genetic and ecosystem diversity, and thus presumably provide a more comprehensive and precise measure of biodiversity risk than simply the number or percentage change of any particular

[1] The irreversible, non-shiftable negative externality caused by human activity to this complex global public good leaves very limited room to yield an "Environmental Kuznets Curve" (EKC) relationship for biodiversity loss (Mozumder et al., 2006). An EKC is a hypothesized, inverted-U relationship between some measure of environmental degradation and some measure of economic growth (e.g., per capita income). If found, degradation will initially increase with economic growth and then will decrease past some income turning point. More than 100 empirical studies have yielded mixed results, showing that an EKC often holds for some measures (directly tangible air and water pollutants), but not for others (e.g., shiftable externalities or measures with broad, global effects, such as CO_2). For a meta-analysis review, see Cavlovic et al. (2000).

[2] It is estimated that since World War II over $1 billion per year has been added to the value of U.S. agricultural output because of plant breeders' access to wild races (Heal, 2002).

[3] The Millennium Ecosystem Assessment (MEA, 2005) provides global trends of reactive nitrogen (a dominant nutrient) on earth by human activities. Since 1960, flows of reactive nitrogen in terrestrial ecosystems have doubled, and flows of phosphorus have tripled. An alarming concern is that more than half of all synthetic nitrogen fertilizer has been used since 1985 (MEA, 2005).